A Longitudinal Examination of the Link Between Youth Physical Fitness and Academic Achievement

Rebecca A. London
Sebastian Castrechini

John W. Gardner Center for Youth and Their Communities
Stanford University

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Contact Rebecca London at:
505 Lasuen Mall
Stanford University
Stanford, CA 94305
rlondon@stanford.edu
650-736-6076

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ABSTRACT

The growing problem of childhood obesity has received much attention due to its correlates with other persistent health problems. There is also a growing body of research showing a potential link between obesity and academic performance. Using matched administrative data, we examine the relationship between academic achievement and both overall physical fitness as well as body mass index for students in a California community, longitudinally tracking their performance from fourth to ninth grades. Comparing those who are persistently fit over time to those who are persistently unfit, findings indicate initial disparities in math and English language arts test scores. These disparities continue as students advance, decreasing some in ninth grade. There are weaker effects of changes in fitness trajectories on changes in academic achievement, though there is evidence of a link between improvements or declines in physical fitness and changes in achievement. Models tend to more strongly associate fitness and academic achievement for girls and Latinos. We find that overall physical fitness is a better predictor of academic achievement than obesity as measured by body mass index.

Key words: physical fitness, obesity, academic achievement, achievement gap

INTRODUCTION

The rise of childhood obesity to epidemic status has received tremendous attention in the media and in various academic literatures. The most recent figures indicate that 30.1% of U.S. children ages 2 to 19 have body mass index (BMI) high enough to classify them as overweight (the 85th percentile on BMI-for-age growth charts), 15.5% have BMI that place them as obese (95th percentile), and 10.9% have BMI that place them as severely obese (97th percentile) (Ogden, Carroll, and Flegal 2008).[1] There has been an historic rise in BMI among children in the U.S., with the childhood obesity rate tripling since the 1970s (Paxson et al. 2006).

A key concern among childhood obesity observers is that because the problem is more heavily concentrated among young people who are already disadvantaged in some ways, it may add to existing social and economic inequalities. For instance, African American and Mexican American children have higher obesity rates (20.7% and 20.9% respectively), compared to their non-Hispanic white counterparts (14.6%) (Ogden, Carroll, and Flegal 2008).[2] Low socioeconomic status children and adolescents – as measured by income and parents' education – are also at higher risk of obesity in the U.S. , but the relationship is complex (Gordon-Larsen, Adair, and Popkin 2003; Wang 2001; Wang and Zhang 2006). Among White children, there is an inverse relationship between BMI and socioeconomic status such that children with a socioeconomic disadvantage are more likely to be obese (Gordon-Larsen, Adair, and Popkin 2003). This same relationship does not always hold for children of other ethnicities, although the link between BMI and socioeconomic status appears to be stronger for girls than

[1] The BMI-for-age growth charts have not kept pace with children's weight gains and therefore the 95th percentile cutoff does not reflect the current children's BMI distribution. As a result, substantially more than 5% of children meet the 95th percentile cutoff (Ebbeling and Ludwig 2008).
[2] The survey from which these estimates are produced does not have enough observations to separately examine Latino children of other ethnicities.

boys. Minority and low-SES youth are also less likely to be physically fit than their more advantaged peers (California Department of Education 2005).

These differences in obesity and physical fitness outcomes mirror other well-documented health disparities among children (Palloni 2006), including in health insurance coverage (DeNavas-Walt, Proctor, and Smith 2007). This is especially troubling because being unfit or overweight is linked to health problems for children, and childhood health problems foreshadow adult health and socioeconomic inequalities (Palloni 2006; Kvaavik et al. 2009). These health disparities are so entrenched that even if we were to equalize income and education levels for these families, we would not eliminate health inequalities (Gordon-Larsen, Adair, and Popkin 2003).

In addition to health disparities related to fitness and obesity, there are reasons to believe that overweight and obesity, and especially physical fitness, may also be linked to academic achievement. A meta-analysis of over 40 studies shows there is a strong association between higher levels of physical activity and improved cognition in children and adolescents (Sibley and Etnier 2003). Another review suggests an important effect of physical activity on concentration, memory, and classroom behavior in school (Strong et al. 2005). There are also effects of obesity on youth mental health outcomes as adolescents with higher BMI are more likely to experience depression and low-self-esteem (Fallon et al. 2005; Johnson et al. 2008; Schwimmer, Burwinkle, and Varni 2003; Strauss 2000; Williams et al. 2005). Again, higher levels of physical activity can abate these problems (Strong et al. 2005). There is evidence that specifically links participation in rigorous physical activities to better academic performance (Coe et al. 2006).

These factors point to a growing concern that physical fitness and obesity may be the next demarcation for the academic achievement gap. Because being unfit or obese has been linked to socioeconomic disadvantage, low socioeconomic status youth are already at greater risk of suffering from health problems as adults as well as more limited access to health care. If higher obesity rates and lower rates of physical fitness also put youth at greater risk of academic failure, their adult outcomes are further jeopardized. In this article, we study the connection between academic achievement and obesity or physical fitness over a four- to six-year period. Findings point to an important link between physical fitness and student achievement, even after controlling for factors such as race, ethnicity, and socioeconomic status. Students who are persistently fit score higher on state-mandated achievement tests than students who are persistently unfit. These disparities persist from fourth to ninth grade, but decline some in the later grades. Improvements and declines in student fitness are somewhat associated with similar changes in achievement test scores.

LITERATURE REVIEW

There is a small but growing literature studying the links between obesity or physical fitness and academic achievement. An early review of studies published from 1994 to 2004 found a total of nine articles on the topic, three of which were based in the United States (Taras and Potts-Datema 2005). The review's broad conclusion was that there is indeed a negative association between obesity and students' academic performance, but the literature has not reliably addressed the directionality of this association. Since that review, the literature has grown but methodological concerns remain.

More recent literature has focused on U.S. students includes both cross-sectional and longitudinal examinations of the association. The cross-sectional studies tend to examine the issue using student health and academic data collected by schools and have found a positive link between physical fitness and academic achievement, but with some variations (Chomitz et al. 2009; Grissom 2005; Castelli et al. 2007). Focusing on students in three different states and of different ages, all three studies found that academic performance increases with the number of physical fitness tests students pass. Chomitz et al. (2009) found larger effects for math than English language arts (ELA) achievement and Grissom (2005) found stronger results for girls than boys. The Grissom study used the same data as our study (California's Physical Fitness Test linked to students' California Standards Test results in math and ELA), but did not track students longitudinally over time. The issue of directionality remains in all of these cross-sectional studies, which limits discussions of the consequences of the findings for policy or practice interventions.

A longitudinal approach to the issue does not entirely solve the directionality problem, but it does allow for an examination of changes over time in fitness or obesity and the effects of these changes, or persistent problems, on academic achievement. Because school records used by researchers are typically unidentified (students' names and identification numbers are removed), creating longitudinal datasets from these "administrative" data is rare. This is a problem because the information contained in these data is superior in terms of the precision of the academic performance measures and in some cases the breadth of the physical fitness information. Many public school districts rely on state-approved or mandated physical fitness testing, and these data often contain more detailed fitness information in addition to BMI. In contrast to the cross-sectional studies on this topic, the longitudinal ones rely exclusively on survey data, and the three most recent longitudinal examinations we uncovered all used the Early Childhood Longitudinal Study – Kindergarten Cohort (ECLS-K), collected by the National Center on Educational Statistics in the U.S. Department of Labor (Datar, Sturm, and Manabosco

2004; Datar and Sturm 2006; Carlson et al. 2008). This is one of the few publicly available national datasets that collects both BMI and academic information, along with important covariates related to child and family demographic and economic characteristics. The survey also includes participation in physical education activities as well as teacher and parent interviews, which are advantages over administrative data. However, because it is one of the few datasets collecting both BMI and academic information, there is little opportunity to contrast the findings from this sample with findings from other samples. Furthermore, the ECLS-K collects BMI as its only fitness measure, which makes comparisons to the cross-sectional fitness studies difficult.

Among the longitudinal studies, the shortest time span examined – kindergarten to first grade – was likely too short to observe any strong trends, particularly because both kindergarten and first grade students are just beginning to master the basics of reading and math. Indeed Datar et al. (2004) found little longitudinal effects of obesity per se; however, they did note that more television watching was associated with worse academic performance. Increased television viewing has also been linked to obesity in medical trials (e.g., Robinson 1999). Datar and Strum (2006) followed these same students through the end of third grade and, like Grissom (2005), found a stronger link for girls than boys. Importantly, they found that a negative transition in BMI (from not overweight in kindergarten to overweight in third grade) was a significant predictor of reduced test scores as well as teacher ratings. Using the same data but focusing on physical education rather than BMI, Carlson et al. (2008) showed that more physical education offered a small benefit to achievement, but also primarily for girls.

Another approach to examining this issue is to use aggregate data on health and school or school district performance to examine how the trends move together or apart over time.

Focusing on California school districts, one study found that reductions in students' health status at the county level are associated with an increased probability that the school district will fail to meet its annual progress required by the State (Stone and Jung 2008). This is important because it suggests that neighborhood or community-level factors, in addition to individual and family risks, may be associated with student fitness, and hence, school district performance. Because school district performance is tied to funding at the state and federal levels, these findings suggest a need for greater examination.

Although there is a clear link between fitness or obesity and academic performance, the causality and directionality remain in question. The present study adds to the literature in that it is a longitudinal examination of physical fitness and BMI (the only of these studies to examine both) and uses matched administrative rather than survey data. We rely on both BMI and physical fitness outcomes because research has shown that BMI measurements can be an unreliable measure of fitness, particularly for youth (Dietz and Bellizzi 1999). Experts have raised questions about the accuracy of cutoff points (Malina and Katzmarzyk 1999) and the inability of BMI calculations to differentiate between fat and muscle (Ebbeling and Ludwig 2008; Prentice and Jebb 2001). In contrast, overall fitness includes measures other than BMI and is more likely to capture differences between students with high BMI and high muscle mass and those with high BMI and low muscle mass.

DATA

We rely on data from the Youth Data Archive (YDA), a collaboration of public, private, and university partners that share administrative data across agencies and come together to ask and answer questions about youth in the community. With the YDA, we link individual-level administrative data over time and across schools, public agencies, and community based organizations to support community partners to make data-driven policy and programmatic decisions to improve outcomes for youth.

One of the most powerful benefits of the YDA is the ability to look at youth pathways over time and across environments. For this analysis, we rely on data from two school districts: Redwood City School District (RCSD) (serving students in grades K-8) and Sequoia Union High School District (SUHSD) (serving students in grades 9-12), both in San Mateo County, CA. The majority of students, whom we track from RCSD to SUHSD, are from Redwood City, a city of 75,000 located in the San Francisco Bay Area. Once considered a commuter suburb to San Francisco, Redwood City has become increasingly comprised of low-income families from Latino backgrounds, including many immigrant families. A total of 67% of RCSD students are Latino, 47% are English learners, and 58% are Free and Reduced Price Lunch participants. Data include student demographics, physical fitness outcomes, and academic achievement from the 2002-03 to 2007-08 school years. We measure student physical fitness using the California Physical Fitness Test (PFT), which consists of the following six fitness standards:

- Aerobic capacity
- Body composition
- Abdominal strength and endurance
- Trunk extensor strength and endurance
- Upper boyd strength and endurance
- Flexibility

Students take the PFT in grades five, seven, and nine and are scored as meeting the standard if their score falls within a designated healthy fitness zone (Fitnessgram 2007).

Academic achievement is measured using California Standardized Test (CST) scores in math and English language arts (ELA). California students take the CST in math and ELA in the spring of every year starting in second grade. The California Department of Education (CDE) reports CST scores as scale scores from 200 to 600. However, test scale scores are not comparable across grades or years. Because we track students longitudinally, we convert scale scores to *z* scores (Rivkin, Hanushek, and Kain 2005). The *z* score is a measure of the number of standard deviations above or below the mean score and essentially gives us a way to norm the data consistently across years. For test scores from grades four to eight, we norm the scale scores against all of the scores for the same test in the same year. Because RCSD is one of eight feeder districts into SUHSD and has a population with distinct demographic characteristics, we norm the high school CST scores only against SUHSD students who came from RCSD schools.

We link RCSD and SUHSD data individually using the California school unique identifier as well as other confidential identifiers such as name, address, date of birth, gender, and ethnicity. For this analysis, we concentrate on students from fourth through ninth grade. We rely on data from the 2002-03 to the 2007-08 school years and include students who have: (i) CST scores from 2002-03 through 2005-06 and who completed all six standards of the PFT in 2003-04 and 2005-06; (ii) CST scores from 2003-04 through 2006-07, with PFT scores in 2004-05 and 2006-07 scores; or (iii) CST scores from 2004-05 through 2007-08, with PFT scores in 2005-06 and 2007-08. In total, there are 1,957 students who we can follow for four consecutive years, including two PFT administrations and CST scores in the year prior to the first PFT administration.

To assess students' physical fitness, we adopt the California Education Code's definition of passing the PFT: taking and passing five of the six standards. In order to examine the relationship between physical fitness and academic performance over time, we divide students into four groups based on their PFT performance in the two years:

- Passed five of six standards in both academic years;
- Passed five of six standards in the first academic year but not the second;
- Passed five of six standards in the second academic year but not the first; and
- Did not pass five of six standards in either year.

We create a similar set of four categories for students focused solely on the Body Mass Index (BMI) in order to align with the literature that looks at overweight and obesity rather than physical fitness.

We also create one small cohort of 400 students that we can track PFT results across grades five, seven, and nine and CST results for grades four through nine. For these students, there are eight possible permutations of PFT and obesity results in the three PFT years. However, we do not have enough observations to fully explore each of these pathways. We therefore combine some of the smaller groups with similar z score trajectories over time and use the resulting six three-year PFT trajectories:

- Passed PFT in all three academic years;
- Passed in fifth and seventh grade but failed in ninth grade;
- Failed in fifth and seventh grade but passed in ninth grade;
- Alternated fifth and seventh and passed in ninth grade;
- Alternated fifth and seventh and failed in ninth grade;
- Failed PFT in all three academic years.

We cluster BMI test results using a comparable set of pathways.

METHODS

We begin the analysis by examining student demographic factors by physical fitness status. We anticipate that the same set of background characteristics that are associated with decreased physical fitness are also associated with lower academic achievement; it is therefore important to carefully construct multivariate analyses that account for these differences and isolate the effects of physical fitness on CST scores. As discussed earlier, the literature shows that low socioeconomic status and minority children are more likely to be obese, and these same children are also at higher risk of academic failure.

Our analyses include tri-level individual growth models with student-years as the first level, students as level two, and school paths as level three. We select this methodology for two main reasons. First, school pathways will likely influence other variables and as such, traditional regression modeling will not provide unbiased estimates. Second, we observe that baseline academic performance of the four PFT groups is very different, but including baseline scores as a control is not appropriate (Fitzmaurice, Laird, and Ware 2004).[3] The obesity literature points to reasons we might assume that school and neighborhood effects can influence physical fitness. For example, school social context can mediate the way in which fitness and obesity affect academic outcomes (Crosnoe and Muller 2004). Neighborhood factors, such as proximity to a fast food restaurant (Davis and Carpenter 2009) and opportunities for physical activity (Duncan et al. 2002) are also important factors. We account for these potential school and neighborhood effects by creating an indicator for students' school path, which we define as the combination of schools a student attends across the years we observe them. We use the school path indicator because it takes into account both neighborhood effects – as most students in RCSD attend their neighborhood school – and also differences in school effects for students who start in the same school but transition to another one.

Because of the physiological, social, and academic differences we would expect to see between students of different ages, we perform all analyses separately for the two age cohorts: fifth to seventh grade and seventh to ninth grade. In addition, we perform all analyses separately

[3] We initially ran all our models in HLM but obtained the same results using SAS's PROC MIXED. For this article, we use SAS. The only way in which we part from HLM's computations is in the choice to use the between-within method of estimating degrees of freedom based on the recommendations of Singer (1998). We use maximum likelihood estimation because of the reliability of its fit statistics in models with mixed random and fixed effects (Singer and Willett 2003).

for boys and girls and also for white and Latino students (the predominant ethnic groups) to examine whether the relationship between physical fitness and academic achievement is consistent across these subgroups.

To determine which random and fixed effects to include in the model, we examine the fit statistics measured by the Akaike Information Criterion (AIC) and covariance parameters. Lower AIC indicates an improved goodness of fit. Starting from a linear model with no level two predictors, we add each random effect at level two and level three individually, assessing the improvement in fit at each step. We find that in almost every case, the model allowing both the intercept and time to vary randomly at both levels two and three fit the data best. The diagnostics point us to a model that allows intercepts to vary at both levels and time.

We next determine the best shape of the model by assessing the goodness of fit as we add predictors to the model. We start from an unconditional means model that includes no predictors and provides the grand mean with no change component. We then add time as the level one predictor, and then level two predictors to control for gender, ethnicity, parental education level, special education status, English language proficiency, participation in the Free or Reduced Priced Lunch program, and physical fitness status.[4,5] Each of these levels improves the fit. Finally, we add a quadratic time term to test whether a linear model is the best fit, and we find that the curvilinear model significantly improves the AIC. Thus, the final composite three-level model is:

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[4] We use four racial/ethnic classifications in the models: White, Latino, African American, and other. White and Latino students comprise nearly 90% of all students in the sample. We perform ANOVA tests of the achievement and fitness status of the ethnic categories that comprise the other ethnicities and find only African Americans to have significantly different characteristics from the other categories. For this reason, we choose to include an African American indicator variable but combine all other categories into other.

[5] The dummy variables for English proficient include: (1) English Only (EO) students, who enter school fluent in English and have no family members who speak other languages at home; (2) Initially Fluent English Proficient (IFEP), who also enter school fluent in English, but have family members at home who speak other languages; (3) English Learners (EL), who are not yet fluent in English; and (4) Redesignated Fluent English Proficient (RFEP), who started as EL and have met the criteria for being reclassified as English proficient.

$$CST = \beta_0 + \beta_1*F + \beta_2*X + \beta_3*F*T + \beta_4*X*T + \beta_5*F*T^2 + \beta_6*X*T^2.$$

In this equation, F is the fitness trajectory (or in some models the obesity trajectory) laid out previously, X is a set of covariates including student and parent demographics, and T is a measure of time because we follow students over four or six consecutive years.

In this model structure, the coefficients for each PFT category (β_1) provide estimates of the effect of the category on the beginning position. The coefficients on the interaction of the PFT category and time (β_3) provide estimates of the effect of the interaction on initial rate of change for the given fitness category. The coefficients on the interaction of the PFT category and the time quadratic (β_5) provide estimates of the effect of the fitness category on the change in the growth rate over time.

We use the same procedure to analyze the six-year CST score trajectories for the cohort of students for whom we have all three PFT results. In these six-year trajectories for both the analyses featuring overall PFT performance as the main predictor and those featuring only the BMI test results, we find that a cubic model fits best for math CST scores but that a linear model fits the ELA CST scores best.

Using the same model four-year individual growth model structure as above, we examine performance on the BMI test to assess the relationship between overweight and academic achievement. In these models, the main predictors are again the four possible BMI trajectories – pass both BMI tests, pass then fail, fail then pass, and fail both tests – as well as their interactions with time. We run similar models using the aerobic capacity test, measured by the mile run, and the upper-body strength test, measured by push-ups, to determine whether these individual measures of fitness are associated with academic achievement.

Finally, we examine outliers more carefully, using logistic regressions to study the characteristics of students who are persistently unfit and academically successful as well as those who are persistently fit and academically unsuccessful.

RESULTS

Variations in fitness by demographic categories

Table 1 shows the demographic characteristics of students by PFT performance over two consecutive test administrations. Reported findings are consistent with the literature that associates lower socioeconomic status with lower levels of fitness. Students in both the fifth-to–seventh-grade and seventh-to-ninth-grade cohorts who pass the PFT in two consecutive years are disproportionately white, native English speakers, not eligible for Free or Reduced Price Lunch, and have parents who graduated from college.

Importantly, we find a wide gap in base year CST scores, particularly among students in the younger cohort. Students who pass both their fifth- and seventh-grade PFTs have average scores of 0.40 and 0.45 standard deviations above the mean in ELA and math, respectively, compared to students who fail the PFT in both fifth and seventh grade, who have average scores of 0.28 and 0.29 standard deviations below the mean. This finding is critically important because it indicates that even before the State of California begins testing students' physical fitness, a fitness achievement gap has already grown. The gap reported in Table 1 is not yet regression-adjusted, but as we show shortly, it persists even after controlling for a host of background characteristics.

These descriptive statistics also show differences by gender. Higher percentages of girls in the younger cohort pass both PFTs, but this changes in the older cohort, where boys comprise a slightly higher proportion of those who pass both PFTs. Also, boys are much more likely than girls to improve from failing the PFT in seventh grade to passing in ninth grade (64.0%), whereas girls make up a disproportionate share of the group that go from passing to failing between seventh and ninth grade (69.4%).

We find similar relationships between background characteristics and PFT outcomes when we examine the longer time period for the students who we can follow consecutively from fifth to ninth grade (Table 1). It is important to note that the group that passes all three PFTs comprises nearly three-fifths of the entire cohort and that some of the PFT pathway categories over this longer time period included smaller numbers of students. However, we continue to find the same main findings that fitness trajectories are worse for those with lower socioeconomic status. Notably, among those who fail all three administrations of the PFT, nearly three-quarters receive Free or Reduced Price Lunch (73.5%). In contrast, just 42.0% of those passing all three administrations are Free or Reduced Price Lunch recipients. The pattern of girls' declining fitness over time continues over the longer time period as well, though small numbers of students in each category prevent strong conclusions.

CST trajectories across two PFT administrations

The results of the four year growth models, which span two PFT administrations, are shown in Table 2 and Figures 1 and 2. These models examine the effects of students' fitness levels and trajectories on their CST math and ELA scores. Each model includes a set of uninteracted regressors, a set interacted with time, and a set interacted with time-squared.

The uninteracted coefficients in Table 2 show differences in CST scores in the base year (fourth or sixth grade, depending on the cohort examined). This first set of coefficients demonstrates an important finding: there is a gap in initial CST scores that is attributable to PFT performance even before students take the PFT. For the younger cohort, students who go on to pass both PFTs and students who fail in the first year but pass in the second have significantly higher math scores in the fourth grade compared to students who go on to fail both PFTs (β=0.244 and β=0.147, respectively). Similarly, both these two groups of students had significantly higher scores on the ELA CST than those who fail both PFTs (β=0.115 and β=0.129, respectively). For the older cohort, the initial CST gap is present only for students who go on to pass both PFTs (β=0.218 in math, β=0.154 in ELA). Other variables have the expected effect on initial CST scores; we find negative effects on CST scores for those who are in minority ethnicities, English Learners, receiving Special Education services, or whose parents do not have a high school diploma.

The differences in baseline CST *z* scores for students who go on to have varying fitness trajectories are important. Even before these students begin taking the PFT in California, there is already an achievement gap that is attributable to fitness. This is shown visually in Figures 1 and 2, which show line graphs of the predicted test scores over the four years of analysis, separately by test subject and cohort using the regression results from Table 2.

Although there are not many statistically significant differences in CST score growth trajectories among the four fitness groups, examining plots of predicted values shows a consistent albeit modest pattern of improvement for students whose fitness improves over time – those who go from failing to passing – compared to students whose fitness declines over time. For the younger students (Figures 1 and 2), those whose PFT performance improves over time have slight gains in their CST scores. However, more noticeable is the decline in scores, particularly among the younger cohort, for students who go from passing the first PFT to failing the second. For the older cohort (Figure 2), there are smaller gaps between each fitness groups' CST trajectories, and there are not large improvements in CST for those improving fitness outcomes, compared with the analogous groups in the younger cohort.

Our main concern with the two switching categories that perhaps these are not students whose physical fitness is changing substantially but instead are students on the margin who are just barely passing or failing the PFT in each of the administrations. They may appear to be improving or declining in fitness but in reality staying much the same. When we examine them more carefully, we fnd that among those who from passing to failing the PFT, about one quarter fail the PFT because they re over the target mile run test by 30 seconds. We therefore do not want to make a dramatic distinction between the pass-to-fail and fail-to-pass groups, as it appears that many of these students are indeed on the margin of the two.

CST Trajectories over three PFT administrations

Table 3 shows the results for the growth models predicting CST scores over the six years from fourth to ninth grade for the 400 students who completed the PFT in each of the three administrations. In contrast to the four-year models, we find no significant differences in initial CST scores or CST growth rates for any of the fitness trajectory groups compared to students who failed all three PFTs, in either math or ELA. However, the magnitude of the coefficients on the uninteracted fitness terms points to a similar story as in the four-year analysis. Students who pass all three PFTs, or those who move from fail to pass, have larger positive coefficients compared to those that consistently fail or move toward failure over time, indicating an initial gap in CST scores that pre-dates the fitness trajectory. This is especially true for the math CST.

The lack of statistical significance in these models is likely related to the smaller sample size for this six-year cohort. The time slopes are relatively small and never approach significance.

Again, looking at the plots of regression-adjusted predicted scores over time helps to show some trends that, although not statistically significant, warrant consideration. Figure 3a shows the predicted math CST scores from fourth to ninth grade. It is difficult to assess differences in growth when examining the model, which was best fit by a cubic growth curve. However, one can see an interesting pattern of similarities in fourth grade baseline scores based on ninth grade PFT performance. The predicted scores for students who pass the PFT in ninth grade are clustered between 0.06 and 0.11 standard deviations above the mean whereas the fourth grade scores for the three groups that failed the ninth grade test are clustered from 0.09 to 0.13 standard deviations below the mean. Over time, the distance between these groups expands; most notably, the predicted scores for the students that pass all three times rise to 0.22 standard deviations above the mean, which is 0.18 standard deviations above the next highest group.

The ELA predicted scores, shown in Figure 3b, show a more apparent difference in the time slopes. Students who fail all three PFTs and those who pass the first two but fail the third have fourth grade predicted scores that are nearly identical. However, by ninth grade, predicted scores for students that fail all three PFTs are nearly a quarter of a standard deviation higher than predicted scores for students who passed the first two PFTs but failed in ninth grade. Similarly, the groups of students who alternate performance on their first two PFTs (either failing then passing or passing then failing) both start at similar points just below the mean ELA score in fourth grade. However, the students who alternate on the first two and go on to pass the PFT in ninth grade have predicted scores of 0.17 standard deviations above the mean, whereas the students who alternate and then fail the ninth grade PFT have predicted scores 0.14 standard deviations below the mean.

Although the models do not show strong effects of PFT performance on CST outcomes, the predicted scores do show patterns indicating a relationship between physical fitness, particularly improvements in physical fitness, and academic performance.

Test scores predicted by longitudinal BMI trajectories

Although our main focus is on physical fitness, we also present the same set of findings substituting BMI for fitness to be consistent with much of the literature on this topic. Table 4 presents the results from two and three administrations of the PFT. In these models, we code BMI as a dichotomous variable (pass or fail) corresponding to the age and sex specified BMI cutoff levels specified by Fitnessgram.

Unlike the models for overall fitness, the BMI models do not show significant differences in initial CST scores or growth trajectories for either the four-year or six-year analyses. Indeed, none of the intercept coefficients associated with BMI trajectories is significant, and the only model with any significant differences in time interactions is that predicting ELA scores for the older cohort. In that model, there are significant negative initial slopes (time interacted with BMI) for students who go from passing to failing the BMI test and those who pass both in reference to the group that failed both BMI tests. However, the quadratic time interaction for both of these groups is significant and positive, resulting in very little difference over the course of the four years of analysis. In addition to the lack of significance in most of the BMI models, the magnitude of the coefficients is also much smaller than in the fitness models.

Models predicting six-year CST score growth by performance on the BMI test at all administrations similarly shows weaker results compared to the same analysis with overall fitness. On the math CST, students who alternate performance on the first two BMI tests and fail the last have significantly higher initial slope, time interacted with "alternate then fail" (β=0.545), but the quadratic time interaction is negative and significant (β=-0.267) whereas the cubic time interaction is positive and significant (β=0.034). It is also notable in the math CST model that the intercept coefficient associated with passing the first two BMI tests but failing the third is negative (β=-0.265), a result that, although not significant, shows a strong negative association of fourth grade math scores with students' fifth to ninth grade BMI changes. In the ELA model, there is a positive but insignificant coefficient (β=0.157) on the intercept associated with passing the BMI test all three times.

We also run similar models using the continuous BMI variable instead of a dichotomous variable as the main predictor (not shown). Findings indicate no consistent pattern of relationship between BMI and academic achievement.

CST trajectories and PFT results for student subgroups

Previous literature indicates differences in male and female students' fitness and academic achievement trajectories as well as markedly different fitness levels for students of different ethnicities. We therefore examine these groups separately in Table 5. We use the same models as presented in Table 3, following students PFT trajectories from fifth to seventh and seventh to ninth grades.

Table 5 shows results separately for female and male students in both age cohorts. For female students in both age groups, we find a statistically significant gap in initial CST scores that is attributable to PFT performance. For the younger girls, students who go on to pass both PFTs have significantly higher math and ELA scores in the fourth grade compared to students who go on to fail both PFTs (β=0.304 and β=0.237, respectively). Among older girls, those who consistently pass the PFT also do substantially better in math and English than those who fail both PFT administrations (β=0.231 and β=0.232, respectively). There appears to be no difference in the slopes of the academic test score trajectories by fitness pathway given almost no statistically significant coefficients for the time interacted variables.

The findings are, in general, not the same for male students. There are significant differences in initial math CST scores for those who pass both PFTs compared to those who fail both PFTs, but in both cases the magnitude of the coefficient is smaller than for girls. For the younger cohort of boys, there appears to be an effect of fitness pathways on math score growth trajectories, but findings do not appear to be consistent. Persistently passing the PFT is associated with an initial growth in English CST scores (β=0.131) for younger boys, but a decline in fitness (movement from pass to fail) is associated with negative initial math CST growth (β=-0.212).

Table 5 also shows the effects of physical fitness trajectories on CST scores for Latino and White students (other ethnic subgroups are too small to be analyzed separately). In both cases, the effects of fitness on academic test scores are in the initial gap in scores, not in growth rates. For Latino students in both the fifth-to-seventh and seventh-to-ninth grade cohorts, there is a significant gap between those who go on to pass both PFTs and those who go on to fail both PFTs in the math CST scores (β=0.287 and β=0.168 for the younger and older groups, respectively). In the younger cohort, there is also a positive effect of moving from failing to passing the PFT compared to failing both PFTs (β=0.168). Older White students show a very similar pattern, but there are no significant differences among students with different fitness trajectories for younger White students.

Other Measures of Fitness

The PFT is comprised of a total of six standards, including BMI, and we were concerned that perhaps one of the other standards was driving the results. For instance, perhaps it is not fitness overall but the ability to pass the mile run that is really the marker that is linked to academic achievement. Table 6 presents findings from several models that focus in on the most challenging of the tests – the mile run and the push-up test – and compare these to passing five out of six standards. Virtually all students pass the other fitness tests (excluding the BMI test). The results do not provide conclusive evidence that one of these tests, rather than the combination of all of them, is responsible for the link with academic achievement. Although fifth grade students who go from failing the mile test to passing in seventh grade experience higher math test scores, those who switch from pass to fail similarly see higher math scores. There are mostly insignificant coefficients for the seventh grade cohort on this test and inconsistent results for both cohorts on the push-up test.

We also run models that exclude BMI from the PFT and create physical fitness trajectories that correspond to passing four of five standards (rather than five of six). The results (not shown) are similar to those for passing five of six, which indicates to us that the well-documented problems with BMI as a measurement of overweight are not unduly influencing the findings.

Although the link between physical fitness and academic achievement is evident, there are still students who are physically unfit and succeed academically as well as those who are fit and do not achieve at a high level academically. We are concerned that our models do not adequately capture the experiences of these students. To further examine these groups, Table 7 presents findings specifically for these two groups – those who are persistently unfit and those who are persistently fit – and we examine which characteristics among these two groups is associated with high achievement and low achievement respectively. We use logistic regression models that predict the probability of high achievement among those who are persistently unfit and low achievement for those who are persistently fit, combining the fifth and seventh grade cohorts.

The results indicate that the mediating factor in these situations may be socioeconomic status. A total of 20.0% of high fitness students were low achieving, with students who are receiving special education services and those receiving Free and Reduced Price Lunch having a higher likelihood of low achievement and White students and those whose parent(s) attended college having a lower probability of low achievement. The pattern for unfit students with high academic achievement mirrors this, though with not as many statistically significant coefficients. The findings indicate that socioeconomic status may be a buffer for students, such that more advantaged students have a greater ability to maintain higher levels of academic achievement despite lower levels of fitness, whereas less advantaged students experience an even greater level of disadvantage when they are also physically unfit.

DISCUSSION

This paper demonstrated the important relationship between students' physical fitness and their academic achievement, as measured by standardized test scores. Using individual growth models, we focused on two main aspects of this relationship: (1) initial differences in students' academic test scores in the year prior to our first observation of their Physical Fitness Test (PFT) results, and (2) differences in the slopes of students' academic progress given their physical fitness pathway. In models that follow students' physical fitness from fifth to seventh grade or seventh to ninth grades, we find that the achievement gap between persistently fit and persistently unfit children begins as early as fourth grade, a year prior to the students' first experiences with the PFT. Students who improve their fitness show some academic gain over those whose fitness worsens or who are persistently unfit across two administrations of the PFT, though there is evidence that some of these switching students may be just barely failing the PFT. Differences in initial test scores for those who go on to be persistently fit and unfit are particularly pronounced for girls and Latinos, especially those in the younger cohort.

The relationship between physical fitness and academic achievement over time trajectories is less pronounced. The rates of growth in academic scores over time are similar for fit and unfit youth. Because fit youth start with a sizeable test score advantage, there is a persistent achievement gap between fit and unfit youth over their academic careers. However, key differences emerge for students whose fitness trajectories tend to worsen, especially in the model that includes the subset of students we can follow from fourth to ninth grade. Small sample sizes make it difficult to draw strong conclusions from that model, but evidence points to a problem for students whose fitness worsens over fifth to ninth grades.

Although findings indicate a positive relationship between fitness and academic achievement, there are, of course, students whose trajectories do not correspond to this pattern. In particular, there is a set of students with poor physical fitness outcomes who continually succeed in school, and those who are physically fit but do not succeed in school. Our analysis indicates that certain background characteristics help to explain these divergent trends.

Socioeconomic status, for instance, is a key buffer for students who are physically unfit. Those from higher socioeconomic backgrounds do not experience as large a negative effect of fitness on academics as those from lower socioeconomic backgrounds. The data suggest that socioeconomic advantages might mediate the negative effects of poor fitness on academic outcomes.

There are multiple ramifications for these findings. First, our robustness testing indicated that overall fitness – the combination of the six components of the PFT – is far more predictive of academic achievement than any one test, including BMI, the measure commonly used to assess overweight and obesity. Because BMI cutoff levels change substantially as children age, and because they differ so greatly for boys and girls, BMI has been criticized as an unreliable measure of child health. Our findings further indicate that the popular focus on the "obesity epidemic" should be refined to consider overall fitness instead of just obesity.

A second is that the achievement gap between fit and unfit students in this community begins even before students begin their physical fitness testing at school. The very early emergence of this achievement gap is troubling. However, it does appear that by ninth grade, the early effects of physical fitness have waned some especially for students whose fitness improves. However, for students experiencing persistent obesity or persistent low fitness levels over the time period, there is cause for concern. In California, this early trend toward a physical fitness achievement gap may warrant earlier fitness testing in order to better track students' needs.

The presence of this fitness achievement gap among students in fourth to ninth grades points to a need for intervention on several levels. To date, most interventions have happened at the individual student or the family levels, with medical trials aimed at young people and sometimes their families to improve physical fitness, physical activity, and nutrition (Ara et al.

2006; Robinson et al. 2003; Story et al. 2003; Weintraub et al. 2008). Schools and school districts have recently begun to address the issue through campaigns to remove high calorie drinks and snacks from vending machines and to serve higher quality foods at mealtimes. Communities and funders are also responding with local and statewide initiatives to prevent childhood obesity and improve child health. These campaigns and initiatives are aimed at reducing obesity for health reasons but have not yet begun to address academic consequences of being in poor physical shape. This research points to a need for a more intense focus on the intersection of physical fitness and academics in order to both improve health and avoid an increasing achievement gap for students who are already at higher risk of low academic achievement and subsequently poorer post-school outcomes.

These findings cannot illuminate the mechanisms at work in the link between fitness and academic achievement. There may be underlying characteristics not measured in administrative data that make unfit students less likely to succeed academically, such as motivation or self-efficacy. Students who are motivated to succeed and feel they are in control of their actions may be both more likely to be physically fit and also to be academically successful. Also, there is evidence that obese children, particularly girls, have lower self-esteem than non-obese youth (Braet, Mervielde, and Vandereycked 1997); it is possible that this lower self-esteem may discourage students from participating in classes and activities. We plan to study these issues in more detail in the future by linking individual-level youth development surveys and program participation data for middle school students to the academic and physical fitness administrative data.

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Table 1: Demographic characteristics for students with two and three years of PFT data, by cohort and fitness trajectory

	Grade 5-7 Cohort				Grade 7-9 Cohort				Grade 5-9 Cohort					
Characteristic	Pass Both (n=568)	Fail→ Pass (n=237)	Pass→ Fail (n=147)	Fail Both (n=373)	Pass Both (n=712)	Fail→ Pass (n=228)	Pass→ Fail (n=180)	Fail Both (n=290)	Pass 3 PFTs (n=157)	Pass-Pass-Fail (n=30)	Fail-Fail-Pass (n=53)	Alt then Pass (n=81)	Alt then Fail (n=30)	Fail 3 PFTs (n=49)
Gender														
Female	54.4%	50.2%	53.7%	41.3%	47.8%	36.0%	69.4%	48.6%	45.2%	80.0%	43.4%	43.2%	60.0%	46.9%
Male	45.6%	49.8%	46.3%	58.7%	52.2%	64.0%	30.6%	51.4%	54.8%	20.0%	56.6%	56.8%	40.0%	53.1%
Ethnicity														
African American	2.8%	1.3%	3.4%	2.9%	2.4%	2.6%	0.6%	3.1%	0.0%	0.0%	1.9%	3.7%	0.0%	4.1%
Latino	50.5%	60.3%	69.4%	71.6%	50.3%	57.0%	70.0%	67.6%	55.4%	73.3%	60.4%	60.5%	80.0%	67.3%
White	39.6%	27.0%	19.0%	18.5%	40.4%	32.5%	21.1%	19.0%	39.5%	16.7%	28.3%	29.6%	6.7%	14.3%
Other Ethnicity	7.0%	11.4%	8.2%	7.0%	6.9%	7.9%	8.3%	10.3%	5.1%	10.0%	9.4%	6.2%	13.3%	14.3%
Educational Services														
Special Education	7.4%	13.5%	13.6%	15.3%	10.1%	14.5%	15.6%	15.9%	10.8%	16.7%	17.0%	8.6%	6.7%	18.4%
English Learner	10.9%	17.3%	27.2%	24.1%	14.2%	18.0%	27.2%	26.2%	17.2%	33.3%	18.9%	17.3%	23.3%	36.7%
Initially Eng Prof	3.7%	2.1%	2.7%	1.3%	5.5%	8.8%	6.1%	7.6%	8.3%	10.0%	11.3%	4.9%	3.3%	6.1%
Redesignated Eng Prof	16.4%	15.2%	15.6%	11.3%	29.8%	29.8%	38.9%	36.6%	28.7%	30.0%	26.4%	40.7%	50.0%	30.6%
English Only	30.3%	19.0%	17.0%	13.7%	50.6%	43.4%	27.8%	29.7%	45.9%	26.7%	43.4%	37.0%	23.3%	26.5%
Socioeconomic Status														
Free/Reduced Lunch	41.2%	60.3%	67.3%	67.8%	44.9%	51.3%	65.0%	67.2%	42.0%	60.0%	50.9%	56.8%	76.7%	73.5%
Parents College Grad	40.3%	28.3%	15.6%	15.0%	33.0%	28.9%	18.9%	16.6%	39.5%	16.7%	35.8%	18.5%	10.0%	16.3%
Parents HS Grad	35.2%	40.5%	40.8%	41.0%	42.4%	41.7%	38.9%	47.9%	35.7%	56.7%	37.7%	42.0%	53.3%	42.9%
Parents not HS Grad	21.5%	25.3%	36.7%	37.8%	23.3%	27.6%	39.4%	33.8%	22.3%	26.7%	26.4%	33.3%	36.7%	38.8%
Base Year Test Scores														
Mean ELA *z* score	0.40	0.13	-0.23	-0.28	0.30	0.07	-0.16	-0.20	0.33	-0.14	0.18	-0.02	-0.22	-0.11
Mean Math *z* score	0.45	0.05	-0.20	-0.29	0.32	0.09	-0.22	-0.21	0.30	-0.16	0.12	0.17	-0.22	-0.14

Table 2. Effects of Fitness Trajectories on CST Scores Student 5th to 7th grade and 7th to 9th grade

	5th-7th Grade						7th-9th Grade					
	Math			ELA			Math			ELA		
Predictor	β		SE	β		SE	B		SE	β		SE
Not Interacted												
Pass both PFTs	0.244	***	0.049	0.115	*	0.046	0.218	***	0.058	0.154	**	0.049
Pass PFT 1, fail PFT2	0.034		0.065	-0.050		0.061	0.052		0.078	0.051		0.066
Fail PFT 1, pass PFT 2	0.147	**	0.057	0.129	*	0.053	0.117		0.072	0.084		0.061
Female	-0.160	***	0.037	0.091	**	0.034	-0.060		0.044	0.084	*	0.037
Black	-0.270	*	0.126	-0.120		0.117	-0.060		0.154	0.121		0.131
White	0.166	**	0.058	0.194	***	0.054	0.237	**	0.077	0.391	***	0.065
Other Ethnicity	0.297	***	0.074	0.146	*	0.068	0.157		0.086	0.015		0.073
English Learner	-0.540	***	0.058	-0.660	***	0.054	-0.660	***	0.092	-0.820	***	0.077
Initially Eng Proficient	0.128		0.097	0.273	**	0.090	0.165		0.098	0.405	***	0.083
Redesignated Eng Proficient	0.204	***	0.055	0.101	*	0.051	-0.030		0.078	-0.010		0.066
Special Ed	-0.680	***	0.059	-0.660	***	0.055	-0.560	***	0.066	-0.640	***	0.056
Free/Reduced Lunch	-0.020		0.054	-0.180	***	0.050	-0.270	***	0.060	-0.300	***	0.051
Parent(s) attended college	0.207	***	0.050	0.198	***	0.047	0.260	***	0.056	0.128	**	0.047
Parent(s) no HS diploma	-0.100	*	0.049	-0.130	**	0.045	0.013		0.058	-0.040		0.049
Interacted with Time												
Time	0.006		0.055	0.000		0.049	0.351	***	0.099	0.067		0.064
Pass both PFTs	0.010		0.040	0.093	**	0.036	0.038		0.063	-0.060		0.041
Pass PFT 1, fail PFT2	-0.040		0.055	0.052		0.049	-0.010		0.084	-0.010		0.055
Fail PFT 1, pass PFT 2	-0.040		0.048	0.029		0.043	-0.040		0.079	-0.080		0.051
Female	0.021		0.031	-0.090	**	0.028	-0.140	**	0.048	0.017		0.031
Black	-0.030		0.108	0.137		0.096	-0.260		0.170	-0.220	*	0.110
White	0.144	**	0.049	0.056		0.044	-0.040		0.084	-0.120	*	0.055
Other Ethnicity	0.028		0.063	0.000		0.056	0.038		0.094	-0.030		0.061
English Learner	0.038		0.049	0.000		0.043	-0.040		0.101	-0.040		0.065
Initially Eng Proficient	-0.110		0.083	0.008		0.074	0.066		0.108	-0.080		0.070
Redesignated Eng Proficient	0.057		0.050	0.076		0.045	-0.050		0.073	0.018		0.047
Special Ed	-0.090	*	0.046	0.044		0.041	0.145		0.085	0.099		0.055
Free/Reduced Lunch	-0.060		0.045	-0.030		0.040	0.022		0.066	0.006		0.043
Parent(s) attended college	0.071		0.042	0.064		0.037	-0.030		0.060	0.027		0.039
Parent(s) no HS diploma	0.020		0.042	0.086	*	0.037	0.078		0.064	-0.030		0.042

Continued

Table 2 (continued)

	5th-7th Grade						7th-9th Grade					
	Math			ELA			Math			ELA		
Predictor	β		SE	β		SE	B		SE	β		SE
Interacted with Time-squared												
Time-squared	-0.010		0.017	0.001		0.015	-0.120	***	0.031	-0.010		0.020
Pass both PFTs	0.000		0.012	-0.020	*	0.011	-0.010		0.020	0.021		0.013
Pass PFT 1, fail PFT2	0.006		0.017	-0.030		0.015	0.007		0.027	0.004		0.017
Fail PFT 1, pass PFT 2	0.015		0.015	-0.010		0.013	0.009		0.025	0.031		0.016
Female	-0.010		0.010	0.029	***	0.009	0.051	***	0.015	-0.010		0.010
Black	0.009		0.033	-0.050		0.030	0.083		0.054	0.069	*	0.034
White	-0.040	*	0.015	-0.010		0.014	0.007		0.027	0.029		0.017
Other Ethnicity	-0.020		0.013	-0.020		0.012	0.004		0.019	-0.010		0.012
English Learner	0.000		0.015	0.011		0.013	0.056		0.032	0.012		0.020
Initially Eng Proficient	0.043		0.026	-0.010		0.023	-0.040		0.034	0.000		0.022
Redesignated Eng Proficient	0.001		0.016	-0.020		0.014	0.030		0.023	0.001		0.015
Special Ed	0.036	*	0.015	0.000		0.013	-0.040		0.027	-0.040	*	0.017
Free/Reduced Lunch	0.011		0.014	0.007		0.012	0.007		0.021	0.005		0.013
Parent(s) attended college	-0.020		0.013	-0.020		0.012	0.004		0.019	-0.010		0.012
Parent(s) no HS diploma	-0.010		0.013	-0.030	*	0.011	-0.030		0.020	0.008		0.013
Intercept	-0.010		0.083	0.041		0.083	0.098		0.108	0.156		0.093

* p <.05; **p <.01; ***p <.001

Note: Reference groups are: failed both fitness tests, male, Latino, English only, and parent(s) high school graduates.

Table 3: Effects of Fitness Trajectories on CST Scores
Student 5th to 9th grade

	5th-9th Grade					
	Math			ELA		
Predictor	β		SE	β		SE
Not Interacted						
Pass 3 PFTs	0.227		0.132	0.125		0.109
Pass-Pass-Fail	0.026		0.185	0.009		0.153
Alt then Pass	0.172		0.143	-0.090		0.117
Alt then Fail	-0.010		0.180	-0.100		0.149
Fail-Fail-Pass	0.210		0.154	0.059		0.127
Female	-0.200	*	0.079	0.158	*	0.066
Black	-0.260		0.330	-0.400		0.277
White	0.296	*	0.134	0.348	**	0.112
Other Ethnicity	-0.620	***	0.160	-1.020	***	0.132
English Learner	0.292		0.163	0.297	*	0.137
Initially Eng Proficient	0.127		0.137	-0.140		0.114
Redesignated Eng Proficient	-0.530	***	0.125	-0.460	***	0.103
Special Ed	0.056		0.115	-0.090		0.096
Free/Reduced Lunch	0.056		0.115	-0.090		0.096
Parent(s) attended college	0.149		0.100	0.257	**	0.084
Parent(s) no HS diploma	-0.060		0.104	-0.080		0.086
Interacted with Time						
Time	-0.060		0.227	0.004		0.028
Pass 3 PFTs	0.098		0.166	0.010		0.020
Pass-Pass-Fail	-0.040		0.231	-0.050		0.028
Alt then Pass	-0.040		0.180	0.024		0.021
Alt then Fail	-0.070		0.229	-0.040		0.027
Fail-Fail-Pass	-0.080		0.197	0.001		0.023
Female	0.182		0.101	0.004		0.012
Black	0.198		0.428	0.020		0.051
White	-0.060		0.170	-0.010		0.020
Other Ethnicity	-0.140		0.196	0.000		0.024
English Learner	-0.160		0.206	0.023		0.024
Initially Eng Proficient	-0.270		0.208	-0.010		0.025
Redesignated Eng Proficient	-0.390	*	0.176	0.019		0.021
Special Ed	0.105		0.159	0.020		0.019
Free/Reduced Lunch	-0.240		0.146	-0.010		0.017
Parent(s) attended college	0.262	*	0.127	-0.010		0.015
Parent(s) no HS diploma	0.125		0.134	0.017		0.016

Continued

Table 3 (continued)

	5th-7th Grade				
	Math			ELA	
Predictor	β		SE	β	SE
Interacted with Time-squared					
Time-squared	0.106		0.111	-	-
Pass 3 PFTs	-0.050		0.081	-	-
Pass-Pass-Fail	-0.020		0.113	-	-
Alt then Pass	0.010		0.088	-	-
Alt then Fail	0.040		0.113	-	-
Fail-Fail-Pass	0.015		0.097	-	-
Female	-0.100	*	0.050	-	-
Black	-0.150		0.214	-	-
White	0.034		0.084	-	-
Other Ethnicity	0.033		0.097	-	-
English Learner	0.069		0.101	-	-
Initially Eng Proficient	0.190	*	0.086	-	-
Redesignated Eng Proficient	0.135		0.103	-	-
Special Ed	-0.020		0.078	-	-
Free/Reduced Lunch	0.085		0.072	-	-
Parent(s) attended college	-0.100		0.063	-	-
Parent(s) no HS diploma	-0.070		0.065	-	-
Interacted with Time-cubed					
Time-cubed	-0.020		0.015	-	-
Pass 3 PFTs	0.008		0.011	-	-
Pass-Pass-Fail	0.005		0.015	-	-
Alt then Pass	0.000		0.012	-	-
Alt then Fail	-0.010		0.015	-	-
Fail-Fail-Pass	0.000		0.013	-	-
Female	0.014	*	0.006	-	-
Black	0.023		0.028	-	-
White	-0.010		0.011	-	-
Other Ethnicity	0.000		0.013	-	-
English Learner	-0.010		0.013	-	-
Initially Eng Proficient	-0.020		0.013	-	-
Redesignated Eng Proficient	-0.020	*	0.011	-	-
Special Ed	0.002		0.010	-	-
Free/Reduced Lunch	-0.010		0.009	-	-
Parent(s) attended college	0.011		0.008	-	-
Parent(s) no HS diploma	0.010		0.009	-	-
Intercept	0.055		0.186	0.192	0.152

* p <.05; **p <.01; ***p <.001

Note: Reference groups are: Fail 3 PFTs, male, Latino, English only, and parent(s) high school graduates.

Table 4. Regression coefficients, standard errors, and covariance parameters for students with 5th and 7th or 7th and 9th grade PFT results, by BMI test results

	Math		ELA		
	β	SE	β		SE
5th-7th Grade					
Not Interacted					
Pass both BMIs	0.073	0.047	0.040		0.043
Pass BMI 1, fail BMI2	-0.022	0.073	-0.059		0.068
Fail BMI 1, pass BMI 2	0.072	0.073	0.044		0.068
Interacted with Time					
Pass both BMIs	-0.041	0.040	0.042		0.036
Pass BMI 1, fail BMI2	-0.097	0.062	0.016		0.056
Fail BMI 1, pass BMI 2	-0.084	0.061	0.017		0.055
Interacted with Time-Squared					
Pass both BMIs	0.012	0.012	-0.013		0.011
Pass BMI 1, fail BMI2	0.036	0.019	-0.012		0.017
Fail BMI 1, pass BMI 2	0.022	0.019	-0.007		0.017
7th-9th Grade					
Not Interacted					
Pass both BMIs	0.075	0.055	0.065		0.047
Pass BMI 1, fail BMI2	0.127	0.107	0.022		0.090
Fail BMI 1, pass BMI 2	0.130	0.085	0.130		0.072
Interacted with Time					
Pass both BMIs	-0.050	0.060	-0.102	*	0.040
Pass BMI 1, fail BMI2	-0.174	0.117	-0.015		0.077
Fail BMI 1, pass BMI 2	0.005	0.093	-0.183	**	0.061
Interacted with Time-Squared					
Pass both BMIs	0.013	0.019	0.033	**	0.012
Pass BMI 1, fail BMI2	0.036	0.037	0.001		0.024
Fail BMI 1, pass BMI 2	-0.013	0.029	0.056	**	0.019
5th-9th Grade					
Not Interacted					
Pass 3 BMIs	0.011	0.11	0.157		0.091
Pass-Pass-Fail	-0.265	0.269	-0.033		0.225
Alt then Pass	0.035	0.151	0.047		0.125
Alt then Fail	-0.172	0.187	-0.016		0.155
Fail-Fail-Pass	0.023	0.188	0.068		0.152

Continued

Table 4 (continued)

	Math			ELA	
	β		SE	β	SE
5th-9th Grade					
Interacted with Time					
Pass 3 BMIs	0.217		0.139	-0.019	0.017
Pass-Pass-Fail	0.327		0.343	-0.053	0.041
Alt then Pass	-0.079		0.190	-0.018	0.023
Alt then Fail	0.545	*	0.237	-0.009	0.028
Fail-Fail-Pass	0.116		0.238	0.006	0.028
Interacted with Time-Squared					
Pass 3 BMIs	-0.104		0.068	-	-
Pass-Pass-Fail	-0.105		0.170	-	-
Alt then Pass	0.079		0.093	-	-
Alt then Fail	-0.267	*	0.117	-	-
Fail-Fail-Pass	-0.009		0.115	-	-
Interacted with Time-Cubed					
Pass 3 BMIs	0.013		0.009	-	-
Pass-Pass-Fail	0.012		0.022	-	-
Alt then Pass	-0.013		0.012	-	-
Alt then Fail	0.034	*	0.015	-	-
Fail-Fail-Pass	-0.003		0.015	-	-

* $p < .05$; ** $p < .01$; *** $p < .001$

Regressions include all covariates included in Table 3.

Table 5. Effects of Physical Fitness Trajectories on CST Scores by Gender and Ethnicity for Students 5th to 7th grade and 7th to 9th grade

	5th-7th Grade						7th-9th Grade					
	Math			ELA			Math			ELA		
Predictor	β		SE	β		SE	B		SE	β		SE
Female Students												
Pass both PFTs	0.304	***	0.069	0.237	***	0.067	0.231	**	0.082	0.232	***	0.070
Pass PFT 1, fail PFT 2	-0.075		0.090	-0.106		0.088	-0.006		0.099	0.087		0.085
Fail PFT 1, pass PFT 2	0.130		0.081	0.124		0.079	0.081		0.110	0.127		0.093
Time*Pass both PFTs	0.030		0.056	0.051		0.049	0.058		0.087	-0.099		0.057
Time*Pass PFT 1, fail PFT 2	0.123		0.077	0.121		0.067	0.030		0.103	-0.047		0.068
Time*Fail PFT 1, pass PFT 2	-0.017		0.070	0.027		0.061	0.026		0.117	-0.123		0.077
Time^2 *Pass both PFTs	-0.004		0.018	-0.013		0.015	-0.016		0.027	0.034		0.018
Time^2 *Pass PFT 1, fail PFT 2	-0.036		0.024	-0.044	*	0.021	-0.007		0.033	0.013		0.021
Time^2 *Fail PFT 1, pass PFT 2	0.012		0.022	-0.006		0.019	-0.019		0.037	0.040		0.024
Male Students												
Pass both PFTs	0.211	**	0.071	0.033		0.063	0.198	*	0.084	0.079		0.069
Pass PFT 1, fail PFT 2	0.161		0.097	0.038		0.087	0.123		0.133	0.034		0.109
Fail PFT 1, pass PFT 2	0.145		0.081	0.147	*	0.073	0.119		0.098	0.027		0.080
Time*Pass both PFTs	0.009		0.056	0.131	**	0.050	0.026		0.093	-0.011		0.059
Time*Pass PFT 1, fail PFT 2	-0.212	**	0.081	-0.044		0.073	-0.044		0.147	0.044		0.092
Time*Fail PFT 1, pass PFT 2	-0.025		0.068	0.030		0.061	-0.045		0.110	-0.045		0.070
Time^2 *Pass both PFTs	-0.003		0.017	-0.033	*	0.016	-0.008		0.029	0.009		0.018
Time^2 *Pass PFT 1, fail PFT 2	0.049		0.025	0.001		0.023	0.024		0.047	-0.011		0.029
Time^2 *Fail PFT 1, pass PFT 2	0.014		0.021	-0.006		0.019	0.022		0.035	0.024		0.022
Latino Students												
Pass both PFTs	0.287	***	0.059	0.067		0.054	0.168	***	0.065	0.100		0.055
Pass PFT 1, fail PFT 2	0.043		0.077	-0.054		0.071	0.034		0.084	0.035		0.072
Fail PFT 1, pass PFT 2	0.168	**	0.068	0.074		0.063	0.065		0.083	0.098		0.070
Time*Pass both PFTs	-0.054		0.047	0.082		0.042	0.086		0.077	-0.024		0.052
Time*Pass PFT 1, fail PFT 2	-0.087		0.065	0.067		0.058	0.002		0.099	0.010		0.066
Time*Fail PFT 1, pass PFT 2	-0.090		0.057	0.051		0.052	-0.063		0.099	-0.097		0.066
Time^2 *Pass both PFTs	0.011		0.015	-0.021		0.013	-0.018		0.024	0.017		0.016
Time^2 *Pass PFT 1, fail PFT 2	0.018		0.020	-0.031		0.018	0.005		0.031	0.000		0.021
Time^2 *Fail PFT 1, pass PFT 2	0.031		0.018	-0.012		0.016	0.028		0.031	0.039		0.021
White Students												
Pass both PFTs	0.157		0.101	0.163		0.098	0.366	***	0.138	0.356	**	0.119
Pass PFT 1, fail PFT 2	-0.149		0.147	-0.151		0.143	0.181		0.192	0.289		0.166
Fail PFT 1, pass PFT 2	0.016		0.124	0.206		0.120	0.372	**	0.163	0.270		0.140
Time*Pass both PFTs	0.147		0.083	0.124		0.075	-0.141		0.138	-0.148		0.087
Time*Pass PFT 1, fail PFT 2	0.094		0.125	0.027		0.113	-0.087		0.194	-0.091		0.123
Time*Fail PFT 1, pass PFT 2	-0.002		0.107	-0.052		0.097	-0.069		0.166	-0.100		0.105
Time^2 *Pass both PFTs	-0.033		0.026	-0.036		0.024	0.030		0.044	0.031		0.027
Time^2 *Pass PFT 1, fail PFT 2	-0.023		0.039	-0.019		0.036	0.035		0.061	0.017		0.038
Time^2 *Fail PFT 1, pass PFT 2	0.013		0.033	0.015		0.030	0.011		0.052	0.027		0.032

* $p < .05$, ** $p < .01$, *** $p < .001$

Regressions include all covariates included in Table 3.

Table 6. Effects of Indivdual Fitness Measure Trajectories on CST Scores for Students from 5th to 7th grade and 7th to 9th grade

	5th-7th Grade						7th-9th Grade					
	Math			ELA			Math			ELA		
	β		SE	β		SE	B		SE	β		SE
<u>Pass 5 of 6 HFZs</u>												
Pass both PFTs	0.244	***	0.049	0.115	*	0.046	0.218	***	0.058	0.154	**	0.049
Pass PFT 1, fail PFT 2	0.034		0.065	-0.050		0.061	0.052		0.078	0.051		0.066
Fail PFT 1, pass PFT 2	0.147	**	0.057	0.129	*	0.053	0.117		0.072	0.084		0.061
Time*Pass both PFTs	0.010		0.040	0.093	**	0.036	0.038		0.063	-0.060		0.041
Time*Pass PFT 1, fail PFT 2	-0.040		0.055	0.052		0.049	-0.010		0.084	-0.010		0.055
Time*Fail PFT 1, pass PFT 2	-0.040		0.048	0.029		0.043	-0.040		0.079	-0.080		0.051
Time^2 *Pass both PFTs	0.000		0.012	-0.020	*	0.011	-0.010		0.020	0.021		0.013
Time^2 *Pass PFT 1, fail PFT 2	0.006		0.017	-0.030		0.015	0.007		0.027	0.004		0.017
Time^2 *Fail PFT 1, pass PFT 2	0.015		0.015	-0.010		0.013	0.009		0.025	0.031		0.016
<u>Pass Mile Run</u>												
Pass both PFTs	1.674		2.666	0.535		2.410	-2.197		2.715	-2.058		2.421
Pass PFT 1, fail PFT 2	5.998	***	2.149	3.209		1.952	0.624		3.046	-1.114		2.715
Fail PFT 1, pass PFT 2	9.148	***	1.999	3.907	**	1.802	2.951		2.238	0.355		1.990
Time*Pass both PFTs	2.930		2.145	1.682		2.006	2.088		2.757	0.907		1.953
Time*Pass PFT 1, fail PFT 2	0.804		1.797	-0.130		1.682	-2.278		3.165	-2.472		2.250
Time*Fail PFT 1, pass PFT 2	2.008		1.548	1.093		1.446	1.739		2.268	2.135		1.609
Time^2 *Pass both PFTs	-1.009		0.662	-0.940		0.620	-0.485		0.882	-0.493		0.621
Time^2 *Pass PFT 1, fail PFT 2	-0.189		0.556	0.162		0.520	0.952		1.011	0.926		0.714
Time^2 *Fail PFT 1, pass PFT 2	-0.404		0.475	-0.111		0.444	-0.420		0.720	-0.550		0.508
<u>Pass Push-Up Test</u>												
Pass both PFTs	1.145		2.282	-1.294		2.055	3.357		3.525	1.229		3.157
Pass PFT 1, fail PFT 2	-1.776		2.570	-2.061		2.320	2.445		3.167	2.973		2.842
Fail PFT 1, pass PFT 2	2.554	*	1.542	0.990		1.389	3.330	*	1.850	2.292		1.660
Time*Pass both PFTs	-0.317		1.926	2.049		1.764	-4.842		3.684	-1.871		2.623
Time*Pass PFT 1, fail PFT 2	-0.714		2.168	3.761	*	1.987	1.140		3.292	-3.911	*	2.346
Time*Fail PFT 1, pass PFT 2	-1.496		1.299	0.927		1.190	-2.144		1.929	-0.920		1.371
Time^2 *Pass both PFTs	0.039		0.597	-0.761		0.546	0.826		1.185	0.554		0.839
Time^2 *Pass PFT 1, fail PFT 2	0.305		0.678	-1.015		0.618	-0.585		1.049	1.347	*	0.745
Time^2 *Fail PFT 1, pass PFT 2	0.341		0.402	-0.315		0.368	0.559		0.618	0.169		0.438

* p <.05; **p <.01; ***p <.001
Regressions include all covariates included in Table 3.

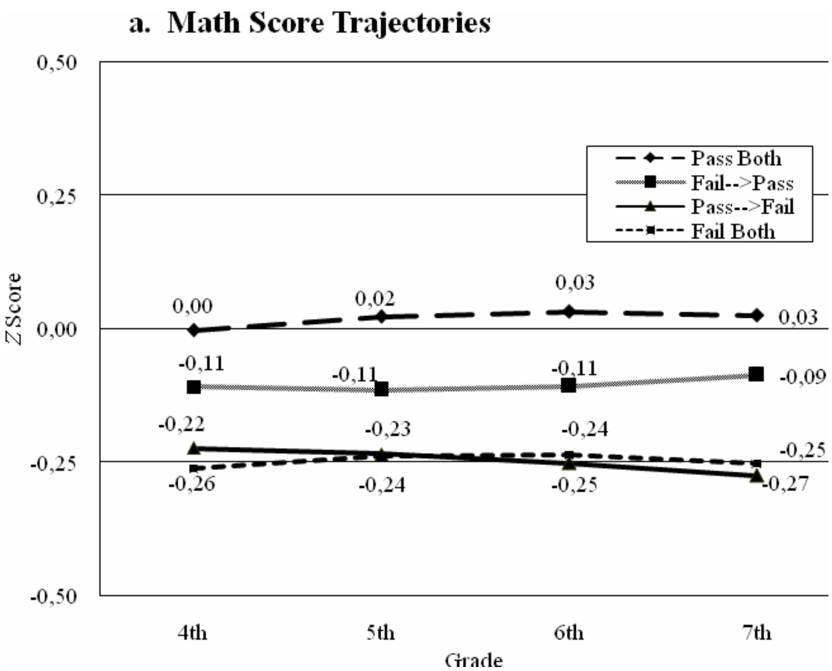
Table 7. Predicting Outliers in Fitness and Academic Achievement

Predictor	Probability of Low Achievement Among High Fitness Youth			Probability of High Achievement Among Low Fitness Youth		
	β		SE	β		SE
Female	-0.304		0.161	-0.198		0.236
African American	-0.653		0.628	0.459		0.630
White	-0.667	*	0.317	0.564		0.347
Other Ethnicity	-0.467		0.388	0.353		0.417
English Only	-0.097		0.279	0.460		0.318
Special Ed	2.068	***	0.247	-2.494	***	0.731
Free/Reduced Lunch	1.023	***	0.228	-0.783	**	0.291
Parent(s) attended college	-1.150	***	0.260	0.291		0.295
Parent(s) no HS diploma	0.305		0.189	-0.461		0.324
Grade 5	-0.061		0.165	0.465		0.253
Intercept	-1.635	***	0.261	-1.530	**	0.357
Raw probability	0.200			0.152		
Number of Students	1,280			663		

* p <.05; **p <.01; ***p <.001

Note: Reference groups are: failed both fitness tests, male, Latino, English only, and parent(s) high school graduates.

Figure 1. California Standards Test (CST) Score Trajectories from 4th to 7th Grade, by Overall PFT Results



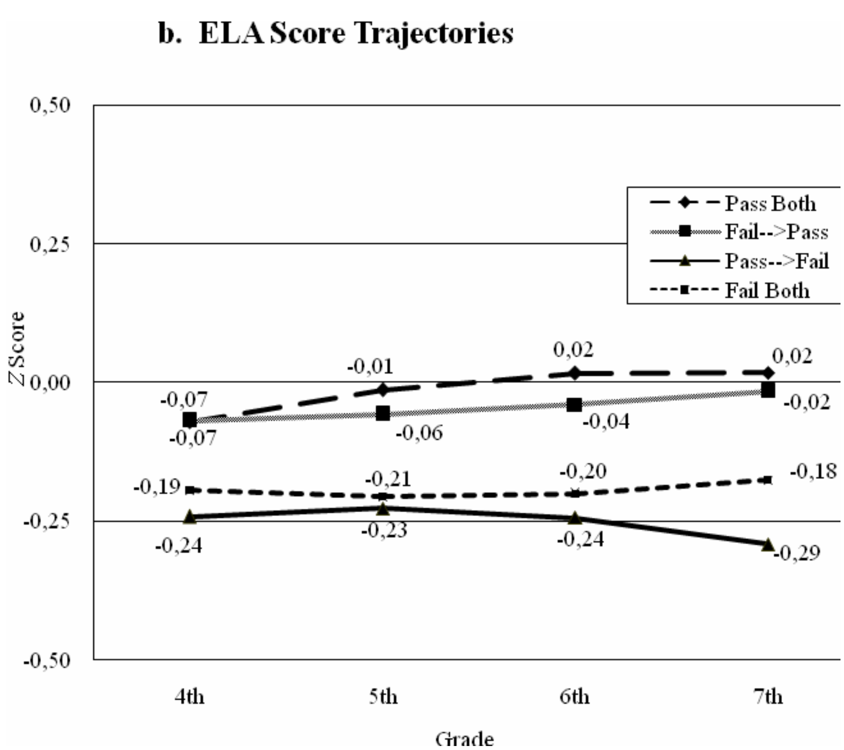
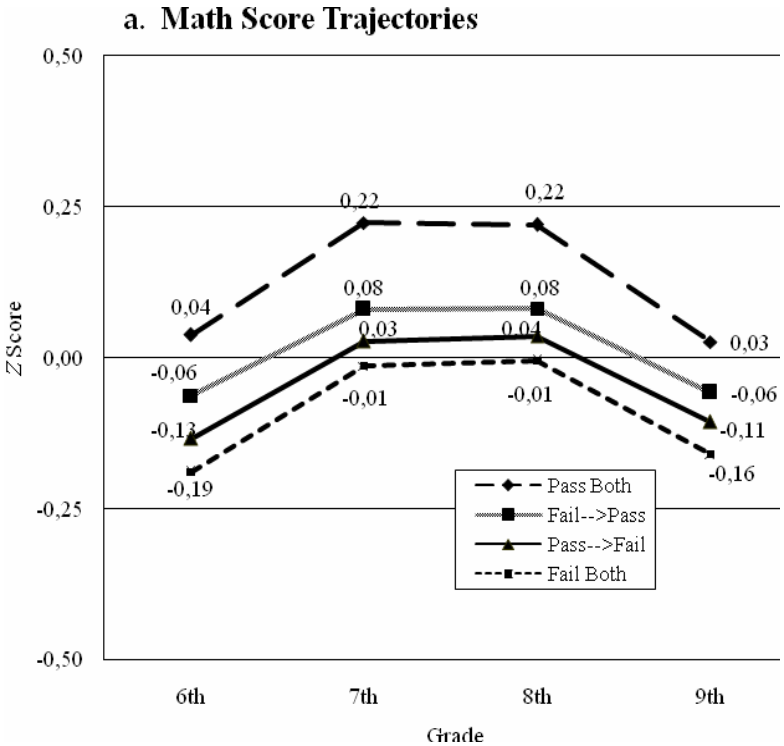


Figure 2. California Standards Test (CST) Score Trajectories from 7th to 9th Grade, by Overall PFT Results



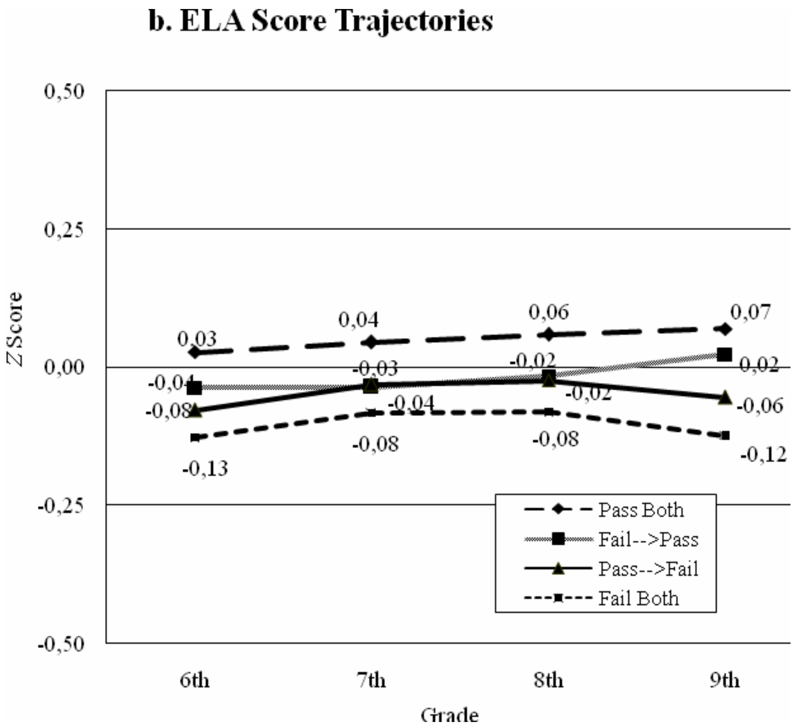
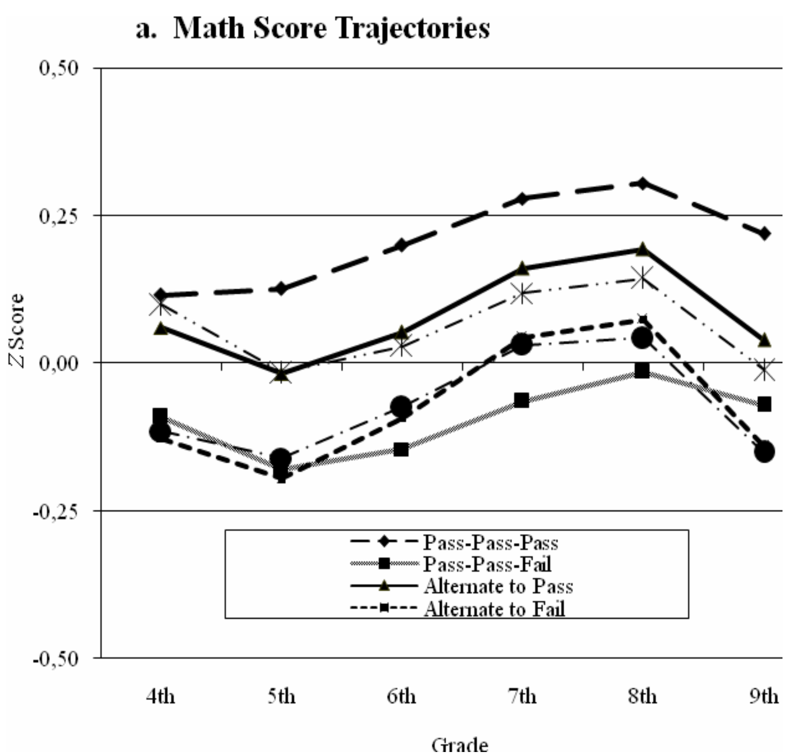
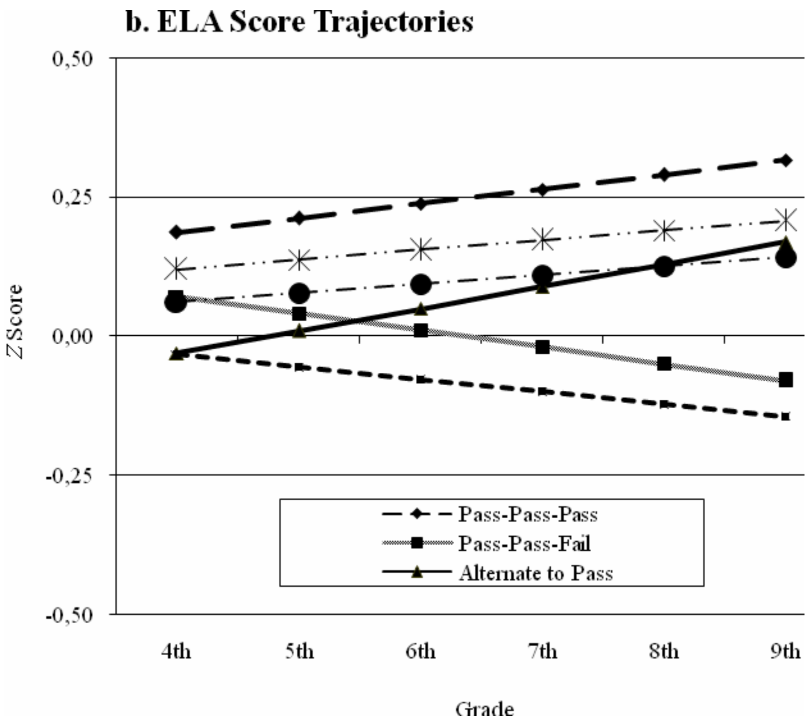


Figure 3. Math and ELA Score Trajectories from 4th to 9th Grade, by Overall PFT Results





b. ELA Score Trajectories
0,50
0,25
0,00
-0,25
-0,50
Z Score
Pass-Pass-Pass
Pass-Pass-Fail
Alternate to Pass
4th
5th
6th
7th
8th
9th
Grade