TRACK AND FIELD

THE CHANGING STATUS QUO

by

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A THESIS

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Since the beginings of track and field the United States has held the dominant position on the international scene. The times however are changing, and in the United States much of the current talk has been focused on the domestic decline in the sport. The goal of this thesis is to examine track and fields troubles statistically and see if the level of performances achieved by American athletes reflects this downward trend in domestic interest.

ACKNOWLEDGEMENTS

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Introduction

Throughout the early twentieth century, while track and field was still a relatively young sport, the United States dominated the world in nearly every event. Now however, the tables are turned. European and Eastern Bloc nations have taken over this role in nearly all events but the sprints. In June of 1991 the most recently contested NCAA Championships was plagued with controversy because the favored team was a contingent constructed mainly of foreigners. Why in American colleges are there track programs that depend more on the prowess of a few foreign superstars than on the talents of our domestic athletes? This year's NCAA pole vault champion, Istvan Bagyula, who set a meet record of nineteen feet, had this to say concerning his scholarship at George Mason University, "If I have taken someone's (an American student's) spot it is no fault of mine. It is a failure of the system. I have been pole vaulting since I was eight, Americans usually don't start till they are thirteen or fourteen.[1]" Perhaps this explains why collegiate coaches are looking to foreigners for the kind of talent that will keep their programs alive.

The May 1991 issue of *Track and Field News* was dedicated to the possibility of an American decline in the sport. In their surveys *Track and Field News* discovered nearly a fifty percent decline in the number of high school age track and field participants. The surveys also pointed out the problems that this causes for college coaches who are trying to maintain

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1. *The Register Guard*, June 1, 1991, p. C1.

quality track and field teams while selecting from a shrinking pool of possible recruits. Collegiate coaches know that their programs and jobs are at risk if they are not successful and this is where the foreign athletes fit into the picture. Not every college coach sees this influx of foreign athletes as bad, though all seem to agree that U.S. track and field is facing big problems and changes are needed to save the sport.

The focus of this paper is not to solve these problems but rather to ask another question. Do the performance levels of United States track and field athletes reflect this decline in domestic interest and participation?

SOURCES OF DATA

To answer this question I chose to make a comparison between the levels of performance of the world's best athletes and those of the nation's best. I also chose to extend this into a comparison of the nation's best athletes and the best collegiate athletes. The first step however was to create a set of performance level indicators. To create these indicators I chose to average the marks of the top six finishers in four different events, the 200 meter run, the 5000 meter run, the pole vault, and the discus throw, at the National Collegiate Athletic Association Championships, the United States Olympic Trials, and the Olympic Games during each olympic year from 1956 to 1988.

This would create a pool of three indicators in each event from each of the nine olympic years in the study for a total of twenty-seven indicators, derived from the 192 performances collected in each of the four events studied.

I considered many different issues before choosing to create the performance level indicators in this particular manner. Most importantly it was neccessary to find a fair set of data to create the indicators from. The three meets used were chosen for several reasons. The purpose of the data was to give an indication of performances at three different levels of competition, international, post collegiate(national), and collegiate levels. Thus the Olympics, the U.S. Olympic Trials, and the NCAA Championships, were chosen to representing the three levels of competition because their difficult entry standards should make them strong indicators of the three respective levels of competition.

The significance placed on winning these meets was another reason they were chosen. Many small meets put high emphasis on setting records or making high marks for bonus money. These three meets, however, are so important that athletes do not concentrate on anything but the competition. The pressure to win these meets is so great that athletes will often lose sight of performances as their desire to win takes over, and consequently results will most often reflect competitive averages for the top finishers as opposed to personal bests. That is to say a pole vaulter who has jumped 19'6" once and averages around 19'0" will usually jump near 19'0" at the Olympics. The reason for this is the effect that pressure has on Athletes Thus the results of these three meets should be good indicators of the level of performance being achieved within each group.

A second reason these meets are a good source of data is their tendency to showcase the best talents at their best. First because only the best athletes are able to enter these meets and second, because the athletes design their training programs to peak at these meets. Consider the U.S. Olympic Trials. This meet is perhaps more important to Americans than the Olympics themselves simply because an athlete cannot win a medal at the Olympics without first placing at the Trials. The Trials showcase the best Americans at their best, because even an athlete ranked nationally number one knows he can be beaten on an off day by a less talented athlete having a great day. The NCAA and the Olympics are similar in this respect.

The competetive significance placed on these meets has another important effect; it reduces the variation in the performances by the top six finishers. To understand this consider the Olympic 5000m run. Because the runners all have a solitary goal in mind, an olympic medal, they will attempt to stay with the pack at all cost until the very last lap of the race. Only then in one last sprint to the finish will a winner be chosen. The result of this type of racing is a tighter finishes than would occur in lesser competitions where perhaps each runner is more concerned with running a specific time then winning the race. This is particularly important in giving a fairer representation of these performance levels. This is also the reason that the data include six places rather than three, because the larger pool tends to reduce the effects on the performance level indicators of having one or two exceptional performances in a given year.

The data begin in 1956 because the decline of which this paper speaks is a relatively recent phenomenon. Shortly after World War II a new era in sports began. With the creation of the several new socialist Eastern Bloc nations sports became political. Since the capitalist economy of the United States was the strongest in the world, the new socialist governments needed to convince the skeptics that they could succeed as well, and one method they chose involved the development of better athletes. These countries invested significantly in athletic facilities, coaching, and technical analysis of athletes. Sports became a science and athletics blossomed. The impact, however, was not felt much prior to 1956 and so in this paper the research begins there[1].

One important note concerning dates is that the year 1968 was removed from the analysis of the running events because the results of the Olympic Trials held in Lake Tahoe and the Olympics held in Mexico City were greatly affected by the altitude of these locations. Results that year deviated so far from the general trends that their inclusion would have greatly increased the variability of the data and possibly reversed the results.

The events chosen were selected to achieve a fair representation of the different levels of performance. The glamour events were avoided so that special emphasis on an event by specific nations would not be likely to skew the results. It

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1. This was explained to me in an interview with Andrzej Krzesinski, coach of the Polish national track and field team from the late fifties to early eighties.

was also important that the study cover each major area of track and field so one event from each of four categories was chosen: from the sprinting events, the 200 meter dash, from the distance events, the 5000 meter run, from the jumps, the pole vault, and from the throws, the discus. In this way each category was to be considered fairly.

It should be noted that there is a significant amount of overlapping in the comparisons that are being made. That is to say the best collegians will often place at the Olympic Trials or the best American will place at the Olympics. This, however, is not a problem when one considers that the world performance levels will more closely follow the U.S. when more Americans are included in the calculation, and they will be farther apart when fewer Americans are among the world's best. Thus the comparison should still be valid if the general premise of an American decline is correct. This argument is similar in the case of collegians at the Olympic Trials.

METHODOLOGY

Under the assumption that there is a decline in interest and participation in track and field and that this decline is limited primarily to the United States, one would expect the gap between the peformance levels of the world's best and that of Americans to be widening. Further one might expect the American post-collegiate athletes to be moving further ahead of the collegiate athletes, this would be particularly true if the decline is rather a more recent phenomenon, because if the current generation of post-collegiate competitors have risen to prominence prior to this period of declining interest they may not be showing any fall in performance whereas the collegiate level is beginning to. To examine the changing performance levels I decided to compare the rates of improvement at each level, because clearly if one group is improving faster than the other that group will eventually begin to move further ahead of the other. Accordingly the first stage of the project involved the estimation of regression models for the performances of each event on time and the square of the time. These models could then be used as the source of rate of improvement information.

FIGURE 1 -- PLOT OF DISCUS DATA

```
         -                                                         A
         -                                            B
         -                                     A      A     A
         -                                     B            B
      208+                              A                          B
         -                        A     B                   C
F        -
E        -                        B
E        -                 A                   C
T     192+                                            C
         -                 B            C                          C
         -          A
         -          B             C
         -
      176+    2            C
         -          C
         -    C
           ------+---------+---------+---------+---------+---------+
               1958      1964      1970      1976      1982      198
                               YEAR
```

A = Olympic Performance Levels B = Trials Performance Levels
C = NCAA Performance Level

Notice the difference in the starting point of the Trials and the NCAA curves in 1956. The question is does this or the differing rates of improvement create the difference in the two curves.

To better understand this consider a comparison of the Olympic Trials discus results to the NCAA discus results. The method is to compare the data sets from each meet to determine whether they are statistically different at a five percent level of certainty and if so determine why. Is the difference simply a reflection of a higher starting point in the Trials data(see Fig. 1), or is it the result of different rates of improvement at the two levels?

To answer this it became necessary to consider the true nature of athletic performances. Most importantly the fact that as performances approach the true limits of human capabilities they begin to advance at a much slower rate. Hence the comparison reduces itself to a final test to determine, with a five percent level of certainty, if the improvements in the two sets of meet results are slowing at different rates.

To answer these questions many tasks had to be performed, performance level indicators were calculated, and for each event these were regressed against time and the square of the time, F-tests were performed to compare the different models, and in the case of a significant F-statistic, T-tests were performed to compare the quadratic coefficients.

Thus as previously mentioned for each event and level of competition being considered it was necessary to find a single indicator for each of the nine Olympic years included in the study. Once this was completed as described in the chapter on data I divided the data into four groups by events, each group containing the performance indicators for each level over time.

Then for each event I estimated five quadratic regression functions with the performance levels as the dependent variable and time and the square of time as the independent variables. One regression was estimated pooling the Olympic Trials data and the Olympic data into one larger combined model, another regression was estimated on only the Olympic data, and still a third was estimated using only the Olympic Trials data. Then to determine if there was a significant statistical difference between the Trials data and the Olympic data, I used an F-test to compare the results of the regression for the combined data with the results of the two separate regressions. In comparing the the results of the Olympic Trials to those of the NCAA Championships I used the same methods only this time the combined model included the Olympic Trials and NCAA Championship data, and it was not necessary to re-estimate the Olympic Trials regression.

In the cases where I was able to demonstrate a significant statistical difference between the combined model and the model of two separate levels, it was then necessary to determine if this difference could be reasonably be attributed to differing rates of improvement at the two levels of competition, which would imply that the gap between the two levels of competition is changing.

Hence, the next step is to examine the models that are significantly different and determine if it can be demonstrated with a high degree of confidence that one level of performance is advancing at a faster rate than the other. The particular interest being to show that the Olympics are moving farther ahead of the Trials or that the Trials are outdistancing the NCAA. In analyzing this question I chose to examine in particular the quadratic coefficients in the regression estimates from each meets individual data sets. This was done because performance level curves all increase(or decrease in the case of running events) continuously through time at a diminishing rate. The quadratic coefficient is the reason for this change in rate, because its sign is opposite of the slope coefficient.

It is known that the Olympic results are at a higher level than the trials results. The issue is whether the Olympic results are moving farther away from the Trials results. This can be answered by examining the magnitude of the quadratic coefficients. If the quadratic coefficient in the Trials regression can be shown with five percent confidence to be of greater magnitude than that in the Olympic regression it would appear that the Trials results are falling further behind the Olympics. Thus I utilized a one sided T-test to discover with what confidence the quadratic coefficient on the Olympic level was of smaller magnitude than that on the Trials level. Again the test was performed similarly in comparing the Trials to the NCAA.

RESULTS

As described in the previous section there were two basic tests performed in this study. The first, the F-test, was used to determine in which events the data indicated significant differences in the performance levels at the three meets.

Particularly two comparisons were made one between the results of the Olympic Games and Olympic Trials and the second between the Olympic Trials and the NCAA Championships.

The results of this test are listed in the following table where the indicated comparisons are listed with their results. The important thing to understand is that an F-test is the calculation of a statistic which is known, upon the condition that the data sets being compared are drawn from the same distribution, to follow a specific probability distribution, the F-distribution. Thus if the calculated value of the statistic falls into the last five percent of the F-distribution, one can say with 95% confidence that the data sets are not distributed the same. The numerical value indicating the lower bound of this last five percent is called the five percent significance level, which is in this case 3.5.

Thus, in the comparisons of the data from the Olympic Games and the Olympic Trials, the 5000m and discus showed significant differences at these two levels with F-tests of both higher than 3.5. Table 1 has the actual results. Further in the comparisons of the Olympic Trials to the NCAA Championships it is clear that 5000m, pole vault and discus all demonstrated differences at the five percent level (again the actual results are listed below).

Table 1 F-TEST RESULTS

	200m	5000m	Pole Vault	Discus	5% Level
Olympics VS Trials	1.3	41.2	0.6	3.8	3.5
Trials VS NCAA's	0.5	5.1	20.3	13.2	3.5

The second test performed was the T-test which was used to determine if the data sets which were indicated to be significantly different displayed significant diffences in rates of improvement, as indicated by the quadratic coefficients. The test is performed much the same as the F-test except that a diffent statistic is calculated and the fact that the T-distribution is centered around zero where the F-distribution is strictly positive. The effect of this is that a significant results in the tests of running events must be less than -1.81, while in the field event it must be greater than 1.78.

Table 2 lists the results of the T-tests for the running events and field events. Looking at the comparison of the quadratic

Table 2 T-TEST RESULTS

The results of the T-tests on the running events are significant only where they are less than the 5% level indicator, and on the field events only where they are greater. T-tests were not performed wherever the * indicates it, because the data was not different in the F-test.

Running Events	200m	5000m	5% Level
Olympics vs Trials	*	-3.44	-1.81
Trials vs NCAA's	*	-0.57	-1.81

Field Events	Pole Vault	Discus	5% Level
Olympics vs Trials	*	0.34	1.78
Trials vs NCAA's	0.45	-1.40	1.78

coefficients from the Olympic Games regressions and the Trials regressions only in the 5000m are the differences significant, where the result of -3.44 is considerably less than the five percent significance level of -1.81.

When the quadratic coefficients of the Olympic Trials regressions were compared to those in the NCAA regressions the results were not as interesting because the differences were not significant in any of the four events.

In summary a significant difference in the following sets of data was found with the use of F-tests in the comparison of the Olympic Games and the Olympic Trials, in the 5000m and discus. Similarly the comparison of the data sets from the Olympic Trials and NCAA Championships showed significant differences in the 5000m, pole vault and discus. However, of these five pairs, which showed significant difference, only in the comparison of Olympic Games and Trials 5000m regressions did the T-tests show the quadratic coefficients to be significantly different also.

DISCUSSION

In this analysis eight F-statistics were calculated and of those, five showed significance at the five percent level. T-tests were then calculated to compare the quadratic coefficients in these five examples, and of these five only one, the 5000m run, demonstrated significant results.

From these results we can say with 95% confidence that in a comparison of the world's best athletes, represented by the Olympic games results, and the United States' best athletes, represented by the U.S. Olympic Trials results, the world's athletes are moving ahead of America's in the 5000m. On the other hand, though the data seems to suggest it, statistical testing does not permit this conclusion to be drawn on the 200m run, discus or pole vault. Neither can it be said with confidence that the U.S. post-collegiate athletes are improving faster than the collegiate athletes in the 200m run, 5000m run, discus, or pole vault.

This, however, does not seem to tell the whole story in four of the five cases where the models were significantly different. The quadratic coefficients in the two models were ordered as would be expected if the two groups of performances were moving apart. The comparison of the NCAA discus to the Trials discus was the only case in which the quadratic coefficients did not suggest that the improvement rates of the lower level of competition were dropping off faster. Thus in the 5000m and discus a comparison of the world and American estimated regressions suggested that the U.S. was falling behind the world. Similarly in the comparison of the 5000m and pole vault, at the U.S. post-collegiate and collegiate levels, the regressions suggest that the decline is reflected in the widening gap between the two groups.

This circumstance would indicate that the differences in the quadratic coefficient are probably more important than these tests with these data can demonstrate. The most likely reason for this discrepancy would be a lack of data. Though the project seemingly started out with a large amount of data, after the calculation of performance level indicators the data set used to estimate the regression equations had shrunk to a group of nine data points for field events and eight for running events. This seems to be enough data to demonstrate the trends but perhaps it's not enough to make them statistically meaningful.

Now that this work is done it would seem perhaps appropriate to repeat the experiment with performance indicators representing every year in the test range as opposed to just the Olympic years. This would quadruple the data field of the regression, and consequently increase the degrees of freedom in the tests, while perhaps even reducing the model's standard deviation, which may be affected by the time gaps between the Olympic years. However, since there are no annual meets conducted at an international level between the Olympic years. I do not know of any way in which unbiased data can be collected on a yearly basis. Moreover there is a cyclical nature to the performances established throughout the years and hence off years, which do not include an the Olympics or World Championships, will tend to reflect lower levels of performance.

The results of this examination may have more significance than to reveal of a lack of data. The fact that track and field in the United States, which is known to be suffering a severe decline in participation at the younger levels[1], is not falling significantly further behind the world may indicate a greater problem for the sport. This decline could be a larger, more worldwide phenomenon than many American track and field coaches,

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1. *Track and Field News*, May 1990, p. 5.

Figure 2 -- PLOT OF 5000M DATA

```
         -                         B
         -
         -    C
    14.70+    B      C
         -
T        -           B
I        -                  C
M        -                  B      2
E   14.00+    A                             C                  C
         -                  A                     C     C
         -           A             C        B                  B
         -                         B              B     B
         -                         A        A     A
    13.30+                                                     A
         -                                              A
         -
           ------+---------+---------+---------+---------+---------+
     YEAR      1958      1964      1970      1976      1982      198
```

A = Olympic Performance Levels   B = Trials Performance Levels
C = NCAA Performance Levels

Note the significant down turn in performances during the last three Olympic years, a trend occuring at all levels.

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athletes, and administrators have been hereto willing to acknowledge. Looking at Figures 1 through 4 one can see a drastic flattening out of the performance curves, occuring not just at the American levels but also at the world levels. In particular the 1980, 1984, and 1988 years are representative of a significant reduction in the rates of improvement in the 5000m (Figure 2), discus (Figure 1), and pole vault (Figure 3). On a national level the 5000m and discus suffered a major decline and in the 5000m even at the world level.

FIGURE 3 -- PLOT OF POLE VAULT DATA

```
         -                                                         A
         -                                            A     B      B
         -                                            B     A
     18.0+                                     A
         -                        A     B      B            C      C
 H       -                              A      C      C
 E       -
 I       -                        B     C
 G   16.5+                 A
 H       -                 B      C
 T       -
         -                 C
         -          B
     15.0+          A
         -    B
         -    2     C
         -
           ------+---------+---------+---------+---------+---------+
     YEAR      1958      1964      1970      1976      1982      1988
```

A = Olympic Performance Level   B = Trials Performance Level
C = NCAA Performance Level

Once again note how the rate of improvement dropped significantly in the last three Olympic years at all levels of competition, as indicated by the flattening of the performance curves.

This result seems particularly strange when one remembers the U.S. boycott of the 1980 Olympics in Moscow and the Eastern Bloc boycott of the the 1984 Olympics in Los Angeles. Presumably the effect of these boycotts would be exactly the opposite of that actually realized. The lack of participation in the 1980 and 1984 Olympics should have diminished the performances in these two years relative to 1988 when world participation was complete, but on the contrary the performances in the 5000m and discus were significantly worse in 1988 than the two previous. Perhaps the decline in track and field is a much more recent issue than this examination can detect. If more data can be found to make a similar but much shorter term examination possible, I believe that this recent decline will be reflected in the performance levels and their rates of change.

In this examination, however, I was unable to discover enough statistical evidence in the data to draw any definite conclusions concerning the relative statuses of international, U.S. post collegiate, and collegiate track and field performances. This doubt does not however negate the many questions which it has brought up. Particularly as concerns the possibility of the current decline in track and field occuring on a broader scale than previously thought, because the data does not reflect well on recent performances at any level. The other question brought up was the possibility of this being a much more recent occurence than was tested for in this study. The thing I fear most is that if neither of these questions are examined statistically the few people with the power to turn track and field from it's current path will never recognize the need.

APPENDIX

The information supplied in this appendix is designed so that the reader may be able to repeat the tests and confirm the results if so desired. Further detail is also included in this appendix as concerns the actual statistical tests that were used.

To simplify the explanation of the testing procedure I will use the tests performed in comparing the Olympic and Olympic Trial 5000m results as an example. To begin with, it is understood that the data sets of each event and year were divided into three categories by the meets from which they were taken. Now in the comparison of two meets the question becomes: Can the data in these two meets be described best by a model that partitions the data from the two meets into two regression equations or by a model that combines the data from both into one larger regression equation? More specifically, does the data give statistically significant differences between the two meets?

To answer this question I calculated an F-test. The test statistic used in the tests is as follows:

$$\frac{(RRSS - URSS) / q}{URSS / (n - k)} \quad \text{which is distributed} \quad F_{q,\, n-k}$$

if the hypothesis of no differences is true.

RRSS = residual sum of squares in the restricted model
URSS = unresticted residual sum of squares
q = number of restrictions
n = number of data points
k = number of regression coefficients estimated in unresticted model

The restricted model, the one in which fewer parameters are estimated, was the model for which the data from the two meets were combined. The model in which the meets were separated was the unresticted model. In the restricted model a single quadratic regression was calculated and thus three coefficients estimated the one on each of the constant, the year, and the year squared, in turn the RRSS is simply the error sum of squares from this regression. The unresticted model was created similarly but instead of using a single regression it used the combination of two separate quadratic regressions, one calculated for each meet. The URSS thus is the sum of the error sum of squares from the Olympic regression and the error sum of squares from the Trials regression. The next point is that, q, the number of restictions in the F-test, is defined as the difference between the number of coefficients estimated in the unrestricted model and the number estimated in the restricted model. Thus for these tests q equals three, that is the six coefficients which are computed in the two quadratic regressions of the unrestricted model minus the three coefficients estimated in the restricted model. The number of data points, n, in the running events equals sixteen and in the field events equals eighteen. I calculated an F-statistic and compared this with the upper five percent point of the F distribution with q degrees of freedom in the numerator and $n - k$ degrees of freedom in the denominator.

In this case if the unrestricted model is appropriate the resulting F-statistic should be large. The five percent significance level for an F-statistic with 3 degrees of freedom in the numerator and 10 degrees of freedom in the denominator is

3.7. Plugging the results from Table 8, and Table 9, on the 5000m, into this equation gives a F-statistic of 41.2 which is much larger than the five percent point of 3.7, demonstrating that the unrestricted model is more appropriate.

This, however, shows only that there is a statistically significant difference between the Olympics and the Trials results. It does not tell us if the Olympic performances are improving faster than the Trials performances. To answer this question it was necessary to calculate a one sided t-test. The idea behind the use of the T-test was to determine if it could be said with confidence that the quadratic coefficient in the Olympic regression would be of smaller magnitude than that in the Trials regression or similarly with the Trials and the NCAA estimates. A one sided T-test on the quadratic coefficients was the best way to answer this question. In the case of a running event comparing the Olympic and Trials levels the test is set up as follows:

$$H0: B_2o >= B_2t$$

$$H1: B_2o < B_2t$$

reject H0 if

$$\frac{B_2o - B_2t}{(s^2(B_2o) + s^2(B_2t))^{1/2}} < -t_{n-k,\ .05}$$

where

B_2o = quadratic coeficient of olympic results
B_2t = quadratic coefficient of trials results
$s^2(B_2o)$ = square of standard error of B_2o
$s^2(B_2t)$ = square of standard error of B_2t
n = total number of data points used in the two regressions
k = total number of parameters estimated in the two regressions

The data required in this test can easily be retrieved from the individual meet regressions which have already been estimated, Table 8 and Table 9 in the case of the 5000m. In this instance from Table 9, B_2o equals 0.00516 and $s^2(B_2o)$ equals the 0.004867^2, from Table 8, B_2t equals 0.0299 and $s^2(B_2t)$ equals 0.005289^2. Plugging these into the above equations gives a t-statistic equal to -3.4420 which is less than $-t_{10,\ .05}$, which equals -1.81, and thus H0 can be rejected with 95% confidence. To make this same comparison between the NCAA and the Trials level, a simple substitution of the Trials estimates for B_2o, and the NCAA estimates for B_2t in the same formula will suffice. It must also be noted that if the test is being done on a field event the test is changed in the following manner. The order notation in the hypothesis would be reversed, H0 becomes $B_2o <= B_2t$ and H1 becomes $B_2o > B_2t$, and the hypothesis is then rejected if the test statistic, which remains unchanged, is greater than positive $t_{n-k,\ .05}$. The reason for this is that the curve coefficient for the field events is negative while it is positive in the running events. Thus to maintain the general principle of the test, which is to determine whether the magnitude of the quadratic coefficient is significantly lesser in the case of the higher level competition, it is necessary to reverse the ordering of the hypothesis and the rejection rule.

To conclude it should be said that this appendix defines only the tests which were determined relevant in the final compilation of the results. A great variety of tests were performed during this study though the results suggested a need to report only on the tests I have just described.

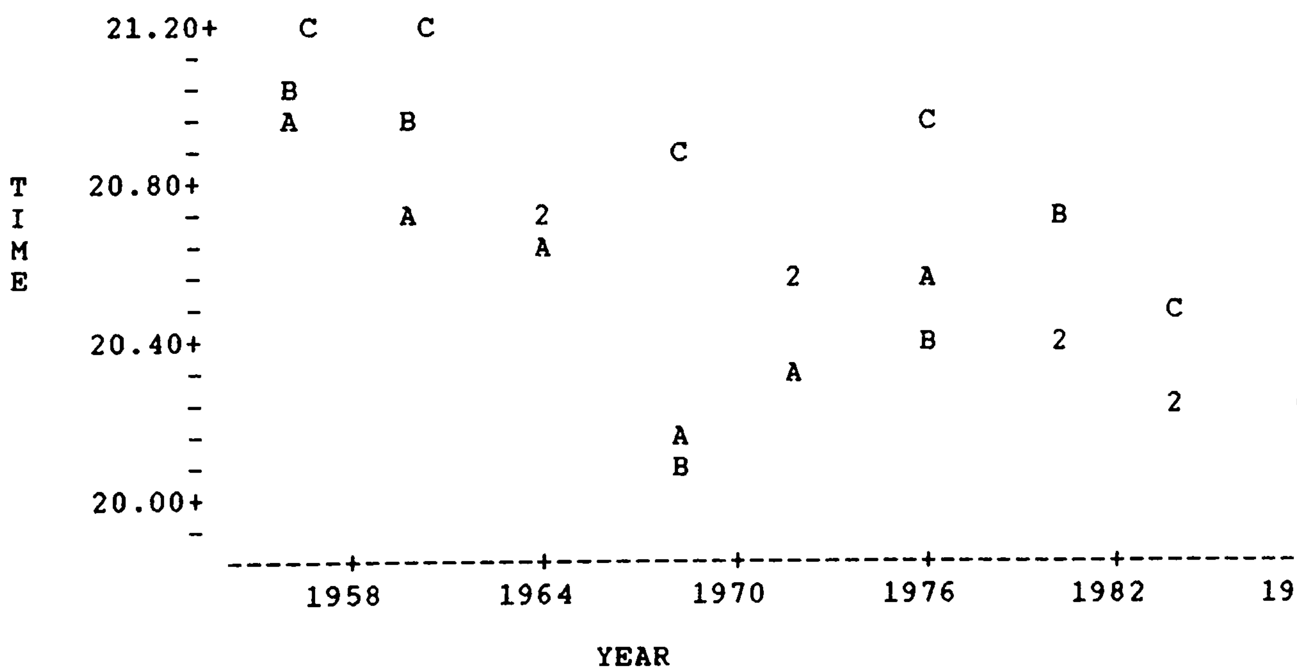
TABLE 1

200m performance level data.
The table lists the adjusted year as it was used in the regression equations. This was defined as such:
(actual year - 1952) / 4.

ROW	year	ncaa	ot	olys	$year^2$
1	9	20.268	20.127	20.077	81
2	8	20.465	20.280	20.230	64
3	7	20.383	20.683	20.362	49
4	6	20.950	20.385	20.540	36
5	5	20.533	20.600	20.328	25
6	4	20.867	20.050	20.200	16
7	3	20.700	20.717	20.617	9
8	2	21.200	20.950	20.717	4
9	1	21.183	21.017	20.967	1

FIGURE 4

PLOT OF 200m DATA.



A = olys vs. year
B = ot vs. year
C = ncaa vs. year

TABLE 2

Regression of NCAA 200m data on year and the square of the year.

The regression equation is
$$ncaa = 21.3 - 0.139\ year + 0.0033\ year^2$$

Predictor	Coef	Stdev	t-ratio	p
Constant	21.3118	0.2850	74.79	0.000
year	-0.1392	0.1365	-1.02	0.355
$year^2$	0.00332	0.01349	0.25	0.815

s = 0.2221   R-sq = 73.0%   R-sq(adj) = 62.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	0.66844	0.33422	6.77	0.038
Error	5	0.24674	0.04935		
Total	7	0.91518			

SOURCE	DF	SEQ SS
year	1	0.66545
$year^2$	1	0.00299

TABLE 3

Regression of Trials 200m data on year and year squared.

The regression equation is
$$ot = 21.1 - 0.0858\ year - 0.00137\ year^2$$

Predictor	Coef	Stdev	t-ratio	p
Constant	21.0805	0.1883	111.94	0.000
year	-0.08576	0.09023	-0.95	0.386
$year^2$	-0.001371	0.008914	-0.15	0.884

s = 0.1468   R-sq = 84.4%   R-sq(adj) = 78.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	0.58136	0.29068	13.49	0.010
Error	5	0.10775	0.02155		
Total	7	0.68911			

SOURCE	DF	SEQ SS
year	1	0.58085
$year^2$	1	0.00051

TABLE 4

Regression of Olympics 200m data on year and the sqare of the year.

The regression equation is
olys = 21.0 - 0.122 year + 0.00290 $year^2$

Predictor	Coef	Stdev	t-ratio	p
Constant	21.0054	0.1485	141.43	0.000
year	-0.12157	0.07116	-1.71	0.148
$year^2$	0.002896	0.007030	0.41	0.697

s = 0.1158 R-sq = 88.4% R-sq(adj) = 83.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	0.51062	0.25531	19.05	0.005
Error	5	0.06702	0.01340		
Total	7	0.57764			

SOURCE	DF	SEQ SS
year	1	0.50835
$year^2$	1	0.00227

TABLE 5

Regression of combined NCAA and Trials 200m data on year and year squared.

The regression equation is
ncots = 21.2 - 0.112 yy + 0.00097 yysquare

Predictor	Coef	Stdev	t-ratio	p
Constant	21.1962	0.1615	131.23	0.000
year	-0.11246	0.07739	-1.45	0.170
$year^2$	0.000975	0.007646	0.13	0.901

s = 0.1781 R-sq = 75.1% R-sq(adj) = 71.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	1.24538	0.62269	19.64	0.000
Error	13	0.41216	0.03170		
Total	15	1.65753			

SOURCE	DF	SEQ SS
year	1	1.24486
$year^2$	1	0.00052

TABLE 6

Regression of combined Olympics and Trials 200m data on year and the square of year.

The regression equation is
$OLY\&OT = 21.0 - 0.104\ year + 0.00076\ year^2$

Predictor	Coef	Stdev	t-ratio	p
Constant	21.0430	0.1210	173.86	0.000
year	-0.10367	0.05799	-1.79	0.097
$year^2$	0.000762	0.005730	0.13	0.896

s = 0.1334   R-sq = 82.5%   R-sq(adj) = 79.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	1.08831	0.54415	30.56	0.000
Error	13	0.23146	0.01780		
Total	15	1.31977			

SOURCE	DF	SEQ SS
year	1	1.08799
$year^2$	1	0.00032

TABLE 7

5000m performance level data.
Again year in this table is adjusted as it was used in the regressions.

ROW	year	ncaa	ot	olys	$year^2$
1	9	13.965	13.766	13.296	81
2	8	13.814	13.532	13.185	64
3	7	13.875	13.588	13.372	49
4	6	13.959	13.717	13.428	36
5	5	13.702	13.635	13.481	25
6	4	14.117	15.053	14.159	16
7	3	14.234	14.123	13.836	9
8	2	14.667	14.445	13.789	4
9	1	14.899	14.639	13.952	1

TABLE 8

Regression of NCAA 5000m data on year and the square of the year.

The regression equation is
$ncaa = 15.4 - 0.470\ year + 0.0352\ year^2$

Predictor	Coef	Stdev	t-ratio	p
Constant	15.3664	0.1617	95.02	0.000
year	-0.47038	0.07748	-6.07	0.002
$year^2$	0.035201	0.007655	4.60	0.006

s = 0.1261   R-sq = 93.9%   R-sq(adj) = 91.4%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	1.21492	0.60746	38.23	0.001
Error	5	0.07946	0.01589		
Total	7	1.29437			

SOURCE	DF	SEQ SS
year	1	0.87889
$year^2$	1	0.33603

TABLE 9

Regression of Trials 5000m data on year and the square of the year.

The regression equation is
$ot = 15.1 - 0.424\ year + 0.0299\ year^2$

Predictor	Coef	Stdev	t-ratio	p
Constant	15.0955	0.1117	135.12	0.000
year	-0.42358	0.05353	-7.91	0.001
$year^2$	0.029918	0.005289	5.66	0.002

s = 0.08709   R-sq = 96.9%   R-sq(adj) = 95.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	1.20189	0.60094	79.23	0.000
Error	5	0.03792	0.00758		
Total	7	1.23981			

SOURCE	DF	SEQ SS
year	1	0.95914
$year^2$	1	0.24274

TABLE 10

Regression of Olympic 5000m data on year and the square of the year.

The regression equation is
$olys = 14.1 - 0.144\ year + 0.00516\ year^2$

Predictor	Coef	Stdev	t-ratio	p
Constant	14.1074	0.1028	137.20	0.000
year	-0.14414	0.04927	-2.93	0.033
$year^2$	0.005165	0.004867	1.06	0.337

s = 0.08015   R-sq = 94.2%   R-sq(adj) = 91.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	0.51700	0.25850	40.24	0.001
Error	5	0.03212	0.00642		
Total	7	0.54913			

SOURCE	DF	SEQ SS
year	1	0.50977
$year^2$	1	0.00723

TABLE 11

Regression of combined NCAA and Trials 5000m data on year and the square of the year.

The regression equation is
$NCAA\&OT = 15.2 - 0.447\ year + 0.0326\ year^2$

Predictor	Coef	Stdev	t-ratio	p
Constant	15.2310	0.1370	111.21	0.000
year	-0.44698	0.06562	-6.81	0.000
$year^2$	0.032560	0.006483	5.02	0.000

s = 0.1510   R-sq = 89.1%   R-sq(adj) = 87.4%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	2.4121	1.2061	52.91	0.000
Error	13	0.2963	0.0228		
Total	15	2.7085			

SOURCE	DF	SEQ SS
year	1	1.8372
$year^2$	1	0.5750

TABLE 12

Regression of combined Olympics and Trials 5000m data on year and the square of year.

The regression equation is
$$OLY\&OT = 14.6 - 0.284\ year + 0.0175\ year^2$$

Predictor	Coef	Stdev	t-ratio	p
Constant	14.6015	0.2238	65.25	0.000
year	-0.2839	0.1072	-2.65	0.020
$year^2$	0.01754	0.01059	1.66	0.122

s = 0.2467   R-sq = 66.9%   R-sq(adj) = 61.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	1.60059	0.80030	13.15	0.001
Error	13	0.79129	0.06087		
Total	15	2.39189			

SOURCE	DF	SEQ SS
year	1	1.43370
$year^2$	1	0.16689

TABLE 13

Discus performance level data.

ROW	year	ncaa	ot	olys	$year^2$
1	9	187.75	209.08	219.70	81
2	8	205.76	210.17	215.07	64
3	7	193.26	216.79	215.76	49
4	6	195.28	210.64	213.83	36
5	5	187.33	203.36	207.33	25
6	4	183.96	197.08	204.58	16
7	3	177.33	189.49	193.94	9
8	2	172.89	183.47	186.08	4
9	1	169.94	177.07	177.38	1

TABLE 14

Regression of NCAA discus data on year and the square of the year.

The regression equation is
$$ncaa = 158 + 8.88\ year - 0.533\ year^2$$

Predictor	Coef	Stdev	t-ratio	p
Constant	158.420	7.334	21.60	0.000
year	8.881	3.368	2.64	0.039
$year^2$	-0.5330	0.3284	-1.62	0.156

s = 5.764   R-sq = 80.9%   R-sq(adj) = 74.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	843.88	421.94	12.70	0.007
Error	6	199.34	33.22		
Total	8	1043.21			

SOURCE	DF	SEQ SS
year	1	756.36
$year^2$	1	87.51

TABLE 15

Regression of Trials discus data on year and the square of the year.

The regression equation is
$$ot = 163 + 12.0\ year - 0.737\ year^2$$

Predictor	Coef	Stdev	t-ratio	p
Constant	163.146	4.338	37.61	0.000
year	11.975	1.992	6.01	0.001
$year^2$	-0.7370	0.1942	-3.79	0.009

s = 3.409   R-sq = 95.4%   R-sq(adj) = 93.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	1439.66	719.83	61.94	0.000
Error	6	69.72	11.62		
Total	8	1509.39			

SOURCE	DF	SEQ SS
year	1	1272.36
$year^2$	1	167.30

TABLE 16

Regression of Olympic discus data on year and yearPT2PT.

The regression equation is
olys = 166 + 11.8 year - 0.661 $year^2$

Predictor	Coef	Stdev	t-ratio	p
Constant	165.859	2.224	74.59	0.000
year	11.764	1.021	11.52	0.000
$year^2$	-0.66113	0.09957	-6.64	0.001

s = 1.748   R-sq = 99.0%   R-sq(adj) = 98.6%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	1727.41	863.71	282.83	0.000
Error	6	18.32	3.05		
Total	8	1745.74			

SOURCE	DF	SEQ SS
year	1	1592.79
$year^2$	1	134.62

TABLE 17

Regression of combined NCAA and Trials discus data on year and year squared.

The regression equation is
NCAA&OT = 161 + 10.4 year - 0.635 $year^2$

Predictor	Coef	Stdev	t-ratio	p
Constant	160.783	7.906	20.34	0.000
year	10.428	3.630	2.87	0.012
$year^2$	-0.6350	0.3540	-1.79	0.093

s = 8.787   R-sq = 66.0%   R-sq(adj) = 61.4%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	2243.8	1121.9	14.53	0.000
Error	15	1158.2	77.2		
Total	17	3402.0			

SOURCE	DF	SEQ SS
year	1	1995.4
$year^2$	1	248.4

TABLE 18

Regression of combined Olympics and Trials discus data.

The regression equation is
$$Oly\&OT = 165 + 11.9\ year - 0.699\ year^2$$

Predictor	Coef	Stdev	t-ratio	p
Constant	164.503	3.047	53.99	0.000
year	11.869	1.399	8.48	0.000
$year^2$	-0.6991	0.1364	-5.12	0.000

s = 3.386   R-sq = 94.8%   R-sq(adj) = 94.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	3157.2	1578.6	137.66	0.000
Error	15	172.0	11.5		
Total	17	3329.2			

SOURCE	DF	SEQ SS
year	1	2856.2
$year^2$	1	301.0

TABLE 19

Pole vault data.

ROW	year	ncaa	ot	olys	$year^2$
1	9	17.727	18.718	18.832	81
2	8	17.792	18.563	18.288	64
3	7	17.514	18.181	18.528	49
4	6	17.337	17.823	17.958	36
5	5	16.875	17.733	17.472	25
6	4	16.312	16.924	17.608	16
7	3	15.625	16.125	16.573	9
8	2	14.542	15.285	14.988	4
9	1	14.333	14.798	14.455	1

TABLE 20

Regression of NCAA pole vault data on year and year squared.

The regression equation is
ncaa = 13.1 + 1.02 year - 0.0548 $year^2$

Predictor	Coef	Stdev	t-ratio	p
Constant	13.1022	0.2550	51.38	0.000
year	1.0167	0.1171	8.68	0.000
$year^2$	-0.05479	0.01142	-4.80	0.003

s = 0.2004 R-sq = 98.3% R-sq(adj) = 97.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	14.1120	7.0560	175.65	0.000
Error	6	0.2410	0.0402		
Total	8	14.3530			

SOURCE	DF	SEQ SS
year	1	13.1873
$year^2$	1	0.9246

TABLE 21

Regression of Trials pole vault data on year and $year^2$.

The regression equation is
ot = 13.7 + 0.990 year - 0.0481 $year^2$

Predictor	Coef	Stdev	t-ratio	p
Constant	13.7026	0.2185	62.72	0.000
year	0.9895	0.1003	9.86	0.000
$year^2$	-0.048077	0.009783	-4.91	0.003

s = 0.1717 R-sq = 98.9% R-sq(adj) = 98.6%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	16.2415	8.1207	275.50	0.000
Error	6	0.1769	0.0295		
Total	8	16.4184			

SOURCE	DF	SEQ SS
year	1	15.5296
$year^2$	1	0.7119

TABLE 22

Regression of Olympic pole vault data on year and year squared.

The regression equation is
$$\text{olys} = 13.2 + 1.28\ \text{year} - 0.0757\ \text{year}^2$$

Predictor	Coef	Stdev	t-ratio	p
Constant	13.1632	0.4554	28.90	0.000
year	1.2843	0.2091	6.14	0.001
year^2	-0.07565	0.02040	-3.71	0.010

s = 0.3579   R-sq = 96.0%   R-sq(adj) = 94.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	18.4771	9.2386	72.11	0.000
Error	6	0.7687	0.1281		
Total	8	19.2458			

SOURCE	DF	SEQ SS
year	1	16.7144
year^2	1	1.7627

TABLE 23

Regression of combined NCAA and Trials pole vault data on year and year squared.

The regression equation is
$$\text{NCAA\&OT} = 13.4 + 1.00\ \text{year} - 0.0514\ \text{year}^2$$

Predictor	Coef	Stdev	t-ratio	p
Constant	13.4024	0.3699	36.23	0.000
year	1.0031	0.1698	5.91	0.000
year^2	-0.05143	0.01656	-3.11	0.007

s = 0.4111   R-sq = 92.3%   R-sq(adj) = 91.2%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	30.299	15.149	89.64	0.000
Error	15	2.535	0.169		
Total	17	32.834			

SOURCE	DF	SEQ SS
year	1	28.669
year^2	1	1.630

TABLE 24

Regression of combined Olympics and Trials pole vault data on year and year squared.

The regression equation is

$$\text{otoly} = 13.4 + 1.14\ \text{year} - 0.0619\ \text{year}^2$$

Predictor	Coef	Stdev	t-ratio	p
Constant	13.4329	0.2426	55.37	0.000
year	1.1369	0.1114	10.21	0.000
year^2	-0.06186	0.01086	-5.69	0.000

s = 0.2696 R-sq = 96.9% R-sq(adj) = 96.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	34.591	17.295	237.91	0.000
Error	15	1.090	0.073		
Total	17	35.681			

SOURCE	DF	SEQ SS
year	1	32.233
year^2	1	2.358

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