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AUTHOR Henson, Phillip; And Others
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ABSTRACT

Talent identification in most sports occurs through mass participation and the process of natural selection; track and field does not enjoy such widespread participation. This paper reports on a project undertaken for the following purposes: improve the means by which youth with the potential for high level performance can be identified; develop normative tables for scores on various tests known to be indicators of track and field performance; develop statistically based equations for predicting future performance from test scores; establish norms for males and females at various competitive levels and different events; begin developing a scientifically rigorous method of predicting potential performance as well as the event that would be most appropriate for a particular athlete; and create a database that could be used for comparisons in the future. Approximately 1,200 male and female athletes throughout the country representing a wide range of abilities were evaluated using a series of tests of muscular power and speed, and anthropometric measures. Based on results, norms and predictive equations were constructed for several categories including sex, event, and level of competition (i.e., high school, college). Recommendations regarding a methodology for future talent identification and 26 statistical tables are included. (Contains 26 references.) (LL)

TALENT IDENTIFICATION IN TRACK AND FIELD

Report Submitted to The Athletics Congress

by

Phillip Henson, Ph.D.
Indiana University
Bloomington, IN

Paul Turner, M.S., M.A.
Indiana University
Bloomington, IN

Michael G. Lacourse, Ph.D.
California Polytechnic State University
San Luis Obispo, CA

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We would also like to thank Roseann Barnhill, Greg Wilson, and Terry Kristan for their assistance in testing at various sites throughout the midwest.

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SUMMARY

The purpose of this project was to begin developing normative tables for the scores on various tests that were known to be indicators of track and field performance, and to develop statistically based equations for predicting future performance from the test scores. Several tests were determined to be related to track and field performance. Approximately 1200 males and females of all ages from throughout the United States were then tested. From this information, normative tables were constructed for several categories, including, sex, event, and level of competition (i.e., high school, college). In addition, equations were developed to predict performance potential based on test scores. Recommendations are made regarding a methodology for talent identification in the future.

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INTRODUCTION

The identification of persons capable of high level performance is an obligatory function of society. This is true not only for identifying future intellectuals, musicians, artists, and writers, but for athletes as well. Athletics, like other performance oriented activities, are a means by which we test the limits of the human potential. The sport of track and field, perhaps the purest of the athletic endeavors, requires a lifelong commitment to achieve the highest levels. This project was undertaken to improve the means by which youths with the potential for high level performance can be identified at an early age (or at any age) and encouraged to participate.

Talent identification occurs in many other sports in the United States and within track and field in many other countries. Identification in most sports occurs through mass participation and the process of natural selection. This means is only effective however, if there is mass participation. This, of course, requires a high degree of organization. Although sports such as basketball, football, baseball, and hockey have organized competition at many levels, track and field (at least at this time) does not enjoy such widespread participation. Consequently, identification through natural selection is insufficient. Thus, an organized means of identifying talent is necessary.

Although talent identification in track and field in the United States is not formal, it is in many other countries throughout the world. In a recent report by the New Zealand Sports Foundation, organized talent identification programs from the German Democratic Republic, the Soviet Union, the Federal Republic of Germany, Australia, and The Netherlands were described. Although their report presents the test batteries and normative scores for track and field, they fail to suggest a longitudinal model for predicting future success that is based upon rigorous statistical procedures. This seems to be an inherent problem in most attempts to develop predictive capacity. This project is one of the first to use rigorous statistical procedures with a large database to develop predictive capacities.

<u>Predictive Testing in Track and Field</u>

Six general categories of factors influencing performance in track and field may be identified: physiological and biomechanical, anthropometric, biological, hereditary, psychological, and sociological. Using this model, tests from each category could be selected and predictions made. There have been many attempts to use this model to develop predictive tests. Some of these will be described.

Investigators have found testing to be most effective for children between the ages of 11 and 13 (Alabin, Nischt, & Jeffries, 1980; Foreman, 1980; Foreman, 1981; Poule, 1980). Atalin, Nischt, & Jeffries (1980) assembled a battery of tests with normative values for children 11 and 12. These tests included 60 meters, 300 meters, trunk bend, five steps, height, and weight. It is uncertain how these tests were determined to be related to future performance.

Foreman (in Gambetta, 1981) outlined a number of factors related to successful performance. These included such factors as speed, power, strength, coordination, movement time, body composition, and aerobic capacity. To measure these factors, Foreman constructed a battery of tests. Although the tests are intuitive, Foreman did not determine which, if any, had more predictive capacity. This would require rigorous statistical analysis, which he did not complete.

Foreman (1980) also established selection criteria for elite athletes in a variety of track and field events. These tests included vertical jump, standing long jump, bounds, five double-leg hops, body fat, and 50 yard sprint. As before, the selection of these tests was not based on any formal statistical procedures, but rather, anecdotal.

Poole (1980) found predictive tests to be useful in selecting talented individuals for further training. He utilized a number of tests to not only predict future performance, but also to place athletes in particular events. His tests were also intuitive and did not represent the results of any formal method of analysis.

A number of investigations have examined predictive testing of performance in the sprints (Bal'sevich, 1980;

Ionov, 1982; Tabatchink, 1979). Tabatchink (1979) recommended the use of tests of muscular strength such as standing long and triple jumps for predicting sprint potential. He also suggested 60-100 meter sprints as measures of speed endurance. He concluded that predicting sprint potential was not difficult and that it was essential to identify sprinters at a young age so that they could be appropriately trained. Ionov (1982) and Radford (1984) both agreed that natural ability was a primary determinant of sprint success and that it could be tested easily.

Tabatchink (1979) stated that the most successful identification would result from comparing athletes with an ideal model of a sprinter. This model would assign relative weightings to each of a number of attributes so as to maximize performance capacity. These attributes might include height, body composition, stride length, stride frequency, and strength. He especially emphasized the need to examine stride frequency and the duration of the support phase to avoid overlooking potential talent. He constructed a model and suggested that it was successful in identifying performance capacity.

Bal'sevich (1980) identified the qualities required of a sprinter who was a candidate for the Soviet Sports School. These included anthropometric characteristics, 30 meters from a flying start, 30 meters from a standing start, standing long jump, 10 jumps with feet together from a squatting position, and other physical qualities that corresponded with the biomechanical characteristics fundamental to maximum speed racing.

Various factors and tests of those factors have also been determined for identifying potential jumpers. Jarver (1983) presented a general battery of tests used in the Soviet Youth Sports Schools. These tests included 30 and 60 meter sprints, standing long and triple jump, pull-ups, and push-ups. Although norms were presented for boys and girls, the means by which these tests were selected for inclusion in the test battery was somewhat arbitrary.

Foreman (1980) constructed a similar battery to test for potential high jumpers. These included 30 meters, 800 meters, alternate leg bounds for distance, five single leg bounds, standing long jump, and five step scissors jump. He developed norms for males and females for each test. Foreman also used similar test batteries to test long and triple jumpers.

Siris (1982) described a two-stage long jump talent identification program. He suggested that the most important factors in the long jump were speed and the ability to accelerate. In the first phase of his process, youths who scored average to better than average on a series of tests and who had favorable anthropometric measurements were selected for a specific training program. At the conclusion of an 18 month training program the degree of improvement was noted and the second phase of selection occurred by choosing those who had demonstrated acceptable improvement. The criteria for selection in each of the phases appeared to be somewhat subjective and was probably arbitrary.

Jarver (1983) also outlined a series of tests to be used in selecting children for the throwing events. These were the tests used by the Soviet Youth Sports Schools, and included height, weight, 30 meter flying start, 60 meters from a standing start, overhead shot throw, push-ups, and pull-ups.

Kamarova & Raschimshanova (1980) attempted to develop an ideal model of a thrower. To do so, they administered a battery of tests to elite Soviet female throwers. Four general factors were deemed important, and tests were selected for those factors. These factors included power development, strength development, static speed development, and speed of response. From these results, they concluded that the primary criteria for selection of potential elite athletes should include basic conditioning elements and genetic factors in anthropometric measurements.

Pintaric (1982) believed that because strength was so vital to performance in the throws, strength was the primary determinant to success. Because strength varies as a result of training, it must be measured across time to update the prediction of potential performance. However, he identified some anthropometric factors that effect the development of strength.

Morrow et al. (1982) examined 49 American discus, hammer, shot, and javelin throwers who had competed in a pre-olympic training camp, and found that performance differed greatly on anthropometric and strength variables, suggesting that these variables alone might be insufficient for predicting elite performance.

It may be concluded from these studies that several attempts have been made to develop guidelines for testing athletes so as to identify potential elite athletes in various events. Although it appears that success has been attained, there has not been a single statistically rigorous attempt at developing a comprehensive model for identifying potential performance in children. Nor has any attempt been made to develop mathematical models for predicting exact potential performance (e.g., a 25' long jumper). This capacity, if successfully attained, could introduce a more scientific basis for selecting and training athletes.

Purpose

The purpose of this project was twofold. First, norms for males and females at various competitive levels and different events were to be established and a database developed that could be used for comparisons in the future. The second purpose was to begin developing a scientifically rigorous method of predicting potential performance as well as the event that would be most appropriate for a particular athlete.

The ultimate goal of this program was to establish a method of predicting both the most appropriate event and the potential performance in that event using the following model:

Predicted performance	Predicted performance	Best potential performance
Test	Test	

This is a proposed model in which a person can be tested at any time and their long range potential determined. In this model, a person could be tested for the first time at any age, or many instances acrcss time. Each time they would be tested, their predicted performance and event could be updated. However, with expanded testing the accuracy of prediction could increase to a degree in which testing at 10 years of age could predict performance at 20 years of age.

TESTING PROTOCOL

Summary

To construct norms and improve the accuracy of prediction, athletes from throughout the country representing a wide range of abilities were evaluated using a series of tests of muscular power, speed, and anthropometric measures. These athletes were tested either by their own coaches, or by the authors at selected sites throughout the midwest. From the results of these tests, norms and predictive equations were constructed. These are presented and their implications discussed.

Testing Sites

The testing was completed at a variety of venues. During the past 18 months, teams from several universities, colleges, high schools, and clubs participated either by testing their own athletes or by having the testing team visit. These teams varied across geographical locations and levels of competition (i.e., Division I, II, and III schools). Each of the participating schools was sent explicit instructions regarding the procedures so as to maintain a high degree of test objectivity and reliability.

A second venue was the many track and field camps held during the summer at various locations in the midwest. In some instances the testing team was present, while in others the instructions were sent. This afforded the opportunity to test junior and senior high school boys and girls with a variety of abilities.

The third venue was the sites selected by the testing team in Chicago and Cincinnati during the summer of 1989. A single testing site was selected in Chicago while two sites were selected in Cincinnati. In Chicago, the team visited an open competition in which high school, college, and post-collegiate athletes participated. All of the athletes at this particular site were tested.

The two Cincinnati sites included a regional qualifying meet of the state sponsored summer games. There were approximately 200 athletes of various ages and abilities in attendance. Most of these were tested. The second Cincinnati site was a practice session of the Cincinnati All Stars Track Club. The ages and ability levels of the club members ranged from junior to senior high school students.

Because of the variety of testing locations and the variation in performance levels, the results of this project are considered to be representative of track and field athletes in the United States.

Tests

It has been found that leg power is a primary determinant of track and field performance. Because of the ease with which tests of leg power can be administered, it was decided to restrict the testing in this project to measures of this factor. In addition, anthropometric measures were obtained because of the ease with which these can also be obtained. Based upon the scientific literature and years of experience conducting predictive tests, a battery of tests was chosen to measure leg power and anthropometric dimensions. Other factors which could have been measured, but were not, included cardiovascular endurance, anaerobic power, motor skill ability, and psychological profiles. These remain for further evaluation. The following tests were administered:

1) Height (measured in inches)
2) Weight (measured in pounds)
3) Standing long jump (measured in inches)
4) Vertical jump (measured in inches from a standing position)
5) Five bounds for distance (this test requires five consecutive bounds beginning from a standing start, and was measured in inches)
6) Body Composition (i.e., % body fat)
   The instrument used for this measure was a skin caliper.
7) Sixty-meter dash from a standing start
   (recorded to the .1 second)
8) Thirty-meter dash from a standing start
   (recorded to the .1 second)
9) Thirty-meter dash from a moving start
   ("On the Fly")
   (recorded to the .1 second)
10) Stride frequency during a thirty-meter dash
    (measured in strides/second)
11) Stride length during a thirty-meter dash
    (measured in inches)

Standard measurement procedures were developed to improve both the reliability and the objectivity of the test.

Performance Criterion

In previous attempts to develop predictive capacity, the relationship between the test scores and performance in track and field was not established. Thus the use of those tests was to a large extent subjective. One of the goals of this project was to eliminate the subjectivity, and to develop a prediction equation that was both scientifically based and statistically rigorous. To accomplish this goal, the performance of each of the athletes in each of their events must somehow have been equated. To equate performances, multievent scoring tables were used (IAAF 1962 Edition for males and IAAF 1971 Edition for females). Each of the athletes who were tested were asked for their best performances in their "best three" events. These performances were then converted to multievent points and the best score used for further analysis. Thus, each of the tests outlined above were examined for their relationship to the athlete's score on the multievent scoring table. It is believed that this is the first attempt to establish a predictive equation that has both a valid and objective performance measure. The combination of the tests and performance measure afforded the opportunity to construct a statistically based prediction equation for the purpose of identifying talent.

In addition to using the multievent scoring tables for a performance criterion, these tables were also used to designate elite athletes. The criterion for this designation was whether the athlete had scored one standard deviation above the mean in their best event. This would mean that they had performed in the top 16% of all those athletes tested.

Procedures

Prior to the testing, each of the athletes was required to complete a warm-up. This consisted of an 800 meter jog and a period of stretching. Following this each athlete continued their warm-up using their personal program. After the warm-up period, each athlete completed a card that contained specific questions regarding their previous experiences, including best performances. In addition, each athlete provided their home address so that the results of the tests could be forwarded to them. They were then explained the order in which the tests would be administered. Each of the athletes completed the tests in the same order so as to have equal benefits of the previous test. For each of the tests two trials were administered and the best performance recorded. This conforms with classical measurement theory. One tester recorded the scores on each test to ensure consistency in scoring methods. The entire test took approximately 30 minutes for a single person. The testing session normally involved a large number of athletes so that the entire testing session lasted from one to several hours depending on the number of athletes tested. The scores were later transferred to a personal computer for analysis.

Analysis

The data analysis was completed in four steps. In the first step, descriptive statistics were completed for males and females, for athletes in different events, and for athletes of varying competitive levels (e.g., junior high school, senior high school, collegiate, and elite). These statistics included means and standard deviations for each of the tests and the performance criterion. From this point separate analysis was completed for each of the two sexes, for each of the competitive categories, and for each of the events. Thus, for instance, an athlete could be categorized as a high school male shot putter or an elite female high jumper. Within each of the categories the tests were intercorrelated and then correlated with the performance measure (i.e., multievent points). These correlations were then used for the third stage of the analysis, factor analysis. This procedure was used to determine the number of underlying dimensions determining performance levels and those tests that were the best measurement of each of those dimensions.

The final stage of the analysis was the construction of the prediction equations using Least Squares Multiple Regression techniques. In these equations multievent scoring points were used as the predicted variable. Thus the equation would allow the test scores to be differentially weighted and summed to produce an estimate of the athlete's potential points on the multievent scoring tables (i.e., 800 points). This estimate could then be transformed into the athlete's best event and their performance predicted (i.e., 800 points corresponds to 22'7 3/4" for a male long jumper).

RESULTS

The results of the testing will be explained in three parts. First, the results of each of the tests will be presented and discussed in the following order: performance (multievent scoring points), height, weight, body fat, 60 meters, 30 meters from a standing start, 30 meters from a flying start, stride frequency, stride length, standing long jump, five bounds for distance, and vertical jump. When discussing each of these tests, separate comparisons will be made for males and females between levels of competition (i.e., junior high school, senior high school, collegiate, and post-collegiate), and between athletes in each of the events.

Two primary statistics will be presented for each test, the mean and the standard deviation. The mean represents the average performance of the group, while the standard deviation represents the degree to which the scores were spread out. The larger the standard deviation, the more the scores were spread. Using the mean and the standard deviation, it is possible to determine the score necessary to achieve the top 25% (.67 standard deviations above the mean) and the top 10% (1.36 standard deviations above the mean).

The second part of the results will be the determination of the underlying dimensions of the tests. Using factor analytic procedures it was possible to eliminate some of the tests as being redundant. This is because there is probably a small number of individual characteristics causing athletes to do well on two or more tests. Finally, the empirical equations for predicting performances based on the test results will be presented.

Athletes

Table 1

The number of athletes tested in the various categories.

Male	JHS	28
	SHS	367
	Collegiate	144
	Elite	103
	110 m Hurdlers	17
	400 m Hurdlers	18
	Sprinters	136
	400 meters	120
	Horiz. Jumpers	110
	High Jumpers	69
	SP/DISC	43
	Vaulters	80
Female	JHS	81
	SHS	354
	Collegiate	68
	Elite	71
	100 m Hurdlers	35
	400 m Hurdlers	7
	Sprinters	167
	400 meters	126
	Horiz. Jumpers	71
	High Jumpers	72
	SP/DISC	57

PERFORMANCE LEVELS
(multievent scoring points)

Females/Competitive Levels

The performance levels of the females were found to increase as the level of competition increased. This is as would be expected. There were 81 female JHS athletes tested and their mean performance level was 557.50 pts. while the standard deviation was 152.85. There were 354 female high school athletes tested and their mean performance was 698.08 pts. with a standard deviation of 114.50 pts. There were 68 collegiate athletes tested. Their mean performance level was 848.19 pts. while their standard deviation was 112.7 pts.. There were 71 elite female athletes tested. They had a mean performance level of 919.48 pts. and a standard deviation of 62.74 pts. As can be seen in Figure 1, relatively equal improvements were observed between the JHS and SHS as well as between SHS and college. However, the rate of improvement decreased following college.

Females/Events

The performance levels will also be described by events. The means and standard deviations are presented in Table 2 and Figure 2.

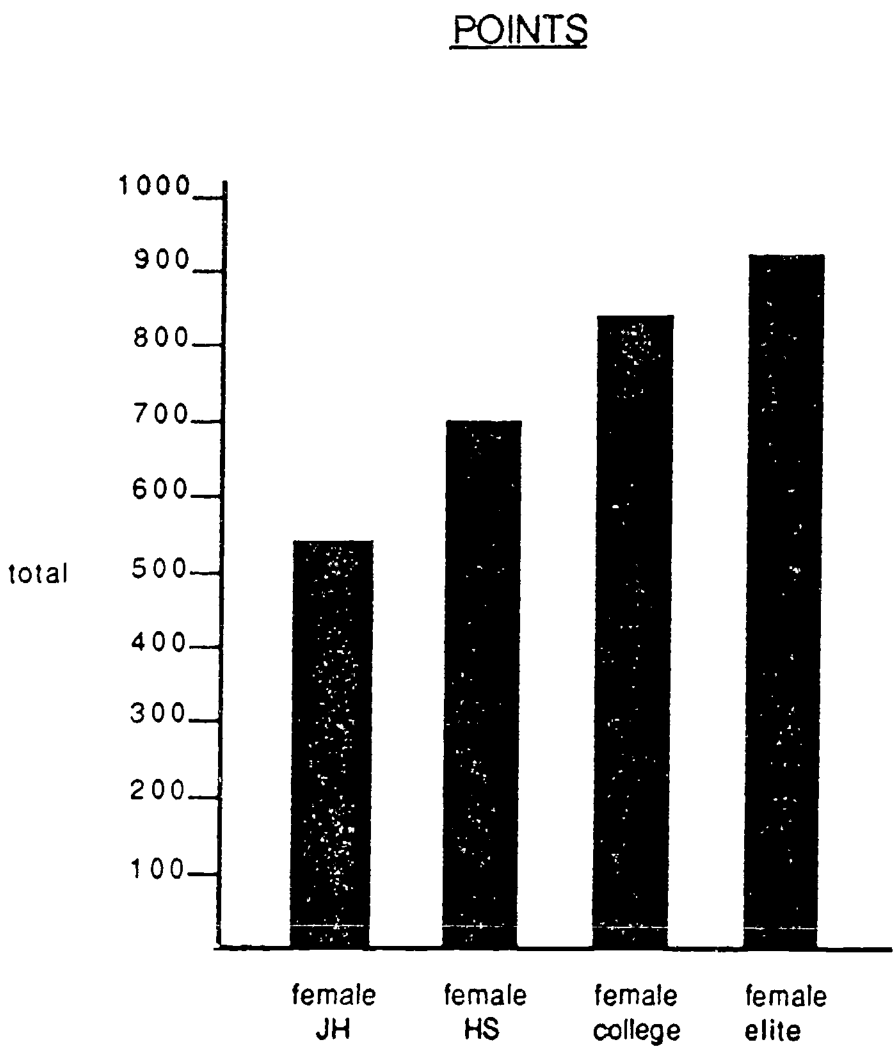

Figure 1. Mean multievent points by level of competition for females.

FEMALE

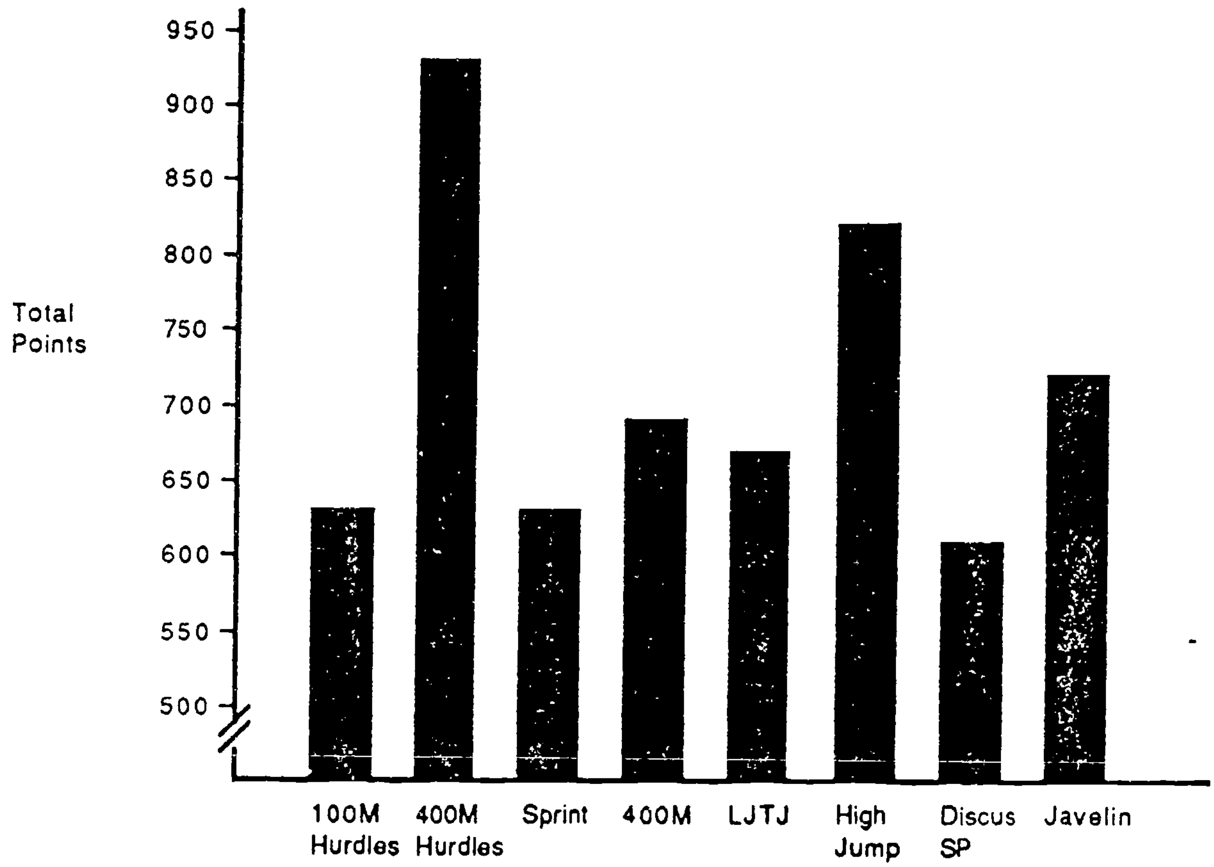

Figure 2. Mean multievent points by event for females.

Table 2

Means and standard deviations of the female athletes by event.

Event	Number	Mean	SD
100 H	35	693.03	140.05
400 H	7	944.14	82.40
Sprnts	167	636.85	132.67
400 m	126	690.98	136.35
HorJmps	71	673.31	153.02
HJ	72	826.44	128.68
SP/DISC	57	628.91	155.17

As may be seen, the 400 meter hurdlers had the best performances, but they were also by far the smallest group. Since the 400m hurdles is not generally conducted on the high school and junior high school levels, these athletes tended to be much older and more likely to be in the elite category. The throwers had the lowest average performance level but they also showed the largest variation.

Males/Level of Competition

The performance level of the males was also found to increase as the level of competition increased. There were 28 JHS males. Their mean performance level was 473.92 pts, while their standard deviation was 138.39 pts. There were 367 high school boys tested. Their mean performance level was 708.63 pts., while their standard deviation was 124.46 pts.. There were 144 collegiate males tested. Their mean performance level was 863.71 pts., while their standard deviation was 125.45 pts. There were 103 elite males tested. Their mean performance was 962.98 pts, while their standard deviation was 51.33 pts.. These results may be seen in Figure 3.

Males/Events

The means and standard deviations of the males by events may be seen in Table 3 and Figure 4.

Table 3

Means and standard deviations of the performance levels of the males by events.

Event	Number	Mean	SD
110 H	17	866.12	83.04
400 H	18	859.44	117.69
Sprnts	136	698.63	144.48
400 m	120	692.87	145.63
Horjmps	110	727.38	170.78
HJ	69	767.94	166. 8
SP/DISC	43	778.77	101.84
Vaulters	80	774.53	196.93

Of the male athletes, the hurdlers appear to have achieved the highest level of performance. This may be either due to a sampling bias or to an inconsistency in the construction of the scoring tables. In the case of the 400 meter hurdles, there were no high school times included, so that the mean represents only the college and elite athletes. This is not the case for the 110 hurdlers.

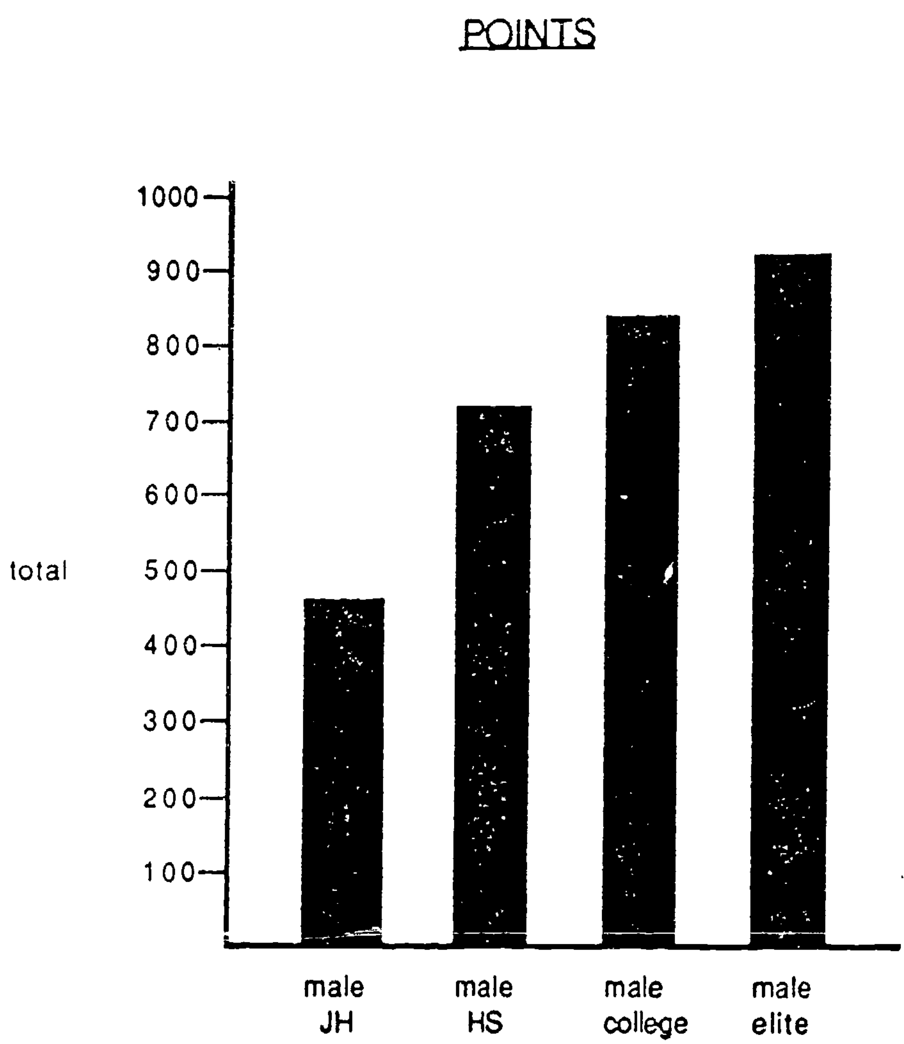

Figure 3. Mean multievent points by level of competition for males.

MALE

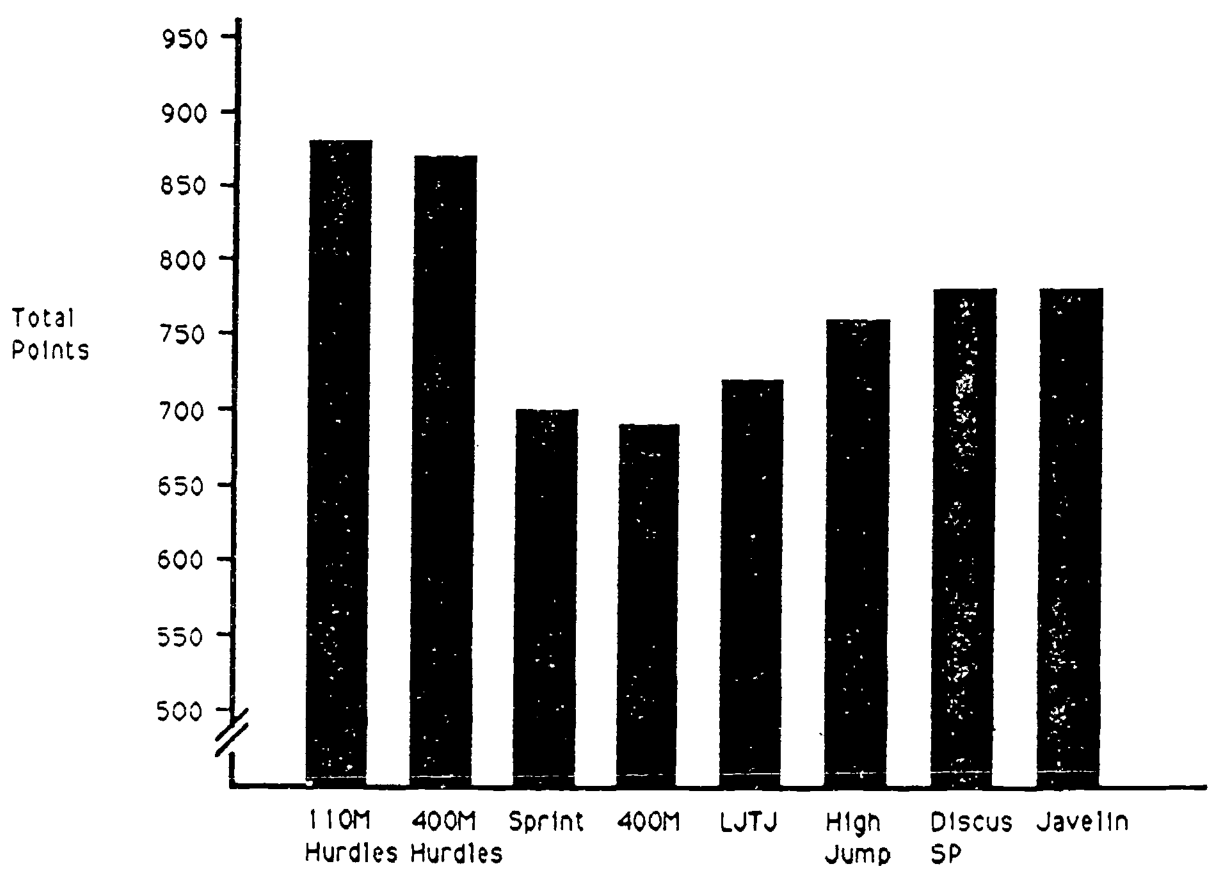

Figure 4. Mean multievent points by event for males.

HEIGHT

Female/Competitive Level

As would be expected, the height of the women increased as a function of competitive level. The mean heights were 64.61, 65.82, 67.21, and 68.28 inches for the JHS, SHS, collegiate, and elite athletes respectively. The standard deviations were 3.25, 2.66, 2.73, 2.35 inches for JHS, SHS, college, and elite athletes (see Figure 5). It appears that the height of athletes becomes more homogenous with age.

Female/Event

The heights of the female athletes by event may be seen in Table 4 and Figure 6.

Table 4

Means and standard deviations of the heights of the female athletes by event.

Event	Number	Mean	SD
100 m H	35	66.06	2.79
400 m H	7	69.00	2.58
Sprnts	167	63.78	4.00
400 m	126	64.85	2.64
Horjmps	71	65.43	3.68
HJ	72	68.03	2.92
SP/DISC	57	67.18	2.21

It appears that the 400 m hurdlers are the tallest, followed closely by the high jumpers. The shortest appear to be the sprinters. (Note: this may be again due to the small number of 400m hurdlers)

FEMALE

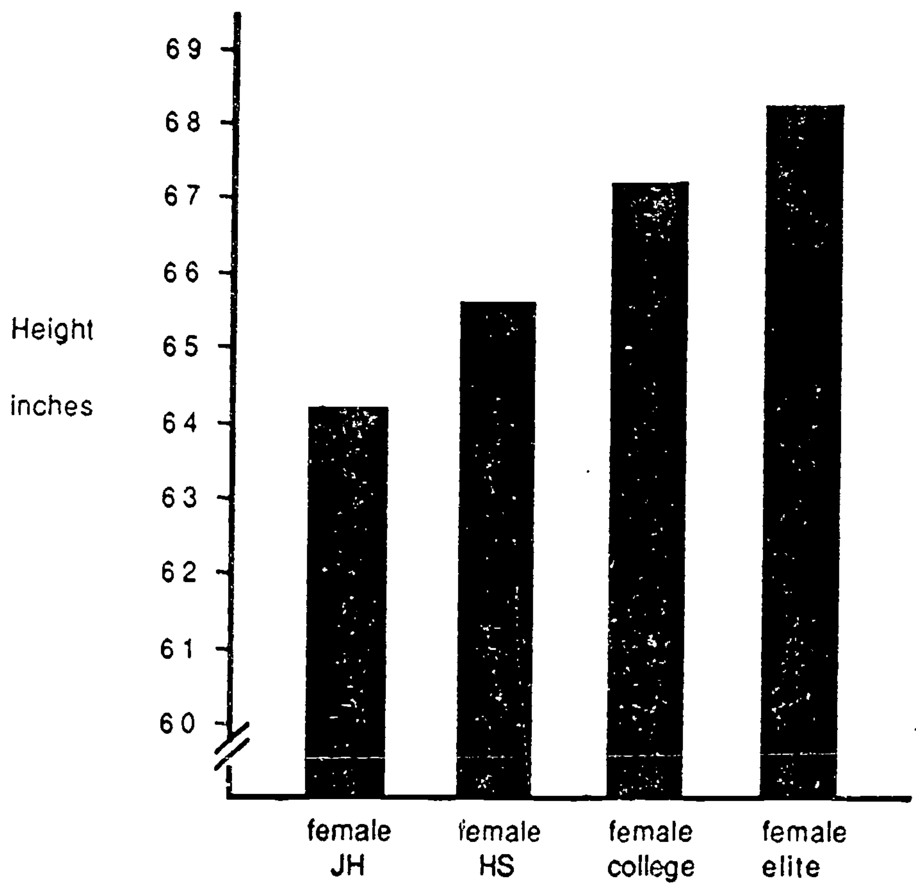

Figure 5. Mean height by level of competition for females.

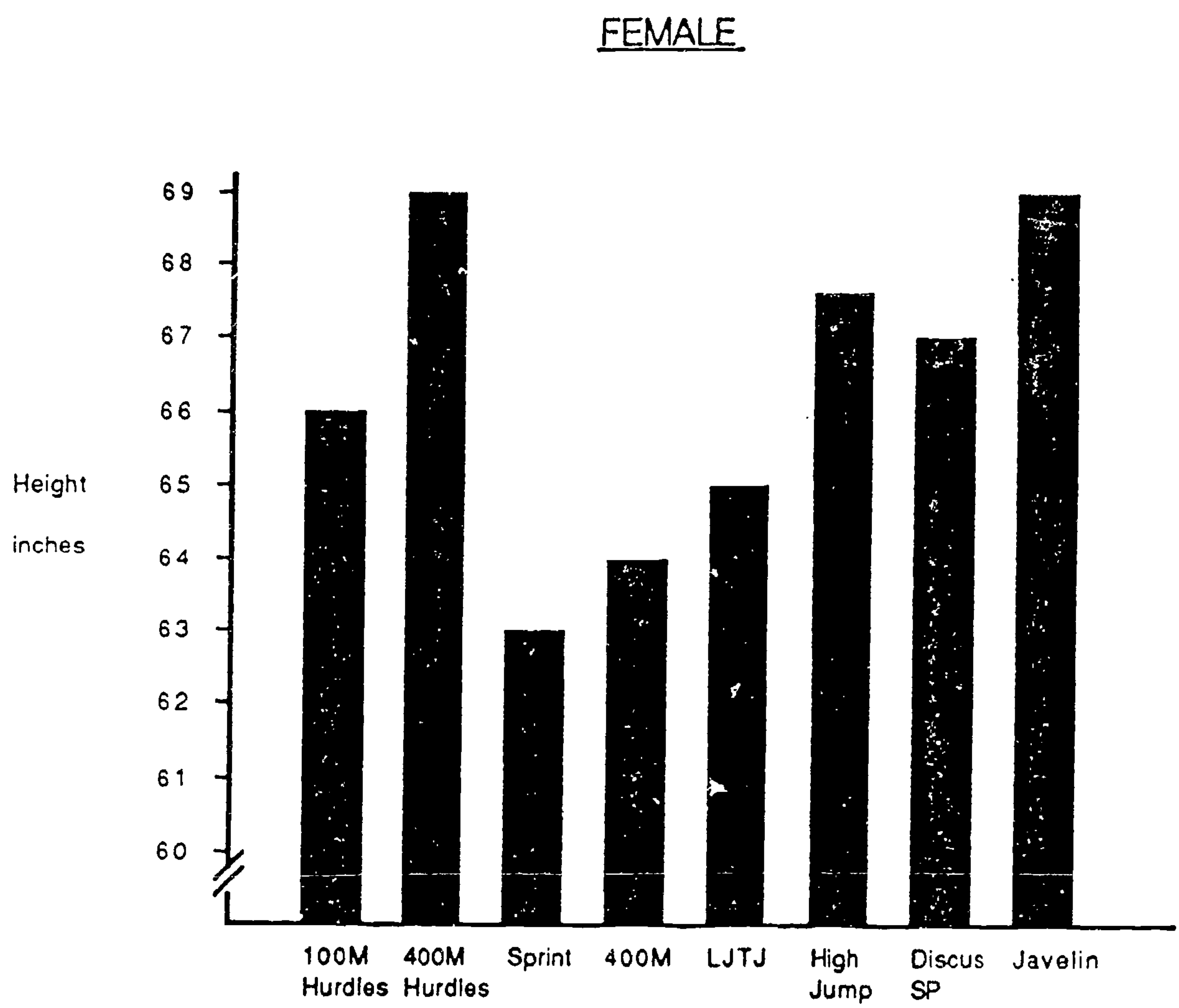

Figure 6. Mean height by event for females.

Male/Competitive Level

The mean height of the male athletes increased with competitive level. The mean heights were 67.17, 71.03, 72.03, and 72.27 inches for the JHS, SHS, college, and elite athletes. The standard deviations of height were 3.39, 2.51, 2.36, and 2.37 for JHS, SHS, college, and elite athletes. As with the females, the variation in the height of the athletes decreased with competitive levels. These may be seen in Figure 7.

Male/Event

The means and standard deviations of the male athletes by event may be seen in Table 5 and Figure 8.

Table 5

Means and standard deviations of the height of the male athletes by event.

Event	Number	Mean	SD
110 m H	17	72.79	1.56
400 m H	18	70.81	2.20
Sprnts	136	70.17	2.78
400 m	120	70.49	3.16
Horjmps	110	71.26	2.75
HJ	69	72.47	3.62
SP/DISC	43	73.08	2.00
Vault	80	70.49	2.17

As may be seen, the throwers, high jumpers, and 110 m hurdlers appear to be the tallest, while there is little difference between the remaining groups of athletes. Based on the standard deviations, it is also apparent that nearly all throwers and 110 m hurdlers were six feet or taller.

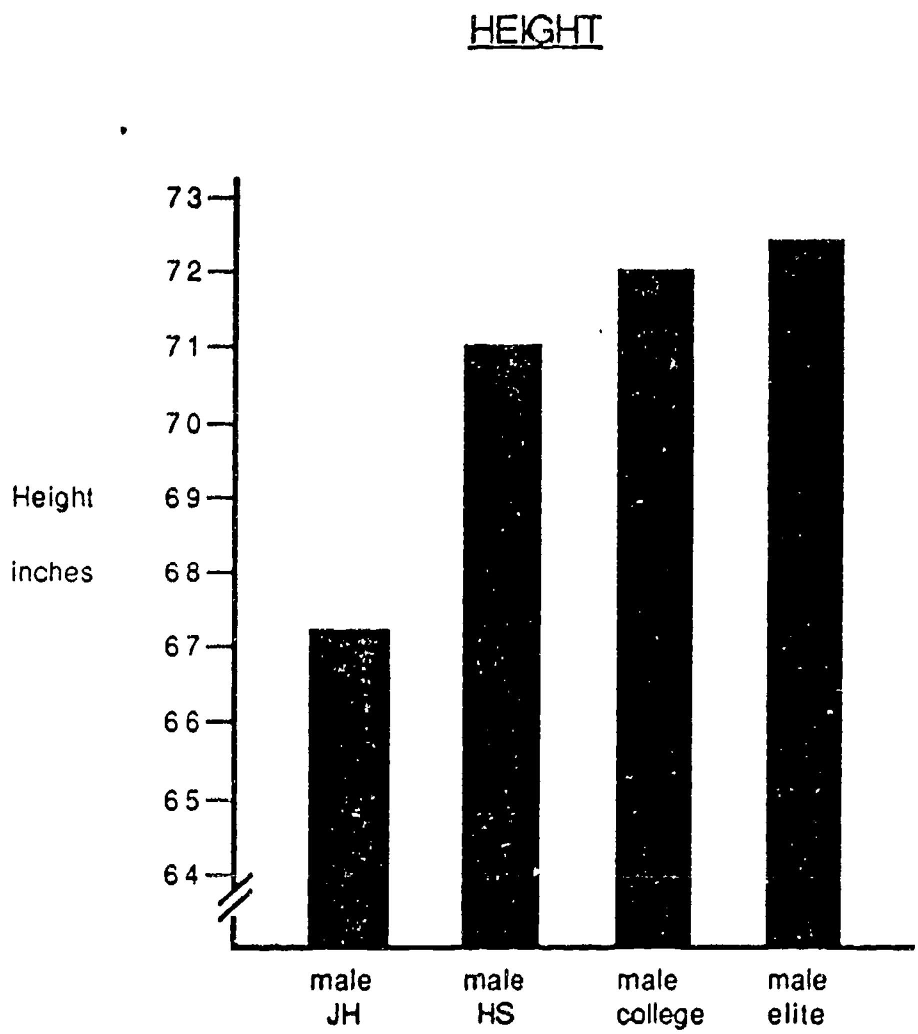

Figure 7. Mean height by level of competition for males.

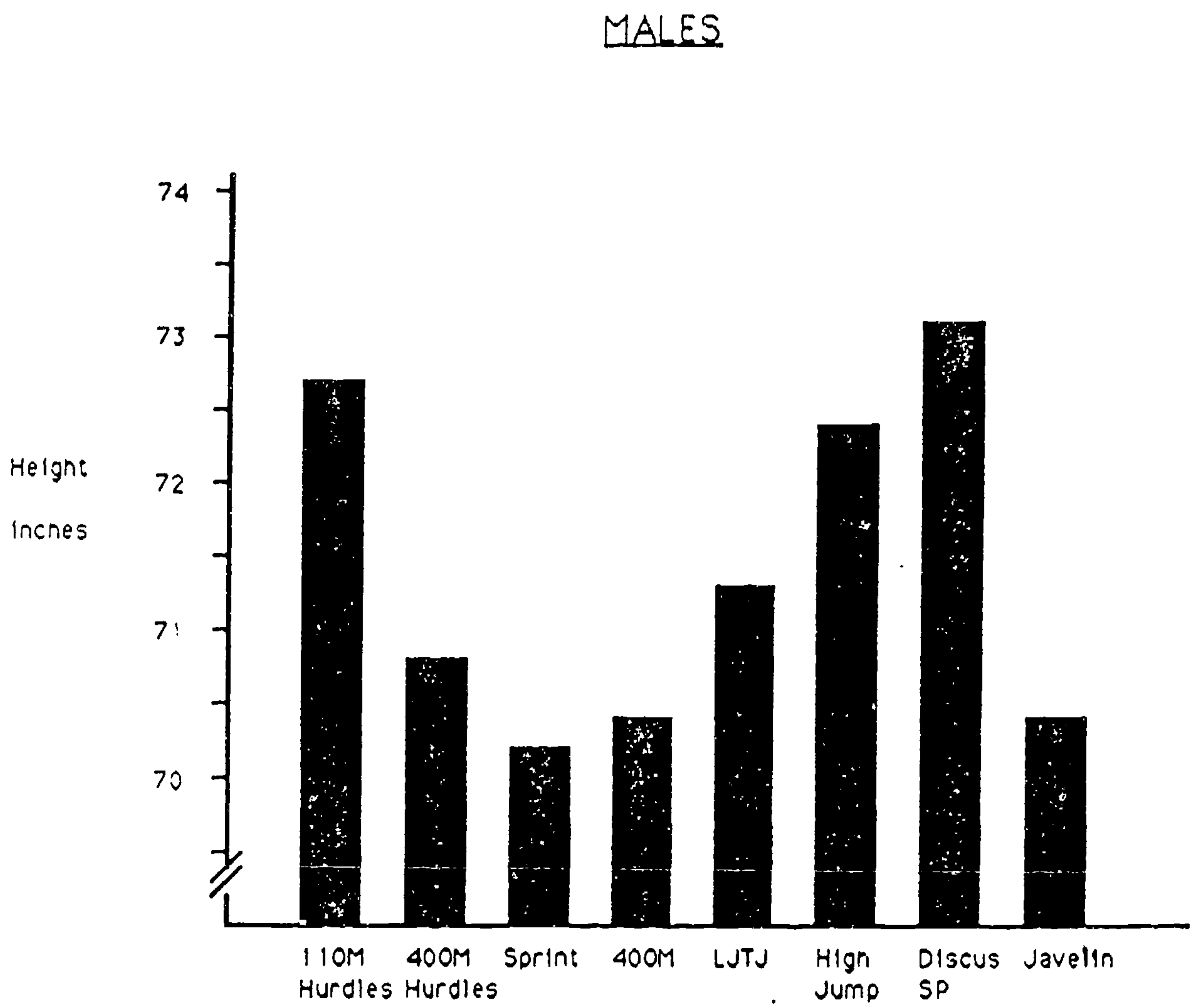

Figure 8. Mean height by event for males.

WEIGHT

Females/Competitive Level

The mean weight of the females increased with competitive levels until college, and then decreased between the collegiate and elite athletes. The mean weights were 115.19, 124.44, 143.03, and 136.91 pounds for JHS, SHS, college, and elite athletes respectively. The standard deviations of weight were 15.61, 19.51, 24.72, and 20.96 pounds for JHS, SHS, college, and elite athletes. This indicates that the college women not only weighed the most, but had the greatest variation as well (see Figure 9).

Females/Event

The means and standard deviations of the weight of the females by events may be seen in Table 6 and Figure 10.

Table 6

Means and standard deviations of the weight of the female athletes by event.

Event	Number	Mean	SD
100 m H	35	121.26	11.74
400 m H	7	134.43	17.83
Sprnts	167	115.77	15.94
400 m	126	116.52	13.34
Horjmps	71	123.58	18.89
HJ	72	126.83	14.27
SP/DISC	57	165.19	31.20

As would be expected the throwers weighed the most. The 400 m hurdlers were next, but they were also the tallest. The remainder of the athletes were quite similar

WEIGHT

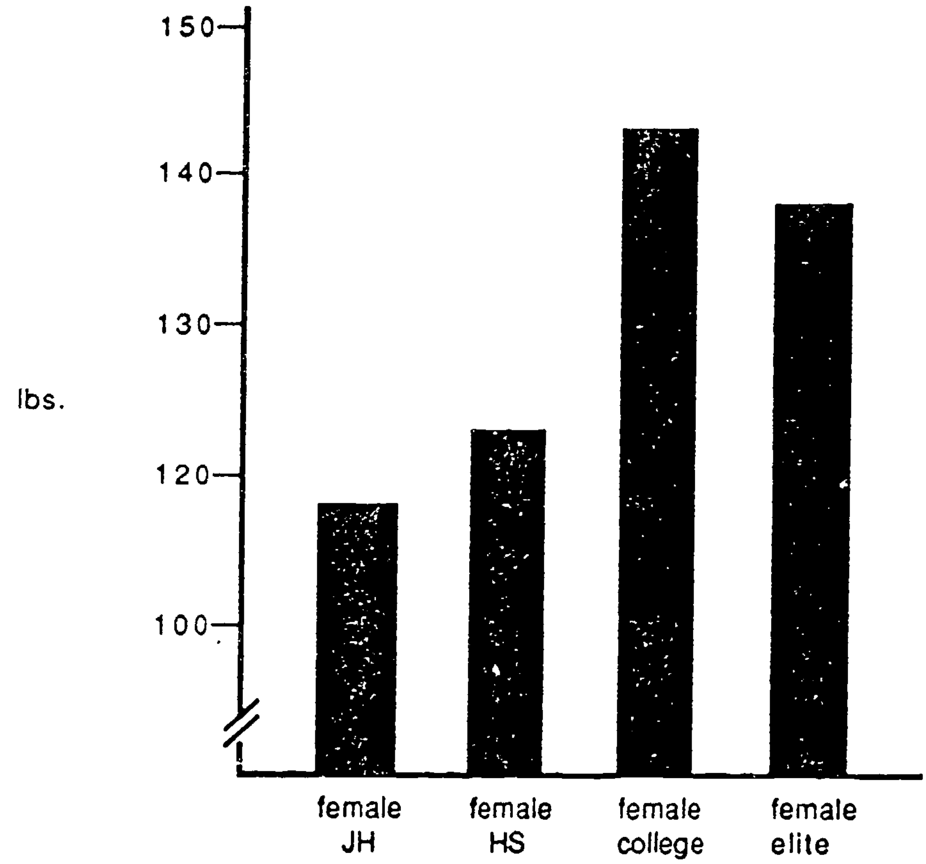

Figure 9. Mean weight by level of competition for females.

FEMALE

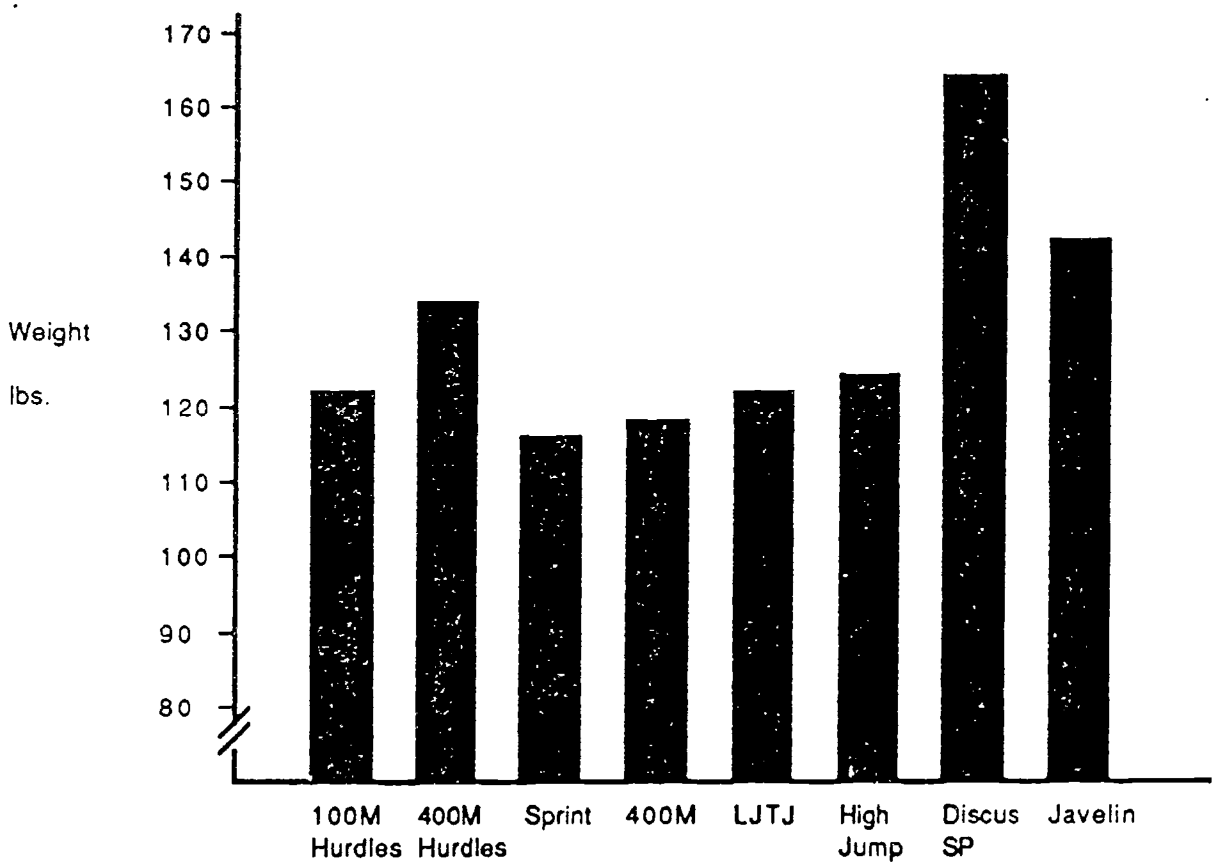

Figure 10. Mean weight by event for females.

in weight.

Male/Competitive Level

As with the women, the weight of the mean increased with competitive level until college, thereafter the weight decreased for the elite athletes. The mean weights were 128.46, 151.11, 178.55, and 170.68 pounds for the JHS, SHS, college, and elite athletes respectively. The standard deviations of weight were 19.47, 15.86, 28.02, and 22.44 pounds for the JHS, SHS, college, and elite athletes respectively. Again the college males were the heaviest, but had the greatest variability of weight (see Figure 11).

Male/Event

The means and standard deviations of weight for the male athletes by event may be seen in Table 7 and Figure 12.

Table 7

Means and standard deviations of weight for the males by event.

Event	Number	Mean	SD
110 m H	17	169.82	13.20
400 m H	18	166.61	17.23
Sprnts	136	151.01	18.18
400 m	120	147.83	19.37
Horjmps	110	153.47	17.67
HJ	69	154.87	21.03
SP/DISC	43	214.70	28.77
Vaulters	80	152.15	16.11

Like the women, the throwers were the heaviest, followed by the 110 m hurdlers. There was little difference

WEIGHT

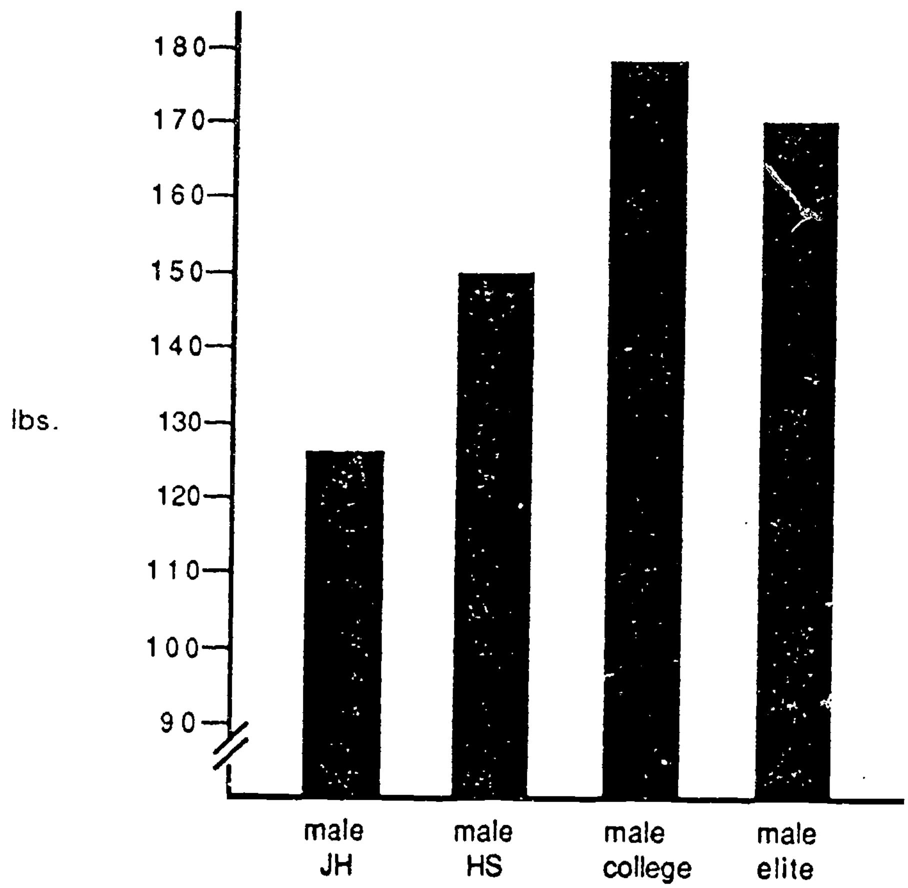

Figure 11. Mean weight by level of competition for males.

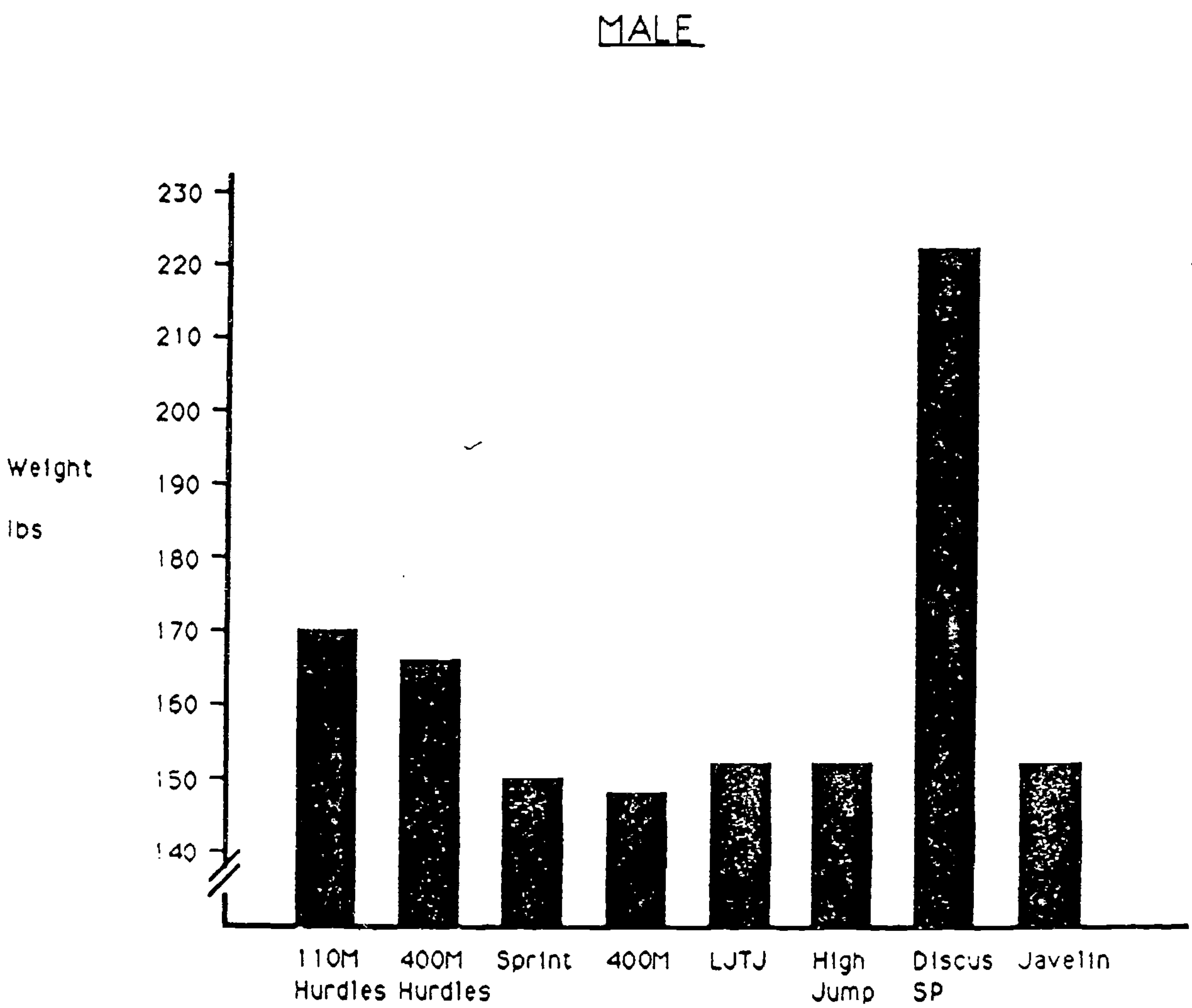

Figure 12. Mean weight by event for males.

between the athletes in the various other events.

BODY FAT

Female/Competitive Level

There was little difference in the mean body fat of the athletes as a result of increasing competitive level. Because the weights increased during this time, it may be concluded that the extra weight was muscle mass. The mean percentage of body fat was 15.99, 15.86, 17.04, and 16.16% for JHS, SHS, college, and elite athletes respectively. The standard deviations of body fat were 3.11, 2.77, 3.25, and 2.92% for JHS, SHS, college, and elite athletes respectively (see Figure 13).

Female/Event

The means and standard deviations of body fat for females by event may be seen in Table 8 and Figure 14.

Table 8

Means and standard deviations of body fat for females by event.

Event	Number	Mean	SD
100 m H	35	15.32	2.46
400 m H	7	15.53	1.69
Sprnts	167	15.40	2.04
400 m	126	14.95	2.12
Horjmps	71	15.63	2.47
HJ	72	15.76	2.16
SP/DISC	57	21.09	3.82

The mean body fat was greatest for the throwers. There was little difference between the athletes of the other

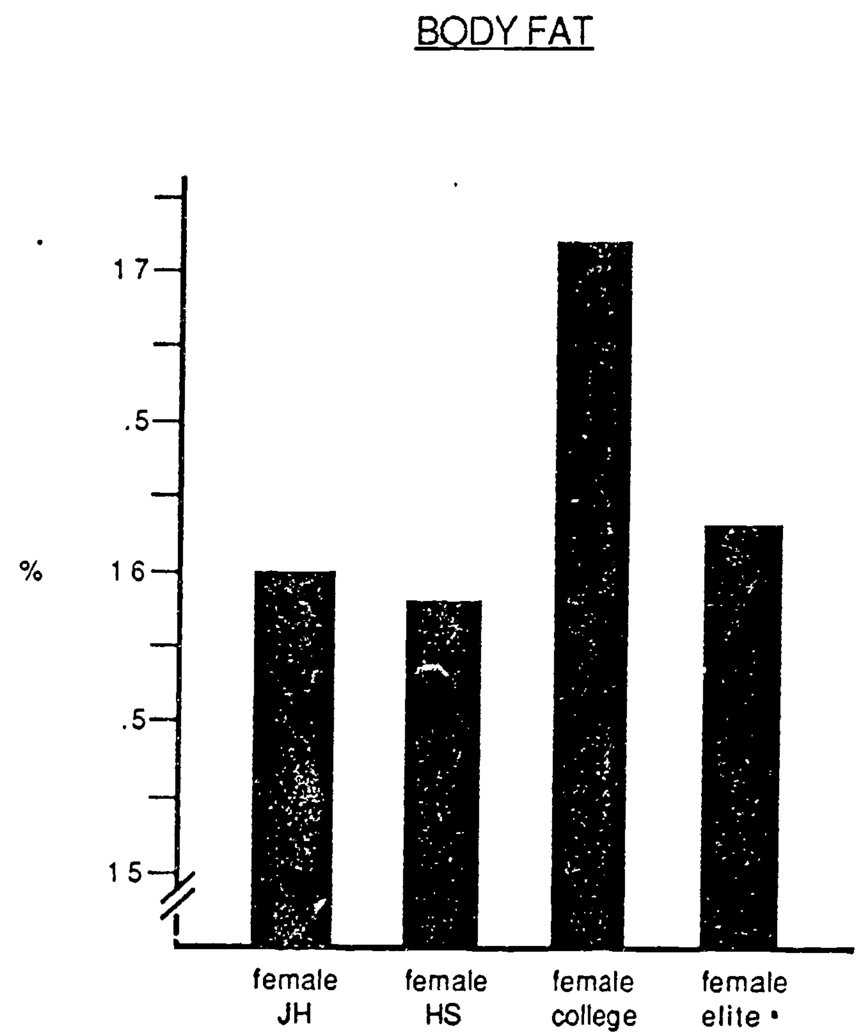

Figure 13. Mean percent body fat by level of competition for females.

FEMALE

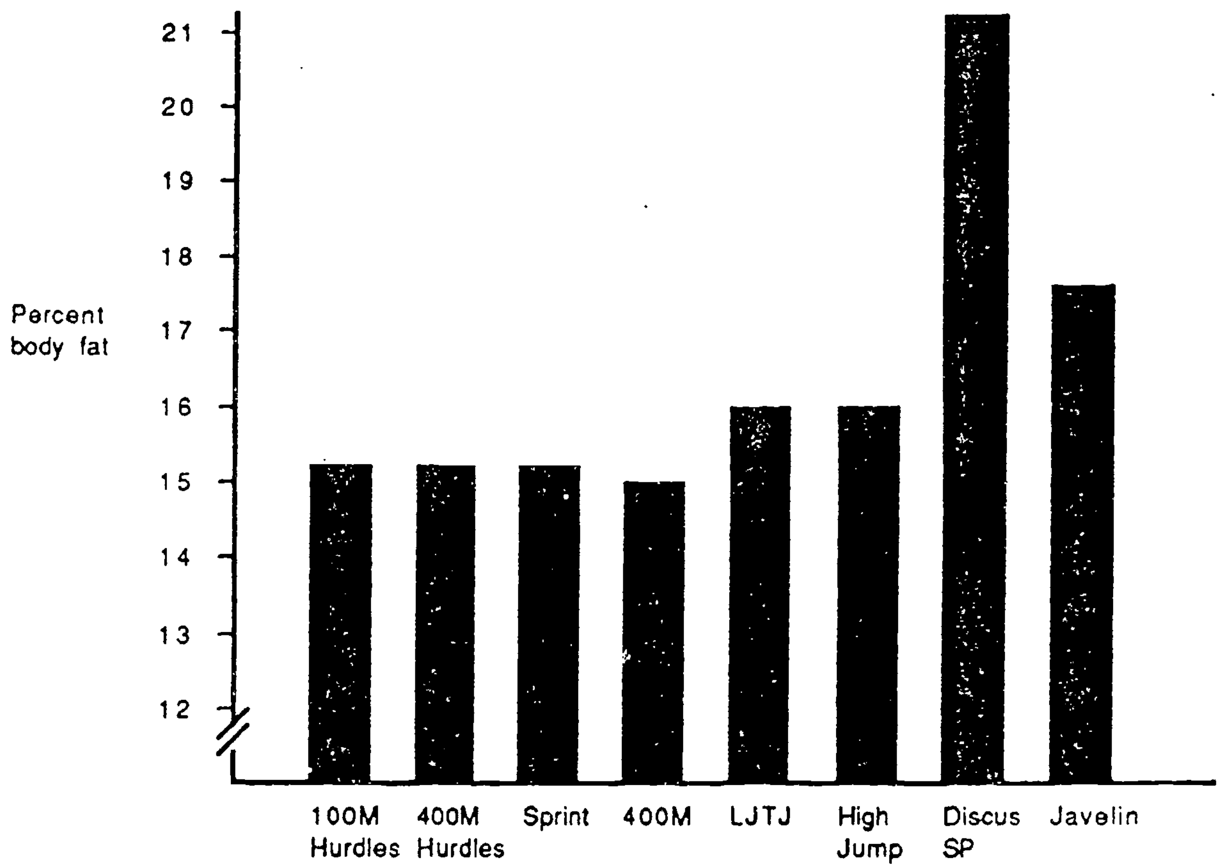

Figure 14. Mean percent body fat by event for females.

events.

Male/Competitive Level

Collegiate males had the greatest amount of body fat. There was little difference between JHS and SHS students The mean body fat was 7.70, 7.74, 9.91, and 8.24% for the JHS, SHS, college, and elite athletes respectively. The standard deviations of body fat were 1.85, 2.12, 3.94, 3.02% for JHS, SHS, college, and elite athletes respectively. Not only did the collegiate athletes have the greatest body fat, but they had the largest variation in fat as well (see Figure 15).

Male/Event

The means and standard deviations of the body fat of males by age may be seen in Table 9 and Figure 16.

Table 9

Means and standard deviations of the body fat of males by event.

Event	Number	Mean	SD
110 m H	17	7.94	1.89
400 m H	18	8.31	2.50
Sprnts	136	8.05	2.42
400 m	120	7.63	2.14
Horjmps	110	7.44	2.21
HJ	69	7.83	2.22
SP/DISC	43	13.13	4.18
Vaulters	80	8.08	2.10

The throwers had the greatest body fat, while the body fat of the others was nearly equivalent. It appears that body fat would be a poor predictor of "best event".

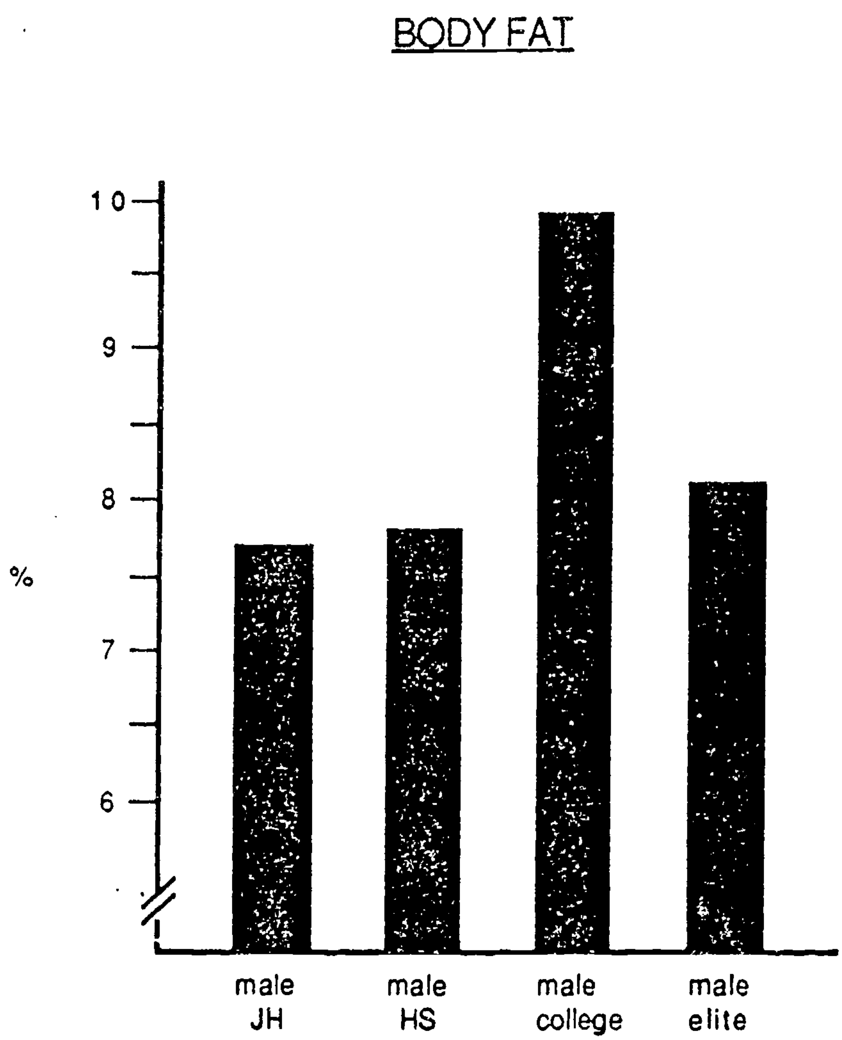

Figure 15. Mean percent body fat by level of competition for males.

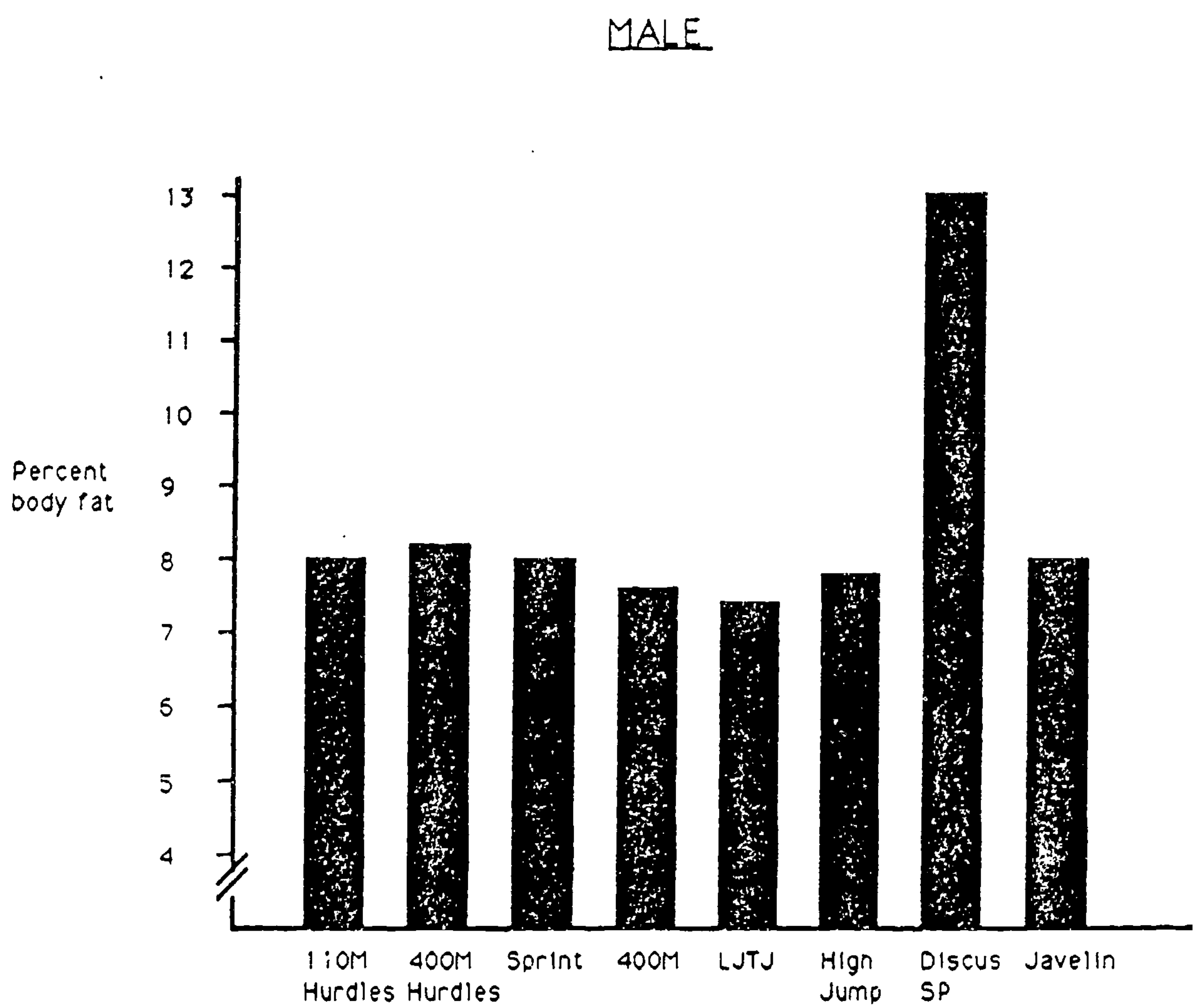

Figure 16. Mean percent body fat by event for males.

Female/Competitive Event

As would be expected the mean 60 meter time decreased progressively between competitive levels, with the elite athletes being the fastest. The mean 60 meter times were 8.97, 8.51, 8.31, and 8.29 seconds for JHS, SHS, college, and elite athletes respectively. The standard deviations of 60 meter times were .65, .56, .62, and .60 seconds for JHS, SHS, college, and elite athletes respectively (see Figure 17).

Female/Event

The means and standard deviations of the 60 meter times of the females by event may be seen in Table 10 and Figure 18.

Table 10

Means and standard deviations of the 60 meter times for females by event.

Event	Number	Mean	SD
100 m H	35	8.36	.51
400 m H	7	8.07	.35
Sprnts	167	8.39	.66
400 m	126	8.55	.52
Horjmps	71	8.45	.53
HJ	72	8.75	.60
SP/DISC	57	9.40	.70

The fastest 60 meter runners were the 400 m hurdlers. This may be somewhat misleading in that there were only seven of these performers and they were primarily collegiate

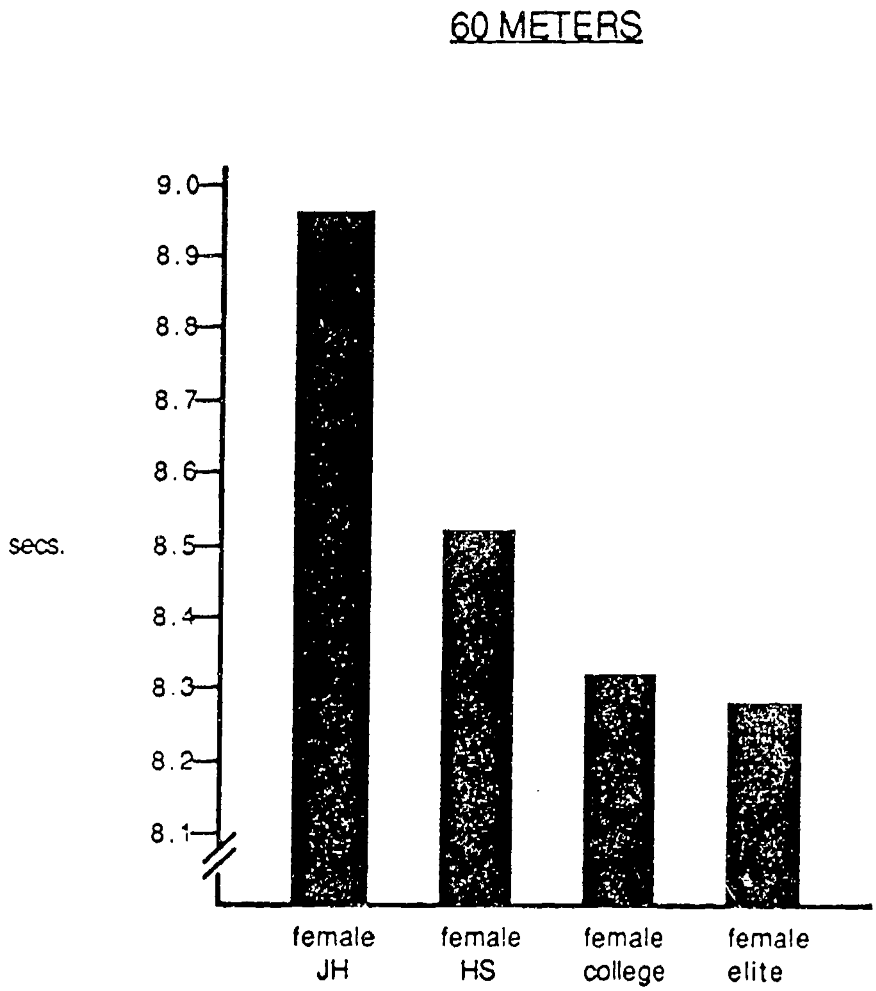

Figure 17. Mean 60 meter dash by level of competition for females.

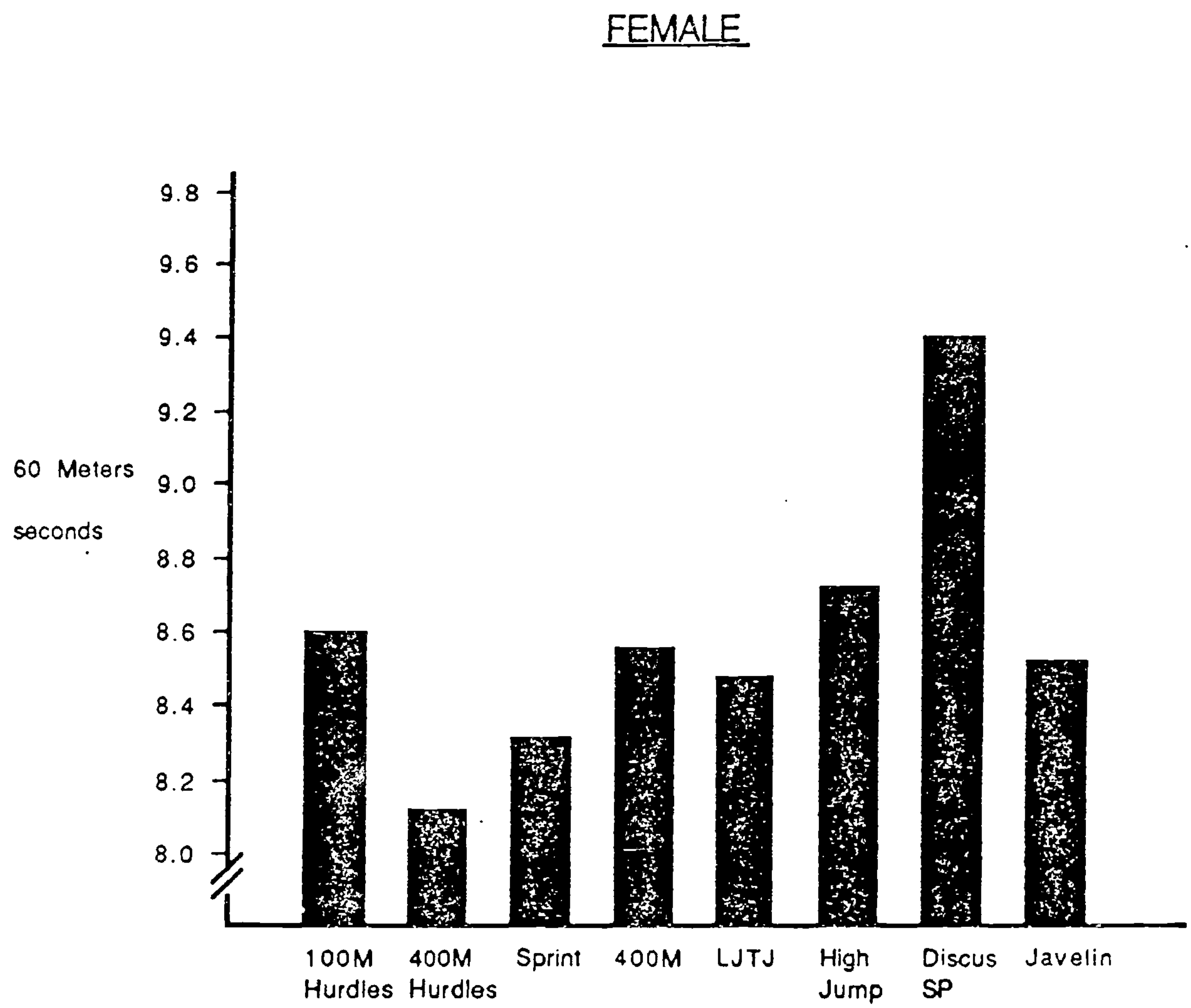

Figure 18. Mean 60 meter dash time by event for females.

and elite athletes. The slowest, as would be expected, were the throwers.

Males/Competitive Event

As with the females, the males improved in the 60 meter test with competitive level, with the elite athletes being the fastest. The mean 60 meter dash times were 8.16, 7.51, 7.41, and 7.25 seconds for JHS, SHS, college, and elite athletes respectively. The standard deviations of the 60 meter times were .58, .39, .48, and .39 seconds for JHS, SHS, college, and elite athletes respectively (see Figure 19).

Males/Event

The means and standard deviations of the 60 meter test for males by event may be seen in Table 11 and Figure 20.

Table 11

Means and standard deviations of the 60 meter test for males by event.

Event	Number	Mean	SD
110 m H	17	7.28	.36
400 m H	18	7.44	.33
Sprnts	136	7.40	.47
400 m	120	7.57	.53
Horjmps	110	7.34	.40
HJ	69	7.75	.61
SP/DISC	43	7.84	.47
Vaulters	80	7.74	.51

Sixty-meter times were very similar for the athletes in each event. The throwers and vertical jumpers were slightly

60 METERS

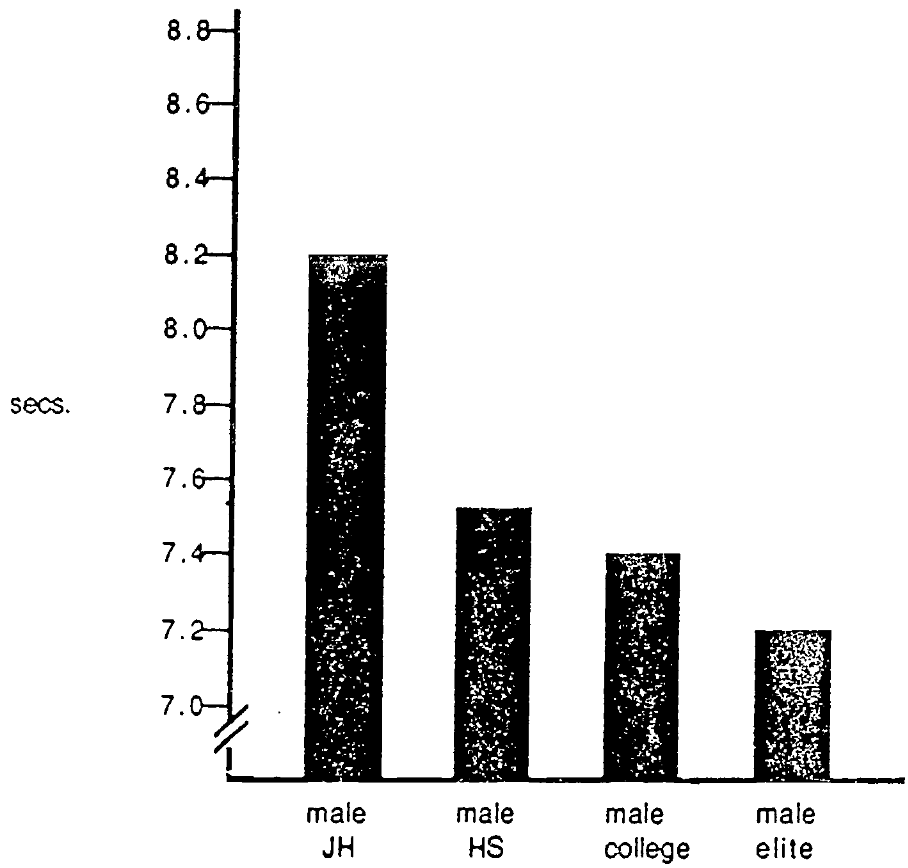

Figure 19. Mean 60 meter dash by level of competition for males.

MALE

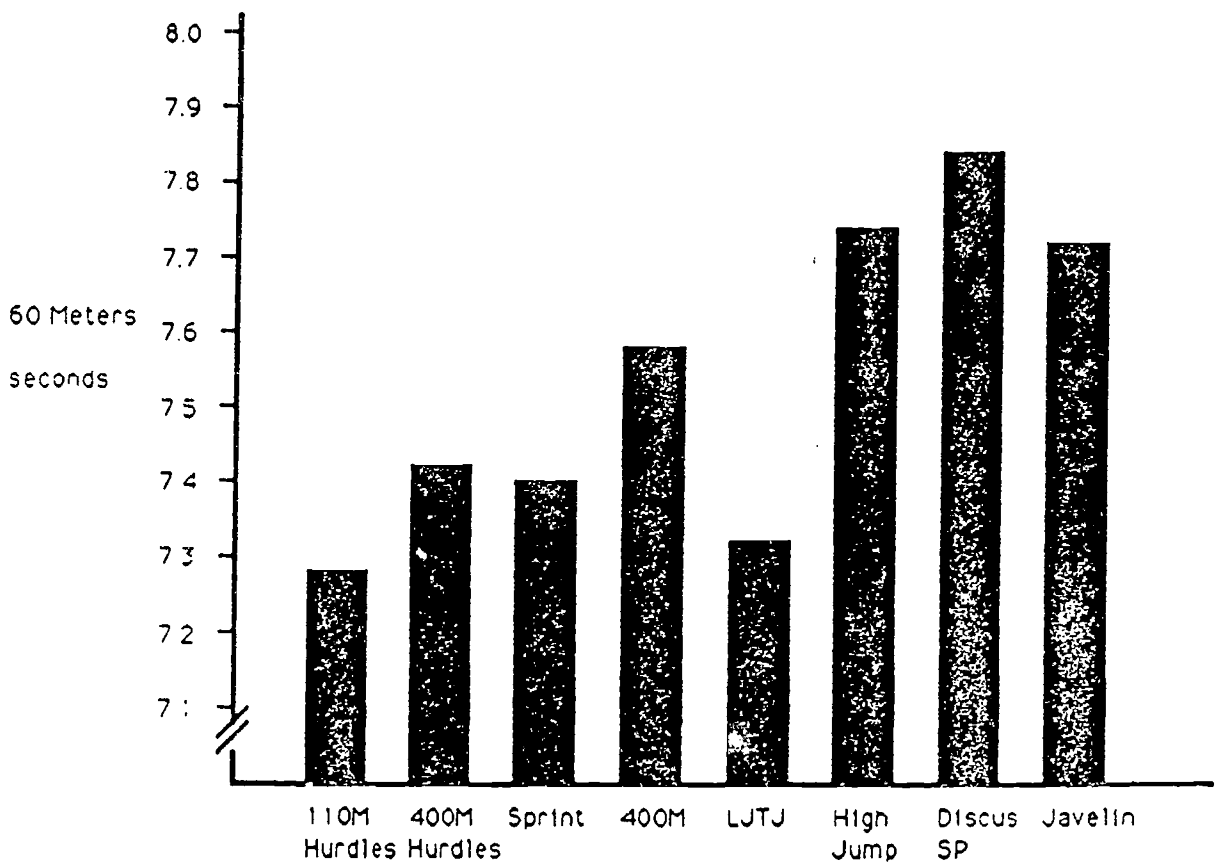

Figure 20. Mean 60 meter dash time by event for males.

slower, but the remainder were essentially equivalent.

30 METERS FROM A STANDING START

Females/Competitive Level

The 30 meter dash from a standing start represents a test of explosive power. It appears that performance in this test increased from JHS to SHS to college, and then performance decreased thereafter. This may be due to a sampling bias or to some other unknown factor. The mean 30 meter times from a standing start were 4.78, 4.59, 4.43, and 4.48 seconds for JHS, SHS, college, and elite athletes respectively. The standard deviations for these groups were .29, .31, .29, and .37 seconds for JHS, SHS, college, and elite athletes respectively. The large variation in the performance of elite athletes indicates that there were some very fast times from this group (see Figure 21).

Females/Event

The means and standard deviations of the 30 meter times from a standing start may be seen in Table 12 and Figure 22.

30 METERS

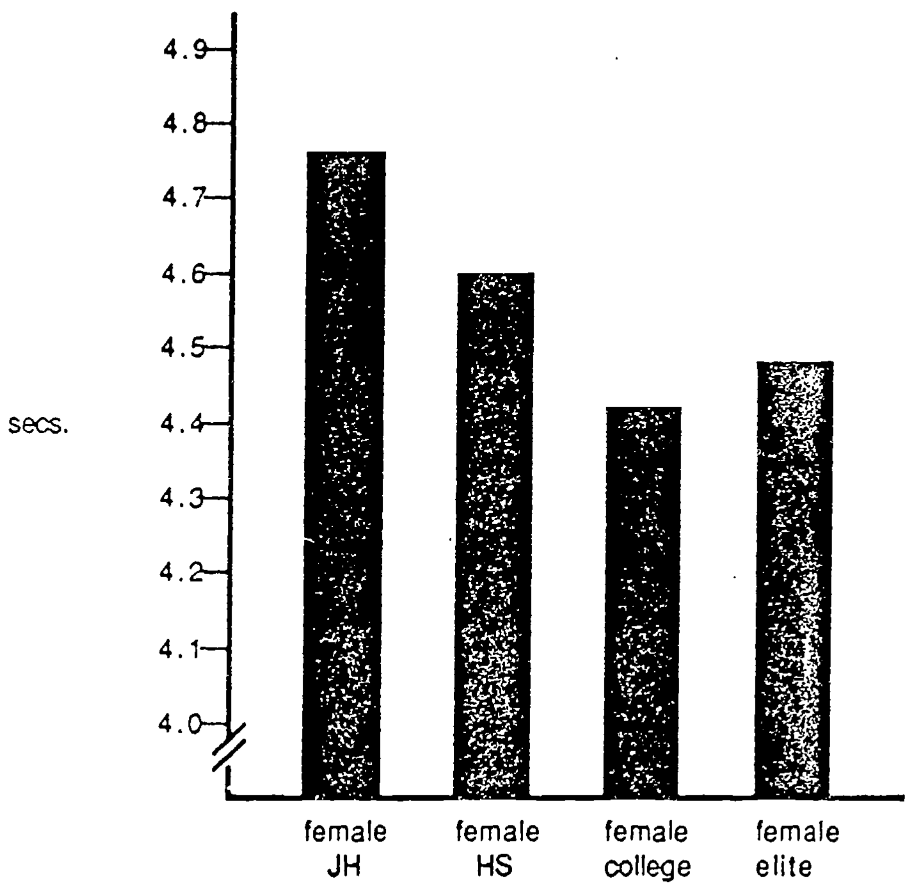

Figure 21. Mean 30 meter dash by level of competition for females.

FEMALE

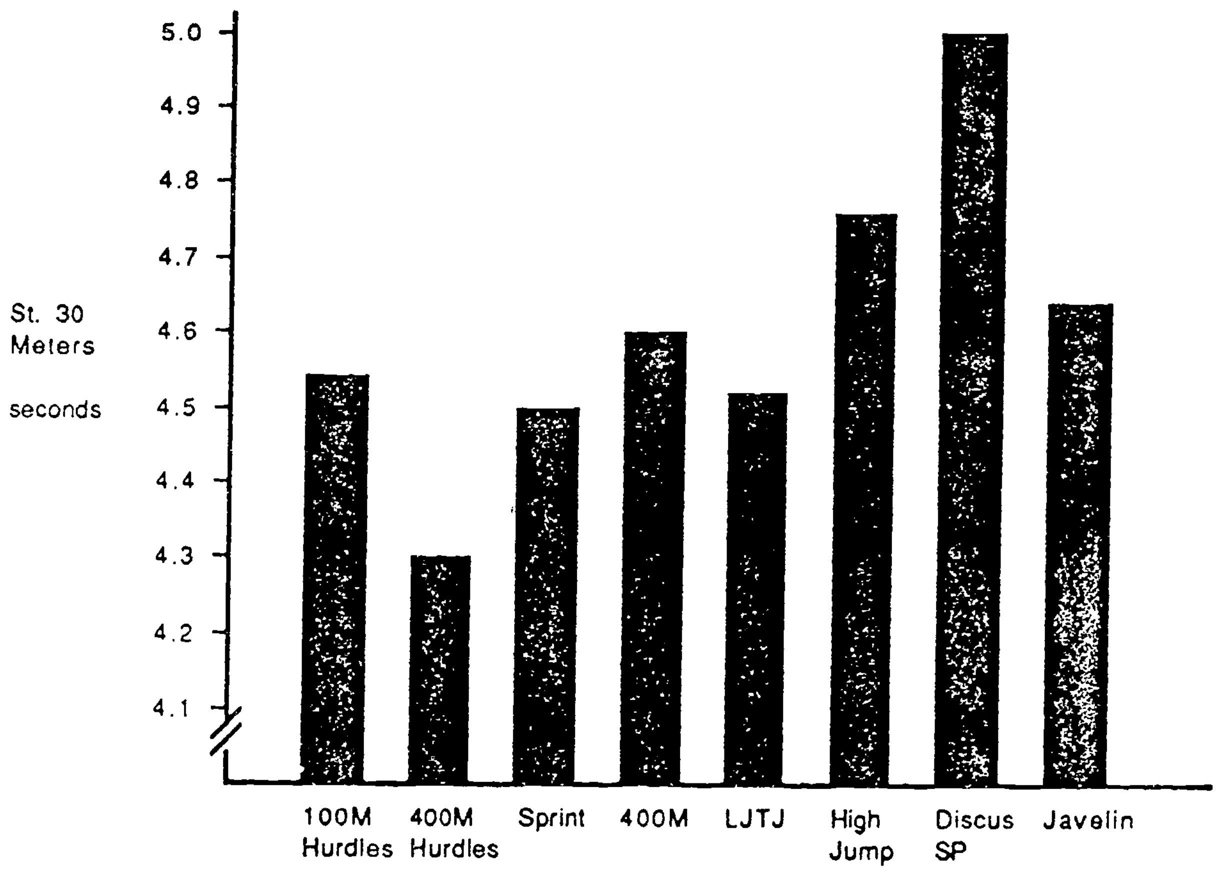

Figure 22. Mean 30 meter dash time by event for females.

Table 12

Means and standard deviations of the females in the 30 meter dash from a standing start by event.

Event	Number	Mean	SD
100 m H	35	4.57	.23
400 m H	7	4.26	.21
Sprnts	167	4.52	.31
400 m	126	4.61	.26
Horjmps	71	4.53	.31
HJ	72	4.76	.33
SP/DISC	57	4.98	.37

The fastest in the 30 meter dash from a standing start were the 400 m hurdlers, while the slowest were the throwers. Again, the speed of the 400 m hurdlers is somewhat misleading, as all of the performers in this group were either collegiate or elite athletes.

Male/Competitive Level

The explosive speed measured by this test was found to increase across the four levels of competition. The mean 30 meter dash times from a standing start were 4.51, 4.15, 4.02, and 3.96 seconds. The standard deviations of this test were .31, .24, .25, and .24 seconds for JHS, SHS, college, and elite athletes respectively (see Figure 23).

Male/Events

The means and standard deviations of the 30 meter dash from a standing start test for the males by events may be seen in Table 13 and Figure 24.

30 METERS

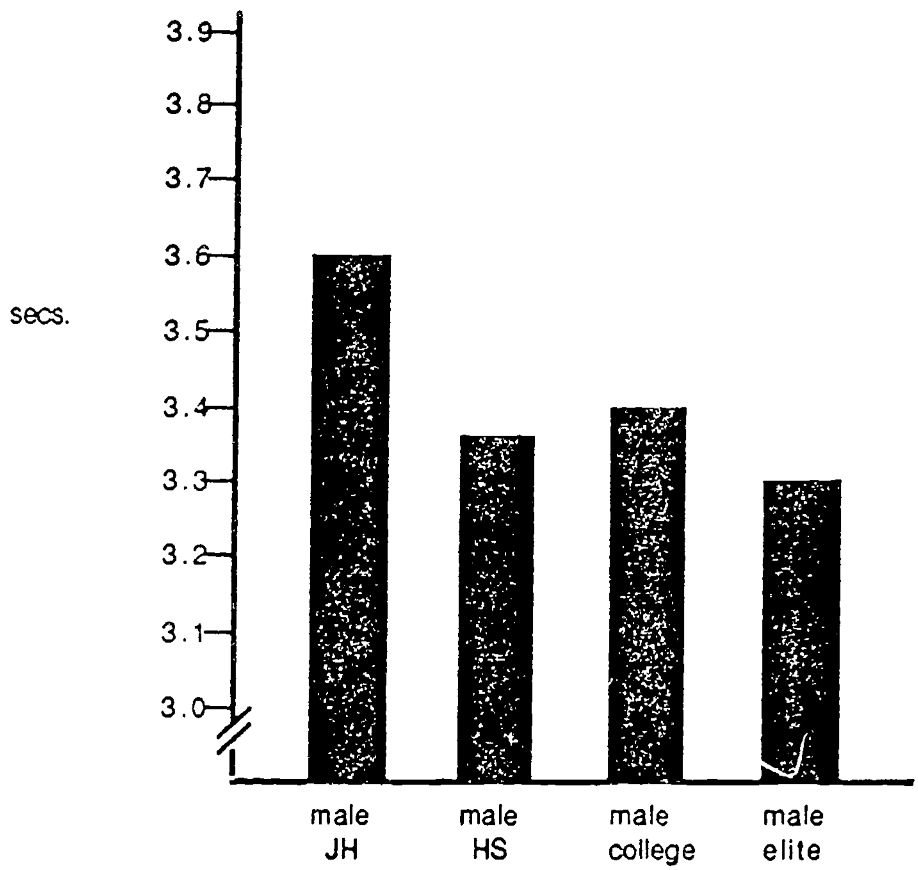

Figure 23. Mean 30 meter dash time by level of competition for males.

MALE

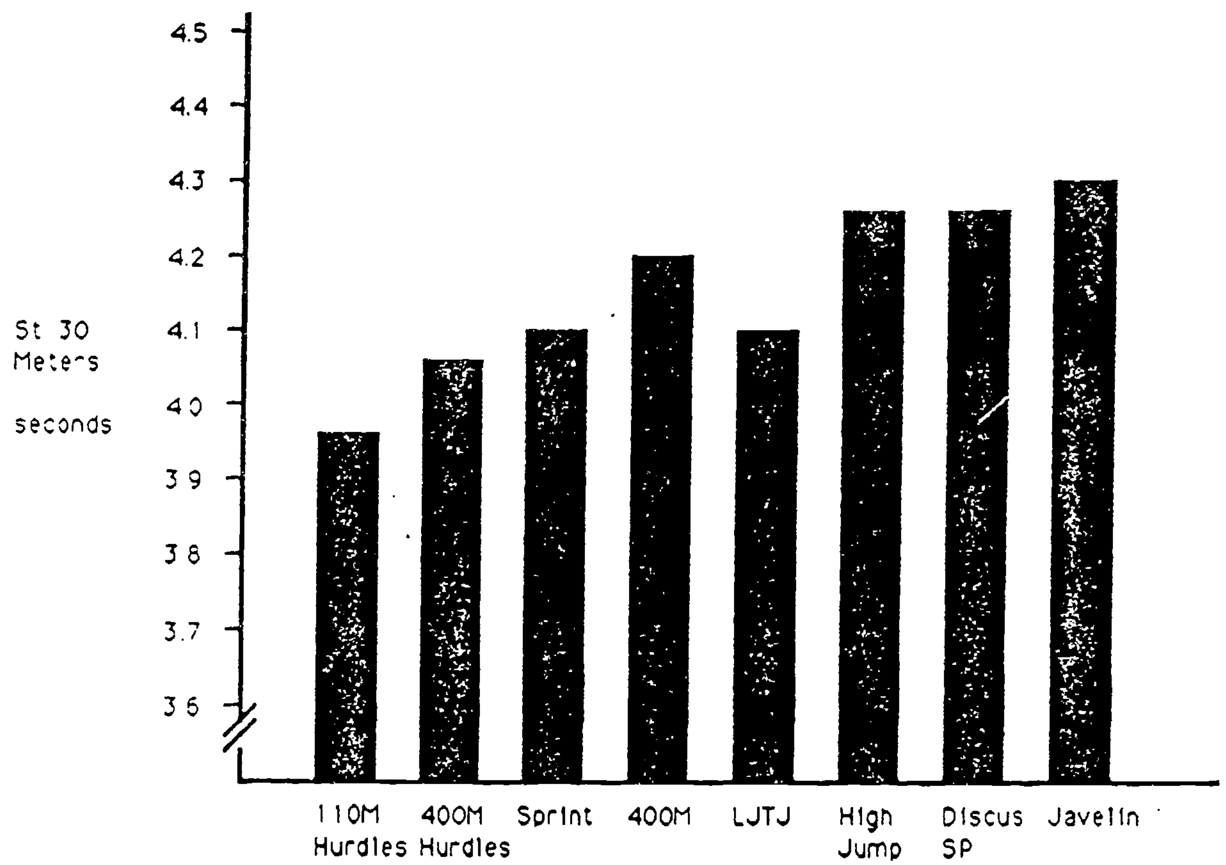

Figure 24. Mean 30 meter dash time by event for males.

Table 13

Means and standard deviations of the 30 meter dash from a standing start test for males by event.

Event	Number	Mean	SD
110 m H	17	3.95	.20
400 m H	18	4.07	.26
Sprnts	136	4.08	.26
400 m	120	4.18	.29
Horjmps	110	4.08	.24
HJ	69	4.24	.33
SP/DISC	43	4.26	.24
Vaulters	80	4.30	.30

Although there was little difference between the athletes in the different events, the vertical jumpers and the throwers were much slower than the other athletes. This would be intuitive, as the vertical jumpers and throwers rely least upon horizontal velocity for their performance.

30 METERS ON THE FLY

Females/Competitive Level

The 30 meter dash on the fly test is different from the previous two sprint tests in that explosiveness is not as important a factor in the performance on this test. This will be discussed later in this report. The mean performances on this test were 4.20, 3.91, 3.88, and 3.81 seconds for JHS, SHS, college and elite athletes respectively. It appears that this ability may be increased only slightly between high school post-collegiate competition. The standard deviations were .44, .35, .39, and .36 seconds for JHS, SHS, college, and elite athletes respectively (see Figure 25).

Female/Event

The means and standard deviations for the performance on the 30 meter dash on the fly test for females by event may be seen in Table 14 and Figure 26.

Table 14

Means and standard deviations of the females on the 30 meter dash on the fly test by event.

Event	Number	Mean	SD
100 m H	35	3.78	.36
400 m H	7	3.81	.24
Sprnts	167	3.88	.40
400 m	126	3.93	.34
Horjmps	71	3.92	.30
HJ	72	3.99	.38
SP/DISC	57	4.42	.45

The throwers appear to be much slower on this test, while the 100 m hurdlers appear to be the fastest. The remainder of the events appear to be approximately equivalent.

Males/Competitive Level

The mean performances on the 30 meter dash on the fly test by the males were 3.64, 3.35, 3.38, 3.29 seconds for JHS, SHS, college, and elite athletes respectively. Like the females, the greatest improvements on this test occur between junior high school and high school, with only slight improvements thereafter. The standard deviations for

ON THE FLY 30 METERS

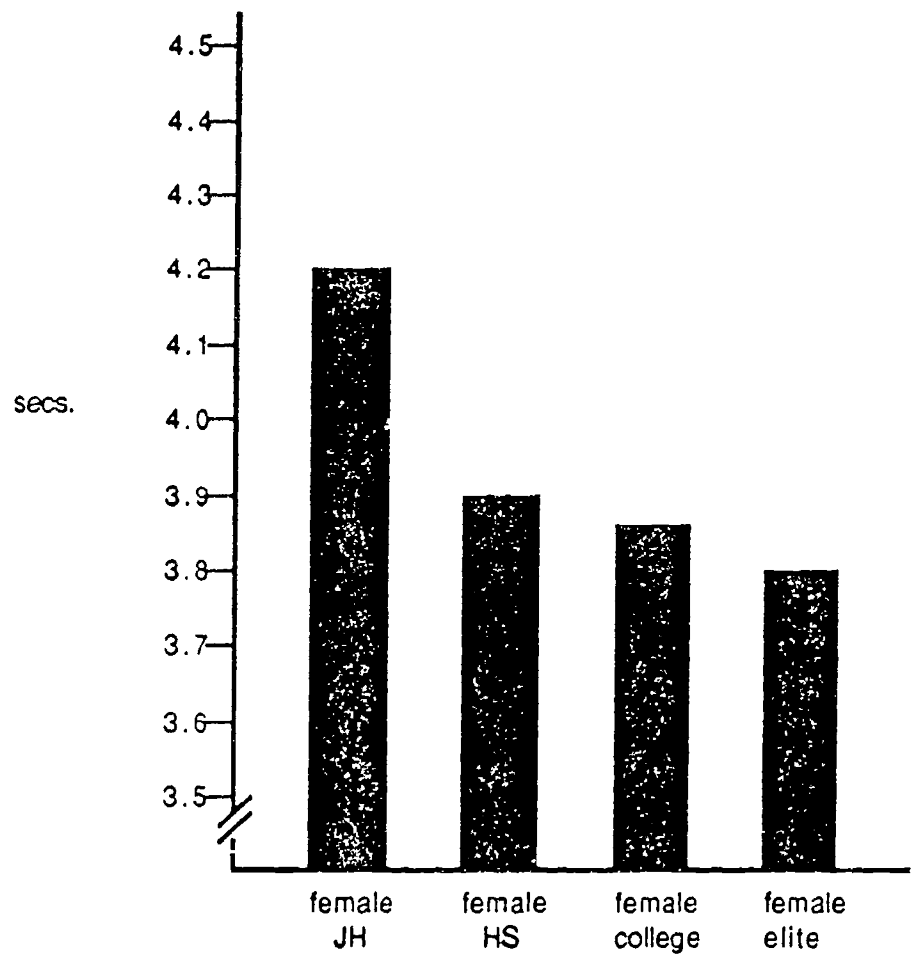

Figure 25. Mean 30 meter time (on the fly) by level of competition for females.

FEMALE

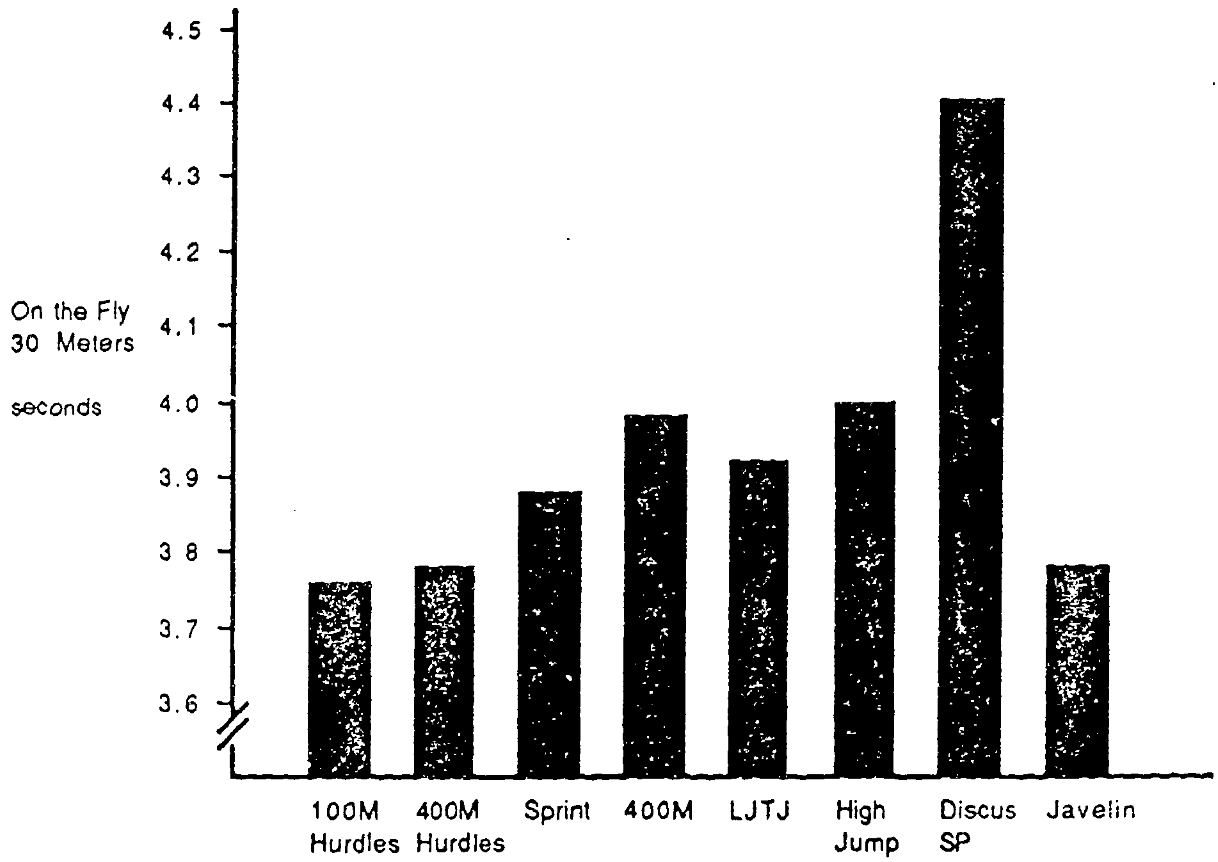

Figure 26. Mean 30 meter dash time (on the fly) by event for females.

the performances on this test were .34, .27, .29, and .26 seconds for JHS, SHS, college, and elite athletes respectively (see Figure 27).

ales/Event

The means and standard deviations of the performances of the males on the 30 meter dash on the fly test may be seen in Table 15 and Figure 28.

Table 15

Means and standard deviations of the males on the 30 meter dash on the fly test by event.

Event	Number	Mean	SD
110 m H	17	3.33	.24
400 m H	18	3.38	.20
Sprnts	136	3.32	.30
400 m	120	3.40	.35
Horjmps	110	3.27	.24
HJ	69	3.51	.39
SP/DISC	43	3.56	.29
Vaulters	80	3.43	.29

There appears to be little variation across events in the performance on this test. Again however, the vertical jumpers and throwers are noticeably slower than the other male athletes.

STRIDE FREQUENCY

Females/Competitive Level

The stride frequency of the athletes was determined by counting the number of strides during the last 30 meters of

ON THE FLY 30 METERS

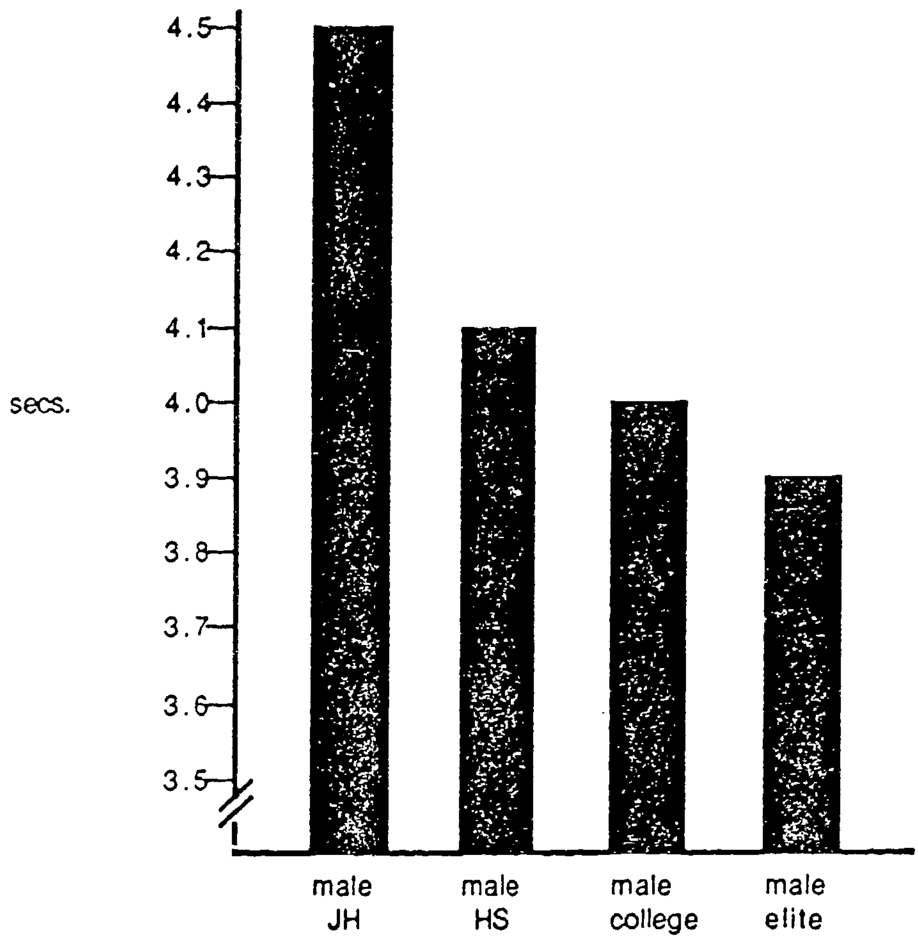

Figure 27. Mean 30 meter dash (on the fly) by level of competition for males.

MALE

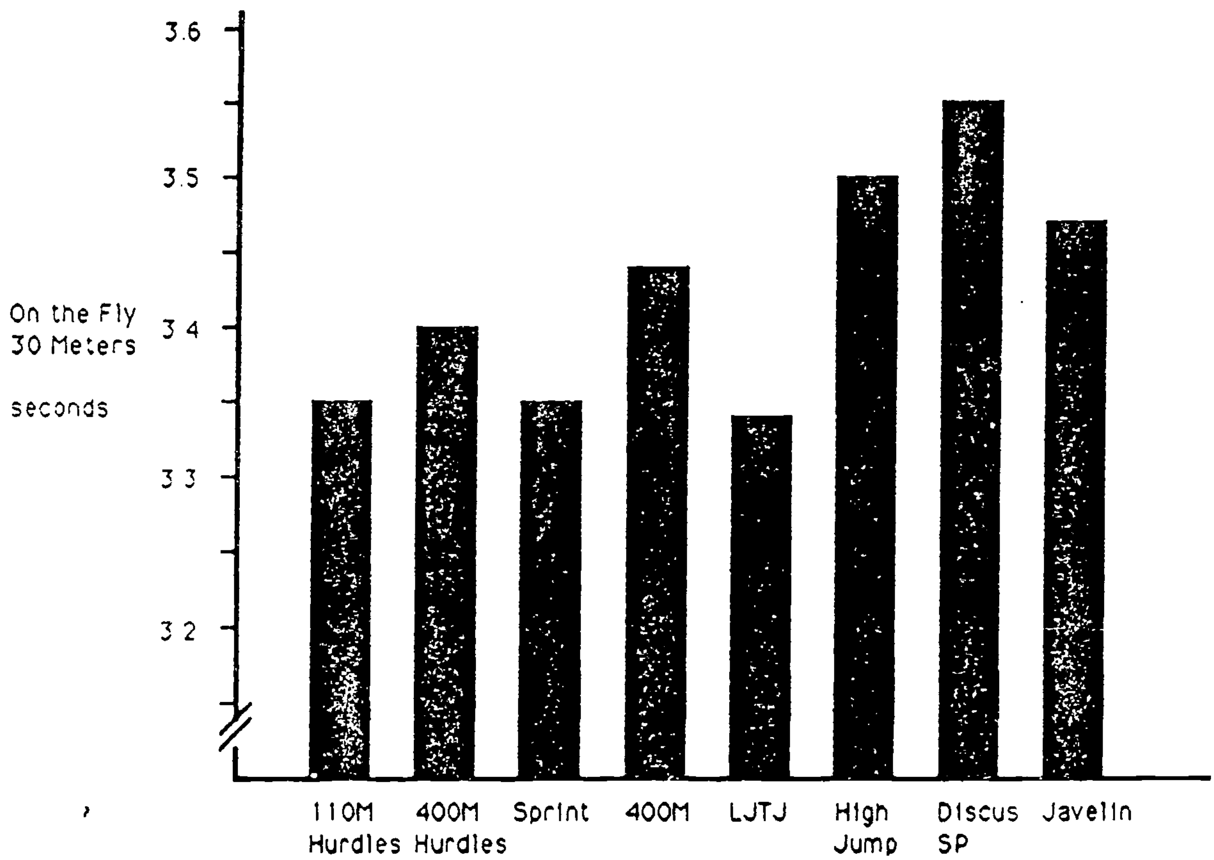

Figure 28. Mean 30 meter dash time (on the fly) by event for males.

a 60 meter sprint. The mean frequencies were 3.84, 3.97, 4.12, and 4.03 strides/second for JHS, SHS, college and elite performers respectively. It appears that there are equivalent improvements in this component of sprint speed between JHS and SHS and between SHS and college. After college, there does not appear to be an improvement in this component. The standard deviations of stride frequency were .37, .38, .45, and .43 for JHS, SHS, college, and elite athletes respectively (see Figure 29).

Females/Event

The means and standard deviations of stride frequency of the females by event may be seen in Table 16 and Figure 30.

Table 16

Means and standard deviations of stride frequency for females by events.

Event	Number	Mean	SD
100 m H	35	4.19	.50
400 m H	7	3.89	.23
Sprnts	167	4.05	.38
400 m	126	3.99	.36
Horjmps	71	3.99	.36
HJ	72	3.83	.38
SP/DISC	57	3.82	.40

Only slight differences were observed between the performers in the different events. The 110 hurdlers m had the greatest stride length and were the most variable.

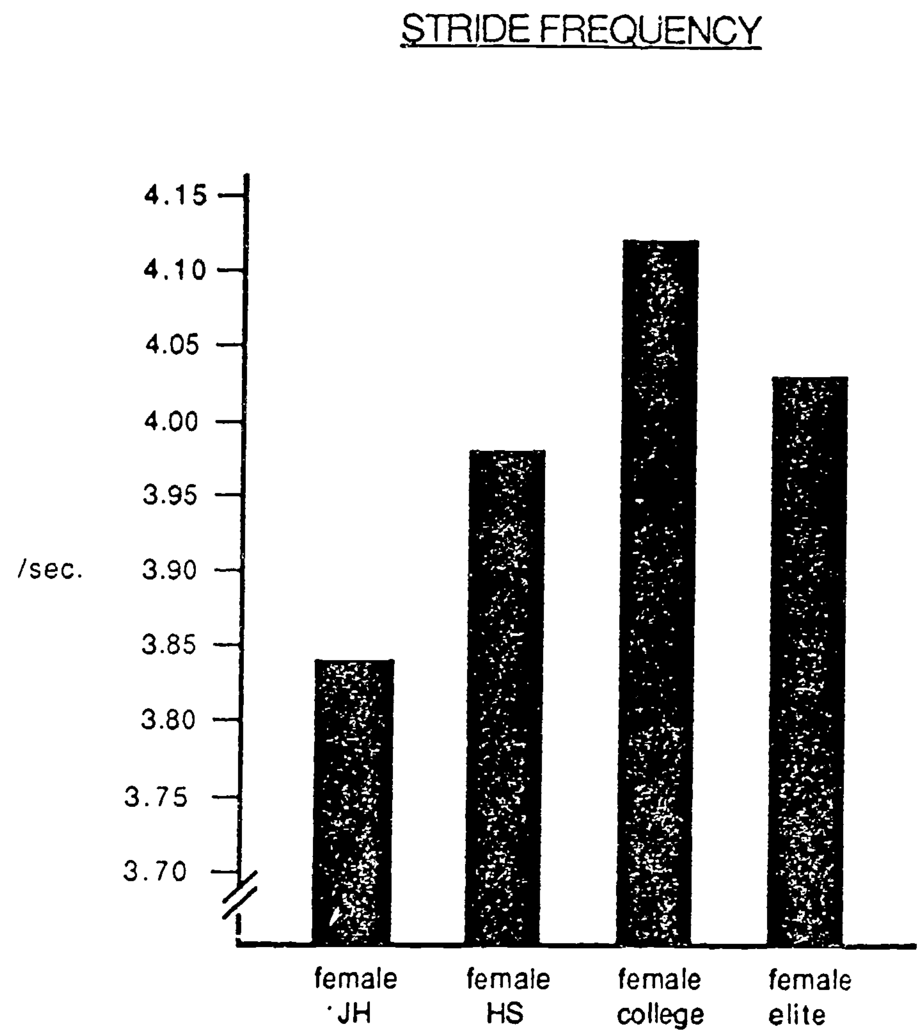

Figure 29. Mean stride frequency by level of performance for females.

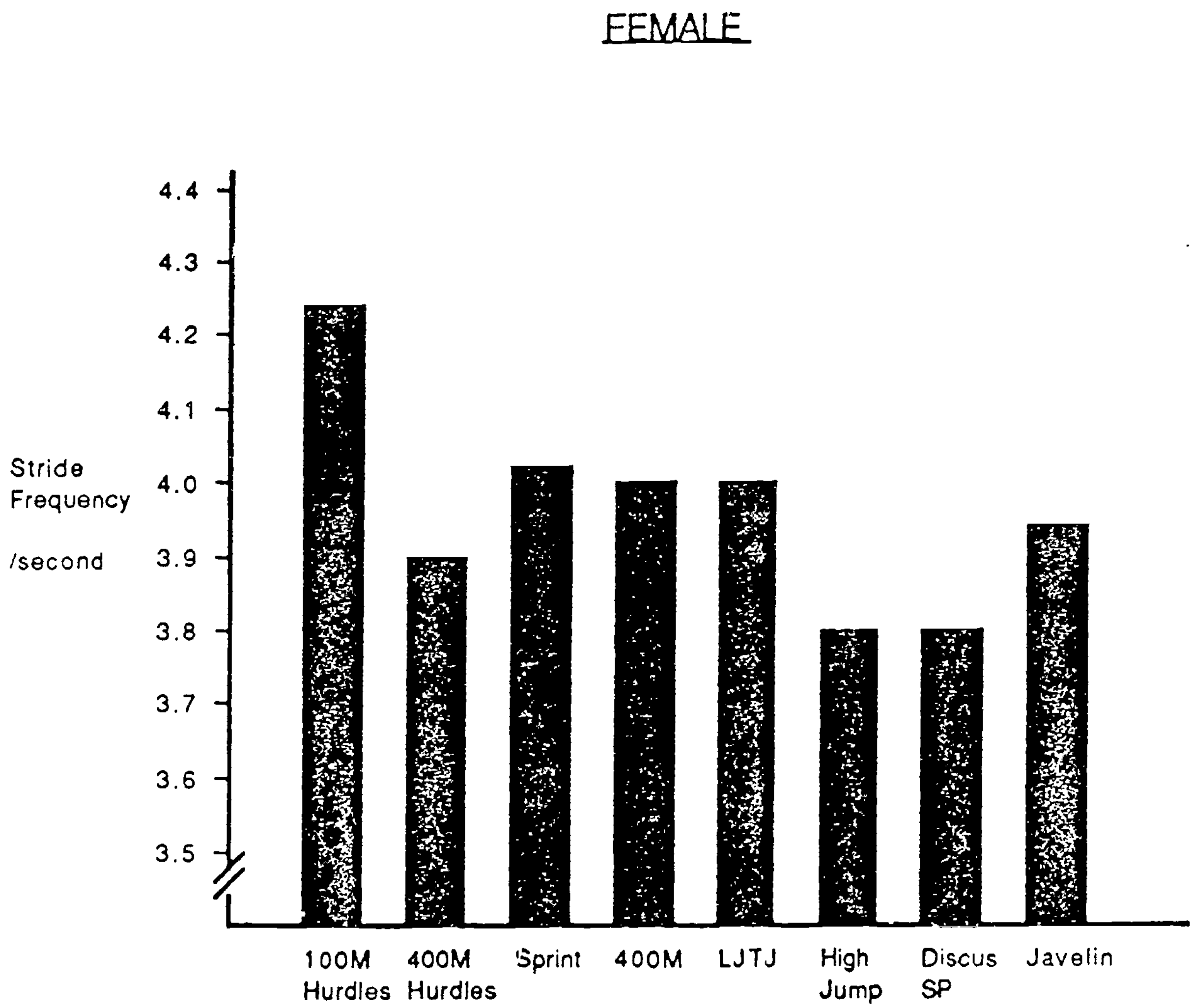

Figure 30. Mean stride frequency by event for females.

Males/Competitive Event

Stride frequency remained relatively unchanged across competitive levels. The mean stride frequencies were 4.13, 4.26, 4.23, and 4.22 strides/second for JHS, SHS, college, and elite athletes respectively. The standard deviations were .29, .41, .36, and .41 strides/second for JHS, SHS, college, and elite athletes respectively. It is apparent that stride frequency is a poor predictor of performance level (see Figure 31).

Males/Event

The means and standard deviations of stride frequency for males may be seen in Table 17 and Figure 32.

Table 17

Means and standard deviations of stride frequency for males across events.

Events	Number	Mean	SD
110 m H	17	4.13	.26
400 m H	18	4.27	.35
Sprnts	136	4.33	.35
400 m	120	4.25	.41
Horjmps	110	4.28	.36
HJ	69	4.02	.43
SP/DISC	43	4.25	.32
Vaulters	80	4.33	.46

There were relatively no differences in mean stride frequency across events as well. This means that stride frequency would be a poor predictor of "best event".

STRIDE FREQUENCY

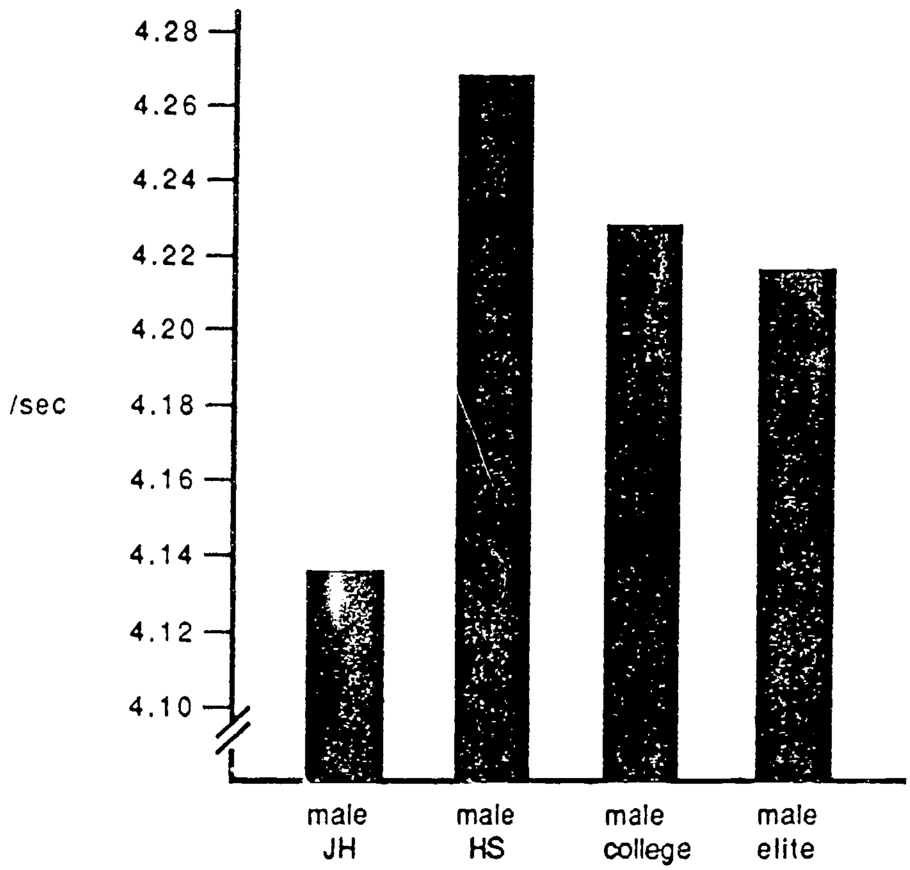

Figure 31. Mean stride frequency by level of competition for males.

MALE

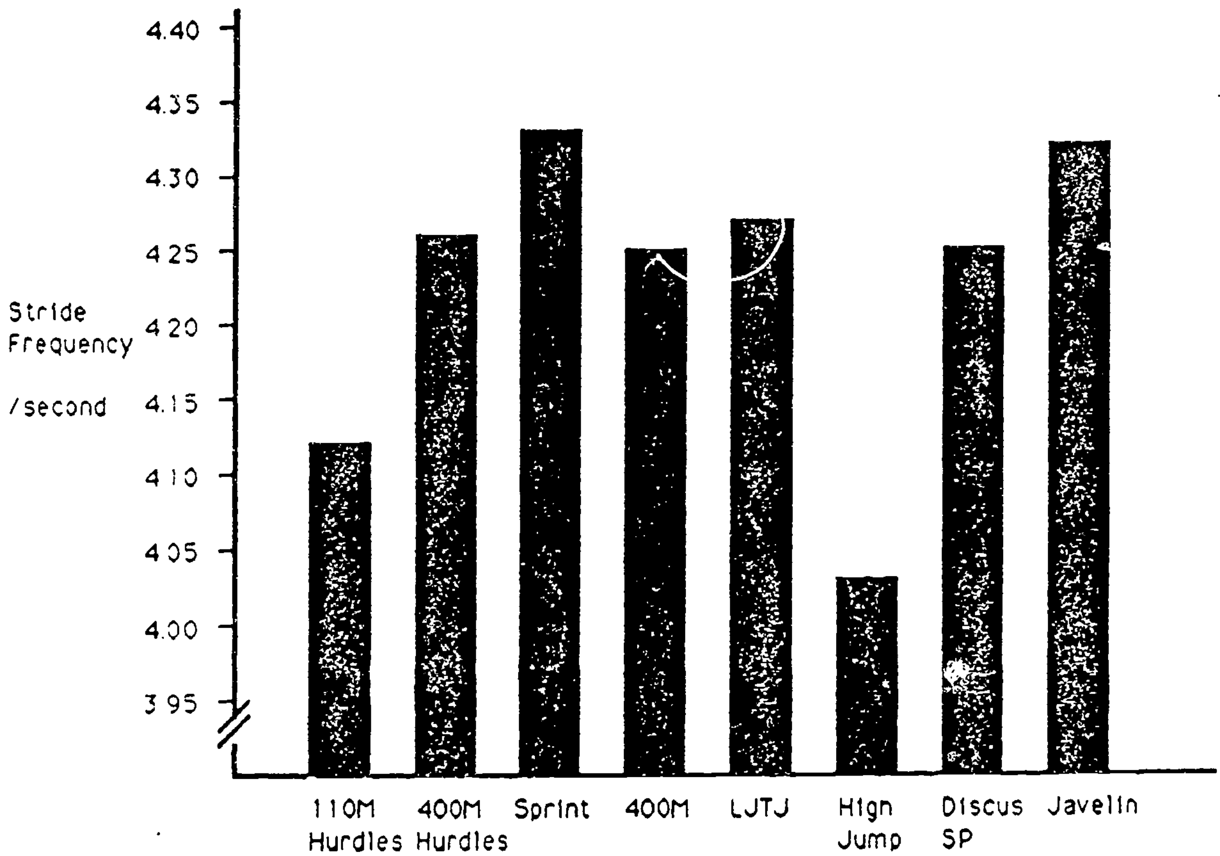

Figure 32. Mean stride frequency by event for males.

STRIDE LENGTH

Female/Competitive Level

As with stride frequency, there were only slight increases in stride length across levels of competition. These small differences may be the result of imprecise measurements, as stride length was the most difficult performance to measure. In addition, these small differences in the length of each stride, coupled with small improvements in stride frequency, would be magnified over a long distance. Thus, these small differences may be misleading. The mean stride lengths were 74.10, 77.10, 75.64, and 78.26 inches for JHS, SHS, college, and elite athletes respectively. The standard deviations were .37, .38, .45, and .43 inches respectively (see Figure 33).

Females/Event

The means and standard deviations of stride length for females across events may be seen in Table 18 and Figure 34.

Table 18

Means and standard deviations of stride length for females across events.

Event	Number	Mean	SD
100 m H	35	76.11	5.07
400 m H	7	80.54	3.57
Sprnts	167	76.31	5.99
400 m	126	76.43	4.69
Horjmps	71	76.61	5.57
HJ	72	78.93	6.22
SP/DISC	57	71.36	5.94

STRIDE LENGTH

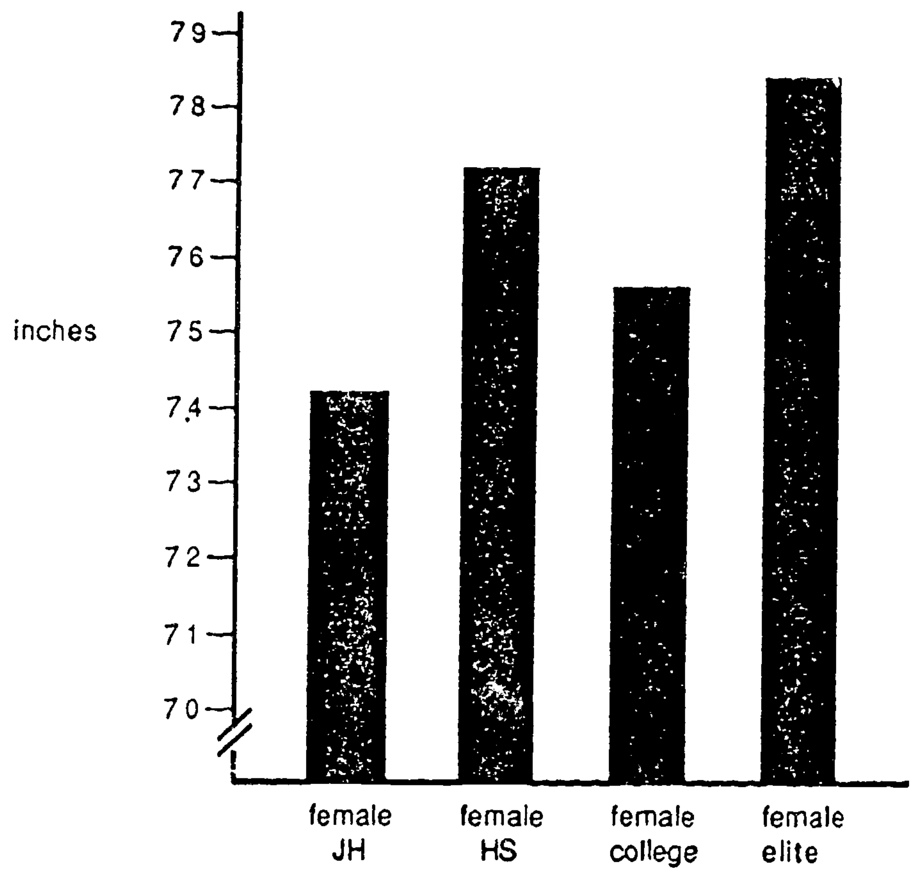

Figure 33. Mean stride length by level of competition for females.

FEMALE

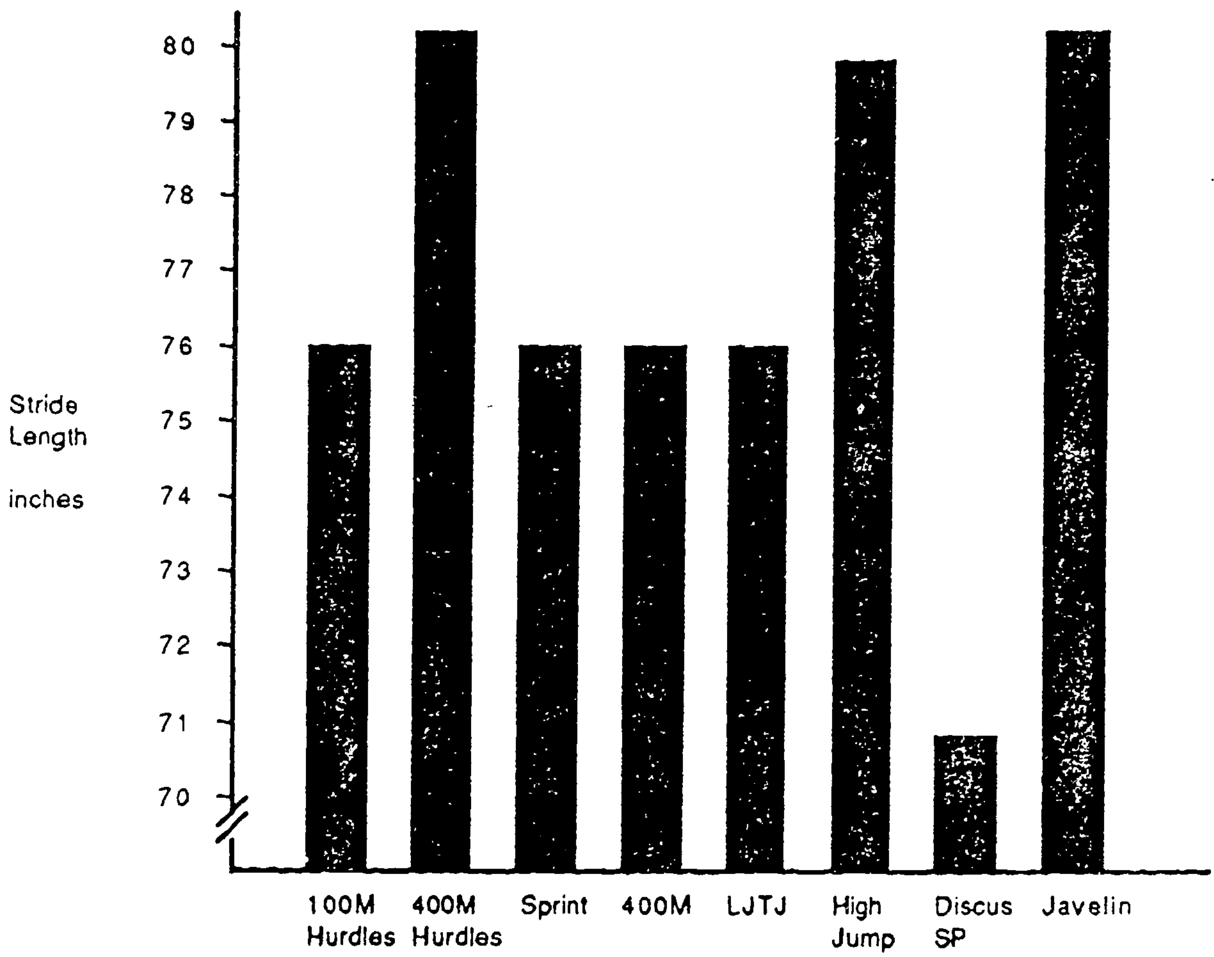

Figure 34. Mean stride length by event for females.

The stride lengths were much higher for the high jumpers and 400 m hurdlers. The athletes in the remaining events were equivalent.

Males/Competitive Level

The stride lengths for the males increased substantially between JHS and SHS and then again between high school and college. Thereafter it seems to level off. Because of the earlier finding of little difference between competitive levels with regard to stride frequency, it appears that the increases in speed with level of competition are due to increases in stride length. The mean stride lengths for males were 79.03, 83.23, 84.98, and 83.23 inches for JHS, SHS, college, and elite athletes respectively (see Figure 35).

Males/Event

The means and standard deviations of stride length for males by event may be seen in Table 19 and Figure 36.

Table 19

Means and standard deviations of stride length for males by event.

Event	Number	Mean	SD
110 m H	17	85.43	5.45
400 m H	18	82.72	6.41
Sprnts	136	83.01	5.52
400 m	120	82.71	6.23
Horjmps	110	84.54	5.74
HJ	69	84.45	6.87
SP/DISC	43	79.91	6.29
Vaulters	80	80.56	5.53

STRIDE LENGTH

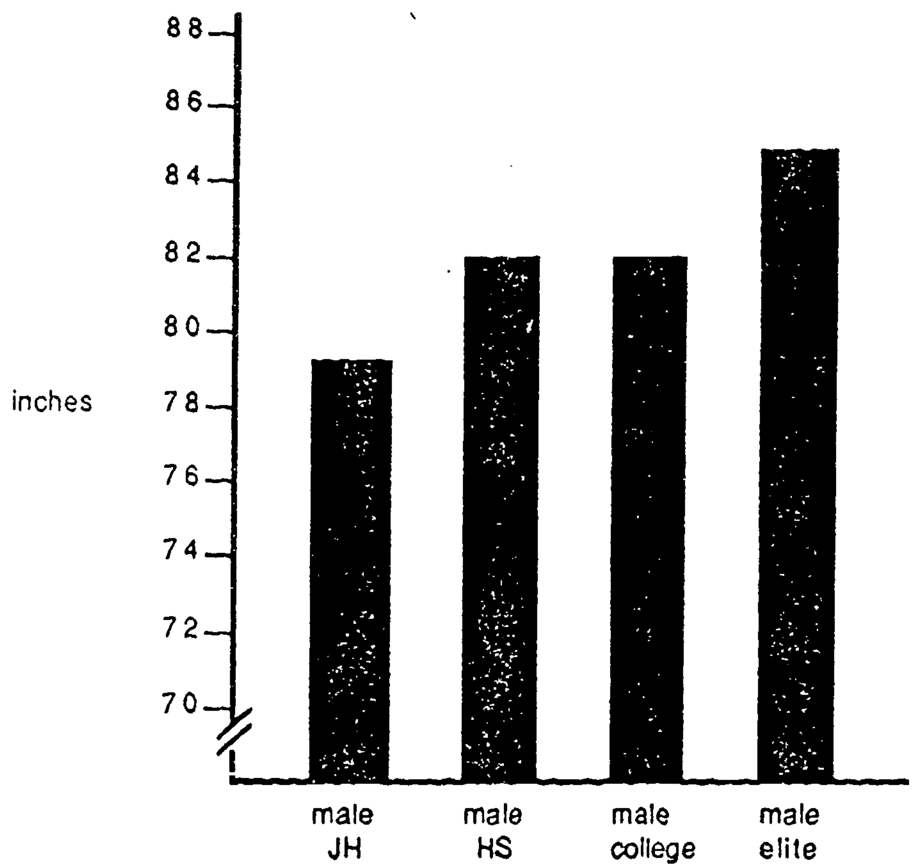

Figure 35. Mean stride length by level of competition for males.

MALE

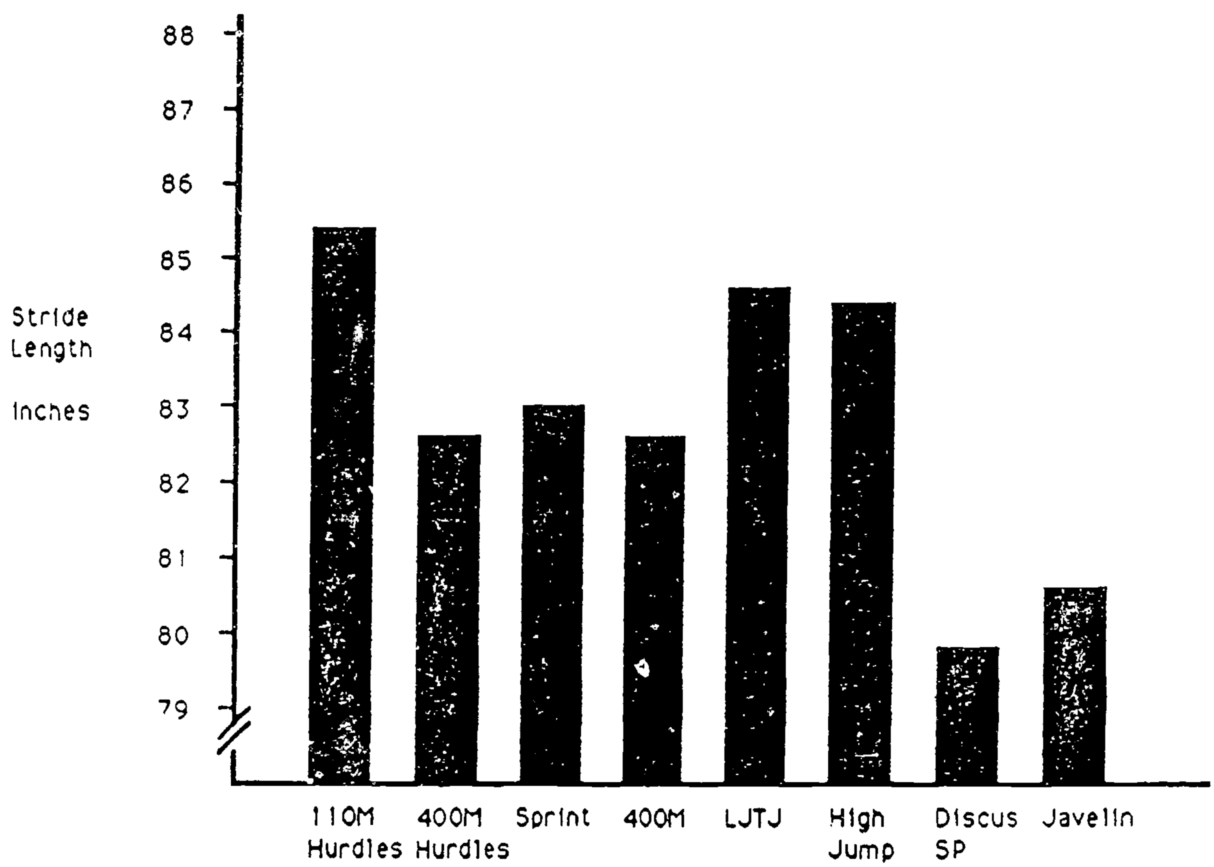

Figure 36. Mean stride length by event for males.

The mean stride lengths appear to be quite varied, with the 110 m hurdlers having the longest stride length and the throwers having the shortest stride length. The variable would appear to have some value in attempting to predict "best event".

STANDING LONG JUMP

Females/Competitive Level

Standing long jump is a test that measures leg power. It appears that there are large increases in leg power across competitive levels. This suggests that increases in performance levels may be related to increases in leg power. The mean performances on the standing long jump test for the females were 79.64, 83.66, 91.19, and 91.68 inches for JHS, SHS, college, and elite athletes respectively. The standard deviation of the performances on the test were 7.83, 7.54, 8.85, and 6.84 inches for JHS, SHS, college, and elite athletes respectively (see Figure 37).

Females/Event

The means and standard deviations of the performances on the standing long jump test for females across events may be seen in Table 20 and Figure 38.

STANDING LONG JUMP

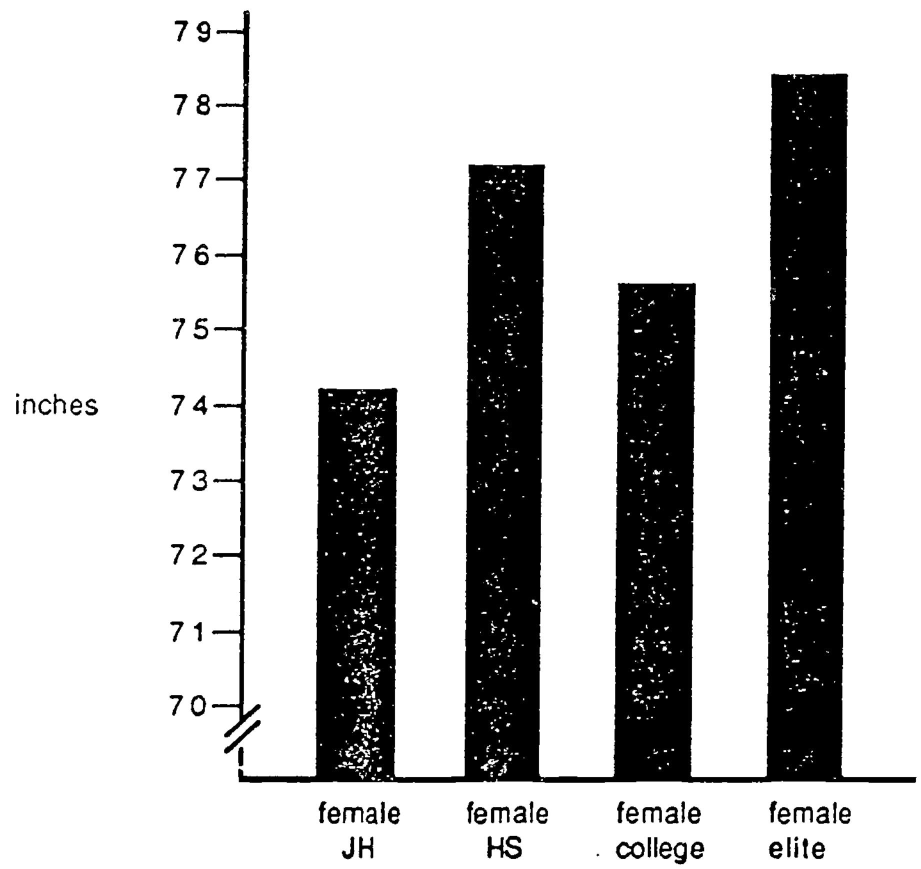

Figure 37. Mean standing long jump by level of competition by females.

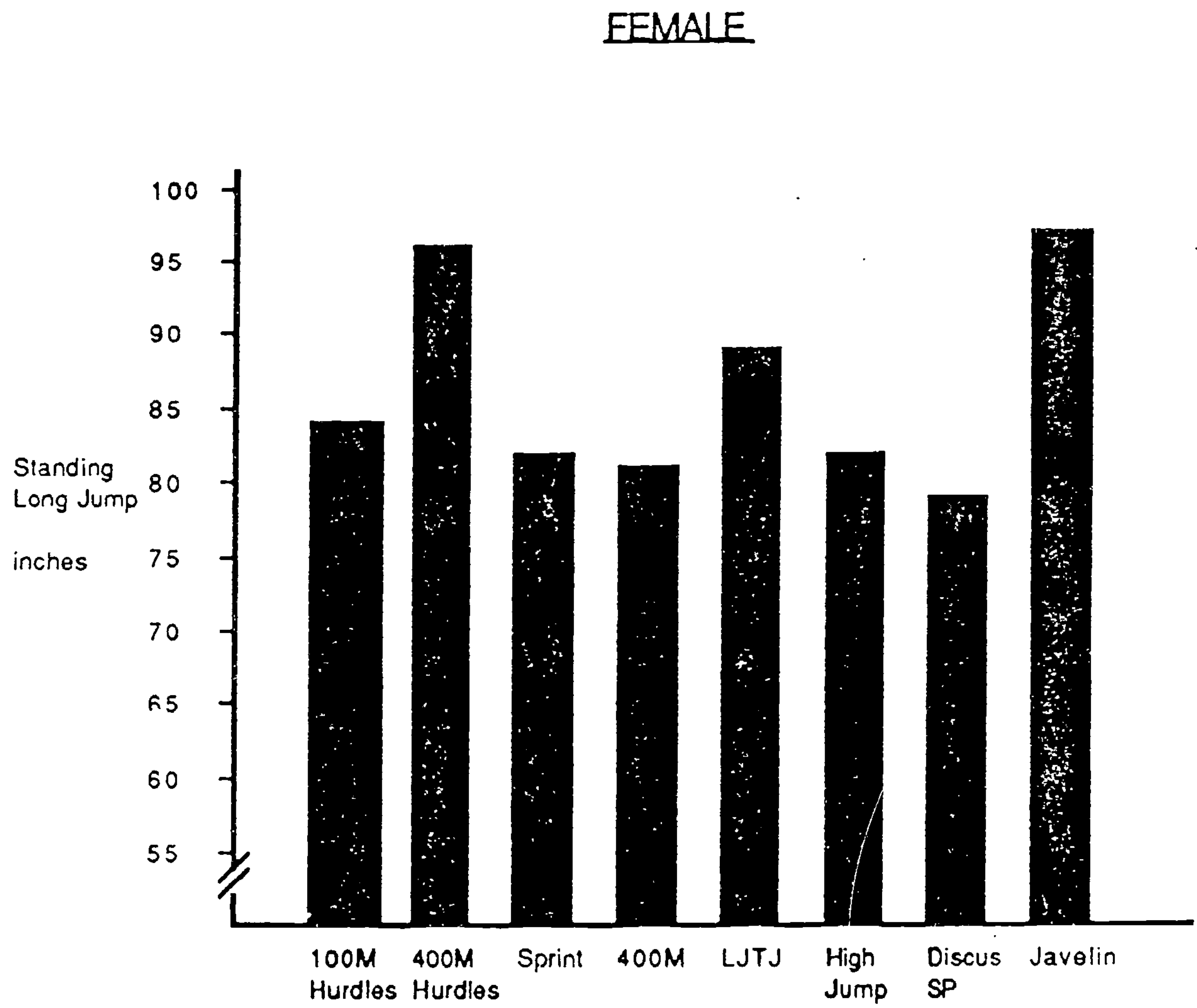

Figure 38. Mean standing long jump by event for females.

Table 20

Means and standard deviations of the females on the standing long jump test by event.

Event	Number	Mean	SD
100 m H	35	85.55	6.82
400 m H	7	96.50	7.51
Sprnts	167	82.30	7.98
400 m	126	81.69	7.85
Horjmps	71	89.11	7.62
HJ	72	85.53	7.82
SP/DISC	57	78.36	10.59

The 400 m hurdlers scored the highest on the test, indicating that they have the greatest leg power. However, it is important to remember that only college and elite athletes are included in this group, so there is a bias in the sample. The next highest scoring group is the horizontal jumpers. It appears that the standing long jump may be a good test of long/triple jump capacity.

Males/Competitive Level

As with the females, the males exhibited large changes in scores on the standing long jump test across competitive levels. The mean performances were 89.92, 103.20, 109.73, and 111.27 inches. Again, this suggests that increases in performance may be related to increases in leg power. The standard deviations of their performances were 12.13, 8.62, 8.20, and 7.88 inches (see Figure 39).

Males/Event

The means and standard deviations of the male performances in the standing long jump test by event may be

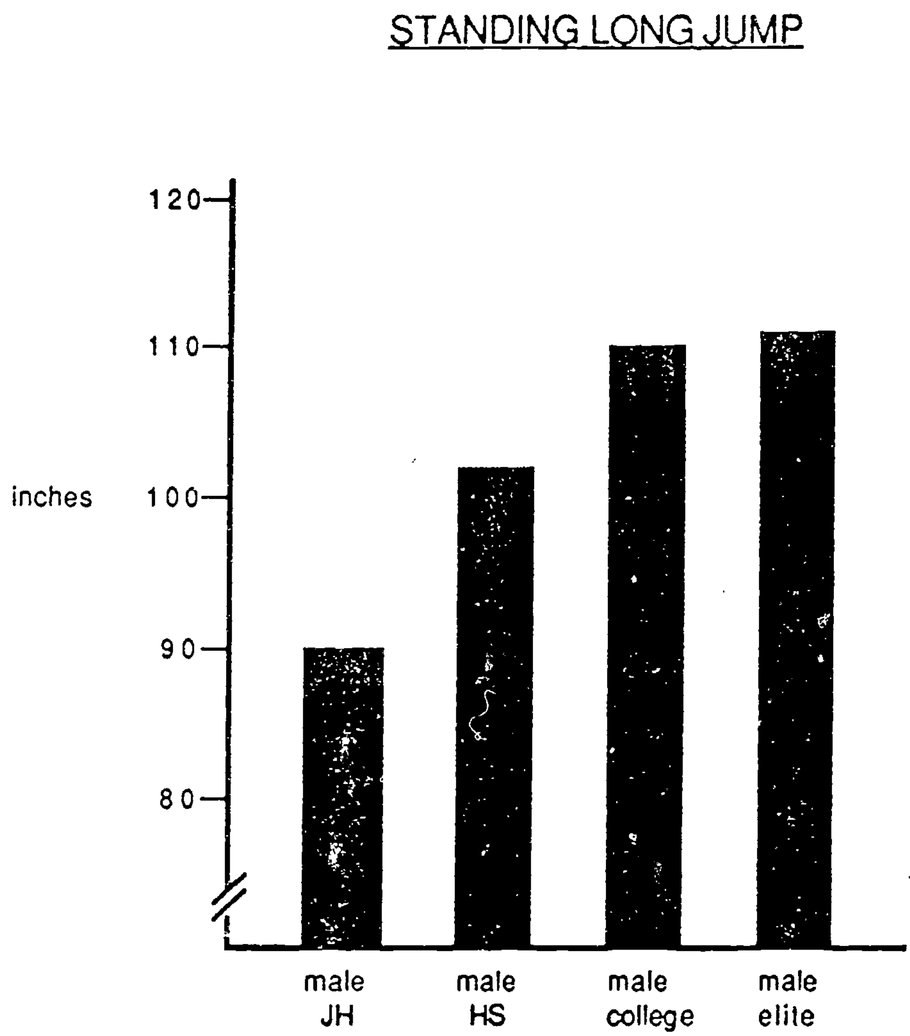

Figure 39. Mean standing long jump by level of competition for males.

seen in Table 21 and Figure 40.

Table 21

Means and standard deviations of the male performances in the standing long jump test by event.

Event	Number	Mean	SD
110 m H	17	111.87	7.57
400 m H	18	105.94	8.36
Sprnts	136	104.87	10.87
400 m	120	100.72	11.33
Horjmps	110	108.06	8.99
HJ	69	102.96	11.11
SP/DISC	43	104.43	8.84
Vaulters	80	99.58	9.00

The 110 m hurdlers appear to have the greatest leg strength, followed by the horizontal jumpers. These two events possess some of the same kinematic and kinetic constraints so that it is not surprising that they are similar in their requirements of leg power.

FIVE BOUNDS FOR DISTANCE

Females/Competitive Level

The five bounds for distance test is similar to the standing long jump in the reliance upon leg power, but it differs in the added component of neuromuscular coordination. As with standing long jump, there were large changes in the performance on this test across levels of competition. This would suggest that neuromuscular coordination also may be a factor in achieving high levels of performance. The mean performances for the females on

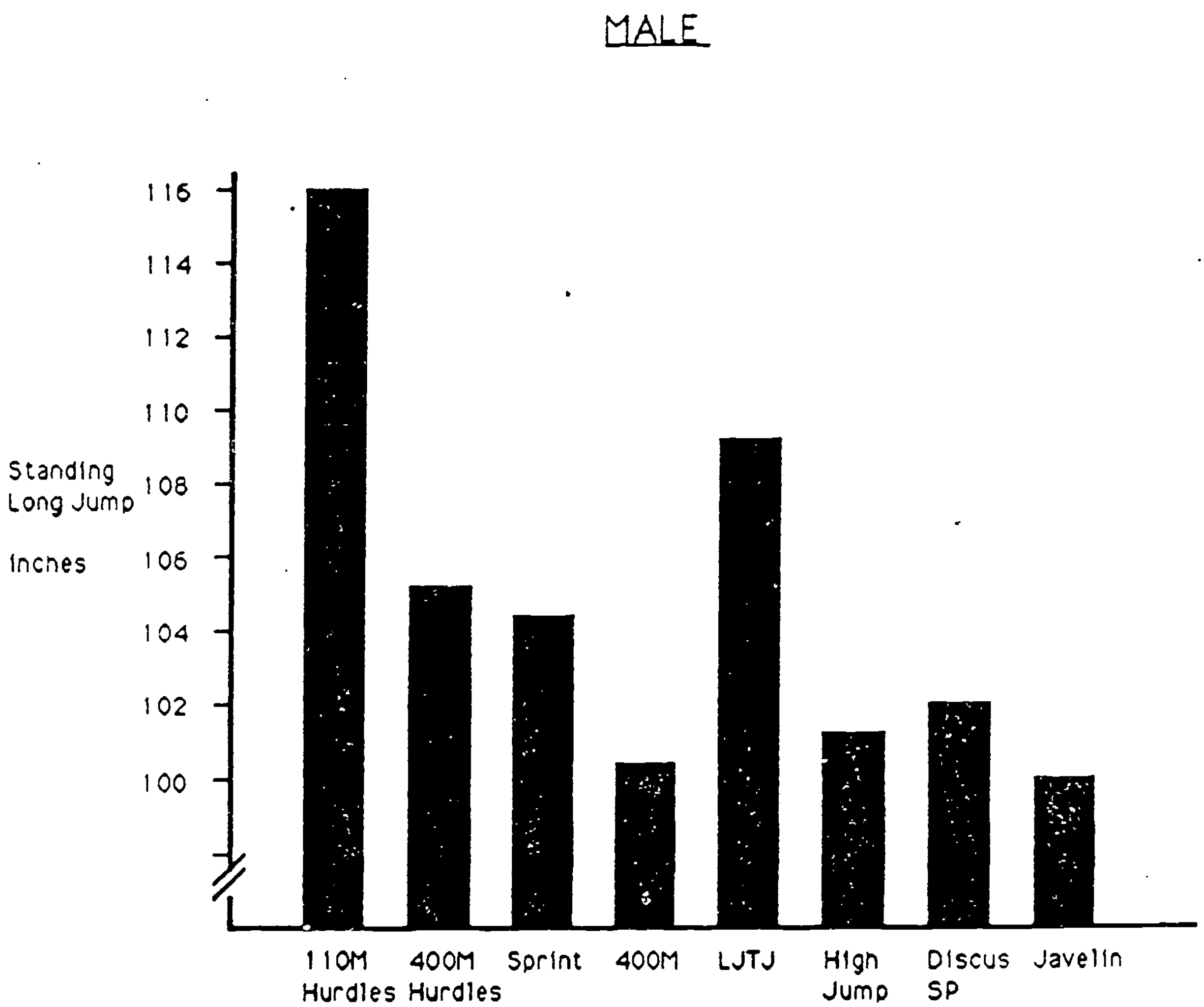

Figure 40. Mean standing long jump by event for males.

this test were 387.84, 407.39, 432.59, and 439.44 inches. The standard deviations for these performances were 26.43, 36.18, 44.26, 40.11 inches (see Figure 41).

Females/Event

The means and standard deviations of the performances of the females on the five bounds for distance test by event may be seen in Table 22 and Figure 42.

Table 22

Means and standard deviations of the female performances on the five bounds for distance test.

Event	Number	Mean	SD
100 m H	35	415.09	34.63
400 m H	7	449.86	34.04
Sprnts	167	401.31	36.67
400 m	126	400.03	34.84
Horjmps	71	427.37	48.18
HJ	72	409.31	36.50
SP/DISC	57	382.32	45.10

The differences across event performances is even more pronounced in this test. This suggests a neuromuscular factor contributing to high level performances in different events. Again the 400 m hurdlers scored highest, but this is probably a biased sample. The next highest scoring events were the horizontal jumpers and the 100 m hurdlers.

Males/Competitive Level

Large differences in performance on the five bounds test were seen across competitive levels. The mean performances on this test for the males were 444.14, 498.99,

FIVE BOUNDS

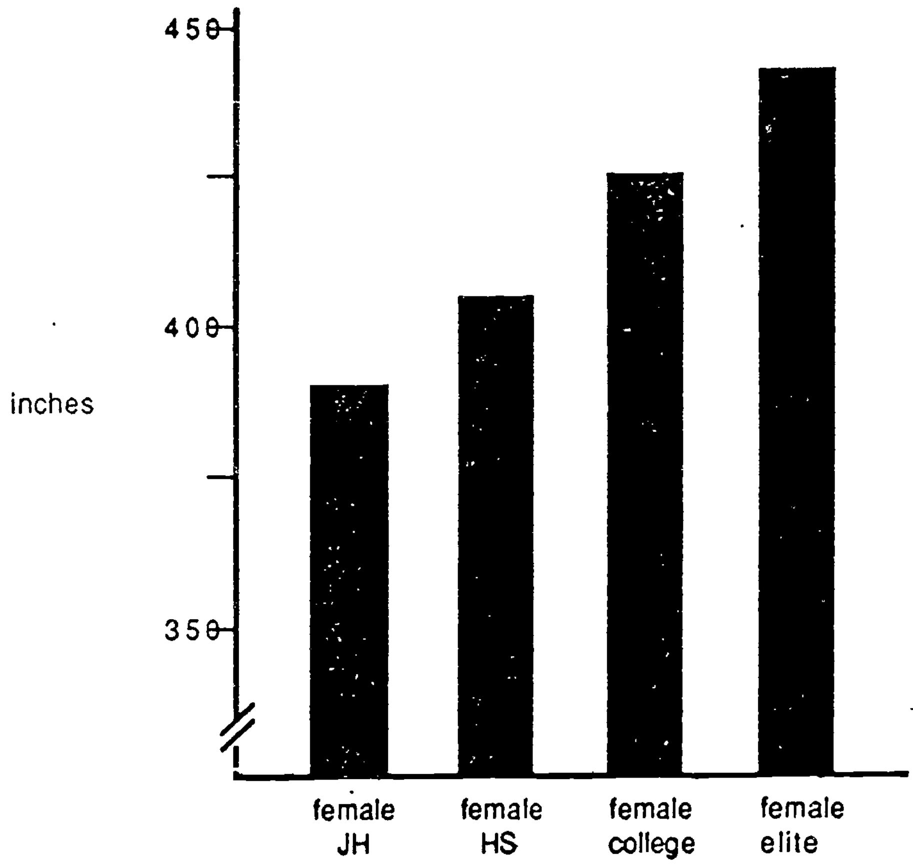

Figure 41. Mean five bounds distance by level of competition for females.

FEMALE

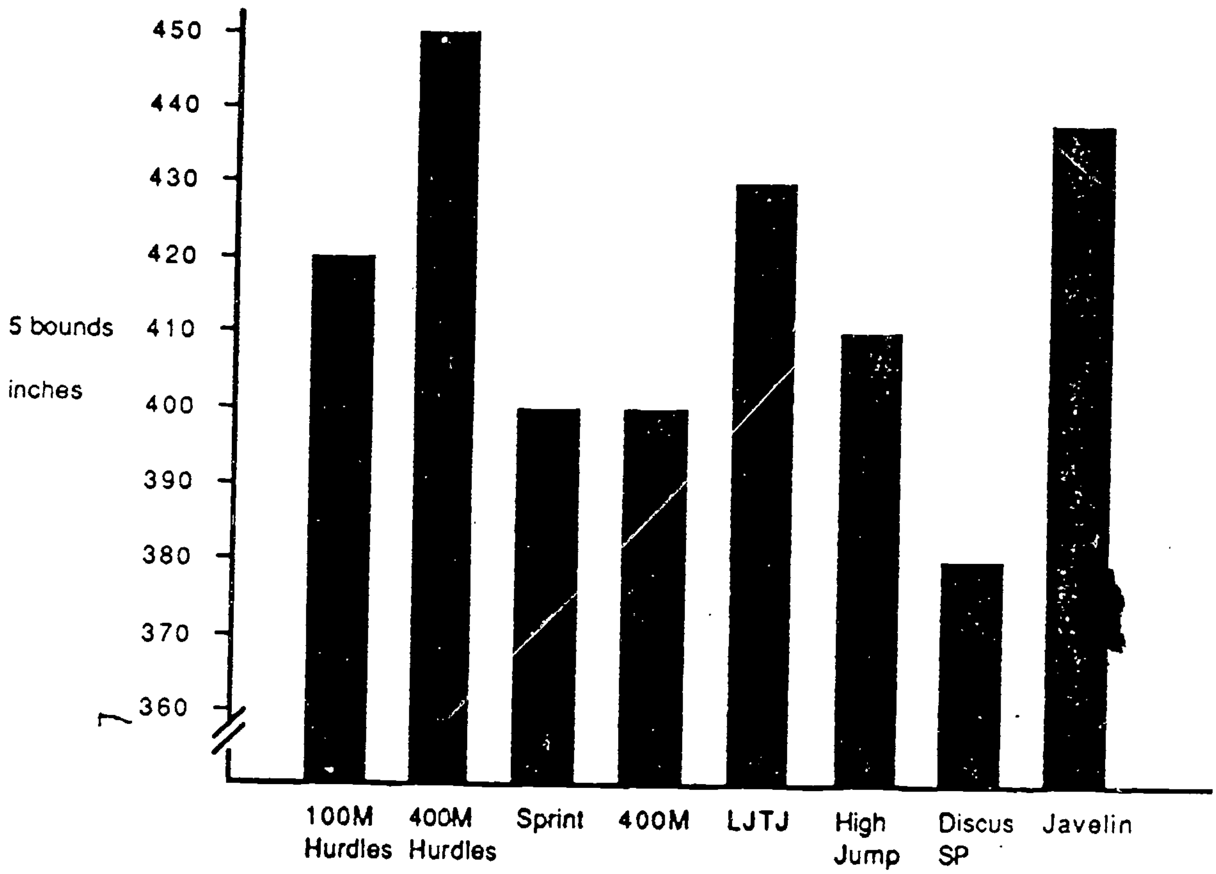

Figure 42. Mean five bounds distance by event for females.

530.74, and 551.07 inches for JHS, SHS, college, and elite athletes respectively. The standard deviations of the performances on this test were 39.37, 45.04, 54.79, 47.78 inches respectively. These findings support the hypothesis that leg power and neuromuscular coordination are factors contributing to higher levels of performance (see Figure 43).

<u>Males/Event</u>

The means and standard deviations of the males on the five bounds test by event may be seen in Table 23 and Figure 44.

Table 23

Means and standard deviations of the male performances on the five bounds test by event.

Event	Number	Mean	SD
110 m H	17	547.41	40.35
400 m H	18	512.94	47.94
Sprnts	136	500.11	52.82
400 m	120	490.80	52.39
Horjmps	110	538.53	59.55
HJ	69	512.00	55.85
SP/DISC	43	489.72	47.48
Vaulters	80	482.52	46.65

As with the females, the 110 m hurdlers and the horizontal jumpers performed best on this test, with large differences across events. This supports the hypothesis that the five bounds test is a good predictor of "best event".

FIVE BOUNDS

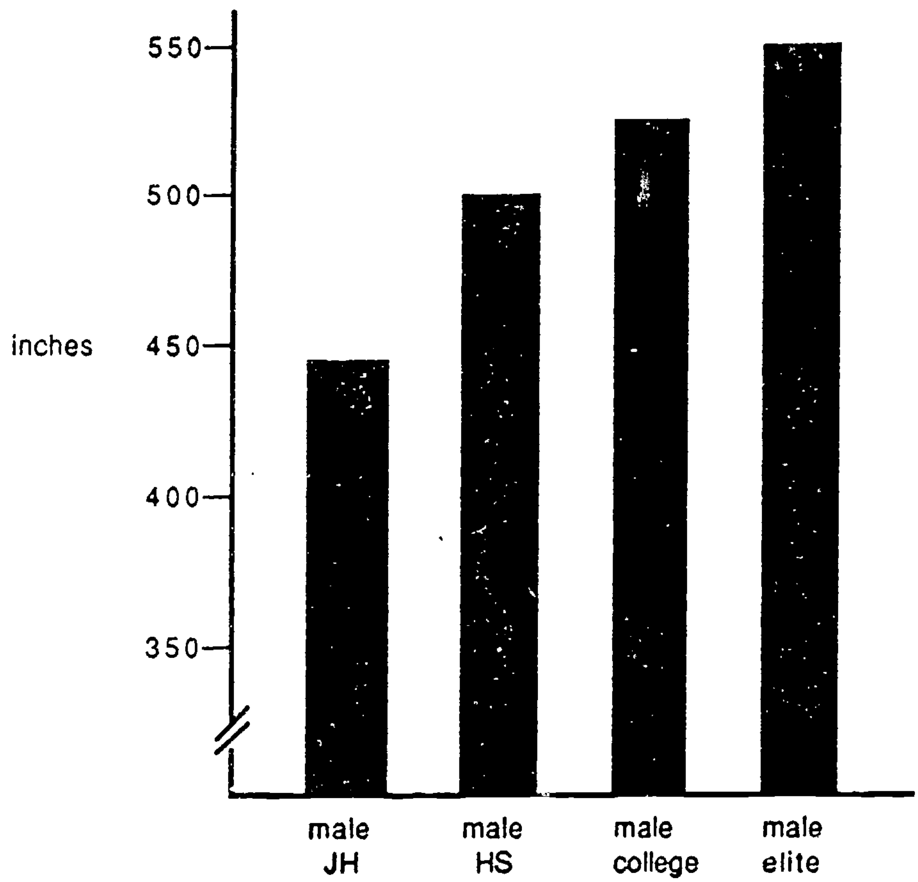

Figure 43. Mean five bounds distance by level of competition for males.

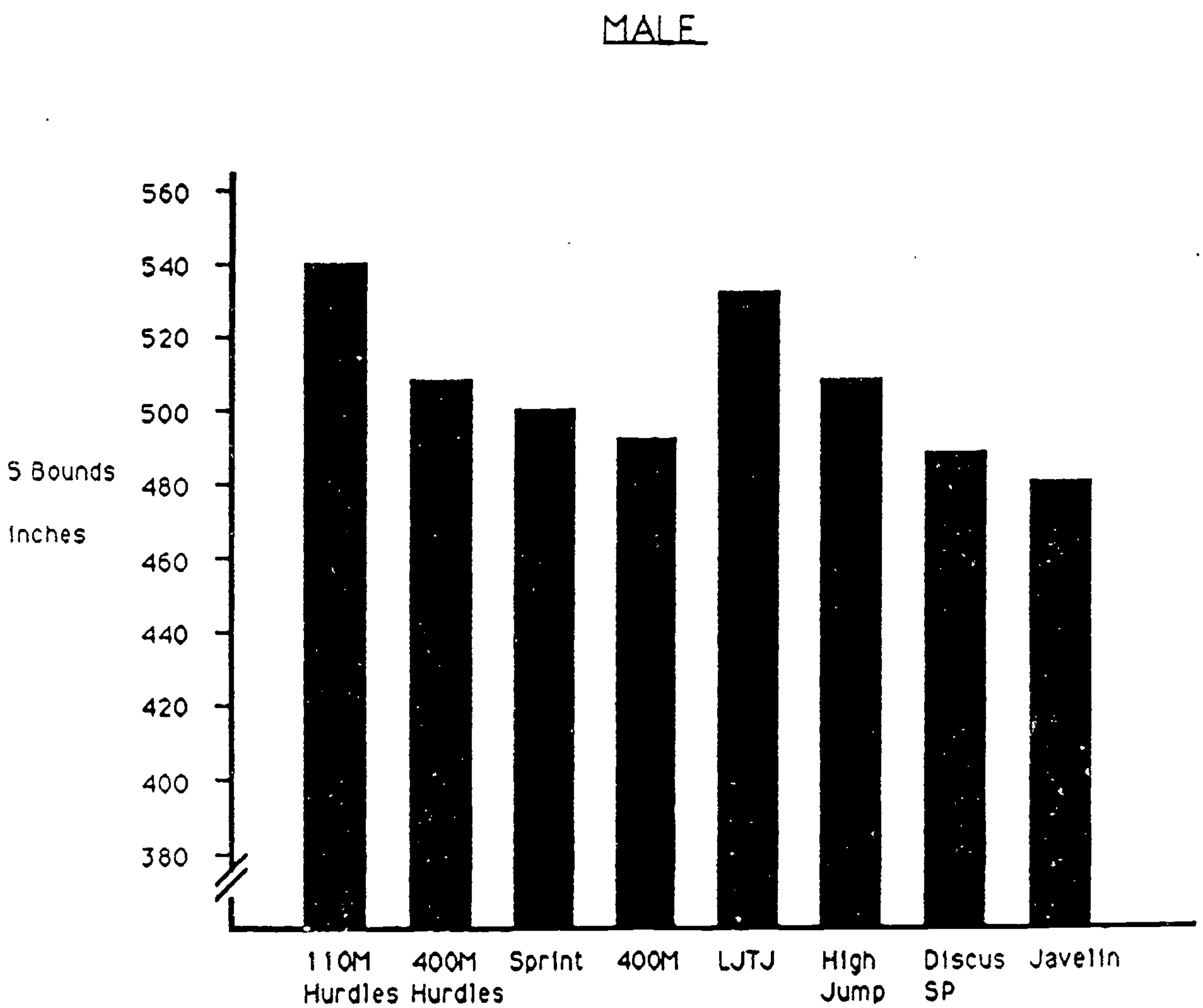

Figure 44. Mean five bounds distance by event for male.

VERTICAL JUMP

Females/Competitive Level

The performance on the vertical jump test is an indicator of leg power. The performances on this test by females increased with competitive level. The mean performances were 17.72, 19.05, 20.78, and 21.07 inches for JHS, SHS, college, and elite athletes respectively. The standard deviation of the performances on this test were 2.47, 2.51, 3.28, and 3.09 inches for JHS, SHS, college, and elite athletes respectively (see Figure 45).

Females/Event

The means and standard deviations of the female performances on the vertical jump test by event may be seen in Table 24 and Figure 46.

Table 24

Means and standard deviations of the female performances on the vertical jump test by event.

Event	Number	Mean	SD
100 m H	35	19.26	1.98
400 m H	7	23.00	3.21
Sprnts	167	18.94	2.78
400 m H	126	18.27	2.80
Horjmps	71	20.21	2.70
HJ	72	19.13	2.38
SP/DISC	57	18.05	3.54

The highest performers on this test were once again the 400 m hurdlers, however this may be sampling bias. The horizontal jumpers and 100 m hurdlers were the next highest.

VERTICAL JUMP

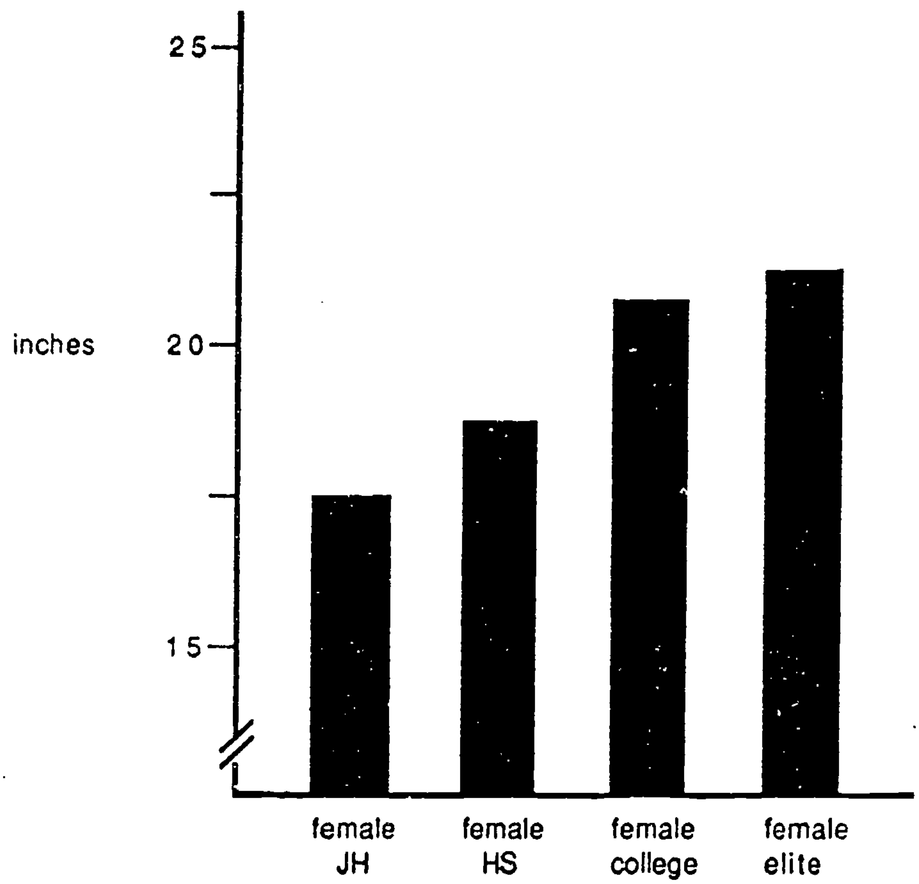

Figure 45. Mean vertical jump by level of competition for females.

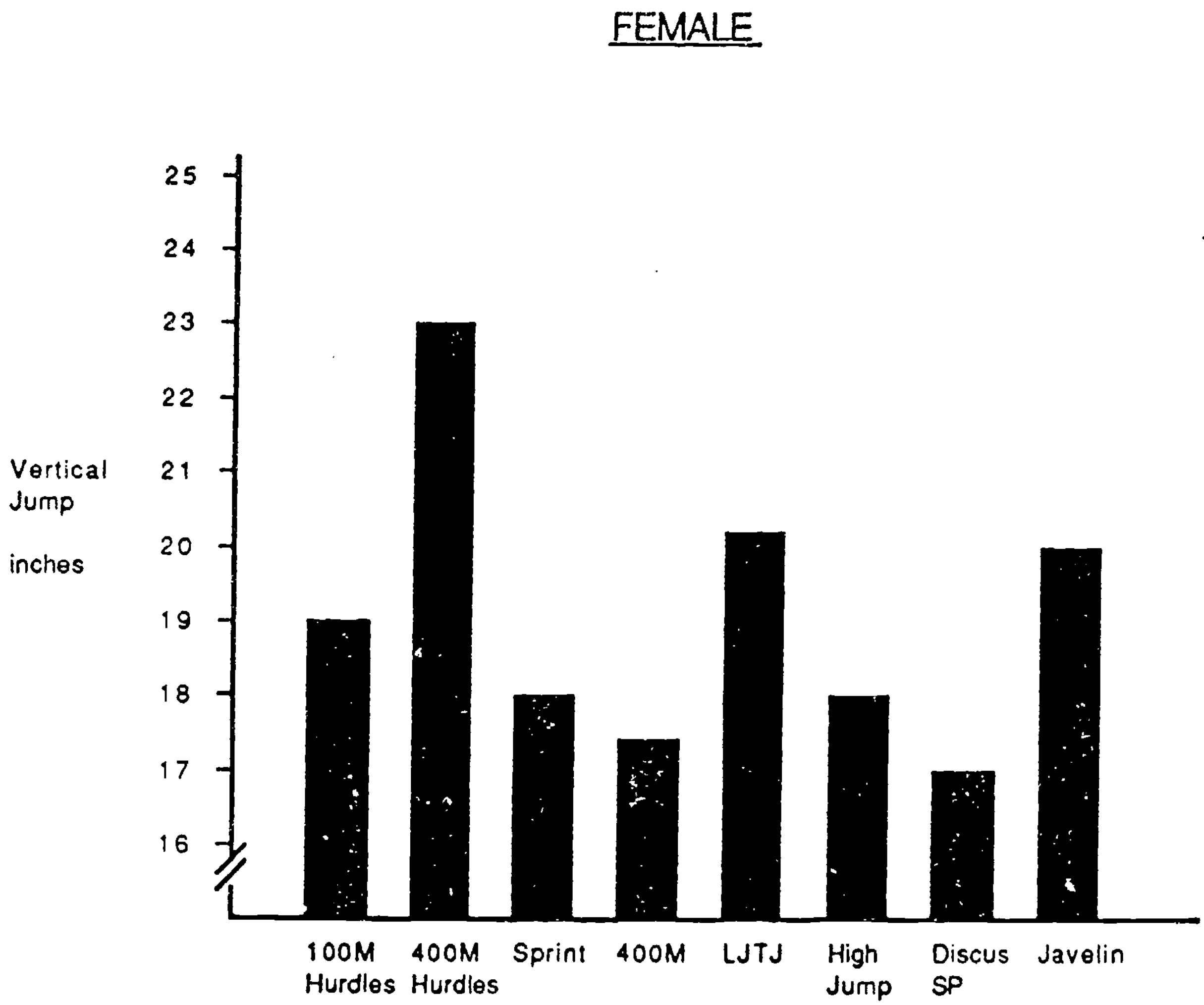

Figure 46. Mean vertical jump by event for females.

This appears to indicate that leg power is a critical factor in performing these events.

Males/Competitive Level

Large increases in vertical jump scores were observed for the males, primarily between JHS and SHS. The mean performances on this test were 21.07, 25.67, 27.40, 28.16 inches for JHS, SHS, college, and elite athletes respectively. The standard deviations of the performances were 2.92, 3.03, 3.51, and 3.26 inches for JHS, SHS, college, and elite athletes respectively (see Figure 47).

Males/Event

The means and standard deviations of the male performances on the vertical jump test by event may be seen in Table 25 and Figure 48.

Table 25

Means and standard deviations of the performances of the males on the vertical jump test by event.

Event	Number	Mean	SD
110 m H	17	28.06	3.15
400 m H	18	26.11	3.31
Sprnts	136	25.80	3.67
400 m	120	24.76	3.62
Horjmps	110	27.16	3.30
HJ	69	25.93	3.70
SP/DISC	43	25.99	4.15
Vaulters	80	24.86	3.16

As with the other test of leg power, the 100 m hurdlers and horizontal jumpers performed the best on this test. The

VERTICAL JUMP

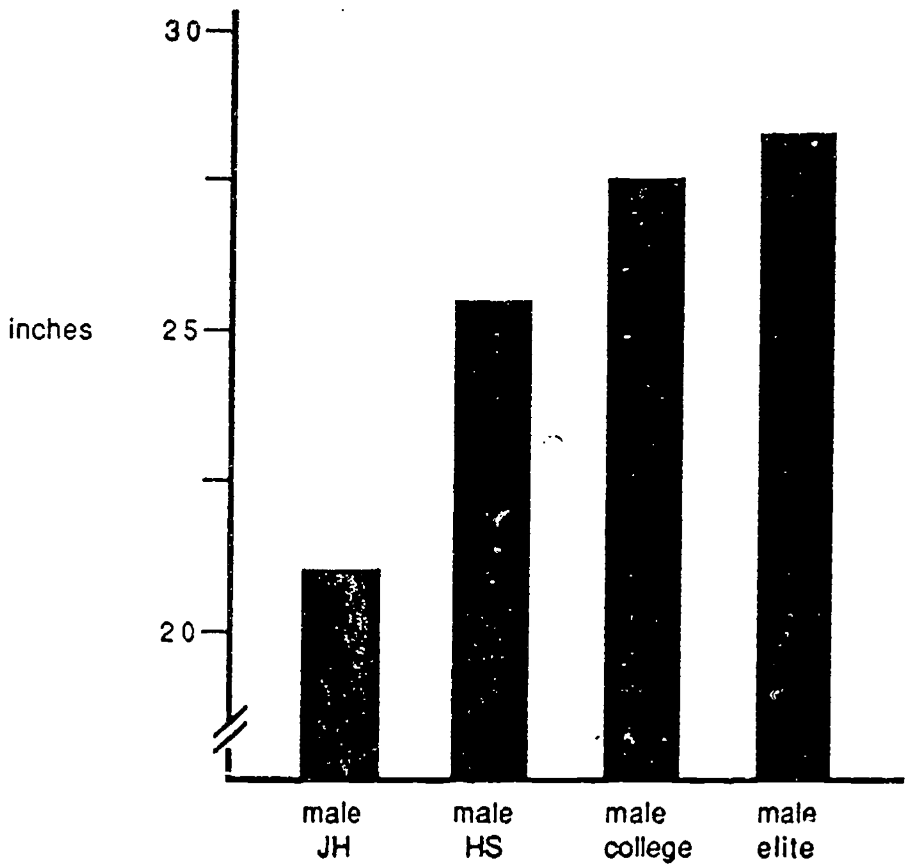

Figure 47. Mean vertical jump by level of competition for males.

MALE

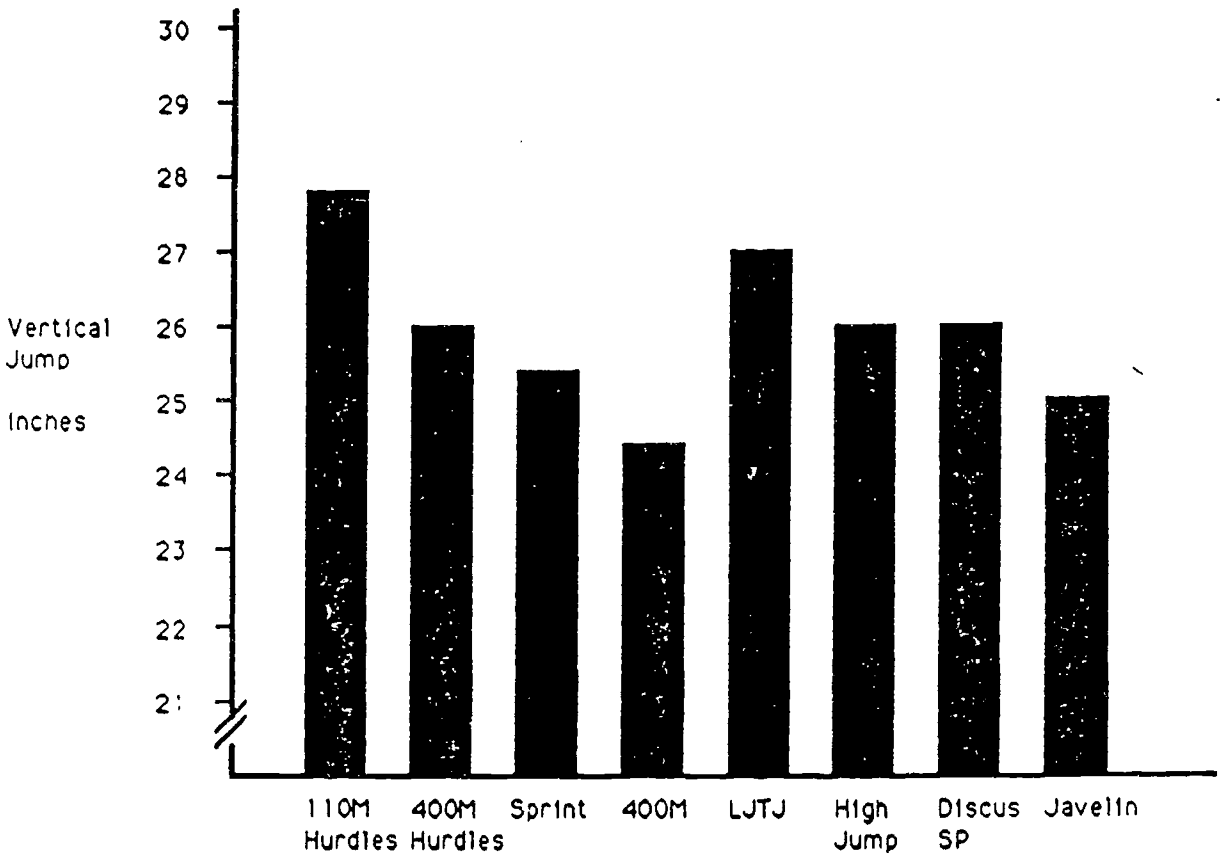

Figure 48. Mean vertical by event for males.

fact that sprinters and 400 meter runners scored relatively low is evidence that leg power is not the primary factor in the performance of these events.

FACTOR ANALYSIS

During the presentation of the results of each of the tests, the relationship among some of the tests was discussed. For example, both the standing long jump and the five bounds test measure leg power. To determine how many dimensions (such as leg power) underlie the 12 tests, factor analytic procedures were employed. This is a statistical technique that groups the tests according to the degree of relationship between the performances of the individuals on these tests. Separate factor analysis will be presented for the males and females.

Females

For the females it appears as though there are three underlying dimensions that determine individual performances on each of the tests. The first dimension (or underlying ability) determines the variability in performance on the vertical jump test, the standing long jump test, the five bounds test, the standing 30 meters, the flying 30 meters, the 60 meters, and stride length. These appear to be measures of leg power.

The second underlying dimension was anthropometric, and determined measurements of height, weight, and body fat.

The third dimension was defined primarily by stride frequency, but was also defined by stride length and the flying 30 meter test. These tests seem to be related by the degree of neuromuscular coordination. Based upon the results of these tests, it seems that female performances are determined, in part, by three underlying factors, body type, leg power, and neuromuscular coordination. The results of the factor analysis may be seen in Table 26.

Table 26

Factor analysis of the test scores for all of the female athletes. The technique used here was Principal Components with a Varimax rotation.

Test	Factor 1	Factor 2	Factor 3	Communality
Height	-0.39	0.63	-.038	0.70
Weight	-0.07	0.93	-0.01	0.88
Fat	0.39	0.77	0.08	0.75
Vertjump	-0.77	0.13	-0.07	0.62
St. LJ	-0.83	0.08	-0.03	0.69
5 Bounds	-0.78	0.14	-0.14	0.64
St. 30	0.80	0.17	-0.16	0.70
Fly 30	0.75	0.24	-0.45	0.83
60 m	0.86	0.23	-0.35	0.92
SL	-0.65	-0.18	-0.58	0.79
SF	-0.21	-0.08	0.94	0.94
Eigenvalue	4.62	2.09	1.75	8.46

An interesting note is that 92% of the variability in 60 meter dash times was explained by the three underlying dimensions. This is strong evidence that sprint performance is for the most part completely predictable with these tests.

Males

Factor analytic techniques also were used to determine the number of underlying dimensions that accounted for the variations in performance on the various tests. The results may be seen in Table 27. The results were only slightly different from the women. Again there were three underlying dimensions with the same tests being predicted by those dimensions. Again 90% of the variation in 60 meter dash performance was determined by performance on the 11 tests. From the three dimensions, the best three tests could be determined. These tests are considered the best, because they predict ability on each of the three dimensions with little redundancy. The tests were the 60 meter dash, stride frequency, and body fat.

Table 27

Factor analysis of the 11 tests for the males using Principal Components Analysis with a Varimax Rotation.

Test	Factor 1	Factor 2	Factor 3	Communality
Height	-0.35	0.66	0.40	0.71
Weight	-0.28	0.23	0.87	0.89
Fat	0.23	-0.16	0.86	0.82
VJ	-0.82	0.12	0.11	0.71
SLJ	-0.84	0.19	0.13	0.76
5Bounds	-0.76	0.31	-0.02	0.67
St. 30	0.77	-0.12	-0.09	0.62
Fly 30	0.83	0.27	0.17	0.78
60 meters	0.94	0.10	0.06	0.90
SL	-0.47	0.70	-0.20	0.74
SF	-0.37	-0.87	-0.02	0.90
Eigenvalue	4.73	2.00	1.76	8.50

PREDICTION EQUATIONS

One of the primary purposes of this project was to develop the capacity to predict future performance based on scores on a series of tests. Using the results of this testing program, prediction equations were developed for males and females. This equation is based on the statistical technique of multiple regression. As a consequence, a mathematical equation is presented that differentially weights the performance of some of the tests in predicting performance levels as measured with the decathlon scoring tables. This procedure is very much like predicting college success based upon high school grade point average and scholastic aptitude test scores (SAT). Different equations for the males and females will be presented.

Females

Using the scores on all of the tests, the following equation can be used to predict performance:

$$\text{Multievent points} = -1225.24 + 8.46\,(\text{HT}) + 1.8\,(\text{WT}) + -5.25\,(\text{FAT}) + 1.32\,(\text{SLJ}) + 3.31\,(\text{5B}) + -101.17\,(\text{ST 30}) + 28.19\,(\text{FLY 30}) + 19.94\,(\text{60 meters}) + 6.91\,(\text{SL}) + 119.9\,(\text{SF})$$

By inserting the scores of an individual into the parenthesis, the individuals predicted performance in decathlon points can be determined. These points can then be converted to specific performances based upon the individuals best event. This equation will predict 51% of the variation in performance. Once the predicted performance is determined, confidence intervals may be constructed. For example, one can be 68% confident that the actual performance capacity is the predicted score +/- 108 pts. One can be 90% certain that the actual performance capacity of the individual is the predicted score +/- 138.2 points.

A more efficient but slightly less accurate equation can be used with only four tests: weight, standing long jump, stride length, and stride frequency. The equation is:

$$\text{Decathlon points} = -1155.92 + 2.17\,(WT) + 5.95\,(SLJ) + 8.99\,(SL) + 97\,(SF)$$

One can be 68% certain that the true capacity is +/- 113 points of the predicted score. One can be 90% certain that the true capacity is +/- 145 points from the predicted score.

Although these predicted scores will not be 100% accurate, they are a good approximation. With additional data, and a greater number of tests, the predictive capacity will increase in the future. In addition, the use of tests of psychological profiles and of motor coordination will have to be used to predict performance more accurately. It is important to note that it will probably not be possible to ever predict with complete accuracy what the performance capacity of an individual is, and one probably wouldn't want to even if it were possible!

Males

The prediction equation for the males using all of the tests is slightly more accurate than for the women. Using all of the tests, the following equation could be used:

Decathlon points = 205.55 + 2.12 (HT) + 1.79 (WT) + -3.31 (FAT) + 2.46 (VJ) + 2.24 (SLJ) + .63 (5B) + -148.96 (ST30) + -71.10 (FLY30) + 41.74 (60 m) + -0.32 (SL) + 17.87 (SF)

One can be 68% confident that the true performance capacity is +/- 110.5 points from the predicted decathlon points. One can be 90% confident that the true capacity is +/- 141.4 points from the predicted decathlon points.

A more efficient but less accurate equation would use four tests: vertical jump, standing long jump, five bounds for distance, and 30 meters from a standing start.
The equation is:

Multievent points = 359.22 + 6.42 (VJ) + 3.58 (SLJ) + .61 (5B) + -113.49 (ST30)

With this equation one can be 68% confident that the true performance is +/- 117.8 points of the predicted decathlon points. One can be 90% confident that the true performance capacity is +/- 150.8 points of the predicted decathlon score.

The equations may be used with a performer of any age and level of competition.

CONCLUSIONS

Based on the findings of this project, the following conclusions are made:

1. It is possible to use a small number of simple tests of leg power to predict performance in track and field with a high degree of accuracy.
2. There are two independent dimensions of leg power that determine track and field performance: dynamic and static power. Static power represents the ability to rapidly develop large amounts of muscular force at a resting position. Dynamic power represents the ability to generate large amounts of muscular force while moving. This factor requires a high degree of neuromuscular coordination as well.
3. Because only 50% of the variation in performance was predicted with this series of tests, performances are determined by other factors. These may include, but are not limited to, perceptual-motor abilities and psychological factors. It is recommended that tests of these factors be included in any future predictive testing.
4. The most effective way to improve running speed is by increased dynamic leg power.
5. The tests used in this project may be insufficient for predicting "best event". This conclusion is based on the observation that performances on most of the tests did not vary across performers of various events.

Additional tests will have to be used to predict which are the "best events" for each athlete.

6. It would appear that for both males and females, improvements in speed primarily result from increases in stride length rather than from improvements in stride frequency. Since increases in speed at 30m and 60m are accompanied by improvements in VJ, SLJ, and five bounds, it would appear that increased explosive leg strength is the best means to greater running speed.

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COACHING ATHLETES FOR MULTIPLE EVENTS

Phillip L. Henson Ph.D.
Indiana University

Each event in Track and Field has specific requirements. Each athlete has a specific range of abilities. An athlete will be most successful when his/her abilities closely match the requirements of the event.

IMPORTANT FACTORS IN PERFORMANCE (APPROXIMATE ORDER OF IMPORTANCE)

SPRINTS & HURDLES

Natural Speed
Power Work/Time
Stride Frequency
Strength (Muscle/Fat)
Movement (Reaction) Time
Anaerobic Power
Low % Body Fat

JUMPS

Power Work/Time
Natural Speed
Stride Frequency
Strength (Muscle/Fat)
Coordination
Low % Body Fat
Body Type

THROWS

Power (Work/Time)
Strength
Body Type
Coordination
Natural Speed

MIDDLE DISTANCE-DISTANCE

Aerobic Capacity
Anaerobic Power
Natural Speed
Low % Body Fat
Strength

* * * * * *

FACTOR	METHOD OF MEASUREMENT	WORLD CLASS ATHLETE	
Natural Speed	30m Sprint from Stand	Men 3.7	Women 4.0
	Flying 30m	Men 3.0	Women 3.4
Stride Frequency	Flying 30m (Strides/Time)	4-5 Strides/Sec.	
Power	Vertical Jump	Men 26" +	Women 21" +
	Standing Long Jump	Men 9-10'	Women 8-9'
	5 Bounds for Distance	Men 50'	Women 40'
Strength	Lift	X Body Weight	
	Bench Press	Men 2.03	Women .95
	Squat	Men 2.13	Women 1.36
	Power Clean	Men 1.44	Women .97
	Snatch	Men 1.08	Women .70
Movement (Reaction)Time	Sound	.11 Seconds	

FACTOR	METHOD OF MEASUREMENT	WORLD CLASS ATHLETE
Body Fat	Distance	Men 4-7% Women 7-13%
	Sprints-Jumps	Men 6-9% Women 9-15%
	Throws	Men 8-15% Women 12-22%
Body Type	Height/Weight Ratio	
Coordination	Agility	Performance in selected Sport Skills
Aerobic Capacity	Max VO_2 (ml/kg-min)	Men 75+ Women 70+
	12 Minute Run	Men 2.75 Women 2.5 miles
Anaerobic Capacity	Guts All Out 800	

SPECIFICITY OF TRAINING

Training should be specific for the events(s) which will be performed.

Muscle Fiber Type

The body contains essentially two types of muscle fibers, Red (slow-twitch) and White (fast-twitch). The average proportion is about 50-50 but the ratio can vary to 90%-10% in either direction.

RED	WHITE
High in Myoglobin	High in glycogen content
High in fat stores	High in PC content
High in mitochondrial content	High in glycolytic enzyme levels
High in oxidative enzyme levels	Rapid contraction
High in capillary density	Rapid fatigue

Energy System Involvement

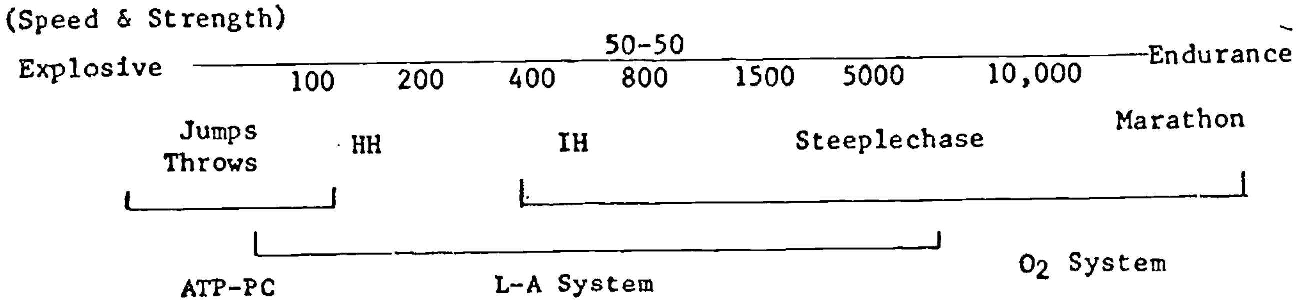
All movement in skeletal muscles is caused by the breakdown of Adenosine triphosphate (ATP) into Adenosine diphosphate (ADP) and free phosphate (P). Most work in the body is directed toward the creation of ATP which can then be used to produce muscular work.

1. ATP-PC System
   No oxygen required (Anaerobic)
   Available immediately
   Lasts for only a few seconds
   Used for short very powerful exercise

2. Lactic Acid System (Glycolysis)
   No oxygen required (Anaerobic)
   Available almost immediately
   Requires glucose
   Produces lactic acid and lowers pH of tissue and blood
   Can last for 2-3 minutes
   Used primarily in sprints and middle-distance events

3. Oxygen System
Oxygen required (Aerobic)
Available as soon as oxygen can be supplied
Requires Glucose or Fat for fuel
Can continue as long as food is available
(glucose 12 miles) (fat 50 miles)
Rate of exercise is determined by availability of Oxygen
(Max VO2 ml/kg-min.)
Used in Middle Distance and Distance Events

EVENT REQUIREMENTS



COMPLEMENTARY EVENTS	CONTRADICTORY EVENTS
Sprints - Long Jump	Jumps - Distance
Long Jump-Triple Jump-High Jump	Throws - Distance
Hurdles-Sprints Hurdles-Long Jump	Hurdles - Distance
Sprints - Throws	Sprints - Distance
Sprints - 400	
400 - Mid-Distance	
Mid-Distance - Distance	

EVENTS INDICATING A THIRD EVENT

Long Jump, High Jump → Triple Jump

Distance, Hurdles → Steeplechase

400-800, Hurdles → Intermediate Hurdles

Hurdles, Sprints → Long Jump

Sprints, Gymnastics → Pole Vault