Chapter II

REVIEW OF RELATED LITERATURE

The literature reveals that little attention has been paid to the relationships that may exist between physical, physiological and psychological variables and performance in track and field events. Most researchers have directed their efforts and attention at establishing the importance of gross body systems, or on predicting ultimate world records in the various running, jumping and throwing events. Little information appears to be available on the prediction of performance for individual athletes regarding specific events in track and field.

The literature relating to this study has been divided into three major sections. Section one will review the literature on physical variables and their relationship to track and field events. A second section will survey the literature which has established relationship between track and field events and physiological variables. The third section will deal exclusively with one of the new areas of research in physical education,
the psychological limitation in running, jumping and throwing events and allied activities.

Degutis\textsuperscript{1} conducted a study on 81 twelve years old boys in the Midford, Oregon, public schools. The correlations between the standing broad jump, as criterion, and 16 maturity, structural, and strength test variables were determined. The following multiple correlations were obtained; anthropometry \(-.408\) with body weight, leg length and lung capacity, coordinated strength \(-.393\) with strength index, back lift, and leg lift, cable-tension strength \(-.520\) with elbow flexion and hip extension, combined variables \(-.694\) with elbow flexion strength, body weight hip extension strength, ankle planter flexion strength and leg length.

Chetia\textsuperscript{2} took up a study to find out the relationship of leg-length, thigh-girth, calf-girth and abdominal

\textsuperscript{1}Ernest W. Degutis, "Relationship Between the Standing Broad Jump and Various Maturity, Structural and Strength Measures of Twelve Years Old Boys" Completed Research in Health, Physical Education and Recreation 2(1960):58.

\textsuperscript{2}Uday Kumar Chetia, "Relationship of Leg-Length, Thigh-Girth, Calf-Girth and Abdominal Strength to Standing Broad Jump" (Unpublished Master's Thesis, Jiwaji University, 1982).
strength to standing broad jump on 44 college male students. The result indicated that there were a significant relationship between standing broad jump and leg length, calf girth, and abdominal strength.

A study of Smith \(^3\) presents some important current information on the relationship of certain structural measures and performance in vertical jump. All the correlations obtained were nonsignificant and almost zero. Similarly a low correlation was found between the vertical jump and the individual's dynamometric leg strength. It could be pointed out once again that the components of both vertical jump and standing broad jump appear highly specific; an ability in one may not necessarily represent ability in the other.

Dolores \(^4\) investigated the relationship of shoulder flexibility and other selected factors to throwing performance by college women. Thirty five

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college freshmen were tested on the overarm throw involving both accuracy and distance throwing. The variables shoulder flexibility, shoulder strength, speed of arm movement, age, height, weight, PE background, athletic background, and number and sex of children in the family were studied. Variables which proved to have predictive value in relation to accuracy throwing were the average of shoulder strength, speed of arm movement, athletic background, and the group of three physiological factors. Those variables which showed a significant relationship to determine throwing were arm shoulder strength and athletic background. Shoulder flexibility was not a significant predictor of throwing, shoulder strength was the best physiological variable; flexibility was highly related to strength; either the accuracy or distance test item could have been used; and the best predictor of throwing found was athletic experience.

Tipton\(^5\) in his book of \textit{"Track and Field Athletics\textquotedblright} had emphasized the need of flexibility for

\footnote{Cretzenev Alley Tipton, \textit{Track and Field Athletics} (St. Louis: The C.V. Mosby Company, 1969), p.50.}
a sprinter and had given variety of exercises for the improvement of flexibility. He was of the opinion that flexibility could bring about beneficial effects on the sprinting, speed of movement and acceleration speed.

Powell⁶ is of the opinion that lack of strength in the lateral abdominal muscles, underdevelopment of the thigh, and the absence of an overall power are reflected in the inability of the young athlete to allow the shot (preparatory to the put) to be maintained, as it must be, at the neck, and yet at the same time outside the rim of the circle, while still being capable of exerting maximum drive across the circle.

Tschine⁷ concluded in his study that strength, is required in the shot-put action but the mobility in the hip axis is also important.


Gooden conducted a relationship study on selected anthropometric measurements of leg and foot to speed and vertical jump of male collegiate track and field athletes. Ss = (N = 32) were assigned to five groups according to their respective events: short sprinters, long sprinters, middle distance runners, distance runners and jumpers. All the subjects were exposed to a one week training period before the testing of the vertical jump and 50 yard dash. An ANOVA was used to determine differences between performance scores of all five groups, in the vertical jump, 50 yard dash, and selected anthropometric measurements. The Newman-Keuls follow up test was employed to make multiple comparisons and a multiple r was used to determine the relationship of selected anthropometric measurements to vertical jump and 50 yard dash. There was a high positive relationship between speed of the 50 yard dash and vertical jump. There was no significant relationship between the 12 anthropometric measurements and speed in the 50 yard dash.

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dash. The short sprinters and jumpers performed significantly greater in the vertical jump and 50 yard dash when compared to the other groups. The short sprinters and middle distance runners performed significantly greater in the vertical jump and the 50 yard dash when compared to the distance runners.

The Bruce Physical Index was administered by Pierson and Rasch to 11 high school cross-country runners in an attempt to determine the relationship between scores and performance. Various anthropometric and physiologic tests also were administered. The results indicated that the BPFI was not useful predictor of performance. Performance and measures of body size were negatively correlated. The efficiency of the BPFI appears to be reduced by the inclusion of the "average respiratory efficiency", which correlated highly with measures of body size.

The purpose of Gouthier, Froulx and Wysanski's study was to develop regression equations to predict performances for the 50 yard run and the 4 x 10 yard shuttle run using as predictors the 50 metre run and 4 x 10 metre shuttle run. Three hundred and twenty one subjects aged seven to nine years participated in this study. The results clearly indicated the possibility of using these prediction equations to compare the results obtained in 1966 to those obtained in 1980 in the CAMPER Fitness Performance Test.

Dintiman in his article of Increasing Running Speed through Flexibility and Weight Training Programme, opinion that although running speed is considered mostly an innate quality, it has been well established that it can be improved through training. The strength of the muscles involved in the running action determines, to

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some extent the maximum speed of the individual. One cannot hope to achieve success in sprinting without the muscular strength, necessary to have the legs with speed.

Burley, et al.\textsuperscript{12} investigated the differences among seventh, eighth and ninth grade girls in speed and found when speed scores were correlated with height and weight that correlations of +.183 and -.003 were obtained. When the speed scores were correlated with the various lever length of the subjects, the following correlations were obtained: speed and olecranon to unequal tuberosity, .161; speed and olecranon to acromion process, .120; speed and greater trochanter to the lateral condyle of the tibia, .184. All these correlations indicate a neutral relation between speed and the anthropometric measures used. The mean scores of the eighth grade was .4 second greater than the mean for the seventh grade, the mean difference being the only one statistically significant.

The purpose of Mersereau's study was to examine the strength and form of relationship between dynamic process measures, output measures, and dynamic stability measures for the running and jumping patterns of female children three to five years of age. Sixteen subjects, all participants in an instructional perceptual motor development program, were involved in this study. The subjects were filmed while running along a 40 foot running surface, and the jumping from a six and half inches elevated take-off board. Output measures of running speed and jumping distance were obtained from the film data, as were the dynamic process measures which included kinetic energy values of the leg, thigh, and total body. Dynamic stability measures, obtained by means of a stabilometer, included time in balance and contact errors for four 30 second trials. Multiple regression procedures were used to evaluate the relation between output and dynamic measures, and between output and dynamic stability measures. Canonical correlation

procedures identified the relationship between the set of dynamic stability measures and the set of dynamic process measures. Results of the statistical analysis indicated that there was a moderate connection between the two output measures of running speed and jumping distance. Kinetic energy variables, served as excellent predictors of running speed, whereas, the same variables were only moderately successful in predicting jumping distance. There was no relationship, either linear or non-linear, between the dynamic stability measures and output measures. Generally, there was no relationship between the set of dynamic stability measures and the set of kinetic energy variables. In addition, the two dynamic stability measures of time in balance and contact errors were found to be nearly independent of one another. In addition to the statistical analysis, normalized kinetic energy variables for the right leg and thigh during the run and the jump were displayed graphically for each age group. For the running stride there was found to be an amazing similarity between the individual curves of the subjects in each age group.
Christian's study was designed to identify the contribution of selected variables to the game performance of 30 members of the 1973 Southeastern State College football team. Each subject was tested on 12 variables and a step-wise multiple regression was used to determine the weight of each of these variables to the ultimate criterion. The ultimate criterion was the percentage of plays executed correctly as determined by grading the film of the ten 1973 regular season football games. From the multiple correlation coefficient, the variables which contributed most to the game percentage scores were determined. In this manner, those variables which were most predictive of football performance, could be identified. It was hoped that by identifying these variables, variable information could be provided for coaches.

It was found that the best predictor of the game percentage score for the backs was lateral movement with a correlation of .33. For the time, the best predictor

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of the game percentage score was bench steps with a correlation of .67. When the back and line groups were combined, the best predictor of the game percentage score was the vertical jump with a correlation of .50. It was concluded that for the total group, the vertical jump and the twelve minute run were the two best predictors. A multiple correlation of .60 was obtained with the combination of these two variables, the multiple correlations for the back line, and total groups, when the entire 12 variables were considered, were .7449, .9979, and .7316, respectively.

Flanagan\textsuperscript{15} reported a validity coefficient of -.89 between pulse-ratio and a ratio between times in two sprinting events -220-yard (201.17 m) and 60-yard (5.86 m) sprints. This relatively high correlation was questioned by Henry and Kleeberger,\textsuperscript{16} who replicated the study and found correlations only -.46 when speed was held constant and -.42 when speed and body weight were held constant. This is probably a moot point.


\textsuperscript{16}Franklin M. Henry and Frank L. Kleeberger, "The Validity of the Pulse Ratio Test of Cardiac Efficiency" \textit{Research Quarterly} 9 (March 1938): 32-46.
since neither the 60-yard (54.96 m) nor the 220-yard (201.17 m) sprint would be considered tests of cardiovascular endurance by modern exercise physiologists.

Kotowski investigated the relationships between the running performance times of elementary school children at selected distances and their maximum oxygen intake. A total of 109 third and fourth grade boys and girls from four elementary schools in Provo, Utah, served as subjects. A maximum oxygen intake test and four running performance field tests at distances of 600, 900, 1200 and 1500 yards were administered to each child. The Pearson Product Moment correlation technique was used to examine the relationship between the run performance time at each distance and maximum oxygen intake. The minimum level chosen for significance was the .05 level. Within the limitation of this study, it was concluded that: (a) there is a significant relationships at the .001 level, between the running performance times of elementary school children at distances of 600, 900,

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1200, and 1500 yards and their VO₂ Max., and (b) all four field tests are equally effective in the assessment of the cardiovascular fitness level of third and fourth grade school children.

Norton¹⁸ investigated the relationship between performance on a circulorespiratory (CR) endurance run of 3.2 Km. and several physiologic and morphologic measures for 20 males and 20 females (X age = 27.9 years). Performance on the run was measured on a 400 metre track and evaluated as both total time of the run (run time) and by the subject's critical running pace (CRP) over the middle six laps of the eight lap run. The run time and CRP were very highly correlated (r=.96, p<0.01). Physiologic measures were taken during a treadmill run at both submaximal and maximal levels and included evaluation of heart rate, respiratory exchange ratio, ventilation and oxygen consumption as well as a determination of the subject's anaerobic threshold (AT) using gas exchange variables. During this incre-

mental test, a second change in the gas exchange variables was noted for 31 subjects and later identified as the threshold of respiratory compensation (Rct). Before the treadmill test and again four to six minutes after the test, four milliliters of blood was drawn for determination of blood lactate values, haemoglobin and hematocrit assessment. Additional measures for each subject included weight, percent body fat, height and activity level, of the variables hypothesized to be related to running performances, maximal oxygen consumption ($V_o_2$ max.) was most highly correlated to run time ($r = .19, p < 0.01$). Other variables correlated with run time with a simple $r$ of at least .60 were AT (mph), percent body fat, activity level and maximal ventilation with $r$'s of -.67, .77, .64 and -.77 respectively. However, for each of these variables the significance of the simple correlation with run time was reduced if the common variance with $V_o_2$ max. was held constant. Maximal blood lactate (an index of anaerobic capacity) was not found to significantly correlate with run time. Thus, of the hypothesized variables, $V_o_2$ max was determined to be the most powerful predictor of run time. Similarly a stepwise multiple regression predicting run time using these variables resulted in $V_o_2$ max and the sum of
the three skinfolds (a body composition measure) as the first and second variables respectively included in the regression accounting for 80.6 percent of the variance. Inclusion of the rest of the variables added only .6 percent to the explained variance. However, the un-hypothesized variable, Rct, was more highly correlated to run time than $V_{O_2}$ max ($r = .90, p < 0.01$) and if used in conjunction with $V_{O_2}$ max to predict run time, was the first variable chosen, accounting for 31.9 percent of the variance. The addition of $V_{O_2}$ max to the equation added 4.3 percent to the known variance. These results suggested that Rct and $V_{O_2}$ max provide somewhat independent information about running performance. In general, men performed better than the women on all exercise tests. However, the addition of gender to the multiple regression predicting run time did not add significantly to the known variance suggesting there was no sex-linked factor affecting performance other than the ones already included in the analysis. Thus, the subjects that performed but on the 3.2 km. run were the individuals who not only had a high $V_{O_2}$ max and low percent body fat but were able to utilize a large percentage of their aerobic capacity during the run (i.e. have a high RCE).
In order to enlarge the range and enhance the scope of descriptive data concerning the relationship of physiological function to distance running performance, selected physiological, training and performance measures were determined by Foster for 24 well-trained competitive runners. $\text{VO}_2$ during submaximal and maximal treadmill running, muscle fiber composition and muscle enzyme activities were determined using commonly employed laboratory techniques. The volume and intensity of training were determined from analysis of training diaries and sprinting speed was determined from 220 yard time trial. Distance running performance was determined from participation in a series of races ranging from 1-10 miles. Both correlation statistics and analysis of variance indicated that $\text{VO}_2 \text{max}$, muscle fibre composition, volume of training and sprint speed were significantly related to distance running performance. Muscle enzyme activity was not related to performance. It was concluded that cross-sectional

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19 Carl Clinton Foster, "The Relationship of Selected Physiological, Training, Performance Measures to Distance Running Performance" Dissertation Abstracts International 37 (February 1977):4953-A.
variations in distance running performance were primarily attributable to differences in \( \text{VO}_2 \max \). and that other factors including muscle fiber composition, training volume and sprint speed might act to attenuate the \( \text{VO}_2 \max \) performance relationship. The finding that muscle enzyme activity was not related to cross-sectional difference in performance was taken as evidence of the need for longitudinal studies of running performance.

Costill\(^{20}\) studied 17 members of the Cortland State College cross country team, who had training formally for at least six weeks before any testing was undertaken. The runners ranged in age from 18.0 to 23.2 years, and all had previously experienced at least three seasons of cross country competition.

Conclusions had been drawn:

1. Although no relationship existed between height and distance running performance, the better physical fitness point of view is a question of body's

runners were significantly higher and appear to possess less body fat.

2. No relationship existed between distance running performance and vital capacity. Yet the better runners were voluntarily capable of forcibly moving longer volume of air as measured by maximal breathing capacity per body surface area.

3. The average resting heart rate for the better runners was lower and appears to be closely related to distance running performance.

4. Blood hematocrit was found to be higher among the better runners with that was significant at the 10 percent level of confidence.

5. The maximal oxygen uptake (liter/minute) and maximal oxygen uptake (ml/kg/minute) demonstrate a direct relationship with distance running performance.

Rampotti\textsuperscript{21} is of the opinion that endurance from physiological point of view is a question of body’s

\textsuperscript{21}Kelevi Rampotti, "The Blood Picture as a Guide to Training" \textit{Track Technique} (September 1960):36.
ability to absorb oxygen, haemoglobin value, therefore, is of great importance in athletic performance.

The purposes of Caardon's study were to determine the value of a cardiovascular capacity measure (Cooper 12-Minute Run) a leg power measure (modified Sargent Jump Reached), an upper body muscular strength and endurance measure (flexed arm hang), a percent of body fat measure (skinfold thickness), and a measure of body height as predictors of basketball playing ability, and to develop a statistical equation for predicting success in playing college basketball. The basketball playing ability or criterion measures were an ability rating a personality rating, a composite ability/personality rating, the Noll Comparative Rating Scale, and a ranking of the players by the coaches. The sample consisted of twenty female basketball players from the 1976–77 University of Arkansas and Northeastern Oklahoma State University teams. Ten players from each school participated in the study. The step-wise Multiple

Regression Programme was utilized to form prediction equation by the five tests for predictor variables being correlated with each of the five basketball playing ability measures. The prediction equations were selected using as a criteria only those variables which had the lowest standard error of estimate and the greatest F-value. The equation determined to yield the greatest prediction ability was the 12 Minute Run and height with the Personality Rating as the measure of basketball playing ability. The equation produced a correlation coefficient of .786 and a standard error of estimate of $\pm .392$. The prediction equation from the step-wise Multiple Regression programme was:

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\text{Basketball Ability} = 9.05327 + 1.36421 \times (12\text{-Minute}) - 0.11303 \times \text{height}
\]

From the results of the study, the following conclusions were made for prediction of basketball playing ability of college women by the researchers:

1. The Cooper 12-Minute Run and height are the best measures for predicting basketball playing ability in this study.

2. Measures of leg power and upper body strength
and endurance are of limited value when the 12-Minute Run is used to predict basketball playing ability.

3. Body composition measures have some value in predicting basketball playing ability of college women.

Rasch\textsuperscript{23} assessed the maximal oxygen intake of young male adults utilizing treadmill. The scores were compared with those predicted by use of a step test and by use of an ergometer. The assessed scores correlated very poorly with the predicted scores. None of the scores were of value in predicting performance in the 1,000 meter, 1.5 mile, or three mile runs. The correlations between the times in these events were too low to permit substitution of one for another.

Novek\textsuperscript{24} et al. assessed eight distance runners

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seven swimmers and five gymnasts. The working capacity was determined on bicycle ergometer, oxygen intake, carbon dioxide, respiratory rate, pulse rate and R.Q. were determined by Siregmost - PD 88. Vital capacity was measured by a spirometer with an automatic readout. Total body water was determined from the ratio of D₂O to H₂O by mass spectrometry. Lean body mass was calculated from total body water assessing 73.2 percent hydration. Anthropometrical appraisal of leanness-fatness included subcutaneous fat-fold measurements and calculations of lean diameters of the limbs. In relative values distance runners showed significantly higher oxygen intake which was also achieved at significantly higher work loads compared to swimmers and gymnasts. Vital capacity was significantly higher in favour of swimmers. However, lean body mass was significantly lower in swimmers, percentagewise. Various subcutaneous skinfolds were higher in swimmers thus substantiating findings of biochemical determinations of total body fat.

The contribution of maximal oxygen uptake and running efficiency in highly trained males to their
performance in a 10,000 meter race was examined by Conley. The twelve selected subjects placed in the top nineteen in the Third Armed North Bank 10,000 meter run in Phoenix, Arizona (a race which had over four thousand entries). These distance runners ranged in age from eighteen to thirty-four years of age. The average amount of distance training experience was ten years. Treadmill running was utilized for the laboratory measurement of maximal and submaximal oxygen consumption because it provides a valid picture of the physiological responses which accompany track running. Maximal oxygen uptake was determined using a continuous protocol. Treadmill speed was kept at 214 m/min. for all stages. Grade was then increased two and half percent for each subsequent minute until the subject reached exhaustion. All three submaximal tests were conducted on the subjects second visit to the laboratory. After a warm up of five minutes at 214 m/min., the subjects completed a series of runs for six minutes each at 214 m/min, 268 m/min and 295 m/min. with three minutes rest between tests. Serial.

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one minute collections of expired air were made over the last three minutes of each six minute run. A correlation analysis was used to determine if a significant relationship existed between distance running performance and (i) maximal oxygen uptake and for (ii) running efficiency. Relationships were analyzed for significance at the five percent level of confidence. The results of this research indicated that the relationship between maximal aerobic capacity and running pace for the 10,000 meter race \( (r = 0.13) \) was not significant at the five percent confidence. Therefore, the first hypothesis of this study was rejected. The rejection does not argue against the importance of a high \( \text{Vo}_2 \) max for success in distance running performance because all the subjects possessed very high maximal aerobic power. Rather, the data suggested that among subjects with equally high \( \text{Vo}_2 \) max's, aerobic capacity is not a determining factor for competitive success. The relationship between running efficiency (\( \text{Vo}_2 \)) at the mean race pace of 312 m/min. and performance in the 10,000 meter race \( (r = 0.76) \) was significant at the one percent level confidence. Thus, the second hypothesis was accepted. It was concluded that of the factors studied in this experiment the significant factor determining
competitive success in the 10,000 meter run for highly trained male distance runners was their running efficiency and not maximal aerobic capacities.

The purpose of Conley's study was to determine the relationship between female distance running performance on a 10 km. road race and body composition, maximal aerobic power \( (V_{O_2} \text{ max}), \) running economy (steady state \( V_{O_2} \) at standardized speeds), and the fractional utilization of \( V_{O_2} \) max at submaximal speed (percent \( V_{O_2} \) max). The subjects were 14 trained and competition-experienced female runners. The subjects averaged 43.7 min. on the 10 km. run, 53.0 ml.Kg.\(^{-1}\) min.\(^{-1}\) on \( V_{O_2} \) max, and 33.9, 37.7, and 41.8 ml.kg.\(^{-1}\) min.\(^{-1}\) for steady-state \( V_{O_2} \) of three standardized running process (177, 196, and 215 m. min.\(^{-1}\) ). The mean values for fractional utilization of aerobic capacity for these three submaximal speeds were 64.3, 71.4, and 79.3 percent \( V_{O_2} \) max, respectively. Significant \( (P<0.01) \) relationship with performance were found for

$V_o_2$ max ($r = 0.66$) and percent $V_o_2$ max at a standardized speed ($r = 0.65$). No significant ($P < .05$) relationships were found between running performance and either running economy or relative body fat. As with male heterogeneous groups, trained female road racing performance is significantly related to $V_o_2$ max and percent $V_o_2$ max, but not related to body composition or running economy. It was further concluded that on a 10 km. road race, trained females operate at a percent $V_o_2$ max similar to that of their trained male counterparts.

Zhou, Hodgson and Soto\textsuperscript{27} in their study of prediction of running speed among middle and long distance runners, anaerobic power output (APO) and heart rates during and after 30 sec. all-out cycling were measured in top level U.S. runners. $V_o_2$ max was measured separately during treadmill running. The groups consisted of 12, 800 m, 10, 1500 m, and nine 10,000 m runners. Height, percent body fat, and $V_o_2$

max (ml. Kg. \(^{-1}\) min. \(^{-1}\)) were comparable among 800 and 1500 m runners, but the longer distance runners were significantly shorter, fatter, and had a higher \(V\text{O}_2\) max (\(P < .05\)). APO was significantly lower in the 5,000 and 10,000 runners than in the 800 and 1500 m runners, as was the maximal heart rate (AHR max), and the heart rate at a two min. of recovery (AHRs) (\(P < 0.001\)). Using all variables to predict the runners best time (\(y^2\) in sec.) during competition, the respective prediction equations were:

\[ 800 \text{ m: } y^2 = 125 - 0.842 \text{ (age)} - 16.10 \text{ (APO)} + 0.15 \text{ (AHR max)} - 0.08 \text{ (AHRs)}; R^2 = .60 \]

\[ 1,500 \text{ m: } y^2 = 261 - 1.54 \text{ (age)} - 24 \text{ (Vo}_2\text{ max)} + 0.105 \text{ (AHRs)}; R^2 = .81 \]

\[ 5,000 \text{ m: } y^2 = 1,033 - 3.74 \text{ (age)} - 2.34 \text{ (Vo}_2\text{ max)} + 0.49 \text{ (AHRs)}; R^2 = .60 \]

\[ 10,000 \text{ m: } y^2 = 1,96 - 9.36 \text{ (age)} - 4.40 \text{ (Vo}_2\text{ max)} + 2.24 \text{ (AHRmax)}; R^2 = .88 \]

Where age is years, APO in NP, and heart rates in \(\text{min.}^{-1}\). Age was an important predictor in each equation and perhaps related to experience and years of training.
Among 200 m. runners, anaerobic power output was the most important predictor whereas \( V_o_2 \) max. became progressively more important as running distance increased. Knowledge of anaerobic power output and/or the associated heart rates could be of value to the coach for event assignment or evaluation of training effectiveness.

In Kanstrup and Ekblom’s study of blood volume and haemoglobin concentration as determinants of maximal aerobic power, changes in blood volume (BV) and haemoglobin concentration (\([Hb]\)) were induced in five healthy youngmen. After acute hypovolemic enemia was achieved by blood withdrawal, \( V_o_2 \) max values decreased, while the same (\([Hb]\)) due to acute plasma volume expansion (6 percent dextran) did not alter \( V_o_2 \) max. After reinfusion of red blood cells, leading to hypervolemia and increased (\([Hb]\)), \( V_o_2 \) max increased. Plasma volume expansion in this situation, leading to hypervolemia at normal (\([Hb]\)), resulted in a slight

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reduction in values. Physical performance, measured as time to exhaustion, corresponded to the changes in Vo₂ max except for the hypervolemic enemic situation, where it decreased. Changes in peak heart rate were inversely related to BV changes, but were also influenced by (Hb). The results point to a significant influence of the total amount of Hb rather than the blood hemoglobin concentration for obtaining a high maximal aerobic power. Thus, a reduced (Hb) concomitantly with an elevated blood volume (plasma volume), may result in an unchanged Vo₂ max, but reduced performance time.

In the study of Shreeve,29 a group of thirty untrained college males, aged 18 to 20 years, volunteered for tests on 100, 200, 400 and 800 yards, runs as well as on 1,2 and 3 miles runs. No practice sessions were given for the track running. In addition, the subjects were tested for maximum aerobic capacity (Max O₂ intake) on a treadmill and anaerobic work capacity (as measured

by method of Margaria). It was concluded that distance beyond half-mile are significantly related to the aerobic work capacity and distances up to and including quarter mile are significantly related to anaerobic work capacity.

The purpose of Berg and Bell's study was to determine the role of various physiological and anthropometric measures in determining mile run time. Subjects were 33 male runners aged 19 to 36 years old. Bivariate and multiple regression analysis were used to determine the amount of variance accounted for by the variables. Independent variables included age, height, weight, hip width as percent of height, lower extremity length as a percent of height, percent body fat, FVC, FEV₁/FVC percent, MVV, hematocrit, leg press strength, 40 yard dash and 440 yard run times, \( \text{Vo}_2 \max (1/\text{min}) \) and \( \text{ml/kg.min} \), and training miles run per week. The 440 yard run time accounted for 60.7 percent of the variance while 440 time, age, \( \text{Vo}_2 \max (1/\text{min}) \), percent fat and

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lower extremity as a percent of height collectively accounted for 90.8 percent. The addition of FEV/FVC percent and hip width as a percent of height raised the explained variance to 93.7 percent. VO₂ max (l/min) accounted for 5.82 percent of the variance. In fit adult males, it appeared that factors other than VO₂ max were major contributors to middle distance running performance.

Robson and Singh's 31 study was to find out the relationship of cardiorespiratory performance of physical education professional student to selected anthropometric measurements and circulatory and respiratory variables. They found, no significant relationship between cardio-respiratory performance to various physiological variables and anthropometric measurements. However, when intercorrelation were worked between independent variables significant correlation at .05 level of confidence was seen.

Nocker\textsuperscript{32} stated that coordination, balance, and relaxation play important roles in triple jump. Agility development of the highest degree is required for fast reaction in controlled movements where accuracy is also a feature. The ability to handle the body quickly and precisely with maximum force is required in all phases of triple jump. Speed training improves the functioning of the nervous system.

Mayhew\textsuperscript{33} carried out a study to determine if selected physiological and anthropometric factors that contribute to endurance running performance in adolescent male track athletes contribute similarly to endurance running performance in adolescent female track athletes. He concluded that significant differences in body composition and structure, hematological parameters


aerobic capacity and endurance running performance exist between adolescent male and female track athletes. It was further concluded that circulorespiratory, body structure and body composition variables contribute significantly to endurance running performance in both male and female track athletes, but the degree to which selected variables contributed was not always the same between sex.

Carbon\textsuperscript{34} took up a study to determine the relative contributions that selected morphological, circulorespiratory and biomechanical measures make in accounting for individual differences in endurance running performance of trained adult recreational runners. He concluded that selected circulorespiratory, body size, composition and structure and biomechanics variables contribute significantly to endurance running performance in trained adult recreational runners. However, the degree of the contribution of the circulorespiratory measures as determinants of endurance

\textsuperscript{34}John Stanely Carbon, "An Examination of Morphological, Circulorespiratory and Biomechanical Model of Endurance Running Performance" Dissertation Abstracts International 41(August 1980):583-A.
performance was greater than the contributions of the body size composition and structure running mechanics variables.

The purpose of Franklin's et al\textsuperscript{35} study was to investigate the physiologic and psychologic characteristics of high trained race walkers, and to compare these results with those noted for distance runners. Nine national caliber race walkers were assessed for body composition, maximal aerobic capacity (\(\text{VO}_2\max\)), blood chemistry, pulmonary function and personality profile (Minnesota Multiphasic Personality Inventory, MMPI). Training (walking) mileage ranged from 45 to 110 miles per week, mean 73.9. Mean \(\pm\) SD age, height, weight, percent body fat, resting heart rate, and \(\text{VO}_2\max\) were 26.7 \(\pm\) 8.0 years, 178.7 \(\pm\) 7.6 cm., 68.5 \(\pm\) 6.0\%, 7.8 \(\pm\) 2.5 percent body fat, 54.1 \(\pm\) 6.4 beats.min\(^{-1}\) and 62.9 \(\pm\) 4.1 ml.l\(^{-1}\) min\(^{-1}\). Relative haemoglobin and hematocrit values were at the lower limits of normal, 14.5 gm/dl and 41.4 percent respectively. The mean total cholesterol triglyceride and HDL-

cholesterol levels were 169, 85, 56, mg/kl. respectively. The total cholesterol/HDL-cholesterol ratio was remarkably low, 3.0. Pulmonary function studies, including vital capacity, forced expiratory volume in 1.0 sec., and maximal voluntary ventilation were within the normal range for untrained men of comparable age and size. MMPI personality and validity scales, expressed as mean T scores, were within normal limits, with the exception of a slightly lower aerobic capacity, the physiologic and psychologic profile of the race walker is quite similar to that of the marathon runner. Perhaps the technique and efficiency of race walking are more important to successful performance than is a great aerobic capacity.

Wilson \(^{36}\) conducted a study to determine the relationship between specific factors of personality adjustment and levels of motor achievement in a select group of junior and senior high school boys. Pertinent scales from the 16 Personality Factory Questionnaire

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\(^{36}\) Philip K. Wilson, "Relationship Between Motor Achievement and Selected Personality Factors of Junior and Senior High School Boys" Research Quarterly 40 (December 1969):841-844.
and the Guilford Zimmerman Temperament Survey were administered to 154 subjects for the purpose of determining existing personality characteristics. The motor achievement data were collected from administration of the McCloy General Motor Ability and Motor Capacity Test. The data were statistically analyzed through the use of the Pearson's Product Moment Correlation technique, the t test, and the multiple regression technique. The study concluded that (a) individual group dependance was a factor in extent of exhibited motor achievement and (b) that levels of motor achievement were predictable with the use of grouped measured personality characteristics.

Cowmeadow took up a study using seventy-two unconditioned university women participated in a ten-week jogging program. Twenty-six subjects were assigned to each training program and twenty to a control group. Miller's treadmill test was used to establish pre and post maximum oxygen uptake. Cattell's

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Sixteen Personality Factor Questionnaire was used as a predictor. Fisher's Aerobic programme showed greater gain in $\text{MV}O_2$ (7.823 ml/Kg/min to 5.545 ml/Kg/min), a higher participation frequency (88 percent to 81 percent) and a superior competition record (50 percent to 42 percent) but did not prove to be statistically significant in comparison with Cooper's Aerobic programme. Both ten week programmes provide significant increases (.01 level) in $\text{MV}O_2$ gain. Age proved to be a negative factor in the amount of $\text{MV}O_2$ gain while initial fitness level was not found to be a statistically significant factor in $\text{MV}O_2$ gain. Weight, smoking, reason for joining study, and jogging alone or with someone did not effect an individual's completion record. Individuals who completed their programmes were more group tied than self sufficient. Cattelle's Sixteen Personality Factor Questionnaire did act as a predictor for $\text{MV}O_2$ gain.

Johnson, Hutton and Johnson conducted a study.

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to evaluate personality traits of twelve national champions by employing Rorschach Ink Blot Test and House Tree Person (H.T.P.) Test. They found that athletes were able to achieve an exceptional levels of concentration on desired goals. The champions were aggressive, highly anxious and demonstrated high level of intellectual aspiration and exceptional feelings of self assurance.

Pearson suggests that in all the sprints, the jumps and the throws speed is a common denominator, the man of extraordinary temperament (not merely apparently so) cannot become a first class athlete.

In the study undertaken by Vincent, college women (N = 37) enrolled in eight physical education activity courses were measured in attitude, strength, and efficiency. Attitudes were evaluated by the Wear

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Attitude Inventory, strength by dynomometers, and efficiency through calculation of net energy cost of an exercise bout, using an indirect closed circuit respirometer. Partial and multiple correlations were calculated between these independent variables and success in physical education activities as measured by grades. Regression equations consisting of various combinations of the three independent variables were formulated and tested by analysis of variance. All prediction batteries were significant in the prediction of success in physical education activities.

Morgan and Costill\(^{41}\) studied psychological characteristics of the marathon runners. Nine (\(N = 9\)) U.S. Marathon runners completed psychological tests which provided measures of (i) introversion - extroversion, (ii) neuroticism-stability, (iii) anxiety, and (iv) depression. It was concluded that the marathon runners who were evaluated in this investigation scored within the normal limits on all of the

psychological variables with the exception of anxiety. The runners scored appreciably lower than the normal group for the anxiety variable. Also, none of the psychological variables were significantly correlated with performance in the marathon.

Meiers administered the Cattell 16 PF to 110 varsity athletes participating in seven different sports. Results of this study indicated that reserve athletes were more outgoing and warm hearted than first string athletes. Specific differences were reported for athlete in swimming, volleyball, waterpolo, wrestling and track.

Shotwells carried out a study on 111 adult male members of the fifteen center who were representative of professional career and upper middle socio-economic status. A submaximal, heart rate, and blood pressure was administered. Additional physical

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measurements included pulmonary function, height, weight and body composition estimates. Aerobic power, or \( V_{O_2} \text{ max} \), was estimated by extrapolating four sub-maximal exercise heart rates to age-predicted maximal levels. The subjects were also administered the 1975 revision of Cattell's Motivation Analysis Test. The test was scored according to the procedures for deriving a result for each of the 10 factor components for each subject. A Pearson Product Moment Correlation analysis was computed between estimated \( V_{O_2} \text{ max} \) and each of the 10 factors of motivation. A statistically significant zero-order correlation coefficient was found between estimated \( V_{O_2} \text{ max} \) and the super-ego sentiment \((r = -.19)\). A multiple regression analysis was computed with established \( V_{O_2} \text{ max} \) as the dependent variable and the factors of motivation as the independent variables. A statistically significant increase in \( R^2 \) was found when estimated \( V_{O_2} \text{ max} \) was correlated with the combined super-ego sentiments and Noeian-Comfort Eng \((R = .28)\). Among the test conditions, only the cups of coffeee item was found to be significantly related to estimated \( V_{O_2} \text{ max} \) \((r = .25)\). The partialling of age was not found to significantly alter the correlation coefficients between estimated \( V_{O_2} \text{ max} \).
and any of the factors of motivations. Statistically significant zero-order correlation coefficients were found between estimated \( \text{VO}_2 \text{max} \) and the following physical measurements: (a) percent fat \( (r = .64) \); (b) resting heart rate \( (r = -.49) \); (c) forced vital capacity \( (r = .37) \), (d) body weight \( (r = .34) \); (e) age \( (r = .30) \); and (f) first-second forced expiratory volume \( (r = .28) \). In the multiple analysis, a statistical significant increase in \( R^2 \) was found when estimated \( \text{VO}_2 \text{max} \) was predicted with percent fat and resting heart rate jointly.

Bennington administered Cattell Junior Personality Questionnaire to 90 male high school subjects. Subjects were selected in such a manner that thirty were gymnasts, thirty were football players and thirty did not participate in organized athletics. ANOVA was utilized to determine whether differences existed between scores for the groups on each of fourteen personality factors.

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The scores for gymnastics and football groups were higher (P < .01) than were the scores for the non-athletic group in intelligence. The groups were not different on 13 of the 14 personality factors.

Gupta selected 36 hockey champions from all over the country and 36 non-athletes from the State College of Education, Patiala (Punjab). The results of the investigation depicted that hockey champions were highest on Ma Scale while lowest on Pt Scale, and low on all the scales of inventory as compared with the non-athletic group. It indicated that playing hockey might be one of the cause of these differences and the individuals who possess these personality traits might become hockey champions.

Hockey champions had greater ability to concentrate, self-confidence, extroversion and interest were psychologically mature, tendency to worry less and less, intelligent as compared with the group of non-athletes.

Rydalch investigated the relationship between fourteen biographical factors and player success in junior college football. The purpose of this study was to identify independent variables that were significantly related to football success and to formulate a regression equation to predict football success. Data was collected on 812 subjects football players from 17 junior colleges located in eight states. Head football coaches at the participating colleges rated their own individual players and the ratings of the coaches were analysed by multiple correlation and regression analysis at Brigham Young University in Provo, Utah. The findings of the study were (1) the twelve independent variables which were analysed were significantly related to football success at the .01 level; (2) six factors - honor, speed, weight, team record in high school, height, and size of high school were selected as those variables with the highest relationship to success.

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Donald Doyle Rydalch, "A Study to Identify and Analyze Biographical Factors Which Predict Player Success in Junior College Football" Dissertation Abstracts International 32 (September 1971):1323-A.
Regression equation, using physical traits and class commitment as predictors, were developed by Atkinson for determining potential skill in beginning tennis, badminton and handball for college men. The physical traits used were: agility, power, hand-eye coordination, and visual acuity. Skill level was determined by a round robin tournament in each sport. Ss were 140 college men enrolled in beginning classes for each sport and taught by the whole-part method. Control Ss included 138 students enrolled in other beginning classes and taught by the part method.

Another purpose of the study was to determine if practice in the sport would significantly improve scores on the physical traits. A paired t was used. A t was used to compare expand control groups. Conclusions were: class commitment is probably an integral part of skill attainment in the sports studied, students taught tennis and badminton by the whole-part method experience greater gains in agility and hand-eye coordination; students taught tennis by the part

method experience greater gains in shoulder girdle power.

Nail studied the relationship of balance, speed, strength, height, arm and leg length to success in collegiate wrestling. Subjects were classed as successful, average or unsuccessful according to their win-loss percentage. A second classification was by weight (light weight, middle weight, heavy weight). All subjects were measured for height, arm length and leg length and tested for RT MT (reaction time, movement time), static elbow flexion strength, explosive leg strength and dynamic balance. Treatment of the data by analysis of variance showed no difference among the wrestlers in the three weight divisions or dynamic balance, explosive leg strength and (RT) reaction time. In elbow flexion strength the middle weight were stronger than the light weight. Light weights and middle weights were faster in movement time and reaction time than the heavy weights.

The successful wrestlers had better balance than the unsuccessful wrestlers. The unsuccessful wrestlers had longer legs than the average and successful wrestlers. Analysis by multiple $r$ and regression showed that no combination of the independent variables were useful in predicting success.

Manly examined the relationship of selected metabolic, pulmonary and anthropometric factors to performance in the 100 yard butterfly swimming event. Physical measurements were taken for 11 varsity swimmers from Virginia Polytechnic Institute and State University and 10 boys aged 13 through 17 who were members of several Blackburg, Virginia area AAU Youth Group Swimming Teams. The performance time for each subject was entered as the dependent variable in a Pearson Product Correlation coefficient. A step-wise multiple regression computer programme was also used. The specific factors maximal oxygen debt, vital capacity, one-half second timed vital capacity, a special somato-type index, skinfold fat, strength and

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bitrochanteric were investigated as the independent variables and as possible predictors of performance time. There were no indices measured for the college group to be of significance at the .05 level of confidence ($P \leq .05$). Maximal breathing capacity was the only predictor in the youth group at the .05 level of confidence. The step-wise multiple regression technique in the college group revealed strength, somatotype index, bitrochanteric and Oxygen debt max vital capacity as predictors. The step-wise multiple regression technique was also used with the youth group. When four variables were used, then high multiple correlations were found between swimming performance and the prediction equation which utilized the variables of maximal breathing capacity, Vital capacity, chest debt and strength.

Crites\textsuperscript{50} conducted a study using forty subjects who were members of two beginning swimming classes. The beginning swimming classes met for forty minutes.

\textsuperscript{50} Jerry Keith Crites, "A Study of Selected Physiological and Psychological Factors to Determine Their Relationship to the Performance of the Crawl Stroke by Beginning Swimmers" Dissertation Abstracts International 36 (October 1975) 2084-A.
twice a week. Prior to any swimming instruction, measurements were collected on shoulder rotation, shoulder extension strength, hip extension strength, body composition, swimming anxiety and swimming ability as measured by the Fox Power Test (revised). After five weeks of crawl/stroke instruction, measurements were again collected on swimming anxiety and swimming ability. The data were then analysed using the Pearson product moment correlation to identify significant relationships. Primary findings of this study were:

(i) shoulder rotation, shoulder extension strength, hip extension strength and body composition were not significant factors in the performance of the crawl stroke, and (ii) a significant relationship was indicated between swimming anxiety and the ability to perform the crawl stroke.

In the study undertaken by Stine, 65 male subjects were tested the first week of the term on the independent variables of strength, power and cardio-vascular endurance and ranked high, medium, [51] Steven W. Stine, "The Relationship of Strength, Power and Cardiovascular Endurance to Selected Variables Relating to Success in Learning Tennis" Completed Research in Health, Physical Education and Recreation 19 (1977) 1101.
or low. Tests on dependent variables were given the last two weeks. These test results determined the dependent variables relationship to independent variables by use of statistical procedures. The findings indicated strength and cardiovascular endurance had no significant relationship to the following dependent variables: speed of serve, combination of service placement and speed of serve, and a combination of placement, speed and Hewitt's backboard test. Correlation coefficient test showed significant predictability of strength and power to Hewitt's backboard test and strength alone to percentage of wins.

Raducha selected 102 freshmen and sophomore students enrolled in physical education activity classes at North Texas State University served as subjects for his study. Each subject took six ability tests: the Side Step for agility, the Bass Stick Test for balance, the Howard-Dolman Depth Perception Test.

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Apparatus for depth perception, Fleishman's Bend, Twist and Touch Test for flexibility, the Hand Manometer for grip strength, and a reaction time and speed of movement test. Each subject performed fifty trials of a wall volley task that involved hitting for speed and accuracy with a wooden paddle and a tennis ball. The scores collected from the fifth trials were grouped into ten stages of practice. The scores for each stage of practice consisted of the sum of the scores for each of the five trials. The data were analysed for the total sample population and for four skills level groups. The four groups, quarters of the total sample population, were determined on the basis of the total score for the last five trials of the gross motor task. A linear stepwise multiple regression was used to determine the relationship between the six abilities measured and performance on the wall volley task at the succeeding stages of practice to determine if there was a systematic change in the abilities that contributed to motor performance as task performance improved.
Lorihi\textsuperscript{53} investigated the relationship between swimming and selected physiological, anthropometric developmental and skill variables in 10-12 year old female competitive swimmers. Each also completed a 400-yard and 50-yard time trial. The data were initially examined by means of a Pearson r matrix. The intercorrelation matrix indicated that the best single predictors of swimming performance were height, aerobic capacity and stroke efficiency. When the better swimmers were compared to the poor, however, the importance of physiological parameters disappeared. Body size, skill and exposure to swimming were the most significant group of factors in differentiating between the two classes of performers (better class performer and the poorer class performer).

\textsuperscript{53}Matheson Lorihi, "Selected Physiological, Anthropometric and Skill Variables Contributing to Success in 10-12 Years Old Female Competitive Swimmers" \textit{Completed Research in Health, Physical Education and Recreation} 20(1978):293.