NAME OF AUTHOR......*Jeno Tihanyi*............

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(Signed)........*John Tihanyi*........

PERMANENT ADDRESS:

Physical Ed......
Laurentian U.......
Sudbury....,*Ont*.

DATED *Sept. 28*......19*72*

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RELATIONSHIP OF SELECTED MATURATIONAL DETERMINANTS
TO COMPETITIVE SWIMMING

by

JENO TIHANYI

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A THESIS

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The undersigned certify that they have read, and
recommend to the Faculty of Graduate Studies and Research,
for acceptance, a thesis entitled "Relationship of Selected
Maturational Determinants to Competitive Swimming" submitted
by Jeno Tihanyi in partial fulfilment of the requirements
for the degree of Doctor of Philosophy.

....
Supervisor

....

....

....
External Examiner

Date. September 25, 1972.

ABSTRACT

The purpose of this study was to investigate the relative importance of certain maturational determinants to competitive swimming. Fifteen independent variables (maturational determinants) were evaluated against six dependent variables (swimming speed).

Thirty-six boys who qualified to participate in the Alberta Provincial Age Group Swimming Championships, in the age group of 11-12 years, from twelve competitive clubs in Alberta were the participants in this study. Each subject was tested three times on all of the performance items and the average of the three scores were utilized for the analysis. All tests were administered to the left side of the body.

Stepwise regression analysis and the generality percentages exhibited close correspondence in the hierarchical selection of maturational determinants. The general contention that strength is basic to athletic performance has been illustrated in this study. Both analyses emphasized the importance of strength in competitive swimming. It is, however, important to recognize that the strength measurements were closely related to movement patterns characterized by specific swimming strokes. Body weight was also shown to be relatively important in competitive swimming. Although flexibility measurements exhibited a less important role among the maturational determinants specific joint movements favoured specific swimming strokes.

Differences of varying magnitude were found to exist among the different achievement groups in the measurement of maturational determinants. The differences were significant for shoulder extension strength (100 free), knee extension strength (100 breast), shoulder flexibility and composite flexibility (100 fly).

Although the number of hours spent on training was not significant among the three success groups the higher ranked swimmers spent more hours on training.

The extreme homogeneous nature of the subjects in terms of competitive swimming ability restricts the generalization of the results to other populations.

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CHAPTER I

INTRODUCTION

Studying the motor performance of children is no longer
a novel undertaking. The long succession of investigations
measuring the general athletic performance capacity of
children and young adults suggests the operation of some
biological phenomena which predispose certain children to be
better performers. It is possible then that individuals with
varying maturational status exhibit varying athletic abili-
ties.

The review of the literature strongly implied that the
rate of growth and maturation of children has significant
effect on their motor behaviour and success in athletic par-
ticipation. Furthermore it was suggested that early maturing
boys are superior to delayed maturers in performance tests
which measure skill and strength levels (5, 7, 9). Studies
contrasting school boys with varying levels of athletic abi-
lity and background generally indicated that outstanding
athletes were more superior in physical characteristics,
acquired better social adjustment and had broader interest
than their lower rated or non-participating peers (6, 9, 13,
18). The recognition of these maturational phenomena is one
of the many avenues by which attempts are made to explain the
variability of children in motor skill performance within the
same chronological age. Whether the athletes' more superior

maturity status is incidental or consequential remains to be explored.

The most popular explanations of the ability differences at specific age levels at the present time are based on the fact that individuals progress toward maturity on the continuum of growth at varying rates. For example, Wickens (17) found the skeletal age range of forty boys at the ages of nine, twelve and fifteen years to be fifty-one, fifty-two and thirty-two skeletal months, respectively. Similarly Santa Maria (15) found differences of 13 skeletal months at age twelve and seventeen skeletal months at thirteen years of age. This type of maturational dispersions seem to provide reasonable explanation in part of why some children, within the same chronological age group, are more capable in individual or team sports, or even within the regular physical education program. Evidence cited above may certainly test the validity of chronological age classification practices still in use for team selection or for selection into specific competitive divisions. The question then, which is often asked by parents, coaches and teachers "what makes one child more successful than the others in athletics?" may well be answered by studies on the maturational patterns of children. For example, Hale (10) and Krogman (11) associated the superior baseball playing ability of their young subjects to their advanced biological status. It was also pointed out that the most demanding positions were occupied by boys exhibiting the highest maturity ratings. Perhaps a more intimate considera-

tion should be given to the relationships which may exist between the various aspects of growth and specific athletic skills. It is difficult to generalize the maturational requirements for successful participation from one athletic skill to another. One such activity may or may not be competitive swimming. Since swimming is a non-weight-bearing sport; water is not a natural human habitat; therefore the maturational variables required for successful participation may be entirely different than in other sports. It seems, therefore reasonable to suggest that accelerated gains in certain maturational attributes, different from those in other sports, may aid in achieving success in competitive swimming.

The tremendous increase in public interest toward recreational aquatic activities inevitably increased the number of competitive swimmers. Along with this increased interest has come an increase in the availability of facilities. These developments allowed an increase in swimming competitions on all levels, from local to international, in Canada. The cumulative effect of the various advancements lead to the recognition of the fact that there is a growing need for more information by coaches and teachers with respect to the variables that affect performance capacity in swimming.

This study attempted to find some association between competitive swimming success and certain maturational determinants. The knowledge of the maturational variables which are related to swimming success may provide coaches with

better insight into the development of more effective training methods. It is also possible that such information might challenge the present method of high-pressure training for young competitors. The information derived may lend itself to promote in part the development of physical attributes necessary for competitive swimming by other means than water training. For example, the development of flexibility and strength related to a specific movement pattern may affect more successful results during the prepubescent and pubescent years than the long and tedious hours spent on training in the water.

This study will be justified if:

(a) it will initiate further inquiry and investigation into other areas of competitive athletics to seek the meaning of maturation in terms of performance ability, and

(b) if it will contribute to the development of better training-practices of young competitive swimmers.

The Problem

The purpose of this investigation was to evaluate the relationship between swimming speed and selected maturational determinants. More specifically:

(a) To investigate the relative importance or predictive strength of certain maturational determinants in terms of competitive swimming success for boys in the age group of 11 to 12 years.

(b) To establish a hierarchical order of relationships

between the independent (maturational determinants) and dependent (swimming speed) variables.

(c) To determine the significance of the difference between high, middle, and low success groups as determined by swimming speed in terms of maturational determinants. The following null hypotheses will be tested under point (c).

1. Maturational determinants will not have a significant effect on the level of performance in any one specific stroke.

2. The number of hours spent on training will not have a significant effect on the level of performance in any one specific stroke.

Definition of Terms

1. Individual Medley consists of butterfly, backstroke, breaststroke, and freestyle in which each stroke must be used for one designated quarter of the total distance of the race.

2. Skeletal Age is the measure of the degree of skeletal ossification of the hand and wrist, expressed in months. It also represents the degree of physical maturity.

3. Strength, for the purposes of this paper, represents the ability to exert maximal force against a strain gauge instrument.

4. Flexibility, for the purposes of this paper, represents the range of movements of a joint and of the associated body segments.

5. Vital capacity represents the amount of air expired

following a maximal inspiration.

6. <u>Maturational determinant</u> is a qualitative and quantitative expression of the biogenetic process in its progress toward attaining maturity.

7. <u>Success</u> (ability) represents the relative position attained by an individual with respect to others in terms of the final competition swimming times. The formation of high, middle, and low groups was based on this concept. The top six formed the high group, the last six formed the low group, all remaining between the high and low groups formed the middle group.

8. <u>Maturation</u> is a constantly changing biogenetic process expressed by the level of performance aptitude in its progress toward maturity which represents the apex of performance capacity.

Maturation: A Point of View

The totality of the living process revealed by the child is usually expressed in terms of growth, development and maturation.

One of the most perplexing problems perpetuated over many years in the study of human growth and development is the question of maturation; or is it maturity? In an historical sense the terms maturation and maturity have exhausted the complete gamut of the available biological synonyms. Krogman (12) commented that the terms maturation and maturity mean "all things to all people": from biological "cell maturation"

to economic "value of a bond at maturity". Krogman himself
defined maturation as aging and the termination of aging as
maturity. Todd (16) defined progressive maturity (the process
of maturation) as growing up, growing older, and growing old.
It is implicit in this definition that there are three major
stages of maturity and each of these stages represent a kind
of dynamic state inherent in all living organisms. The dyna-
mic state implies that maturity (as a process) represents a
constantly changing tissue state. It is only a vaguely defined
end product, viz; it will occur some time along the chrono-
logical age-scale. Greulich (8) explained the concept of
maturity in terms of the developing reproductive system and
the bones of the wrist and hand. He also stated that in rea-
lity any organ system may be used for determining the develop-
mental status of the organism as a whole. According to the
above definition acquisition of reproductive ability or the
union of the epiphyses with their diaphyses indicate the
termination of maturation. One would assume that quantita-
tively it may be true but qualitatively it only represents
another stage in the process of maturation. In other words
the attainment of adult value in any one physical parameter
does not terminate the process of maturation. Baldwin (3)
stated that maturation and maturity mean an increase in com-
petency and adaptability. This definition implies a dynamic
biological process and only the termination of functional
capacity may cease this process. Acheson (1) declared matura-
tion as a process of metamorphosis of the biological and

chemical nature of the tissue. Acheson intended the applica-
tion of his definition to the skeleton, but by following
Greulich's (8) contentions the definition may be applied to
any organ system. Breckenridge (4) stated her definition in
similar fashion to Baldwin. She asserted that during their
growth children pass through successive stages of development.
These stages of development represent qualitative changes in
functional complexity, which is an expression of human gene-
tical heritage, within a progressively maturing biological
unit.

Obviously any one of the above stated definitions des-
cribe a process, a dynamic biological state, but within a
narrow operational application. Maturation is growth; matura-
tion is development; maturation is the sum total of a biogene-
tic process which is seen as a constantly appearing series of
turning points in the life cycle of the organism. There is
no terminal point, only successive transformations of certain
specific points of the total biological unit in a more-or-less
predictable (orderly) fashion, which is expressed by struc-
tural, functional and behavioural dimensions. This contention
is consistent with Baldwin's definition of maturity. The
theme of maturation within this investigation with respect
to athletic ability and success attempted to follow the same
general reasoning.

The process of maturation or the metamorphosis of the
biological parameters involves rates, directions, and patterns
which are functionally inseparable and mutually susceptible to

extrinsic and intrinsic environmental influences. Since no
two individuals will progress in the same fashion, great indi-
vidual differences are inevitable in the sum total of the bio-
genetic process as revealed by children at any one age. Per-
haps the diversity of performances exhibited in the motor
skills of children may be explained more readily within the
context of their maturational status. The implication of the
above comment is that the more mature children will attain a
higher level of performance adaptability than their less
mature peers. Less mature infers the persistence of some
earlier biologic patterns in the qualitative and quantitative
sense. The ability to attain higher level of adaptability
may be true more so with children who are exposed to continued
athletic participation especially within an age group in-
herently sensitive to structural changes.

Let us then raise the question again "what is matura-
tion?" in terms of performance ability. Is it (a) the attain-
ment of adult values or dimensions in one or several aspects
of the biogenetic process; or is it (b) the attainment of some
functional quantity within which qualitative changes may pre-
vail as exhibited by a performance capacity regardless of the
effects of learning? The latter point is implying a kind of
biological continuity in terms of maturation. That is, once
maturity is achieved within one system quantitatively a con-
tinuous process of qualitative changes will prevail as long
as performance ability continues to rise, level out, or even
decline. The latter is only relevant to the aspect of quali-

tative changes. This narrow trifurcation of the maturational concept remains operational at least within one aspect of the biogenetic process (although several units may experience the same rate of change) until life goes on, or until performance is feasible. Therefore, it is possible to improve functionally beyond the hypothetical adult status and perhaps well above the levels of expectancy as defined by some maturational criteria. The above considerations may perhaps point toward a logical explanation of the phenomenally high-level performance of long distance runners, cross-country skiers, etc., after passing thirty years of age. This point may be well illustrated by the amazing performance of a Japanese Olympic runner. At the age of 31 years during the 1960 Olympic Games "...Sandanaga ran the 25 kilometres in 2 hours 35 minutes 11 seconds. At the age of 41, running in the... 25 kilometre event, his time was actually faster - 2 hours 23 minutes 52 seconds." (14). Certainly one would have to be cautious in stating that all those above-thirty athletes are slow maturers and perhaps just attaining their adult maturity status. It is more than probable that with persistent qualitative changes (likely the result of long years of training) a greater performance ability is maintained, which in turn perpetuates the continuity of maturation, as measured by the level of performance. Gerentologist Antonini (2) supports this contention by stating that functional deterioration may be prolonged by constant organic stimulation.

Maturation then, in the context of performance ability

as measured by an achieved level, is a constantly changing biogenetic process. Maturity, the ultimate status of maturation, is the apex of performance ability* which is probably an unknown point on the chronological age-scale.

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* (Ability alone may not be truly measurable since the measurement of genetic potential is still the challenge of tomorrow.)

REFERENCES

1. Acheson, R.M., Maturation of the Skeleton, in Falkner, F., (ed.), <u>Human Development</u>, Philadelphia: W.B. Saunders, p. 465, 1966.

2. Antonini, F.M., Why We Grow Old, <u>World Health</u>, pp. 27-30, April, 1972.

3. Baldwin, A.L., <u>Behavior and Development in Childhood</u>, New York: Dryden Press, 1955.

4. Breckenridge, Marian E., Margaret N. Murphy, <u>Growth and Development of the Young Child</u>, Toronto: W.B. Saunders, p. 8, 1969.

5. Clarke, H.H., J.C.E. Harrison, Differences in Physical and Motor Traits Between Boys of Advanced, Normal, and Retarded Maturity, <u>Research Quarterly</u>, 33: 13-25, 1962.

6. Clarke, H.H., K.H. Petersen, Contrast of Maturational, Structural, and Strength Characteristics of Athletes and Non-Athletes 10 to 15 Years of Age, <u>Research Quarterly</u>, 32:162-176, 1961.

7. Espenschade, A.S., Motor Performance in Adolescence, <u>Monograph of the Society for Research in Child Development</u>, 5:1-126, 1940.

8. Greulich, W.W., The Relationship of Skeletal Status to the Physical Growth and Development of Children in Boell, E.J., (ed.), <u>Dynamics of Growth Processes</u>, Princeton: Princeton University Press, pp. 212-223, 1954.

9. Hale, C.J., What Research Says About Athletics for Pre-High School Age Children, <u>Journal of Health, Physical Education, and Recreation</u>, 30:19-21, 1959.

10. Hale, C.J., Physiological Maturity of Little League Baseball Players, <u>Research Quarterly</u>, 27:276-284, 1956.

11. Krogman, W.M., Factors in Physical Growth of Children as They May Apply to Physical Education, <u>AAHPER Proceedings</u>, p. 60, 1954.

12. Krogman, W.M., The Concept of Maturity from a Morphological Viewpoint, <u>Child Development</u>, 21:25-32, 1950.

13. Olson, A.L., Characteristics of Fifteen Year Old Boys Classified as Outstanding Athletes, Scientists, Fine Artists, Leaders, Scholars or as Poor Students or Delinquents, Microcarded Doctoral Dissertation, University of Oregon, 1961.

14. Pointu, R., Age is No Barrier, World Health, p. 25, April, 1972.

15. Santa Maria, D.L., Longitudinal Analysis of Maturity and Physical Growth for Boys Ages 12 through 17 Years, Microcarded Doctoral Dissertation, University of Oregon, 1968.

16. Todd, T.W., Atlas of Skeletal Maturation (Hand), St. Louis: C.V. Mosby Co., 1937.

17. Wickens, J.S., Maturity, Structural, Muscular Strength, and Motor Ability Growth Curves of Boys Nine to Fifteen Years of Age, Microcarded Doctoral Dissertation, University of Oregon, 1958.

18. Wiley, R.C., Single Year and Longitudinal Comparisons of Maturity, Physique, Structural, Strength, and Motor Characteristics of Twelve-Year-Old Elementary Athletes and Non-Participants, Microcarded Doctoral Dissertation, University of Oregon, 1963.

CHAPTER II

REVIEW OF RELATED LITERATURE

The literature considered pertinent to this investigation has been reviewed to cover the following areas. First, investigations covering chronological age, skeletal maturation, height, and weight are discussed as they relate to motor performance. The second area is apportioned to the relevance of flexibility to athletic performance. In the third area the relationship between strength and athletic performance is presented. The fourth and final area deals with studies related to vital capacity and athletic performance.

Chronological Age and Motor Performance

Chronological age, from the initial studies in physical growth, has been used as the measure of extent of maturation. While chronological age seems to be a relatively satisfactory standard, it possesses certain shortcomings for comparative purposes. Chronological age is a variable that is not effected by changing characteristics within the individual or by environment. The rate of growth and development is highly individual and exhibits a wide range of normal variation within specific chronological limits. Following the above reasoning chronological age, although applied as a basis

for many developmental norms, appears to be an unsatisfactory index of development. McCloy and Young (64) pointed out that there is a limited causal relationship between chronological age and athletic performance in that with increasing age there may be a greater muscular maturity and a stronger will to use complete effort.

Chronological age as a standard has often been used to demonstrate individual differences in size, weight, and the time of maximum growth velocities. Shuttleworth (86), for example, grouped children for his longitudinal study according to their chronological age. He found that the maximum growth age of 711 boys on various anthropometric measures occurred at 14.80 years.

The individuality of the growth and maturation processes limits general developmental comparisons and assumptions based on chronological age. For example, to assume that a child who might compare well in height and weight to his age-peers is progressing within normal developmental channels may be rather imprudent. Greulich (35) stated that such assumptions may be valid only in general terms in a country where the populace is more homogeneous genetically; however, on the American continent people are heterogeneous in both national and racial origin. The limited relationship between chronological age and the amount of progress children make towards achieving maturity is expressed eloquently by Greulich (35:213). He stated that the chronological age of children up to the early part of the second decade of life is nothing more than just

the indication of the length of time they lived. This may be the very reason why chronological age is only a gross predictor of performance ability for general motor skills or for specific athletic skills. It may well be expected that large chronological age discrepancies will affect performance capacity. However, the same differences in terms of performance may be also observed within the same chronological age range. Since the literature generally examines performance capacity in terms of maturational progress, chronological age is rarely considered as a satisfactory standard.

Skeletal Age and Motor Performance

The concept of skeletal age offers valuable information on the rate of the development of a child which may serve as a basis for making objective growth evaluation.

It is conceivable to study any of the systems of the body, as the development of the normal child progresses in comparable order. However, invivo methods for such procedures have obvious limitations. In order to establish a reliable maturational standard, it is necessary to investigate both physiological and anatomical development. Since functionally the two systems are very closely linked, investigations based on anatomical development presented less problem. The assessment of the maturational status of individuals, based on the x-ray of the bones of the hand and wrist was introduced at the beginning of the 19th century. Pryor (72), one of the first pioneers, introduced the use of the hand-wrist x-ray

method to appraise the skeletal maturity status of children. In applying the skeletal age technic, he investigated the development of children from the time of birth to maturity. Pryor's main concern was the time of the appearance of bones, epiphysial unions, and the occurrence of sex differences in relation to skeletal maturation. His investigation pointed out, probably for the first time, that girls mature earlier and progress faster than boys in skeletal development.

First Ratch (76) and later Flory (32) reported that the carpal bones and the lower epiphyses of the radius and ulna were representative of the joints and bones in the rest of the body. They suggested that these anatomical structures could be used to indicate the maturational status of the entire bony framework. Flory further stated that x-rays of the hand and wrist are relatively inexpensive and require minimum time and effort, and that early investigations may provide baselines or norms to which later findings may be compared.

Baldwin (4) and Carter (11), in two independent studies, developed a method in which the maturity status was determined by the total ossified area of the wrist. This was derived by measuring bone shadows directly from radiograms with the use of a planimeter. Carter also developed a quotient which he called "ossification ratio", by summing the carpal shadows (the total ossified area) and dividing it by the carpal area to be filled by ossification. Apparently this procedure provides a partial correlation for sex and individual differences in body size.

Flory (32:15) disagreed with Carter's ossification ratio scheme on at least two major issues. Because of the great variations in individual statures, the ossification ratio seemed inadequate in determining maturity status. Secondly, early roentgenographic techniques were rather inadequate for the development of reliable standards based on the measurement of carpal shadows. Flory, on the other hand, developed a method in which bone appearance and development, epiphyseal appearance and development, and general developmental characteristics were used as criteria of skeletal age. Standardization, representing successive stages of skeletal maturity, was based on numerous x-rays of eight to eighteen year-old boys and girls. The comparison of x-rays to the standard series gave a skeletal maturity rating in months. For girls and boys separate standards were developed. Correlations between independent workers for the same assessment ranged between 0.87 to 0.97. These correlations, Flory concluded, were sufficient to meet the criterion of reliability.

In 1939 Todd (94) published an atlas of skeletal maturation in which he proposed a standard for the evaluation of the hand and wrist bones. The majority of the standards were based on normal, healthy, white children of above average economical and educational status of North European ancestry. The rest of the sample was taken from a more heterogeneous group in nationality and less privileged economically. The two groups were not entirely comparable, which imposes a possible weakness in the applicability of the norms. Todd empha-

sized the importance of the metacarpal and phalangeal epiphy-
ses in the evaluation of hand-wrist x-rays. He supported this
by stating that these centers, which appear at birth, are
consistent while the centers which appear later are more sub-
ject to developmental insults. This viewpoint casts some doubt
on the validity of the ulnar and radial epiphyses and the car-
pal bones in the evaluation of skeletal maturity status.
Based on this technic he reported reliability coefficients,
of independent and experienced assessors, in the range of 0.75
to 0.95. This is almost identical with the range reported by
Flory (32).

Pyle and Manino (73) studied the reliability of the
standards established by Flory and Todd. In their assessment
of 150 children, ranging from birth to five years, they found
the Todd standard more consistent. It is worth noting, how-
ever, that Flory based his standard on children eight to
eighteen years of age.

Greulich and Pyle (37), in 1950, published a new and
more refined atlas of skeletal development of the hand and
wrist. They based their work on the Brush Foundation Growth
Study which Todd initiated and in part documented in his atlas.
Greulich and Pyle had the advantage of studying a large homo-
geneous sample. What is more important, by using Todd's
earlier roentgenographs, they were able to study pre-pubescent
and adolescent progresses of the same children. At a certain
chronological age, when the various maturity indicators
appeared, the most representative film was chosen as the in-

dicator of skeletal maturity at that specific age. Greulich
and Pyle suggested that past the age of five years the skele-
ton did not mature rapidly enough to warrant a more frequent
interval standard than one year. Because of the rapidly chang-
ing development of the skeleton, during the early puberal
period, they added another standard at fifteen and one-half
years for boys, and thirteen and one-half years for girls.
Their recommended method of assessment involved comparing the
individual x-ray of the hand and wrist to one in their atlas
at the approximate chronological age.

Skeletal maturation appears to be orderly and sequential.
Greulich (36) pointed out that the skeleton of a healthy,
well-nourished child develops in unison; there is a marked
tendency for the various parts to keep in pace with one an-
other in their maturation. Since ossification within the
skeletal frame has a definite sequence and pattern, it is
often used and thought to be the best age indicator. There-
fore, it seems reasonable to suggest that the development of
the hand and wrist mirrors the status of the remaining parts
of the skeleton. Tanner (91) confirms this by stating that,
in theory, any or all skeletal segments could be used to
assess bone age; but, in practice, the hand and wrist are the
most convenient areas and the ones generally used. Todd (95)
and Bayley (7) also emphasized the same observation. Bayley
in addition stated that there is a highly acceptable relation-
ship in the rate of maturation between the knee and the bones
of the hand up to the age of thirteen years. Greulich and

Pyle (37:36) in a way summarize the foregoing discussion by
stating:

> ...the bones of the hand and wrist, like those of
> other areas, tend to maintain a regular sequence
> at the beginning and in the various subsequent
> stages of their ossification. In most normal child-
> ren there is a sufficiently good balance in osseous
> development to permit one to assign to the hand a
> single skeletal age which describes adequately the
> status of the bones which compose it.

Alteration in the sequence and rate of skeletal matura-
tion is usually the result of some environmental insult. The
most often occurring conditions are the result of poor nutri-
tion or some pathological trauma. Greulich and Pyle (37:26)
suggested that retardation is only temporary and affects only
a given center or centers which are due to appear at the time
of interference. Also, these irregularities seem to occur
more frequently in the carpal bones than any other centers.
Harding (40) and Pyle and Sontag (74) feel that the order of
ossification is not upset significantly and the rate tends to
remain fairly constant, even when the illness was severe
enough to produce bone scars.

Several studies expressed confidence and a high degree
of reliability in the technic developed and recommended by
Greulich and Pyle (37).

Reynolds and Asakawa (77) studied the skeletal develop-
ment of 357 infants. Their finding support the convictions
of Greulich and Pyle on a total and harmonious bodily and
development. Reynolds and Asakawa compared the ratings of
the hand and wrist with total body skeletal rating. It was

found that 69.5 per cent of the ratings agreed exactly; 29.1 per cent disagreed with just one category rating; and only five cases showed marked disagreement.

Seils (83), in his study of primary school children, using the Greulich-Pyle standards, reported a reliability co-efficient of 0.87 between two independent assessments. Whittle (99), using the same technic as Seils, obtained a reliability coefficient of 0.89 in assessing x-rays of twelve-year-old boys.

Hayman (42) investigated the feasibility of a shorter method of assessing skeletal maturity by using the Greulich-Pyle standards. His investigation included boys from nine to fifteen years of age. The various correlation coefficients computed between the skeletal ages of the individual bones and their relationships to the total skeletal age of the hand and wrist ranged from 0.945 to 0.998. These were significant beyond the 0.01 level of confidence. The highest multiple correlation coefficient was 0.999, which included the meta-carpal IV, distal phalanx I, triquetral, proximal phalanx I, distal end of radius, and middle phalanx II. By using only four bones, he obtained a multiple correlation coefficient of 0.9989 between the full complement of the skeletal age of the hand and wrist bones and the four bones located centrally along the same axis. These four bones are: capitate, meta-carpal III, proximal phalanx III, and middle phalanx III. In his conclusion, Hayman states that these bones will provide a highly accurate skeletal assessment. Hayman reported a

reliability coefficient of 0.99. In the reliability study, between the first and second assessments, he permitted a six-month interval. The fact that Hayman has considered only one carpal bone somewhat confirms Todd's (94:15) conviction that the metacarpal and phalangeal bones are more important in skeletal status evaluation than the carpal bones.

The critical evaluations of the skeletal age method of estimating children's maturity by Mainland (62, 63) pointed out some of its weaknesses. The two main types which Mainland listed are as follows: (i) systematic error, or error of bias, which is the persistently occurring difference between the investigator's rating and the rating of the same x-ray by a trained and experienced evaluator; (ii) variable or fluctuating error, which is the error of difference between independent assessments made by the same rater on the same x-ray. Other fluctuating errors may result from the use of different atlases; differences between skeletal ages and chronological ages of the subjects; individual differences of children; and differences in x-ray technics and in the quality of the x-ray films. Errors will occur inevitably when more than one assessor is involved. Mainland pointed out that the consistency of a single rater in two-thirds of the cases is within plus or minus three months for two independent assessments; and in ninety-five per cent of all cases within plus or minus six months.

Acheson (1) reported systematic error of just over four skeletal months among eight independent observers. Koski (55)

encountered systematic error of only two months in his study of Finnish children aged 5-18 years. Both reports, in essence, support the contention that the inspectional method of skeletal assessment is a valid procedure, especially in clinical use.

The predictability of skeletal age from chronological age, or vice versa, has not yet reached the stage of documental acceptance as a truism. Several studies show very close association between the two maturity criteria, while others disagree. Wickens (100), for example, observed a near straight-line rise of the mean growth curve for skeletal age, with only a slight dip at age ten years (Table I). The ten-year-olds were six months retarded in skeletal age (significant at the 0.05 level), while at fourteen years, these same boys were six months advanced (significant at the 0.01 level).

TABLE I

COMPARISON OF CHRONOLOGICAL AGE
AND SKELETAL AGE IN MONTHS

Years	Chronological Age	Skeletal Age	Differences
9	108	106	-2
10	120	114	-6
11	132	132	0
12	144	146	2
13	156	161	5
14	168	174	6

In their respective studies, Kurimoto (56), Harrison (41), Watt (97), and Santa Maria (80) also indicated a near-linear rise in skeletal maturity, height, and lung capacity. At age 17 a general deceleration and 'levelling-out' is noted. After 16-17 years of age standard deviations tended to decrease.

Dearborn and Rothney (25) found no significantly predictable relationship between children who were matched skeletally and crhonologically on the same standard. House (46), while studying grade one pupils, arrived at similar results. Of the pupils studied, 21 per cent reached a specific skeletal age ten or more months sooner than their chronological ages would predict; while some 13 per cent reached their predicted skeletal age ten or more months later. Oyster (70) lends support to the above studies by suggesting that the skeletal age is a factor of maturation, of physical growth, and of the nutritional status of the individual. The low correlation between skeletal age and chronological age (0.51 in her study) clearly indicates that the two are not measuring the same aspect of growth. Johnston (49) also supports this contention by stating that chronological age will arbitrarily position a child on a standard with respect to "normal" population, "but will do little to answer the important question 'why?'."

Greulich and Pyle (37:36), in an attempt to clarify some of the existing confusions regarding the terms skeletal and chronological age, pointed out that the former is used only to express the skeletal status of the individual, and

the latter is only a relative standard. They proceed by saying that:

> As thus employed, skeletal age corresponds to the chronological age at which the children on whom the standards were based usually attained that same degree of skeletal development. This device makes it possible to relate a child's skeletal status to chronological age, which provides the basis for evaluating every other measurable aspect of its growth and development.

It is without doubt that the assessment of maturational status from skeletal hand-wrist x-rays will not answer all the questions in growth analysis. No single test has such potential. It is, however, universally accepted that the skeleton offers the most conclusive evidence of the progressive maturation in the growing child. The evidence supporting the above statement is summed up by Johnston (49) in the following two points:

> ...first, skeletal maturation establishes beginning and end points: only a few of the accessory centers of ossification are present in the newborn, while the attainment of adult morphology as well as completed epiphyseal union is found in everyone, save the grossly pathological.

> ...second, the skeleton changes continuously throughout the growing period - its appearance records the maturation level at all times.

In the preceding pages on several occasions references was made to the individuality of the maturation process. One of the many implications the individuality of maturation offers is the premise that individuals with varying maturational status exhibit varying athletic abilities. The contention that a definite positive relation exists between the level of physical maturity and motor skill performance is supported

by extensive research literature (12,18,24,30,38,41,43,51).
The common observation appears to be that early maturation
is accompanied by accelerated gains in certain structural
attributes. Furthermore, it is pointed out that early matur-
ing boys are superior to delayed maturers in almost all motor
skill performance tasks.

Several studies have been carried out to contrast the
maturational, structural, strength, and motor traits of school
boys with varying levels of athletic ability and background.
Clarke and Petersen (13) differentiated boys at elementary
school and junior high school levels in terms of their success
as participants on interschool competitive teams. It was in-
dicated that outstanding junior high school athletes had signi-
ficantly higher skeletal age means, they were taller, heavier,
and stronger than their lower rated or non-participating peers.
Wiley (101), Shelly (85), and Olson (69) observed similar
results in their respective studies. Bloomfield (8), in an
effort to identify factors which differentiate swimmers of
different ability, found that higher ability swimmers were
more advanced maturationally than swimmers at lower levels.
Hale (39) in a survey examined the research on the effects
of competition upon young boys. His survey revealed a general
agreement that those who engaged in competitive sports were
more mature physically, demonstrated high skill level in
several activities, acquired better social adjustment, and
had broader interest than their non-participating chronologi-
cal peers.

One particular weakness noted in these studies is that there was no attempt made to determine the effects of participation upon the subjects. Such effects may only be found when tests are administered over a long period of time during which control and experimental groups are under different treatment conditions. Whether the athletes' more superior maturity status is incidental or consequential remains to be explored. This appears to be the reason why it is still a common practice to use chronological age as a basis for team selection in primary and secondary schools. It may well be pointed out, however, that a kind of natural selection takes place within each age category, viz., only those who are beyond their chronological peers in physical maturation appear to survive the rigors of team competition.

There appears to be only two studies that investigated the role of maturation as selective criterion for gaining membership on a team or for a particular position on a team (38, 52). Both studies assessed the maturational status of the boys, 10 to 15 years of age, who participated in two different Little League World Series. The findings indicate that the top 50 per cent of the boys were as mature as the average status attained by boys two years older chronologically. It was also pointed out that the more mature boys obtained the most demanding positions such as pitching, order of batting, and base positions in baseball. It appears obvious that these boys succeeded because they were more mature, biologically more stable, and structurally and functionally more advanced.

The question remains to be answered is what maturational para-
meters contributed more to the success attained by these
children or children generally in competitive athletics; and
is the developmental acceleration of the parameters of matura-
tion attributable to training or something else?

Height, Weight and Motor Performance

Of the many factors, which influence abilities in the
motor realm of individuals, height and weight have always
enjoyed prominence and popularity in differentiating children
on physical skills. Growth and development literature on many
occasions discussed the relative importance of height and
weight in the performances of physical skills during the ele-
mentary and junior high school years. The implication is that
the taller and heavier children are stronger and more profici-
ent at most of the physical skills than their chronological
peers who are shorter and lighter.

One of the earliest discussions on the effects of phy-
siological maturity on growth was carried out by Crampton (18).
He stated that there is a constant increase in height, weight,
and strength from the time of pre-pubescence well into post-
pubescent years. The greatest accelerations were noted be-
tween pubescent and post-pubescent groups. It was also noted
that the rapidity of maturation controls the extent or rapid-
ity of gains in height, weight, and strength. In his conclu-
sion he stated that growth rates are dependent upon pubescent
periods, (which are under the influence of skeletal maturation),

and not chronological age.

Dimock (27), using Crampton's criteria of pubescent divisions, supported Crampton with his findings. He pointed out that the pubescent status of boys in his study was more important than chronological age, when he was trying to explain the boys' differential status in height and weight. He further stated that at twelve or thirteen the pubescent boy is taller and heavier than a boy two years his senior who is still pre-pubescent. At the age of fourteen, between pre- and post-pubescent boys, he found a mean difference of four and one-half inches in height and 23 pounds in weight, in favour of the latter group.

Using the criterion of puberty, Richey (78) studied its effects on height and weight. He observed that the boys who attained puberty before their fourteenth birthday were, and remained heavier and taller than both those who attained puberty between their thirteenth and fourteenth birthday, and those who attained puberty after their fourteenth birthday. Over seventeen years of age, however, no statistically significant differences were found in height measurement between the different maturity groups.

Bayley (7) studied the effects of early and late maturation on body size. Her three criteria of early-, average-, and late-maturing groups were based on the level of skeletal status at a specific chronological age. She found that early maturing boys were relatively large, for their chronological ages. On the other hand, late-maturing boys, between 11 and

16 years of age, were small. However, when these boys were compared on skeletal status, the differences were minimized or completely eliminated.

Stolz and Stolz (89), in their study of 67 boys found that skeletal age indicates somatic maturity more accurately than chronological age. Early maturers had more of a tendency to make greater puberal gains than late maturers.

Elgenmark (28) studied the relationship between body length and the number of ossification centers present during the first five years of life. He revealed that they correlated 0.44 during the first year of life, and 0.34 between the second and fifth year. Larger children, he concluded, were skeletally more advanced even when they differed chronologically. Acheson and Hewitt (2), on the other hand, reported that slow maturers surpassed the rapid maturers in height when a mean-height comparison was made between the two groups.

Krogman (54) studied the relationship between skeletal maturation and success in athletic participation. Two groups of students, 524 athletes and 524 non-athletes, were paired according to chronological age. He found that athletes were significantly taller, heavier, and more advanced in skeletal age.

Growth in height is most commonly expressed by a certain graphical distance travelled during a specific length of time. This growth motion, stated Tanner (92), varies in velocity with various degrees of interruptions until the final height is gained. The intensity and duration of the various major

periods of growth vary from one individual to another. Evidence indicates (9, 90) that growth in height is continuous although nutritional, climatic, and racial factors tend to control the velocity of growth and the ultimate height attained.

Shay (84) pointed out that standing height is one of the two most frequently used anthropometric criteria to describe body build. This is particularly true during adolescence, contended Bayley (6). She also stated that height is closely related to rates of physical maturity. For example, early-maturing boys and girls appear to have consistently large average heights with no exceptional spurts. Slow maturers, on the other hand, are slender and short with small gains in height, until a sharp increase is reached at puberty. The relationship of height and skeletal maturity status is further confirmed by Harrison (41), Hindmarch (44), and Santa Maria (80). All three showed that children who were assessed as more mature skeletally were also consistently taller. In all instances the greatest discrepancies were found between advanced and retarded maturity status. Santa Maria further stated that the mean differences tend to decrease as the children grow older. This supports Bayley's (6) observation that slow maturing children tend to experience greater spurt in height during adolescence. This spurt is probably responsible for the reduced differences in body size during adolescence.

The general trend in physical maturity has indicated an accelerative path for the past century. Cone (16) indicated

that children in the U.S.A. and Western Europe are not only growing taller in successive generations, but they are also reaching biological maturity at an earlier age. This secular accelerative trend seems continuous, without 'slackening'. For example, between the years of 1944 to 1959 preparatory school boys in England gained two inches in height at 11 years; two and three-quarter inches at 12 years, and two and one-half inches at 13 years. The possible causes are attributed to better nutrition, control of childhood diseases, improvement of health habits, etc. There does not appear to be a single factor responsible for this trend.

Body weight occupies a prominent position in the various strength formulae and indices, as well as in athletic exponent and classification plans. Shay (84) reported that body weight was shown to be one of the most common measurements used in anthropometry. Shuttleworth (86) called body weight "an overall general measure of everything and hence a poor measure of anything in particular." However, since growth is a regular process, body weight as one component representative, may be useful in understanding the summation of the diverse growth factors operating throughout the body.

Most growth processes of the various body components follow the typical S-shaped growth curve, characteristic of the developing child. Tanner (91) stated that there are exceptions, and one of these is body weight. Body weight represents a mixture of the various components of the body; therefore its curve is somewhat less informative and more

divergent than the characteristic pattern. The usefulness of
a weight index is overshadowed to a large extent by its severe
limitations. Weight increase, which is expected from year-to-
year, may be due to bone, muscle, or merely to fat. Variations
in any one of these components may leave a child's growth
curve in weight quite unchanged. From these points of view,
one can easily appreciate the reason why height and weight
indices should be supplemented by measurements more representa-
tive of the body constituents.

Age-height-weight tables do represent a better overview
of an individual than any one factor by itself. Their limited
value in physical education is obvious, as these tables are
merely the average values based on a large sample at specific
ages. The common contention is that early maturers are hea-
vier and taller than late maturers. Clarke and Harrison (12)
observed in a study of 273 boys, aged nine, twelve, and fifteen
years, that standing and sitting heights and body weight in-
creased significantly at each subsequent age and maturity
level. The most significant increase found at all three ages
was in body weight. Johnston (50) found a significant corre-
lation between weight and skeletal age for girls. The implica-
tion is that heavier girls are more advanced skeletally, there-
fore weight may be a good predictor of skeletal age for girls
between 7-17 years of age.

Height and weight, as meaningful tools for maturity
appraisal, are losing their earlier research significance.
Garn (33) commented that there is an increasing tendency in

using these two measures as reference standards, rather than
as prime variables.

Several studies (5, 7, 87) have shown that the percent-
age of adult mature size is closely related to skeletal matura-
tion. Convincingly enough, high positive correlations were
found between chronological age and height, and weight. Sawtell
(82) supported these findings in an earlier study in which she
attained a definite relationship between skeletal maturation
(ossification) and total body size.

Flexibility and Motor Performance

Flexibility has long been considered an important aspect
of physical fitness. Empirical data supporting this contention
is scanty, perhaps because of the problems encountered in
arriving at a total flexibility profile. This may be ex-
plained by the fact that flexibility is not only specific to
the joints of the body, but it is also specific to individual,
within-joint, movements. Dickinson (26), for example, found
no statistically significant relationship between flexion and
extension of the wrists and ankles. Hupprich and Sigerseth
(48) observed similar results when they found no significant
relationship among twelve flexibility measurements. The
authors concluded that the absence of common factors among
the various joint movements was the reason for low coeffici-
ents of correlation. By comparing four joint movements Cureton
(22) found low correlations among them and concluded that
flexibility is specific for specific joints, and there is no

evidence of general flexibility quality.

Zankel (102) stated that the measurement of the range of motion in the joints is an important requirement in the evaluation of injury or disease involving the locomotor systems. Athletes and coaches in general recognize the importance of good flexibility; not only as a deterrent to muscle injuries, but also as possible quality in athletic proficiency. There appears to be no scientific definition as to the various qualities of flexibility needed for success in specific sports. However, several observations (8,20,21,22,52,57,58,71) revealed that athletes in the same sport show similar qualitative patterns in flexibility; and that there is a considerable variation from one sport to another. Within sport variations are due to differing levels of proficiency, viz., high caliber athletes show higher levels of flexibility than athletes on lower levels.

The assumption has been made that good flexibility is associated with success in competitive swimming. Cureton (21, 22) stressed that ankle flexibility is a most important characteristic for an efficient kick. He observed that expert swimmers showed 23 per cent higher ankle flexibility than the poorer swimmers. Apparently this flexibility difference corresponded to a speed advantage of 29 per cent. Bloomfield (8) has pointed out that high flexibility for swimmers is a desirable quality. Recovery of the arms, for example, in the butterfly and front crawl strokes may be performed with greater facility when the shoulder joints are more flexible. The

recovery movements in such cases may be carried out without
disturbing body alignment. On the other hand Cureton (20)
cautioned that certain flexibility qualities may be specific
to a particular type of event only and may not be recommended
to all swimmers. In an attempt to establish some guidelines
as to the desirability of high flexibility quality for swimmers,
Cureton (20) measured the flexibility (ankle and shoulder
flexibility, trunk forward flexion, and trunk back extension)
of the 1948 United States Olympic Swimming Team. He found
no outstanding scores in flexibility with the exception of
the 200 meter breaststrokers who ranked high in shoulder and
trunk extension. Cureton concluded that swimmers flexibility
is considerably higher than the average. He suggested that
flexibility is probably related to outstanding swimming per-
formance, especially in the shorter events. Leighton (57, 58)
confirmed Cureton's observations in his comparative study on
the flexibility characteristics of several different skill
groups of college and champion athletes. Swimmers and base-
ball players showed the greatest overall flexibility. It was
also observed that significant differences existed between
the means in flexibility among the athletes of different
skill groups. The reliability of measurements in these studies
were between 0.860 to 0.999.

Leighton (59, 60) developed a Flexometer with which he
measured 21 flexibility tests of 33 joint movements. Validity
of all movements was based upon the now clearly recognized
and defined segmental joint movements of the body. Reliability

of the measurements, based on the first and second measurement
of 120 boys, ranged from 0.913 to 0.996. In an effort to
establish some basis for comparable studies of flexibility
Leighton (16) studied the flexibility characteristics of boys
at the ages of 10, 12, 14, 16, and 18 years. He suggested
that age 16 should be used for the establishment of norms
because it appears that this is the age level where changes
from increase to decrease, or vice versa, takes place. In an
effort to show the objectivity of his measuring instrument
Leighton acquired consistent results of 16 year old boys from
different geographical areas.

Strength and Motor Performance

Strength has been a popular parameter in the evaluation
of maturity and fitness of children since time immemorial. In
most literature strength, in general, is considered the ability
of the muscles to exert force against resistance.

From the time of Sargent (81) to the present day the
most popular strength appraisal of children utilized the grip
strength test (65). The grip test in the various research
studies purportedly evaluates: (a) general strength status;
(b) level of physiological growth; (c) its relationship to
motor performance; and, (d) its relative contribution to phy-
sical fitness. The limitations of grip strength testing for
general strength appraisal and other physiological appraisals
have become obvious in the early 1940's. Consequently studies
began to explore the existing strength levels of children by

employing many joint movements. Some of the noted studies
are by Clarke and Wickens (15), Clarke and Petersen (13),
Rarick and Oyster (75), Howell, et al. (47), Singh, et al. (88).

To avoid tedious testing procedures, which employ many
tests, abbreviated strength tests have been constructed. One
such strength test battery was developed by Clarke and Schopf
(14). The original 38 cable-tension strength battery was
reduced to 18 joint movements which included the major muscle
groups found throughout the body. From the 18 strength tests
four tests were chosen by multiple correlation procedures (by
correlating each of 18 strength tests to the criterion, which
was the mean of the 18 strength tests). The abbreviated test
battery is composed of shoulder extension, ankle planter flex-
ion (ankle extension), trunk extension, and knee extension.
These four test items correlated with the criterion in the
range of 0.795 to 0.889. The sum of these four items is
designated as the strength composite. Clarke and Schopf (14:
517) suggested that the selected four tests represent almost
equally strong movements, and they all measure extension
strength of the joints involved. This was of particular
interest to this study as the subjects were swimmers, and
swimming movements are virtually all extension movements.

Strength is basic to performance in activities. Its
importance as an adjunct to athletic performance was recognized
as early as 1925 by Rogers (79) who developed a Strength Index
for classification purposes. It has been used extensively as
a basis of athletic grouping, and employed frequently as a

measure of motor ability. Zimmerli (103) foresightedly
stated that capacity for any physical activity must be pro-
portional to strength, and that the two were inseparable.

To illustrate the contention that strength is probably
the most basic contributing component to the level of motor
performance, few selected studies will be sighted. Burley and
Anderson (10) studied the musclar power of 1,013 high school-
aged boys as measured by the vertical jump test. They found
a close relationship of strength (explosive power) to track,
swimming, basketball, and baseball. Also, a close association
was found between power status and athletic success. Bloom-
field (8) measured the shoulder extension strength of swimmers
classified into three ability levels. He found that high
ability level swimmers possessed greater extension strength
or pulling force than those of lesser ability. Since shoulder
extension is an important swimming movement, the pertinent
strength is potentially a good indicator of the relative com-
petitive swimming success. Similarly Cureton (20:58-60) found
that the 1948 U.S. Olympic swimmers had higher dynamometrical
strength than their chronological peers. Everett (31) and
Hooks (45) used the measurement of strength for predicting
baseball playing ability. Both found strength a satisfactory
criterion in selecting high and low baseball ability groups.
The importance of strength becomes a more dramatically illus-
trated asset when athletic and non-athletic groups are com-
pared. In such comparisons Clarke and Petersen (13) and Wiley
(101) found that in upper and lower body strength measures

the athletic groups were significantly greater than their
non-athletic peers.

Implications have been made that strength is closely
related to certain measures of growth, and continually in-
creases with chronological age during childhood and adolescence
(66,67,93). Particularly close relationships were found be-
tween grip strength and height and weight for pre-school boys
and girls (34, 65). Crampton (18) suggested that growth rates
are dependent upon pubescent periods. He further suggested
that the relationship between strength and growth appears to
be the most intimate during the pubescent period. Jones (51:
181) substantiated Crampton's comments by observing that
individual differences in the rate of physiological maturation
during adolescence were associated with differing rates of
growth of dynamometrical strength. Early maturing boys and
girls had greater strength than their late maturing peers.
It appears that strength development depends more on physio-
logical than chronological maturity, at least up to and includ-
ing the adolescent period.

Vital Capacity and Motor Performance

Normal growth is accompanied by corresponding changes
in all functioning organs of the body. Vital capacity also
varies concomitantly with the growth of the body, therefore
factors which affect growth will also affect the vital capa-
city. Several investigators have shown that the vital capacity
of children constantly increases, especially during the adole-

scent period (98,93,64:384-395). It is suggested that this is probably due to great increases in body size. More specifically the linear individuals have greater vital capacity in proportion to their height and weight than the more stocky individuals (17,19,29,68). Tomaras (96) contended that vital capacity is a useful predictor of body size for boys between the ages 12 to 14 years. He found correlations between vital capacity and body height, body weight, skeletal age, hip width, McCloy's Classification Index ranging from 0.75 to 0.86.

Vital capacity has been used extensively as an index of physical condition and as an index of athletic involvement. Cureton (19) and Tihanyi (93), for example, found that the more active groups had greater vital capacity than their less active peers. This difference appears to be greater during the pubescent years. Clarke and Petersen (13) reported a significant difference (P<0.5) of the vital capacity means between athletic and non-athletic groups, in favour of the athletic groups. Andrew, et al. (3) in a study comparing swimmers and non-athletes lended support to the above findings. He reported significantly greater differences (P < 0.5) for vital capacity in favour of the swimmers. Bloomfield (8), while comparing swimmers of three different ability levels, found no significant differences between their vital capacity. Davis (23), on the otherhand, contended that prolonged training, as in middle distance swimming, favourably alters vital capacity. He reported correlation of 0.59 between swimming time and vital capacity, which was the highest among all anthropometric and physiological parameters.

REFERENCES

1. Acheson, R.M., _et al._, Studies in the Reliability of Skeletal Maturity from X-rays. Part I. Greulich-Pyle Atlas, _Human Biology_, 35:317-349, 1963.

2. Acheson, R.M., D. Hewitt, Oxford Child Health Survey, Stature and Skeletal Maturation in the Pre-School Child, _British Journal of Preventice Social Medicine_, 8:59-65, 1954.

3. Andrew, G.M., _et al._, Heart and Lung Functions in Swimmers and Nonathletes During Growth, _Journal of Applied Physiology_, 32:247, 1972.

4. Baldwin, Bird T., _The Physical Growth of Children from Birth to Maturity_, University of Iowa Studies in Child Welfare, Iowa City: University of Iowa Press, 1:1, 1921.

5. Bardeen, C.R., The Relation of Ossification to Physiological Development, _Journal of Radiology_, 2:1-8, 1921.

6. Bayley, Nancy, Growth Curves of Height and Weight by Age for Boys and Girls, Scaled According to Physical Maturity, _Journal of Pediatrics_, 48:187-194, 1956.

7. Bayley, Nancy, Skeletal Maturing in Adolescence as a Basis for Determining Percentage of Completed Growth, _Child Development_, 14:47, 1944.

8. Bloomfield, J., Anatomical and Physiological Differences Between Three Groups of Swimmers of Varying Abilities, Microcarded Doctoral Dissertation, University of Oregon, 1967.

9. Bogert, W.J., _Nutrition and Physical Fitness_, (6th ed.), Philadelphia: W.B. Saunders Company, 1954.

10. Burley, L.R., R.L. Anderson, Relation of Jump and Reach Measures of Power to Intelligence Scores and Athletic Performance, _Research Quarterly_, 26:28-35, 1955.

11. Carter, T.M., Techniques and Devices Used in Radiographic Study of the Wrist Bones of Children, _Journal of Educational Psychology_, 17:237-247, 1926.

12. Clarke, H.H., J.C.E. Harrison, Differences in Physical and Motor Traits Between Boys of Advanced, Normal, and Retarded Maturity, Research Quarterly, 33:13-25, 1962.

13. Clarke, H.H., K.H. Peterson, Contrast of Maturational, Structural, and Strength Characteristics of Athletes and Non-Athletes 10 to 15 Years of Age, Research Quarterly, 32:162-176, 1961.

14. Clarke, H.H., T.G. Schopf, Construction of Muscular Strength Test for Boys in Grades 4, 5, and 6, Research Quarterly, 33:515-522, 1962.

15. Clarke, H.H. J.S. Wickens, Maturity, Structural, Muscular Strength, and Motor Ability Growth Curves of Boys 9 to 15 Years of Age, Research Quarterly, 33:26-39, 1962.

16. Cone, T.A., Dr., Secular Acceleration of Height and Biologic Maturation in Children During the Past Century, Journal of Pediatrics, 59:736-740, 1961.

17. Cook, C.D., J.F. Hamman, Relation of Lung Volume to Height in Healthy Persons Between the Ages of Five and Thirty Eight Years, Journal of Pediatrics, 59:710-718, 1961.

18. Crampton, C.W., Physiological Age - A Fundamental Principle, Child Development, 15:1-52, 1944.

19. Cureton, T.K., Analysis of Vital Capacity as a Test of Condition for High School Boys, Research Quarterly, 7:80-92, 1936.

20. Cureton, T.K., Physical Fitness of Champion Athletes, Urbana: University of Illinois Press, pp. 84-93, 1951.

21. Cureton, T.K., Mechanics and Kinesiology of Swimming, Research Quarterly, 1:112, 1930.

22. Cureton, T.K., Flexibility as an Aspect of Physical Fitness, Research Quarterly, 12:381-390, 1941.

23. Davis, J.F., Effects of Training and Conditioning for Middle Distance Swimming Upon Measures of Cardiovascular Condition, General Physical Fitness, Gross Strength, Motor Fitness, and the Strength of the Involved Muscles, Microcarded Doctoral Dissertation, University of Oregon, 1955.

24. Deach, D.F., Genetic Development of Motor Skills of Children Two Through Six Years of Age, Dissertation Abstract, University of Michigan, p. 376, 1950.

25. Dearborn, W.F., J.W.M. Rothney, Predicting the Child's Development, Cambridge, Mass.: Scientific Art Publishers, 1941.

26. Dickinson, R.B., The Specificity of Flexibility, Research Quarterly, 39:792-793, 1968.

27. Dimock, H.S., A Research in Adolescence, Child Development, 6:177-195, 1968.

28. Elgenmark, O., The Normal Development of Ossific Centers During Infancy and Childhood, A Clinical, Roentgenological, and Statistical Study, Acta Paediatrica, (Uppsala) 33, Suppl. No. 1, 1946.

29. Emerson, P.W., H. Green, Vital Capacity of the Lungs of Children, American Journal of Diseases of Children, 22:202-211, 1922.

30. Espenschade, A.S., Motor Performance in Adolescence, Monograph of the Society for Research in Child Development, 5:1-126, 1940.

31. Everett, P.W., The Prediction of Baseball Ability, Research Quarterly, 23:15-19, 1952.

32. Flory, C.D., Osseous Development of the Hand as an Index of Skeletal Development, Monographs of the Society for Research in Child Development, 1:1-141, 1936.

33. Garn, S.M., Research in Human Growth, Human Biology, 29:1-11, 1957.

34. Gates, A.I., The Nature and Educational Significance of Physical Status and of Mental, Physiological, Social, and Emotional Maturity, Journal of Educational Psychology, 15:329-358, 1924.

35. Greulich, W.W., The Relationship of Skeletal Status to the Physical Growth and Development of Children, in Boell, E.J., (ed.), Dynamics of Growth Processes, New Jersey: Princeton University Press, p. 212, 1954.

36. Greulich, W.W., The Rationale of Assessing the Developmental Status of Children from Roentgenograms of the Hand and Wrist, Child Development, 21:33-44, 1950.

37. Greulich, W.W., S.I. Pyle, Radiographic Atlas of Skeletal Development of the Hand and Wrist, Standford, California: Stanford University Press, 1959.

38. Hale, C.J., Physiological Maturity of Little League Baseball Players, Research Quarterly, 27:276-284, 1956.

39. Hale, C.J., What Research Says About Ahtletics for Pre-High School Age Children, Journal of Health, Physical Education, and Recreation, 30:19-21, 1959.

40. Harding, Vernette S.V., A Method of Evaluating Osseous Development from Birth to 14 Years, Child Development, 23:247-272, 1952.

41. Harrison, J.C.E., The Relationship Between Selected Physical and Motor Factors and the Skeletal Maturity of 9, 12, and 15 Year Old Boys, Microcarded Doctoral Dissertation, University of Oregon, 1959.

42. Hayman, N.R., Reduction of the Number of Bone Assessments Necessary for Skeletal Age Determination of Adolescent Boys, Microcarded Doctoral Dissertation, University of Oregon, 1959.

43. Heaton, K.L., Physical Development of Children of High and Low Mental Ability Groups, American Physical Education Review, 30:127-130, 1925.

44. Hindmarch, R.G., Significance of Physique, Maturational, Body Size, Strength, Motor Ability and Reaction Time Characteristics of Eight Year Old Boys, Microcarded Doctoral Dissertation, University of Oregon, 1962.

45. Hooks, G.E., Prediction of Baseball Ability Through an Analysis of Measures of Strength and Structure, Research Quarterly, 30:38-43, 1959.

46. House, R.W., Stage of Bodily Maturation Found in 318 First Grade Pupils, Journal of Educational Research, 37:214-217, 1943.

47. Howell, M.L., et al., Strength of Edmonton School Children, Unpublished Study, University of Alberta, 1966.

48. Hupprich, Florence, L., P.O. Sigerseth, The Specificity of Flexibility of Girls, Research Quarterly, 21:25-33, 1950.

49. Johnston, F.E., The Concept of Skeletal Age, <u>Clinical Pediatrics</u>, 1:133-144, 1962.

50. Johnston, F.E., The Relationship of Certain Growth Variables to Chronological and Skeletal Age, <u>Human Biology</u>, 36:16-27, 1964.

51. Jones, H.E., <u>Motor Performance and Growth</u>: A Developmental Study of Static Dynamometrical Strength, Berkeley: University of California Press, pp. 53-79, 1949.

52. Kiphuth, R.J.H., <u>Swimming</u>, New York: A.S. Barnes and Co., p. 110, 1942.

53. Krogman, W.M., Maturation Age of 55 Boys in the Little League World Series, 1957, <u>Research Quarterly</u>, 30:54-56, 1959.

54. Krogman, W.M., Factors in Physical Growth of Children as They May Apply to Physical Education, <u>AAHPER Proceedings</u>, p. 60, 1954.

55. Koski, K.J., <u>et al.</u>, Skeletal Development of Hand and Wrist in Finnish Children, <u>American Journal of Physical Anthropology</u>, 19:379-382, 1961.

56. Kurimoto, E., Longitudinal Analysis of Maturity, Structural, Strength, and Motor Developments of Boys Fifteen Through Eighteen Years of Age, Microcarded Doctoral Dissertation, University of Oregon, 1963.

57. Leighton, R.J., Flexibility Characteristics of Four Specialized Skill Groups of College Athletes, <u>Archives of Physical Medicine and Rehabilitation</u>, 38:24-28, 1957.

58. Leighton, R.J., Flexibility Characteristics of Three Specialized Skill Groups of Champion Athletes, <u>Archives of Physical Medicine and Rehabilitation</u>, 38:580-583, 1957.

59. Leighton, R.J., Simple Objective and Reliabile Measure of Flexibility, <u>Research Quarterly</u>, 13:205-216, 1942.

60. Leighton, R.J., An Instrument and Technic for the Measurement of Range of Joint Motion, <u>Archives of Physical Medicine and Rehabilitation</u>, 36:571-578, 1955.

61. Leighton, R.J., Flexibility Characteristics of Males
    Ten to Eighteen Years of Age, Archives of Physical
    Medicine and Rehabilitation, 37:494-499, 1956.

62. Mainland, D., Evaluation of the Skeletal Age Method of
    Estimating Children's Development. I. Systematic
    Errors in the Assessment of Roentgenograms,
    Pediatrics, 12:114-129, 1953.

63. Mainland, D., Evaluation of the Skeletal Age Method of
    Estimating Children's Development. II. Variable
    Errors in the Assessment of Roentgenograms,
    Pediatrics, 13:165-173, 1954.

64. McCloy, C.H., Norma D. Young, Tests and Measurements in
    Health and Physical Education, New York: Appleton-
    Century-Crofts, Inc., 1954, p. 55.

65. Metheny, E., The Present Status of Strength Testing for
    Children of Elementary School and Pre-school Age,
    Research Quarterly, 12:115, 1941.

66. Metheny, E., Breathing Capacity and Grip Strength of
    Pre-School Children, University of Iowa Stuides
    in Child Welfare, 18:1-207, 1941.

67. Meredith, H.V., The Rhythm of Physical Growth: A Study
    of 18 Anthropometric Measures on Iowa City Males
    Ranging in Age Between Birth and Eighteen Years,
    University of Iowa Studies in Child Welfare, 11:
    128, 1936.

68. Morse, M., et al., The Lung Volume and Its Subdivisions
    in Boys 10-17 Years of Age, Journal of Clinical
    Investigations, 31:380-391, 1952.

69. Olson, A.L., Characteristics of Fifteen Year Old Boys
    Classified as Outstanding Athletes, Scientists,
    Fine Artists, Leaders, Scholars or as Poor Students
    or Delinquents, Microcarded Doctoral Dissertation,
    University of Oregon, 1961.

70. Oyster, Nancy, The Relationship Between Skeletal Age
    and Measures of Motor Performance and Muscle
    Strength Second Grade Girls and Boys, Microcarded
    M.S. Thesis, University of Wisconsin (Madison),
    1961.

71. Pickens, W.L., A Study of Flexibility in Swimmers,
    Microcarded Master Thesis, University of Oregon,
    1950.

72. Pryor, J.W., Time of Ossification of the Bones of the Hand of the Male and Female and Union of Epophyses with the Diaphyses, American Journal of Physical Anthropology, 8:401-410, 1925.

73. Pyle, S.I., Camille Manino, Observations on Estimating Skeletal Age from the Todd and Flory Bone Atlases, Child Development, 10:27-34, 1939.

74. Pyle, S.I., L.W. Sontag, Variability in Onset of Ossification in Epiphyses and Short Bones of the Extremities, American Journal of Roentgenology, 49: 795-798, 1943.

75. Rarick, G.L., N. Oyster, Physical Maturity, Muscular Strength and Motor Performance of Young School Age Boys, Research Quarterly, 35:522-528, 1964.

76. Ratch, T.M., The Development of the Bones in Childhood Studies by the Roentgen Method, with a View of Establishing a Developmental Index for the Grading and Protection of Early Life, Transactions of the Association of American Physicians, 24:603, 1909.

77. Reynolds, E.L., T. Asakawa, Skeletal Development in Infancy, The American Journal of Roentgenology and Radium Therapy, 65:403-410, 1951.

78. Richey, H.G., The Relation of Accelerated, Normal and Retarded Puberty to the Height and Weight of School Children, Monographs of the Society for Research in Child Development, 2:1-67, 1937.

79. Rogers, F.R., Physical Capacity Tests in the Administration of Physical Education, (Contributions to Education No. 173), New York: Bureau of Publications, Teachers College, Columbia University, 1925.

80. Santa Maria, D.L., Longitudinal Analysis of Maturity and Physical Growth for Boys Ages 12 through 17 Years, Microcarded Doctoral Dissertation, University of Oregon, 1968.

81. Sargent, D.A., Intercollegiate Strength Tests, American Physical Education Review, 2:108, 1897.

82. Sawtell, Ruth O., Ossification and Growth of Children from One to Eight Years of Age, American Journal of Diseases of Children, 37:61-87, 1929.

83. Seils, L.G., The Relationship Between Measures of Physical Growth and Gross Motor Performance of Primary School Children, Research Quarterly, 22:244-260, 1951.

84. Shay, C.T., The Relationship Between Selected Anthropometric Measurements and Loss of Strength in Selected Muscle Groups, Microcarded Doctoral Dissertation, Springfield College, 1954.

85. Shelley, M.E., Maturity, Structure, Strength, Motor Ability, and Intelligence Test Profiles of Outstanding Elementary School and Junior High School Athletes, Microcarded Master Thesis, University of Oregon, 1960.

86. Shuttleworth, F.L., The Physical and Mental Growth of Girls and Boys Age Six to Nineteen in Relation to Age at Maximum Growth, Monograph of the Society for Research in Child Development, 4:1-191, 1939.

87. Simmons, Katherine, The Brush Foundation Study of Child Growth and Development, II. Physical Growth and Development, Monographs of the Society for Research in Child Development, 9:49-54, 1944.

88. Singh, M., et al., The Strength and Physical Work Capacity of the Native Indian Children of Alberta, A Paper Presented at the XVLL Wcrld Congress of Sports Medicine, Mexico City, October, 1968.

89. Stolz, H.H., L.M. Stolz, Somatic Development of Adolescent Boys, New York: The Macmillan Company, pp. 137-138, 1951.

90. Stucliffe, A., J.W. Canhan, The Heights and Weights of Boys and Girls, London: John Murray, 1950.

91. Tanner, J.M., Education and Physical Growth, London: University of London Press, p. 36, 1961.

92. Tanner, J.M., Growth at Adolescence, Oxford: Blackwell Scientific Publications, p. 1, 1962.

93. Tihanyi, J., The Effects of an Accelerated Physical Education Programme on Certain Physical and Motor Traits of Children in Grades One, Three, and Four, Unpublished Master Thesis, University of British Columbia, 1966.

94. Todd, W.T., Atlas of Skeletal Maturation (Hand), St. Louis: C.V. Mosby Co., 1937.

95. Todd, W.T., The Roentgenographic Appraisement of Skeletal Differentiation, Child Development, 1:309, 1930.

96. Tomaras, W.A., The Relationship of Anthropometric and Strength Measures of Junior High School Boys to Various Arm Strength Criteria, Microcarded Doctoral Dissertation, University of Oregon, 1957.

97. Watt, N.S., Maturity, Structural, Strength, and Motor Convergence Growth Analysis of Boys Seven Through Seventeen Years of Age, Microcarded Doctoral Dissertation, University of Oregon, 1963.

98. Whittenberger, J.L., L.R. Gallagher, Maximum Breathing Capacity and Vital Capacity of Male Children and Adolescents, Pediatrics, 9:659-670, 1952.

99. Whittle, H.D., Effects of Elementary School Physical Education Upon Some Aspects of Physical, Motor, and Personality Development of Boys Twelve Years of Age, Microcarded Doctoral Dissertation, University of Oregon, 1956.

100. Wickens, J.S., Maturity, Structural, Muscular Strength, and Motor Ability Growth Curves of Boys Nine to Fifteen Years of Age, Microcarded Doctoral Dissertation, University of Oregon, p. 87, 1958.

101. Wiley, R.C., Single Year and Longitudinal Comparisons of Maturity, Physique, Structural, Strength, and Motor Characteristics of Twelve-Year-Old Elementary Athletes and Non-Participants, Microcarded Doctoral Dissertation, University of Oregon, 1963.

102. Zankel, H.T., A New Method of Measurement of Range of Motion of Joints, Archives of Physical Medicine, 32:227, 1951.

103. Zimmerli, E., Studies of Unusual Physical Fitness Indices, Research Quarterly, 6:244-249, 1935.

CHAPTER III

METHODS AND PROCEDURE

The purpose of this investigation was to examine the relationship between selected maturational determinants and competitive swimming performance. In an attempt to realize the purpose of this study the following research procedure was adopted.

Experimental Design

The review of the literature, presented in Chapter II, indicated that factors of body structure, maturational status, strength, and flexibility of children are prominently associated with athletic participation. Also, the investigator consulted a large number of coaches who believed that the chosen maturational parameters are the most important factors to be had for successful competitive swimming. The following fifteen independent variables were included in the above four factors:

1. Maturation: Chronological Age
   Skeletal Age
   Height
   Weight

2. Flexibility: Shoulder Flexion and Extension
   Trunk Flexion and Extension
   Ankle Flexion and Extension
   Composite Flexibility

3. Strength: Shoulder Extension
   Knee Extension
   Trunk Extension
   Ankle Plantar Flexion
   Composite Strength

4. Vital Capacity

5. Length of Training.

The fifteen independent variables were treated as matura-
tional determinants. The dependent variables were the four
competitive strokes and the individual medley:

1. Freestyle (100 and 200 meters) time.

2. Back Stroke (100 meters) time.

3. Breast Stroke (100 meters) time.

4. Butterfly (100 meters) time.

5. Individual Medley (200 meters) time.

Subjects

Thirty-six boys, from twelve competitive clubs who parti-
cipated at the 1970 Alberta Age Group Provincial Swimming
Championships at Edmonton, were the subjects. The subjects
were all experienced competitive swimmers with two to four
years of training background. Their approximate annual train-
ing exposure ranged from 235 to 564 hours. The subjects were
anticipated to be a highly select group as the entry regula-
tions to the championships were of high standard.

Letters requesting permission to test the swimmers were
sent to the Alberta Swimming Federation and to each participat-
ing club-coach. Samples of the letters are included in the
Appendix. There was no attempt made to differentiate the
subjects geographically, racially, or socio-economically. The
mean age of the subjects was 12.11 years (145.31 months); the
standard deviation was 0.61 of a year (7.30 months); and the

range was 11.00 to 13.00 years (133.00 to 156.00 months).
The selection of the subjects in terms of chronological age
for this study was based on the following assumption. It is
generally accepted that boys in the age range of 11-12 years
are just entering into the puberal period. Therefore it is
possible that the subjects within this age range may be more
sensitive to structural changes, resulting from puberal growth
spurt and athletic training, than other age groups may be.
If it is true then the individuality of the process of growth,
development and maturation may well differentiate the subjects
in terms of performance capacity.

General Procedures

All testing was carried out at the location of the
Championships, the Coronation Park Swimming Pool, Edmonton,
Alberta. The Championships were held on two consecutive half-
day periods which provided approximately seven hours of test-
ing. An attempt was made to test each subject prior to his
competitive event. Those who were tested after competition,
however, were given a substantial rest before commencement of
testing. The order of testing was the same for all subjects,
i.e., hand-wrist x-ray, strength, flexibility, vital capacity,
height and weight.

Each subject performed three trials on the performance
test items. The average score of the three trials was uti-
lized in the statistical computations. Henry (6) expressed
his preference to the use of average scores by stating that

average scores are more representative of individual ability than best scores. Kroll (8) confirmed Henry's contention and pointed out that when no trial-to-trial trend was present, the correct criterion measure was the mean of all available trials.

Preceding the testing procedure, each individual was thoroughly instructed and shown the mechanics of the particular test. Before the actual testing trial each individual was given a practice trial. After the practice trial and before the first test trial, and after each additional test trial, a rest interval of 30 seconds was given to each subject. When a test item may have been administered on either the right or the left side of the body, the left side was chosen for consistency. Uniformity in the testing conditions and procedures were ensured by keeping the same examiner at the same station throughout the testing period. No motivational devices or encouragements were used beyond the explanation and practice trial of each test item. All testing was administered by physical education graduate students. The testing team received extensive familiarization in all the test items. A sample of the personal record and test profile sheet is included in the Appendix.

Specific Procedures

(1) Maturation

Under this heading the study considered the parameters of Chronological Age, Skeletal Age, Height, and Weight. This

classification is consistent with the operational definition
of maturation stated in Chapter I.

    1. <u>Chronological Age</u>. In accordance with the Canadian
Amateur Swimming Association (1), any competitor whose eleventh
birth date was on or before, and whose thirteenth birth date
was not on or before the first day of the competition, is eli-
gible to swim in the 11-12 year age group. This of course
provides a wide dispersion in chronological age. Figure 1
illustrates the chronological age dispersion of the subjects.
The chronological age of the swimmers was not considered as
such for any specific grouping. The subjects were grouped
for the purpose of data analysis according to their attained
swimming times.

    2. <u>Skeletal Age</u>. Skeletal age was estimated by the
hand-wrist roentgenographic technic outlined by Greulich and
Pyle (5). Hand-wrist roentgenographs were taken by a regis-
tered x-ray technician from the University of Alberta Hospital
in Edmonton. The roentgenographs were interpreted by the
investigator. A test of reliability was carried out two
months after the first interpretation and it was found to be
0.942. To determine the objectivity, a random sample of
twelve roentgenographs was sent to the University of Saskat-
chewan Hospital at Saskatoon.[1] The objectivity was found to

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    [1] The objectivity roentgenographic interpretations were
made by Dr. C. Stuart Houston, Professor and Assistant Director
of the Department of Diagnostic Radiology and consultant to
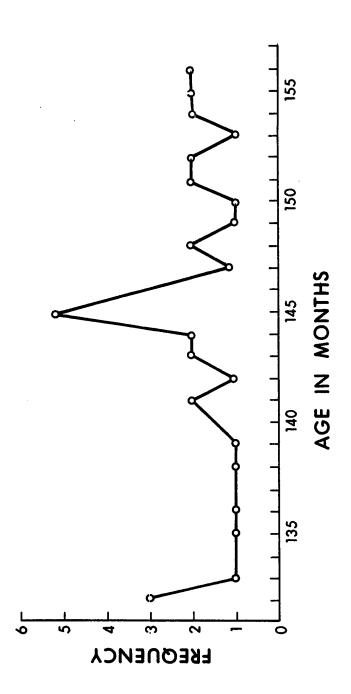the Saskatchewan Growth and Development Study.

FIGURE 1

Chronological Age Dispersion

be 0.920.

The specification of the roentgenogram, materials, and procedures were as follows:

1. Type of x-ray unit: General Electric Mobile "200", HRT-3 x-ray tube, 1.0mm focal spot

2. Film size and type: 8x10 Kodak blue brand (BB-14) screen film

3. Focal distance: 40 inches

4. Amperage (miliamperes): 50

5. Voltage: 44 KVP

6. Exposure time: 1/12 second

7. Developing process: Kodak M4-B automatic processor (4 minutes)

8. X-ray screens: Dupont Cronex par speed.

The subjects were seated with their left arm resting on a table, flexed to 90° angle at the elbow joint and the palm facing down. One roentgenograph was taken of each subject. Figure 2 illustrates the roentgenogram unit employed in the study.

3. Height. This is the measurement of erect body length. Care was taken to have the head held in such manner that the Frankfort line (line from the lower border of the right orbit to the upper margin of the external auditory meatus) was horizontal. Measurement was recorded to the nearest one-quarter of an inch. Figure 3 illustrates subject being tested for standing height.

4. Weight. The measuring instrument was a beam-type platform scale. Measurement was recorded to the nearest
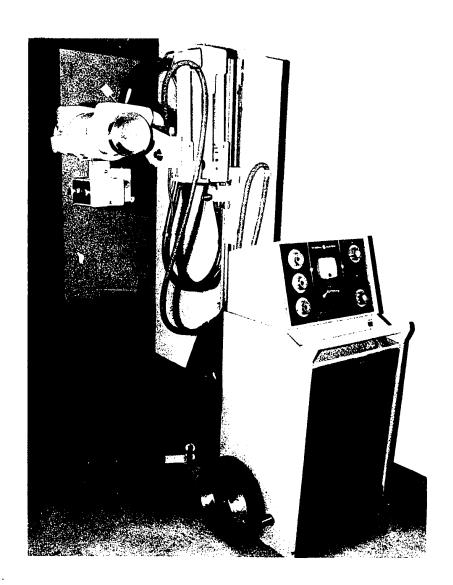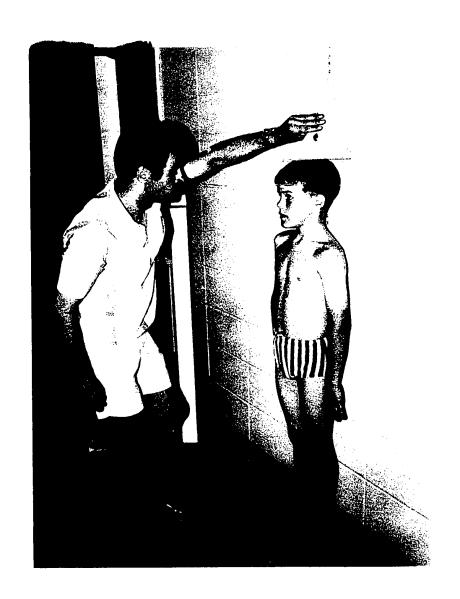
FIGURE 2

Roentgenogram Unit

FIGURE 3

Standing Height

one-half of one pound. Figure 4 illustrates subject being
tested for body weight. The accuracy of the platform scale
was confirmed by the measurement of recognized weight plates.

(2) Flexibility

Flexibility was measured in degrees and designated the
range of movement of a joint and of the associated body seg-
ments. More specifically, flexibility was indicated as the
measure of movement between two extreme positions (flexion
and extension). The measuring instrument was the Leighton
Flexometer (9) illustrated in Figure 5. The testing procedure
followed Leighton's outline, taking care that the instrument
was attached in such a manner that direct reading of the
number of degrees (which the movement accomplished) was poss-
ible. A composite score of the test items was recorded by
summing the average score for each individual test. The test
of flexibility included the following parameters.

1. Shoulder Flexibility. Figures 6 and 7 illustrate
subject being tested for shoulder flexion and extension res-
pectively. The reliability estimate was 0.959.

2. Trunk Flexibility. Figure 8 and 9 illustrate sub-
ject being tested for trunk extension and flexion, respectively.
Note that trunk extension and flexion is accompanied by hip
extension and flexion. Therefore, to obtain the values for
trunk flexibility alone, the values of hip extension and flex-
ion were subtracted from trunk extension and flexion. The
reliability estimate was 0.981. (The reliability estimate
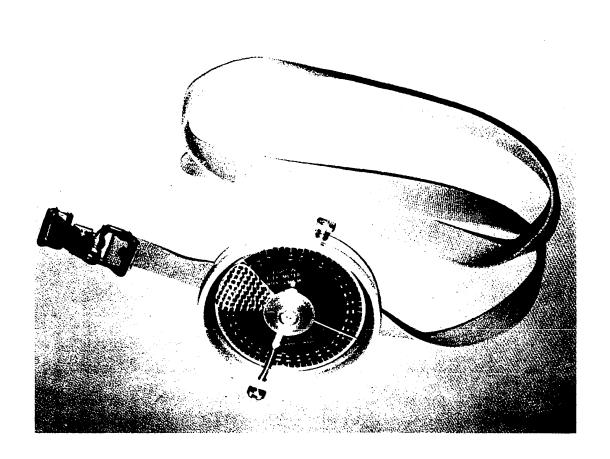
FIGURE 4

Body Weight

FIGURE 5

Leighton Flexometer

FIGURE 6

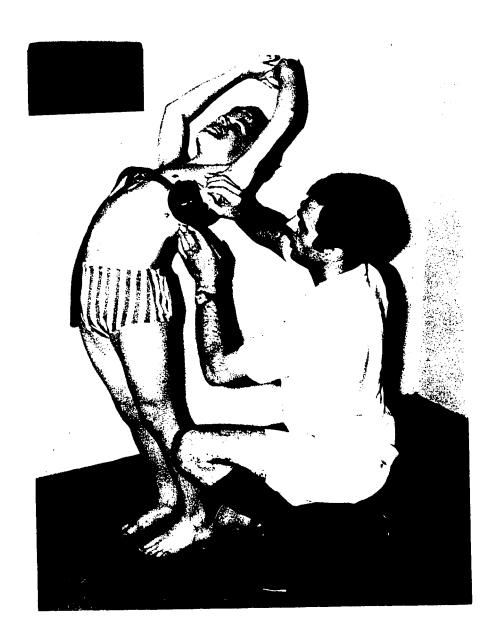Shoulder Flexion

FIGURE 7

Shoulder Extension

FIGURE 8

Trunk Extension

FIGURE 9

Trunk Flexion

for hip flexibility was 0.992.)

3. Ankle Flexibility. Figure 10 illustrates subject being tested for ankle flexion. (Ankle extension, which is not illustrated, is opposite to the movement depicted in Figure 10.) The reliability estimate was 0.971.

(3) Strength

Strength was measured in pounds and designated as the amount of force exerted against a strain-gauge apparatus. The apparatus consisted of four strain gauges (SR-4, 120 ohms, type A-3-S6, manufactured by the electronics division of Baldwin-Lima-Hamilton, Waltham, Mass.) and mounted on "U-shaped" tooled steel cantilever beams (7). The mounted strain gauges were arranged to form a Wheatstone bridge. Strain upon the tooled steel apparatus disarranged the balance of the Wheatstone bridge and the amount of strain (magnitude of the force against the testing apparatus) was traced on a Sargent Recorder (Model SR). The disturbed balance caused voltage changes which is then recorded in terms of the amount of resistance applied. The changes in the magnitude of the voltage always increase linearly with the changes in resistance. Similarly, the resistance changes experienced by the strain gauges will be linearly related to the amount of strain suffered by the metal beams. This means that for each pound of added weight the amount of voltage registered is linearly increasing on the recorder. The accuracy of the linear relationship was confirmed by recognized weight plates. The

FIGURE 10

Ankle Flexion

results were consistent with those obtained by Hetherington
(7). Figure 11 illustrates the apparatus used in strength
testing.

The testing procedure followed Clarke's outline (2) and
utilized Clarke's testing table. The pulling assemblies were
slightly modified from Clarke's methods with the intention
to prevent slipping and to provide more standardized strap
positions. It should be noted that the pulling assemblies
were at a right angle to the body segment. Individual measure-
ments were recorded to the nearest pound. A composite score
of the test items was recorded by summing the average score
for each individual test. The test of strength included the
following parameters.

1. Shoulder Extension. Figure 12 illustrates subject
being tested for shoulder extension strength. The strap
position was six inches from the olecranon process of the
ulna. The reliability estimate was 0.972.

2. Knee Extension. Figure 13 illustrates subject being
tested for knee extension strength. The strap position was
nine inches from the axilla of the knee joint, just below
the gastrocnemius muscle. The reliability estimate was 0.958.

3. Trunk Extension. Figure 14 illustrates subject
being tested for trunk extension strength. The strap position
was directly beyond the axilla of the arms. The reliability
estimate was 0.974.

4. Ankle Plantar Flexion (Ankle Extension). Figure 15
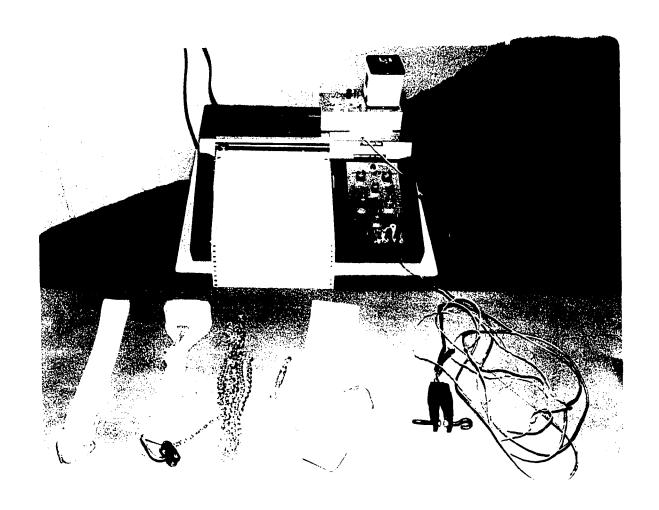illustrates subject being tested for ankle plantar flexion

FIGURE 11

Strength Testing Apparatus and Implements
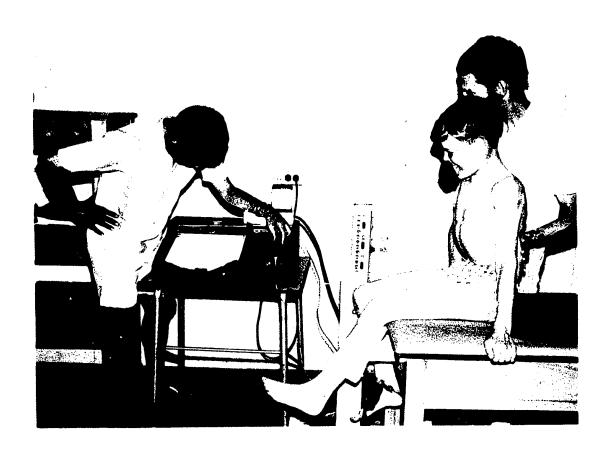
FIGURE 12

Shoulder Extension

FIGURE 13

Knee Extension

FIGURE 14

Trunk Extension

FIGURE 15

Ankle Plantar Flexion

strength. The strap position was four inches from the end of the great toe. Note that a piece of board was attached to the strap to eliminate cutting and squeezing of the strap. The reliability estimate was 0.903.

(4) Vital Capacity

Vital capacity was measured in cubic inches and designated as the amount of air expired after maximal inspiration. The measuring instrument was a standard Wet Spirometer of 400 cubic inch capacity. Figure 16 illustrates the Wet Spirometer and subject being tested for vital capacity. The reliability estimate was 0.974.

Statistical Procedures

Reliability estimates for the various performance tests were determined by single factor analysis with repeated measures from the three repeated trials. Unadjusted reliabilities were accepted as these numbers indicate best the reliability of how well the mean score represents the three trial scores. The calculation of reliability estimates was adopted from Winer (10). The reliability estimate for skeletal age was determined by a simple test-retest method based on the coefficient of correlation by the product-moment method (4). The objectivity estimate was calculated in similar fashion.

The dependency of competitive swimming ability on maturational determinants was evaluated by regression analysis

FIGURE 16

Vital Capacity

in stepwise order (3).[1] Ordinarily the procedure examines
the input data (independent and dependent variables) in such
a manner that the best possible combination of sets of obser-
vations are selected. This involved a stepwise re-examination
of the variables incorporated into the model at previous
stages. Any variable which provides a non-significant con-
tribution is removed from the model. This process continued
until all variables had been looked at and no more were ad-
mitted to or rejected from the model. The generalized equa-
tion of the model is:

$$\hat{Y} = B_0 + B_1 X_1 + B_2 X_2 + \ldots + B_n X_n$$

where $\hat{Y}$ = predicted Y

B_0 = constant term

B = regression weight

X = predictor variable.

The actual application or interpretation of the stepwise
regression procedure in the investigation was somewhat differ-
ent from the conventional use. In accordance with the state-
ment of the problem the investigation was to evaluate the
relative predictive values of the independent variables (ma-

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[1] All computations were carried out on IBM 360 computer.
The name of the programs were MULRO 6, ANOV 14 and ANOV 15
and were supplied by the Division of Educational Research
Services, University of Alberta, Edmonton, Alberta.

turational determinants) to each of the dependent variables
(swimming speed). Since the order of selection indicates the
predictor's (independent variable) predictive strength, based
on its partial correlation contribution, a definite level of
significance was deemed unnecessary. The elimination of
certain non-significant predictors may also eliminate rele-
vant information. All information should be included if they
collectively make better overall prediction of the criterion.
Inspite of the minor alteration in the stepwise regression
procedure it still follows the regular cycle and will always
pick the predictor with the highest partial correlation to
the criterion. However, the restriction for selection is
set at 1.00 to allow the selection of all predictors in a
hierarchial order of prediction. In the section on the
evaluation of the data the probability level of each predic-
tor was indicated at the time it was allowed into the predic-
tion model.

Generality percentages (r^2 x 100) were calculated from
the coefficients of correlation between the independent and
dependent variables.

Comparisons between high, middle and low success groups
within each criterion measure was tested with a standard one-
way analysis of variance model (10:46-104). The probability
level for significance, before the commencement of the investi-
gation, was set at the 0.05 level.

REFERENCES

1. Canadian Amateur Swimming Association, <u>Swimming Rules</u>, pp. 67-72, 1972.

2. Clarke, H.H., <u>A Manual - Cable-Tension Strength Tests</u>, Springfield: Springfield College Press, 1953.

3. Draper, N.R., H. Smith, <u>Applied Regression Analysis</u>, New York: John Wiley and Sons, Inc., pp. 171-195, 1967.

4. Garrett, H.E., R.S. Woodworth, <u>Statistics in Psychology and Education</u>, New York: David McKay Co., pp. 139-142, 1958.

5. Greulich, W.W., S.I. Pyle, <u>Radiographic Atlas of Skeletal Development of the Hand and Wrist</u>, Stanford: Stanford University Press, 1959.

6. Henry, F.M., 'Best Versus Average' Individual Scores, <u>Research Quarterly</u>, 38:317-320, 1967.

7. Hetherington, M.R., Trainability and Generality/Specificity Ratios of the Ability of Grade Five Boys to Develop Torque, Doctoral Dissertation, The University of Alberta, pp. 60-65, 1971.

8. Kroll, W., Reliability Theory and Research Decision in Selection of a Criterion Score, <u>Research Quarterly</u>, 38:412-419, 1967.

9. Leighton, J.R., An Instrument and Technic for the Measurement of Range of Joint Motion, <u>Archives of Physical Medicine and Rehabilitation</u>, 36:571-578, 1955.

10. Winer, B.J., <u>Statistical Principles in Experimental Design</u>, Toronto: McGraw-Hill Book Company, Inc., pp. 105-132, 1962.

CHAPTER IV

RESULTS

The general purpose of this investigation was to evalu-
ate the relationship between swimming speed and selected
maturational determinants. In order to investigate the
stated purpose fifteen independent variables were weighed
against six dependent variables. The premise that competi-
tive swimming success depends, to some extent, on maturational
determinants was evaluated by the stepwise regression analysis
procedure. This statistical method arranged the independent
variables in an order which provided the best combination of
predictors in terms of success for each dependent variable.
No level of significance was established for the independent
variables. This procedure permitted the inclusion of all
maturational determinants into the regression equation model
based on their relative predictor strength.

The stepwise regression procedure has the ability to
indicate the best prediction Y from a number of predictors X.
This procedure, however, cannot indicate with confidence which
predictor is more important over another as the one chosen at
step number one, for example, may become unimportant at step
number four. Therefore, to find a hierarchical order of
predictors in terms of importance the generality and specifi-
city of the predictors were calculated. It is possible, how-
ever, that the selection order into the regression model and

the generality-specificity order coincide as no limiting con-
fidence levels were declared. The predictors with the highest
generality percentage were declared the most important.

To test the relative significance of the maturational
determinants the subjects were separated into three groups
(high, middle, low) in terms of their swimming speed. Com-
parisons between the groups were made by one-way analysis of
variance (21). The source of the significance of the differ-
ences were determined by the Newman-Keuls (15) posteriori test
and the differences at 0.5 level were declared as significant.

Stepwise Regression Analysis

The analysis of the results in the stepwise regression
procedure was not restricted to a specific level of signifi-
cance, therefore the variables were admitted in the prediction
equation as they appeared in their respective order of pre-
dictive ability. The order of variables was chosen on the
strength of their partial correlation coefficients with res-
pect to the criterion. This procedure of course presents a
difficult case in selecting the best regression equation. The
elimination of a particular level of significance as a select-
ing criterion into the regression equation warranted some
personal judgment based on certain available statistical
values. This methodology may cast doubt on the usefulness
of the derived prediction equation. Draper and Smith (9),
however, stated that "To make the equation useful for predic-
tive purposes we should want our model to include as many X's

as possible...."

In essence regression analysis examines how changes in the independent variables affect the values of the dependent variables. This relationship may not be linear over the range of variables X_1, X_2, ..., X_k with respect to response Y. However, when the range of the X's is limited an adequate representation of the function X_k with respect to response Y may be observed within the chosen range. For predictive purposes, of course, only the values of X's within the restricted range would be useful. The restricted range was based on the squared multiple correlation, (R^2). The definition of R^2 is:

R^2 = (SS due to regression)/(total SS, corrected for mean) (9:26). This means that R^2 is the "proportion of total variation about the mean $\overline{Y}$ explained by the regression." It follows then, the larger the R^2, is the better the prediction equation explains the variation in the data. The addition of new variables to the prediction equation will always increase R^2, but will not necessarily improve the precision of the estimate of the response. When R^2 showed a levelling trend no more variables were added. The precision of the regression equation was also determined by the size of the standard error of the predicted Y. This statistic stands at minimum when $X_k = \overline{X}$. The response X_k shows an increase when moved away from $\overline{X}$ in either direction. This implies that the smaller the error term the more precise will be the prediction. Generally the levelling trend of R^2 and the inverse trend of the error term statistic coincided well enough to employ both in determining

the size of the regression equation.

In the following the dependent variables are listed with the predictors in the order they were admitted into the regression equation.

(1) <u>100 Meter Freestyle</u>

Table 2 illustrates the results of the stepwise regression procedure for the 100 meter freestyle. The suggested prediction equation for this criterion is

$$\hat{Y} = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9)$$

$$\hat{Y} = 137.385 + (-0.054)X_1 + (-0.017)X_2 + (-0.072)X_3 +$$

$$0.054X_4 + (-0.014)X_5 + (-0.063)X_6 + (-0.731)X_8 + 0.130X_9.$$

(2) <u>200 Meter Freestyle</u>

Table 3 illustrates the results of the stepwise regression procedure for the 200 meter freestyle. The suggested prediction equation for this criterion is

$$\hat{Y} = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9)$$

$$\hat{Y} = 230.087 + (-0.069)X_1 + (-10.806)X_2 + 0.247X_3 +$$

$$0.394X_4 + (-10.861)X_5 + (-10.834)X_6 + 10.667X_7 +$$

$$(-0.106)X_8 + (-10.579)X_9.$$

TABLE 2

THE ORDER OF PREDICTORS AND GENERALITY PERCENTAGES IN 100 METER FREESTYLE
N=23

Predictor	Partial r	Probability Level of Entry	Regression Weight	Standard Error of Predicted Y	Squared Multiple Correlation	Percent Generality
Shoulder Extension	-0.525	0.010	-0.054	2.77	27.53	27.55
Training	-0.345	0.059	-0.017	2.59	39.66	7.75
Knee Extension	-0.226	0.176	-0.072	2.53	45.33	12.33
Ankle Extension	-0.228	0.109	0.054	2.42	52.83	0.02
Composite Flexibility	0.109	0.246	-0.014	2.39	56.52	7.40
Trunk Extension	-0.159	0.244	-0.063	2.36	60.16	24.57
Weight	-0.162	0.135	0.204	2.25	65.83	1.20
Height	-0.133	0.118	-0.731	2.13	71.48	11.20
Chronological Age	-0.134	0.179	0.130	2.06	75.32	2.66
Trunk Flexibility	0.045	0.671		2.12	75.70	1.16
Ankle Flexibility	-0.049	0.694		2.20	76.06	3.11
Shoulder Flexibility	0.007	0.626		2.28	76.65	7.06
Vital Capacity	-0.004	0.958		2.40	76.65	9.73
Skeletal Age	-0.003	0.967		2.55	76.66	8.70
Composite Strength	-0.001	1.000		2.73	76.66	16.27

TABLE 3

THE ORDER OF PREDICTORS AND GENERALITY PERCENTAGES IN 200 METER FREESTYLE
N=19

Predictor	Partial r	Probability Level of Entry	Regression Weight	Standard Error of Predicted Y	Squared Multiple Correlation	Percent Generality
Training	-0.515	0.024	- 0.069	6.93	26.37	26.50
Shoulder Extension	-0.506	0.008	-10.806	5.91	52.99	16.29
Chronological Age	-0.287	0.091	0.247	5.31	61.39	9.79
Weight	0.218	0.180	0.394	5.17	66.20	5.90
Knee Extension	-0.171	0.070	-10.861	4.71	74.01	0.50
Trunk Extension	-0.146	0.122	-10.834	4.42	78.88	4.91
Composite Strength	0.093	0.066	10.667	3.93	84.68	1.89
Trunk Flexibility	-0.175	0.069	- 0.106	3.47	89.16	4.67
Ankle Extension	0.001	0.064	-10.579	2.99	92.74	3.87
Height	-0.055	0.146		2.76	94.51	0.14
Shoulder Flexibility	-0.055	0.214		2.61	95.67	8.27
Composite Flexibility	0.009	0.286		2.55	96.48	12.79
Ankle Flexibility	-0.046	0.120		2.14	97.93	1.91
Vital Capacity	0.038	0.053		1.42	99.27	0.06
Skeletal Age	-0.004	0.856		1.63	99.28	0.37

(3) 100 Meter Back Stroke

Table 4 illustrates the results of the stepwise regression procedure for the 100 meter back stroke. The suggested prediction equation for this criterion is

$$\hat{Y} = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7)$$

$$\hat{Y} = 165.996 + (-0.121)X_1 + 0.052X_2 + 0.125X_3 + (-0.474)X_4 +$$

$$(-0.158)X_5 + (-0.071)X_6 + 0.035X_7.$$

(4) 100 Meter Breast Stroke

Table 5 illustrates the results of the stepwise regression procedure for the 100 meter breast stroke. The suggested prediction equation for this criterion is

$$\hat{Y} = f(X_1, X_2, X_3, X_4, X_5, X_6)$$

$$\hat{Y} = 93.177 + (-0.219)X_1 + (-0.011)X_2 + 0.281X_3 +$$

$$(-0.116)X_4 + 0.250X_5 + 0.054X_6.$$

(5) 100 Meter Butterfly Stroke

Table 6 illustrates the results of the stepwise regression procedure for the 100 meter butterfly. The prediction equation for this criterion is

$$\hat{Y} = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8)$$

TABLE 4

THE ORDER OF PREDICTORS AND GENERALITY PERCENTAGES IN 100 METER BACK STROKE
N=19

Predictor	Partial r	Probability Level of Entry	Regression Weight	Standard Error of Predicted Y	Squared Multiple Correlation	Percent Generality
Trunk Extension	-0.446	0.055	-0.121	3.94	19.91	19.91
Ankle Extension	0.455	0.023	0.052	3.44	42.70	10.14
Weight	0.257	0.146	0.125	3.30	50.46	4.71
Height	-0.165	0.107	-0.474	3.11	59.10	1.64
Chronological Age	-0.149	0.378	-0.158	3.13	61.56	0.68
Ankle Flexibility	-0.156	0.315	-0.071	3.12	64.78	8.33
Trunk Flexibility	0.114	0.455	0.035	3.17	66.60	4.70
Training	0.099	0.524		3.25	67.99	3.49
Vital Capacity	0.053	0.620		3.38	68.91	0.47
Composite Strength	-0.045	0.524		3.49	70.54	1.47
Shoulder Flexibility	-0.082	0.446		3.57	73.05	13.26
Composite Flexibility	-0.006	0.522		3.71	74.98	15.78
Skeletal Age	0.057	0.644		3.97	76.13	0.89
Shoulder Extension	0.014	0.900		4.43	76.24	10.14
Knee Extension	-0.002	1.000				1.48

TABLE 5

THE ORDER OF PREDICTORS AND GENERALITY PERCENTAGES IN 100 METER BREAST STROKE
N=17

Predictor	Partial r	Probability Level of Entry	Regression Weight	Standard Error of Predicted Y	Squared Multiple Correlation	Percent Generality
Knee Extension	-0.498	0.042	-0.219	4.19	24.79	24.80
Trunk Flexibility	0.324	0.152	-0.111	4.02	35.33	8.88
Weight	0.121	0.376	0.281	4.03	39.25	4.27
Trunk Extension	-0.274	0.143	-0.116	3.84	49.57	12.92
Chronological Age	0.154	0.269	0.250	3.78	55.10	4.42
Vital Capacity	0.071	0.490	0.054	3.87	57.30	4.98
Shoulder Extension	-0.051	0.711		4.04	57.98	16.05
Composite Flexibility	-0.070	0.591		4.21	59.56	0.61
Training	-0.124	0.128		3.77	71.62	17.99
Skeletal Age	0.088	0.461		3.88	74.28	3.78
Ankle Extension	0.076	0.059		2.88	88.19	8.54
Ankle Flexibility	-0.036	0.633		3.11	88.93	16.30
Composite Strength	0.008	0.721		3.51	89.47	21.51
Height	0.018	0.398		3.43	93.28	2.58
Shoulder Flexibility	-0.000	0.970		4.85	93.29	0.57

TABLE 6

THE ORDER OF PREDICTORS AND GENERALITY PERCENTAGES IN 100 METER BUTTERFLY STROKE
N=19

Predictor	Partial r	Probability Level of Entry	Regression Weight	Standard Error of Predicted Y	Squared Multiple Correlation	Percent Generality
Shoulder Extension	0.418	0.074	-0.047	4.23	17.50	17.51
Ankle Flexibility	0.330	0.129	-0.195	4.05	28.88	17.31
Trunk Extension	0.370	0.047	-0.100	3.65	45.79	10.85
Vital Capacity	0.156	0.344	0.089	3.65	49.26	1.78
Knee Extension	-0.147	0.264	-0.093	3.61	54.08	8.06
Training	-0.153	0.355	-0.019	3.62	57.36	5.31
Weight	0.109	0.409	0.125	3.66	60.04	0.16
Trunk Flexibility	-0.155	0.381	-0.052	3.69	63.14	0.05
Skeletal Age	-0.084	0.489		3.78	65.14	1.32
Shoulder Flexibility	-0.142	0.421		3.84	68.02	0.05
Composite Strength	0.071	0.080		3.25	79.95	14.42
Composite Flexibility	0.006	0.604		3.42	80.90	0.08
Height	-0.048	0.263		3.27	85.51	3.39
Chronological Age	-0.001	0.980		3.65	85.51	4.78
Ankle Extension	-0.002	1.000		4.22	85.51	0.76

$$\hat{Y} = 142.635 + (-0.047)X_1 + (-0.195)X_2 + (-0.100)X_3 +$$

$$0.093X_4 + (-0.093)X_5 + (-0.019)X_6 + 0.125X_7 + (-0.052)X_8.$$

(6) <u>200 Meter Individual Medley</u>

Table 7 illustrates the results of the stepwise regression procedure for the 200 meter individual medley. The suggested prediction equation for this criterion is

$$\hat{Y} = f(X_1, X_2, X_3, X_4, X_5)$$

$$\hat{Y} = 434.839 + (-0.140)X_1 + (-0.483)X_2 + (-1.285)X_3 +$$

$$0.535X_4 + 0.668X_5.$$

Generality-Specificity Analysis

In an effort to evaluate the common variance between two variables an estimate is usually made of the degree of the underlying generality. The most frequent method of estimating such generality is by the statistic derived from the squared correlation (r^2) between two variables. Recently Hetherington and Maguire (13) questioned the validity of the purported relationship of r^2 in the measure of generality. They suggest that at best r^2 provides only an ordinal indication of the percentage of common underlying processes.

The generality-specificity calculations in this investigation were not intended to specifically appraise and evaluate the underlying generality of the variables. The exclusive

TABLE 7

THE ORDER OF PREDICTORS AND GENERALITY PERCENTAGES IN 200 METER INDIVIDUAL MEDLEY
N=17

Predictor	Partial r	Probability Level of Entry	Regression Weight	Standard Error of Predicted Y	Squared Multiple Correlation	Percent Generality
Training	-0.384	0.128	-0.140	22.85	14.76	14.77
Shoulder Extension	-0.444	0.050	-0.483	20.51	35.86	11.95
Skeletal Age	-0.349	0.100	-1.285	19.11	48.28	7.41
Weight	0.223	0.200	0.535	18.53	55.16	0.48
Ankle Flexibility	0.199	0.275	0.668	18.28	59.96	0.17
Trunk Extension	0.102	0.402		18.48	62.81	0.64
Composite Flexibility	-0.150	0.400		18.69	65.77	4.96
Ankle Extension	0.133	0.099		16.54	76.16	1.83
Height	-0.030	0.149		15.08	82.67	1.10
Trunk Flexibility	0.137	0.279		14.65	85.97	0.01
Shoulder Flexibility	0.017	0.072		11.26	93.10	5.76
Chronological Age	0.045	0.637		12.19	93.52	4.73
Knee Extension	0.033	0.497		12.86	94.59	0.02
Vital Capacity	0.015	0.670		14.87	95.18	0.12
Composite Strength	0.000	1.000		21.03	95.18	0.73

purpose of this procedure was to list the independent variables under each dependent variable in a hierarchical order of importance based on generality percentages. This procedure appears to be legitimate as the degree of generality and specificity is purportedly based on the relationship of one set of scores with another.

Tables 2 through 7 illustrate the per cent generality of the fifteen independent variables for each dependent variable. General overview of the results indicate some consistency between the order of selection of the predictors in the stepwise regression procedure and the degree of generality of the predictors.

High, Middle and Low Group Comparative Analysis

The purpose of this procedure was to examine the association between swimming speed and the maturational determinants among the three groups. Differences in terms of maturational determinants between groups were declared significant at the 0.5 level. This was accomplished by employing a single factor analysis of variance. In an effort to determine the nature of the differences between group the Newman-Keuls Test (15) was applied.

Table 8 illustrates comparisons of the means for the maturational determinants in 100 meter freestyle stroke.

TABLE 8

MEANS AND STANDARD DEVIATIONS FOR HIGH, MIDDLE AND LOW GROUPS IN 100 METER FREESTYLE

Maturational Determinants	High			Middle			Low		
	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD
Chronological Age	6	148.33	5.57	11	145.82	5.96	6	143.17	9.85
Skeletal Age	6	150.87	13.95	11	150.24	15.35	6	141.58	9.58
Height	6	59.96	2.11	11	59.64	3.42	6	58.92	3.09
Weight	6	95.38	11.64	11	97.00	10.90	6	93.63	24.31
Vital Capacity	6	190.44	19.43	11	183.94	25.77	6	178.72	25.61
Training	6	437.67	102.06	11	422.18	91.05	6	393.75	93.79
Trunk Extension	6	69.72	26.27	11	47.24	20.73	6	50.55	25.12
Knee Extension	6	123.22	20.08	11	112.63	27.43	6	90.55	25.47
Shoulder Extension*	6	82.22	40.59	11	53.00	11.25	6	44.61	11.08
Ankle Extension	6	151.44	50.10	11	147.18	32.96	6	142.00	26.56
Composite Strength	6	426.60	80.38	11	360.05	72.59	6	327.71	79.31
Shoulder Flexibility	6	209.77	15.40	11	208.57	17.55	6	213.44	14.00
Trunk Flexibility	6	73.39	24.96	11	70.70	20.97	6	74.94	15.05
Ankle Flexibility	6	95.44	4.87	11	88.39	8.67	6	90.72	10.30
Composite Flexibility	6	378.60	23.38	11	367.66	27.29	6	379.11	33.84

* Significant differences indicated.

Shoulder extension strength provided significant differences between the groups.

Table 9 illustrates the results of the Newman-Keuls test of significance. Differences were significant between the high versus middle (W_2) and high versus low groups (W_3).

TABLE 9

NEWMAN-KEULS TEST RESULTS FOR SHOULDER EXTENSION
STRENGTH IN 100 METER FREESTYLE

N	Means	High 82.22	Middle 52.99	Low 44.61
6	44.61	37.61*	8.39	0.00
11	52.99	29.22*	0.00	
6	82.22	0.00		

* Difference significant at the 0.05 level.

$q_2 = 2.95$ $q_3 = 3.58$

$$W_r = q_r \sqrt{\frac{MSerror}{\tilde{n}}} \quad \text{where } \tilde{n} = \frac{k}{(1/n_1) + (1/n_2) + \ldots + (1/n_k)}$$

$$W_2 = 2.95 \sqrt{\frac{505.82}{7.07180}} = 2.95 \times 8.457 = 24.950$$

$$W_3 = 3.58 \times 8.457 = 30.278.$$

Mean differences in general favoured the high group, however, only in two instances were they appreciably approaching statistical significance. For knee extension strength the mean

difference between high and low groups was 32.67, however, the W_3 obtained from the studentized range statistic was 34.03. The same prevailed for composite strength between high and low groups where the actual mean difference was 98.89 and the obtained W_3 was 102.72.

Table 10 illustrates the comparisons of the means in the 200 meter freestyle stroke. There were no statistically significant differences among the groups.

Table 11 llustrates the comparisons of the means in the 100 meter back stroke. There were no statistically significant differences among the three groups. For trunk flexibility mean differences between middle and low groups favouring the low group approached significance. The obtained W_3 was 25.25 and the actual mean difference was 24.23.

Table 12 illustrates the comparison of the means in the 100 meter breast stroke. Knee extension strength provided significant differences between the groups.

Table 13 illustrates the results of the Newman-Keuls test of significance. The differences were significant between the high versus middle (W_2) and high versus low (W_3) groups.

For composite strength the differences between high and low groups approached statistical significance. The actual mean difference between the groups was 84.75 and the obtained W_2 was 87.11. The same prevailed for ankle flexibility between the high and middle groups where the actual mean difference was 14.52 and the obtained W_3 was 15.94.

TABLE 10

MEANS AND STANDARD DEVIATIONS FOR HIGH, MIDDLE AND LOW GROUPS IN 200 METER FREESTYLE

Maturational Determinants	High			Middle			Low		
	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD
Chronological Age	6	146.33	4.80	7	146.43	6.48	6	140.33	7.61
Skeletal Age	6	148.44	12.97	7	151.52	9.98	6	147.47	11.42
Height	6	58.83	2.68	7	60.32	1.96	6	58.46	2.99
Weight	6	91.21	15.36	7	99.64	9.30	6	96.21	20.86
Vital Capacity	6	181.41	20.26	7	194.66	20.51	6	177.88	29.75
Training	6	444.33	115.00	7	471.29	87.83	6	358.25	94.21
Trunk Extension	6	63.50	28.73	7	67.33	18.77	6	44.33	22.88
Knee Extension	6	116.72	20.91	7	114.85	30.28	6	103.33	22.96
Shoulder Extension	6	78.00	43.13	7	54.81	9.10	6	48.44	12.21
Ankle Extension	6	138.89	49.46	7	162.57	22.51	6	138.05	36.27
Composite Strength	6	397.15	97.96	7	399.51	61.70	6	334.15	73.26
Shoulder Flexibility	6	212.72	5.99	7	210.28	18.07	6	200.50	16.98
Trunk Flexibility	6	73.22	24.43	7	66.05	12.60	6	71.84	17.56
Ankle Flexibility	6	95.00	4.59	7	91.48	10.49	6	92.44	9.12
Composite Flexibility	6	380.94	22.61	7	366.38	16.21	6	364.77	25.15

TABLE 11

MEANS AND STANDARD DEVIATIONS FOR HIGH, MIDDLE AND LOW GROUPS IN 100 METER BACK STROKE

Maturational Determinants	High			Middle			Low		
	N	X̄	SD	N	X̄	SD	N	X̄	SD
Chronological Age	6	144.67	5.75	7	145.43	7.19	6	146.17	7.52
Skeletal Age	6	149.86	13.41	7	156.08	7.94	6	152.88	9.96
Height	6	59.42	2.44	7	59.79	2.16	6	59.88	2.75
Weight	6	93.96	12.95	7	100.00	15.84	6	108.00	16.73
Vital Capacity	6	177.55	23.14	7	186.38	13.28	6	197.16	35.15
Training	6	427.33	109.71	7	385.00	136.26	6	388.75	104.30
Trunk Extension	6	66.39	25.68	7	56.14	24.38	6	49.22	19.49
Knee Extension	6	113.16	25.22	7	110.14	23.91	6	109.66	33.72
Shoulder Extension	6	76.50	44.49	7	55.80	11.30	6	54.33	9.26
Ankle Extension	6	140.00	49.16	7	157.28	33.19	6	162.22	28.80
Composite Strength	6	396.10	99.14	7	379.37	60.54	6	375.35	82.81
Shoulder Flexibility	6	211.38	7.14	7	206.62	21.95	6	203.22	12.32
Trunk Flexibility	6	71.39	25.65	7	64.00	8.70	6	88.22	15.97
Ankle Flexibility	6	93.16	5.30	7	92.67	7.56	6	85.66	14.94
Composite Flexibility	6	375.94	27.43	7	363.28	19.29	6	377.11	20.73

TABLE 12

MEANS AND STANDARD DEVIATIONS FOR HIGH, MIDDLE AND LOW GROUPS IN 100 METER BREAST STROKE

Maturational Determinants	High			Middle			Low		
	N	X̄	SD	N	X̄	SD	N	X̄	SD
Chronological Age	6	146.33	5.28	5	145.60	4.34	6	141.41	10.73
Skeletal Age	6	154.37	12.09	5	138.64	18.79	6	141.37	13.10
Height	6	60.38	3.02	5	57.55	2.18	6	58.50	2.46
Weight	6	98.17	9.86	5	88.25	11.62	6	87.67	18.23
Vital Capacity	6	191.83	15.04	5	161.46	11.19	6	180.22	37.82
Training	6	455.17	106.56	5	403.50	118.20	6	348.50	80.35
Trunk Extension	6	50.22	24.83	5	49.40	17.12	6	37.22	20.79
Knee Extension*	6	130.27	16.54	5	86.26	10.00	6	91.27	37.38
Shoulder Extension	6	61.55	11.32	5	56.86	20.20	6	45.16	14.18
Ankle Extension	6	155.38	38.53	5	124.66	39.44	6	139.11	33.63
Composite Strength	6	397.43	67.98	5	311.25	8.90	6	312.68	95.12
Shoulder Flexibility	6	210.55	23.79	5	216.26	5.71	6	202.44	18.40
Trunk Flexibility	6	63.83	15.74	5	76.73	28.61	6	80.28	19.23
Ankle Flexibility	6	95.39	7.08	5	80.86	14.36	6	84.88	9.87
Composite Flexibility	6	369.77	23.00	5	373.85	31.45	6	359.27	40.97

* Significant difference indicated.

TABLE 13

NEWMAN-KEULS TEST RESULTS FOR KNEE EXTENSION
STRENGTH IN 100 METER BREAST STROKE

N	Means	High 130.27	Middle 91.27	Low 86.26
6	86.26	44.01*	5.01	0.00
5	91.27	39.00*	0.00	
6	130.27	0.00		

* Differences significant at the 0.05 level.

$q_2 = 2.95$ $\qquad q_3 = 3.58$

$$W_r = q_r \sqrt{\frac{MSerror}{\tilde{n}}} \quad \text{where} \quad \tilde{n} = \frac{k}{(1/n_1) + (1/n_2) + \ldots + (1/n_k)}$$

$$W_2 = 2.95 \sqrt{\frac{625.26}{5.62514}} = 2.95 \times 10.543 = 31.102$$

$$W_3 = 3.58 \times 10.543 = 37.744.$$

Table 14 illustrates the comparisons of the means in the
100 meter butterfly stroke. Statistically significant differ-
ences were found between the groups in shoulder flexibility
and composite flexibility.

Table 15 illustrates the results of the Newman-Keuls
test of significance for shoulder flexibility. Differences
were significant between the high versus low (W_3) group. Be-
tween high versus middle (W_2) group the differences approached
significance. The actual mean difference was 15.35 and the

TABLE 14

MEANS AND STANDARD DEVIATIONS FOR HIGH, MIDDLE AND LOW GROUPS IN 100 METER BUTTERFLY STROKE

Maturational Determinants	High			Middle			Low		
	N	X̄	SD	N	X̄	SD	N	X̄	SD
Chronological Age	6	146.50	4.18	7	146.86	6.18	6	142.33	8.76
Skeletal Age	6	151.00	14.07	7	152.26	10.49	6	148.82	6.47
Height	6	59.75	1.99	7	59.36	2.69	6	58.63	2.85
Weight	6	97.38	12.07	7	91.43	11.89	6	97.79	12.70
Vital Capacity	6	189.39	18.39	7	172.62	20.67	6	182.94	24.93
Training	6	461.17	113.59	7	439.57	76.52	6	381.92	93.24
Trunk Extension	6	74.55	22.12	7	49.66	13.31	6	53.11	28.81
Knee Extension	6	121.22	19.21	7	113.14	31.10	6	105.61	22.99
Shoulder Extension	6	81.27	41.46	7	52.38	12.07	6	50.99	10.65
Ankle Extension	6	151.61	50.18	7	148.42	29.19	6	146.22	35.09
Composite Strength	6	428.71	79.70	7	363.57	77.73	6	355.93	64.07
Shoulder Flexibility*	6	219.83	10.44	7	204.47	12.09	6	200.55	16.74
Trunk Flexibility	6	67.66	25.15	7	69.09	13.80	6	68.17	15.52
Ankle Flexibility	6	95.94	5.54	7	92.09	7.10	6	87.78	9.23
Composite Flexibility*	6	383.44	23.33	7	364.23	11.80	6	356.50	18.39

* Significant differences indicated.

obtained W_2 was 15.61

TABLE 15

NEWMAN-KEULS TEST RESULTS FOR SHOULDER FLEXIBILITY IN 100 METER BUTTERFLY STROKE

N	Means	High 219.83	Middle 204.47	Low 200.55
6	200.55	19.28*	3.92	0.00
7	204.47	15.36	0.00	
6	219.83	0.00		

* Differences significant at the 0.05 level.

$q_2 = 2.95$ $\qquad$ $q_3 = 3.58$

$$W_r = q_r \sqrt{\frac{MSerror}{\tilde{n}}} \quad \text{where } \tilde{n} = \frac{k}{(1/n_1) + (1/n_2) + \cdots + (1/n_k)}$$

$$W_2 = 2.95\sqrt{\frac{176.50}{6.30027}} = 2.95 \times 5.293 = 15.61$$

$$W_3 = 3.58 \times 5.293 = 18.94.$$

Table 16 illustrates the Newman-Keuls test of significance for composite flexibility. The differences were significant between the high versus low (W_3) group. Between middle versus low (W_2) group the differences approached significance. The actual mean difference was 19.20 and the obtained W_2 was 21.27.

TABLE 16

NEWMAN-KEULS TEST RESULTS FOR COMPOSITE
FLEXIBILITY IN 100 METER BUTTERFLY STROKE

N	Means	High 383.43	Middle 364.23	Low 356.50
6	356.50	26.93*	7.73	0.00
7	364.23	19.20	0.00	
6	383.43	0.00		

* Differences significant at the 0.05 level.

$q_2 = 2.95$ $q_3 = 3.58$

$$W_r = q_r \sqrt{\frac{MSerror}{\tilde{n}}} \quad \text{where } \tilde{n} = \frac{k}{(1/n_1) + (1/n_2) + \ldots + (1/n_k)}$$

$$W_2 = 2.95 \sqrt{\frac{327.81}{6.30027}} = 2.95 \times 7.213 = 21.78$$

$$W_3 = 3.58 \times 7.213 = 25.82.$$

Two other parameters in the 100 meter butterfly stroke which exhibited an appreciable closeness to significance warrants recognition. For ankle flexibility the actual mean difference between high and low groups was 8.16 and the obtained W_3 was 10.58. For shoulder extension strength the actual mean differences between high and middle groups was 28.89 and the obtained W_2 was 29.43.

Table 17 illustrates the comparisons of the means in the 200 meter individual medley. There were no statistically signi-

TABLE 17

MEANS AND STANDARD DEVIATIONS FOR HIGH, MIDDLE AND LOW GROUPS IN 200 METER INDIVIDUAL MEDLEY

Maturational Determinants	High			Middle			Low		
	N	X̄	SD	N	X̄	SD	N	X̄	SD
Chronological Age	6	147.00	4.15	5	144.60	7.16	6	142.67	9.42
Skeletal Age	6	152.00	13.53	5	150.48	10.68	6	146.65	11.14
Height	6	59.58	2.24	5	59.00	1.70	6	60.13	3.38
Weight	6	95.29	15.04	5	90.70	3.49	6	102.46	21.17
Vital Capacity	6	187.89	19.23	5	181.93	22.20	6	193.44	29.65
Training	6	483.00	108.50	5	417.20	95.35	6	408.92	85.32
Trunk Extension	6	66.94	27.82	5	44.86	23.13	6	67.72	21.62
Knee Extension	6	119.11	20.67	5	103.26	26.68	6	112.50	32.49
Shoulder Extension	6	77.50	43.53	5	54.33	12.87	6	50.94	11.41
Ankle Extension	6	145.72	51.02	5	132.46	35.08	6	158.55	25.54
Composite Strength	6	409.32	93.78	5	334.85	72.04	6	389.71	80.48
Shoulder Flexibility	6	218.72	11.02	5	194.53	20.78	6	209.94	4.25
Trunk Flexibility	6	68.05	25.05	5	69.93	13.51	6	65.72	12.43
Ankle Flexibility	6	96.61	5.50	5	93.20	8.76	6	89.93	10.87
Composite Flexibility	6	383.38	23.36	5	357.66	15.45	6	363.83	20.65

ficant differences among the three groups. For shoulder
flexibility, however, the mean differences between middle and
low groups approached significance. The actual mean differ-
ence was 15.41 and the obtained W_2 was 16.36.

Analysis and Discussion of the Results

The data was analyzed by three different statistical
procedures (p. 76). In the following the results of each pro-
cedure are elaborated in terms of the stated purposes of the
investigation.

The first purpose was to investigate the relative impor-
tance or predictive strength of certain maturational determin-
ants for competitive swimming. For each dependent variable
(swimming speed) a prediction equation was suggested. The
equation included those independent variables (maturational
determinants) which depicted an improvement in the precision
of the equation.

Table 18 indicates the relative orders in which the
independent variables were selected under each dependent vari-
able. The sums under the 'Total' column are derived by adding
the numbers horizontally in line with each maturational de-
terminant.

The premise that strength is basic to performance, and
probably proportional to performance capacity is well illust-
rated in Table 18. Trunk extension strength and should exten-
sion strength appeared to be the two most important strength
attributes. Trunk extension strength is not associated directly

TABLE 18

LIST OF THE MATURATIONAL DETERMINANTS BASED ON THE
TOTAL POINTS ORDER OF REGRESSION SELECTION

Independent Variables (I.V.)	Total Per I.V.	100 Meter Free Style	200 Meter Free Style	100 Meter Back Stroke	100 Meter Breast Stroke	100 Meter Butterfly	200 Meter Individual Medley
Trunk Extension	26	6	6	1	4	3	6
Shoulder Extension	27	1	2	14	7	1	2
Training	27	2	1	8	9	6	1
Weight	28	7	4	3	3	7	4
Knee Extension	42	3	5	15	1	5	13
Trunk Flexibility	45	10	8	7	2	8	10
Chronological Age	48	9	3	5	5	14	12
Ankle Extension	49	4	9	2	11	15	8
Ankle Flexibility	49	11	13	6	12	2	5
Composite Flexibility	56	5	12	12	8	12	7
Height	58	8	10	4	14	13	9
Vital Capacity	60	13	14	9	6	4	14
Skeletal Age	64	14	15	13	10	9	3
Shoulder Flexibility	70	12	11	11	15	10	11
Composite Strength	71	15	7	10	13	11	15

with movement generation in swimming. The muscles involved perform supplementary work by acting as a link between the power applied by the arms and by the legs (5). The major contribution of trunk extension strength is in effect the maintenance of the most desirable body position which minimizes the resistance caused by faulty body position. The importance of effective body streamlining is recognized by Counsilman (5:2) in stating that "Probably the greatest improvements in stroke mechanics in recent years have been in the reduction of resistance." Stability in the horizontal and lateral planes require powerful thoracic and lumbar muscles to eliminate negative movements. Perhaps this is one of the reasons why trunk extension strength is rated first among the maturational determinants.

The main source of propulsion in swimming is found in the extension movement of the arms and shoulder joints. Shoulder extension strength in this study exhibited an important quality for competitive swimming. This is in agreement with a study reported by Bloomfield (3). The low ranking of shoulder extension in the back stroke may be due to the supine body position, as opposed to the prone body position in other strokes, where the initial movement is shoulder flexion.

Training without doubt is the single most important factor in successful athletic participation. Table 18 depicts its relative importance for competitive swimming among the other independent variables. The factor of training becomes more important for competitive swimming in later years, espe-

cially when stroke specialization is more evident. Young age group swimmers tend to be more generalists. Also, training is considered more important in endurance events; this study considered distances which are basically sprinting events.

Weight also ranked high enough to merit a special comment. Weight in terms of competitive swimming success may be considered only with respect to gains in musculature and consequently strength. It is suspected that weight gain in the age range of six to twelve years is basically due to gains is musculature. Rarick (18) stated that 50 to 60 per cent of the weight gained during the elementary school years is attributed to gains in muscle tissue. If this is true then weight may be an important attribute to competitive swimming success in terms of strength gains for the young age group competitor. Bloomfield (3) lends support to this contention with his study in which he found that high ability swimmers were heavier than low ability swimmers.

Although flexibility is an important quality in competitive swimming it did not rate highly in this study. It appears that different joint movement patterns favour different swimming strokes which suggests a certain quality of specificity related to a particular joint movement. For example, trunk flexibility is considered important in breast stroke which may be illustrated by its high rank in that stroke. This is in agreement with Cureton (6) who found high trunk flexibility measures among breast strokers. The same general observation was made for ankle flexibility (7, 8), however,

in the present study ankle flexibility appeared to be import-
ant only for the butterfly stroke. The flexibility of the
shoulder joint is considered a very important quality in com-
petitive swimming (3, 5:305). Shoulder flexibility in this
study rated relatively low for all strokes. One cannot say
with confidence why shoulder flexibility appeared unimportant
in this study, however, the observation by Leighton (16) may
help explain this phenomenon. He suggested that there is a
decreasing tendency of flexibility in children between the ages
10 to 18 years. This may be due to the disproportionate growth
rate of bone and muscle tissues (including the fascia) which
will ultimately restrict the range of joint motion (14).

Skeletal age is a factor of physical growth and matura-
tion and consequently advanced skeletal status may be con-
sidered important for successful athletic participation.
Several studies (4,17,20) stated that outstanding athletes
of elementary and junior high school age possessed higher
skeletal age means than their less successful peers. It was
also shown that high ability level swimmers were more advanced
maturationally than their low ability peers (3). These
observations are not supported totally by this study as ske-
letal age rated relatively low among the maturational deter-
minants. One possible explanation may be the fact that the
swimming events in this study are basically sprinting events
in which athletic endowment, rather than the level of matura-
tion, in relation to success may be relatively more important.
One exception is the 200 meter individual medley where skeletal

age is rated third. This event is a very demanding swimming task where the level of maturation may be a deciding factor for successful participation. The foregoing contention is not supported by Table 19 in which the means of the maturational determinants for each stroke are summarized. The mean skeletal age for the 200 meter individual medley is 149.66 months which is only the third highest behind 153.10 months for back stroke and 150.77 months for butterfly. The total mean skeletal age of 149.34 months compared to the total mean chronological age of 145.01 months cannot be considered great differences. However, slight acceleration in maturation is indicated which is consistent with some of the reviewed studies.

Vital capacity, also, rated relatively low among the maturational determinants in this study. This appears to be strange as the capacity for exchanging large volumes of used and unused air may be advantageous for swimmers. Davis (10) stated that large vital capacity may be advantageous for swimmers who swim longer distances.

The second purpose of this study was to establish a hierarchical order of relationships between the independent and dependent variables. Table 20 presents the total points hierarchical order based on the degree of generality between specific independent and dependent variables. This procedure was carried out in an effort to support the order established by the stepwise regression procedure. Definite agreements in the order of selection between the two procedures may be

TABLE 19

SUMMARY OF THE MEANS AND STANDARD DEVIATIONS OF INDEPENDENT VARIABLES

Independent Variables	100 Free (N 23) X̄	SD	200 Free (N 19) X̄	SD	100 Back (N 19) X̄	SD	100 Breast (N 17) X̄	SD
Chronological Age	145.78	6.83	144.47	6.51	145.42	6.34	144.35	7.17
Skeletal Age	148.14	13.41	149.26	10.63	153.10	9.99	145.15	14.97
Height	59.53	2.87	59.26	2.47	59.59	2.25	58.88	2.63
Weight	95.69	14.54	95.89	14.69	100.61	15.11	91.54	13.49
Vital Capacity	184.27	23.05	185.08	22.99	186.99	24.13	178.79	25.80
Training	418.80	89.68	427.07	94.21	399.55	110.68	402.32	102.63
Trunk Extension	53.96	23.73	58.85	23.79	57.18	22.54	45.38	30.34
Knee Extension	109.63	26.51	111.80	24.02	110.94	25.48	103.56	30.13
Shoulder Extension	58.43	25.52	60.11	26.63	61.87	26.13	52.62	15.53
Ankle Extension	146.93	34.39	147.34	35.84	153.38	35.90	140.60	35.88
Composite Strength	368.97	80.07	378.12	77.67	383.38	75.00	342.17	75.53
Shoulder Flexibility	210.15	15.24	207.96	14.66	207.04	14.70	209.36	17.46
Trunk Flexibility	72.50	19.47	70.13	17.27	73.98	19.15	73.42	20.65
Ankle Flexibility	90.83	8.32	92.89	8.02	90.61	9.77	87.40	11.36
Composite Flexibility	373.50	26.88	370.46	20.85	371.64	21.67	367.26	30.32

TABLE 19 (CONTINUED)

Independent Variables	100 Fly (N 19) X̄	SD	200 I.M. (N 17) X̄	SD	Total X̄	SD
Chronological Age	145.31	6.39	144.76	6.82	145.01	6.67
Skeletal Age	150.77	9.99	149.66	11.06	149.34	11.67
Height	59.25	2.37	59.60	2.39	59.36	2.49
Weight	95.31	11.58	96.47	14.96	95.91	14.06
Vital Capacity	183.75	20.09	188.09	22.46	184.49	23.08
Training	428.18	92.73	437.50	94.24	418.90	97.36
Trunk Extension	58.61	22.85	60.72	24.40	55.78	22.94
Knee Extension	113.31	24.08	112.11	25.37	110.25	25.93
Shoulder Extension	61.06	26.77	61.30	27.91	59.33	24.74
Ankle Extension	148.73	35.49	146.34	36.82	147.22	35.72
Composite Strength	381.72	75.42	380.49	81.54	372.47	77.53
Shoulder Flexibility	208.08	14.65	208.50	15.41	208.51	15.35
Trunk Flexibility	68.34	17.03	67.78	16.60	71.02	18.36
Ankle Flexibility	91.94	7.54	93.21	8.35	91.14	8.89
Composite Flexibility	367.85	19.96	368.91	21.50	369.93	23.53

TABLE 20

HIERARCHICAL ORDER OF MATURATIONAL DETERMINANTS BASED ON
TOTAL POINTS PLACEMENT FOR GENERALITY PERCENTAGES

	Total Per I.V.	100 Meter Free Style	200 Meter Free Style	100 Meter Back Stroke	100 Meter Breast Stroke	100 Meter Butterfly	200 Meter Individual Medley
Shoulder Extension	16	1	2	5	5	1	2
Training	28	8	1	9	3	6	1
Trunk Extension	30	2	7	1	6	4	10
Composite Strength	40	3	11	12	2	3	9
Ankle Flexibility	45	11	10	6	4	2	12
Composite Flexibility	46	9	3	2	14	13	5
Knee Extension	47	4	12	11	1	5	14
Chronological Age	52	12	4	13	10	7	6
Shoulder Flexibility	52	10	5	3	15	15	4
Ankle Extension	54	15	9	4	8	11	7
Height	58	5	14	10	13	8	8
Skeletal Age	60	7	13	15	12	10	3
Weight	60	13	6	7	11	12	11
Trunk Flexibility	66	14	8	8	7	14	15
Vital Capacity	66	6	15	14	9	9	13

observed. Shoulder extension was selected first by both pro-
cedures in 100 meter free and 100 meter butterfly strokes and
second in the 200 meter free and 200 meter individual medley.
Trunk extension ranked first in 100 meter back stroke by both
procedures. Training was ranked first by both procedures in
200 meter free and individual medley. The knee extension
strength ranked first in 100 meter breast stroke by both pro-
cedures. The strength items ranked high enough to be consider-
ed the most important maturational determinants. This is
supporting Counsilman's (5:277) contention in that strength
development by means other than swimming is essential for good
swimming performance.

Flexibility again showed a less important role among
the maturational determinants. Ankle flexibility may be an
exception which showed reasonable correspondence by both pro-
cedures in 100 meter back and butterfly strokes. According
to Tables 18 and 20 the following maturational determinants
may be considered the most important contributors to competi-
tive swimming success: trunk extension, shoulder extension,
training, weight, knee extension, composite strength and ankle
flexibility.

The third purpose of this study was to define the signi-
ficance of the differences between high, middle and low suc-
cess groups as determined by the relevance of maturational
determinants to swimming speed. The hypotheses to be tested
were: that maturational determinants will not have a signifi-
cant effect on the level of performance in any one specific

swimming stroke; that the number of hours spent on training will not have a significant effect on the level of performance in any one specific stroke. The criterion for the rejection of the null hypothesis was set at the 0.05 level of significance.

The hypothesis that maturational determinants will not have a significant effect on the level of performance was rejected for the 100 meter freestyle, 100 meter breast stroke and 100 meter butterfly stroke. This hypothesis for the 200 meter freestyle, 100 meter back stroke and the 200 meter individual medley was not rejected.

Shoulder extension strength in the 100 meter freestyle in this study significantly separated the three different achievement groups. The differences were significant between the high and the middle groups and between the high and low groups (Table 9, p. 95).

Shoulder extension strength utilizes the main arm depressor muscles (latissimus dorsi, pectoralis major and teres major). These muscles are also referred to as the prime movers which in effect propel the swimmer through the water most effectively (5:50). The differences for shoulder extension strength were also large in 200 meter freestyle, but contrary to what one would expect not large enough for statistical significance.

Knee extension strength in the 100 meter breast stroke was significantly different between the high and middle and between the high and low groups (Table 13, p. 100). It was

also ranked the most important maturational determinant by
both the stepwise regression and by the generality percentage
ranking. In the breast stroke kick the prime movers are the
leg extensor muscles which provide the strength for knee
extension (5:279). This became more evident when swimmers
begin to change the manner of kicking from the conventional
'frog' kick to the present 'whip' action type kick. Ankle
flexibility according to Counsilman (5:122) is a very import-
ant factor in the performance of breast stroke. The results
of this study are not in agreement with the above contention.
There were no statistically significant differenes among the
three groups in ankle flexibility. In terms of importance as
a maturational determinant ankle flexibility for breast stroke
ranked relatively low.

Shoulder flexibility and composite flexibility in the
100 meter butterfly showed significant differences between
the different ability groups. The differences were signifi-
cant between the high and low groups for both flexibility
components (Table 15, p. 102; Table 16, p. 103). The simul-
taneous nature of the arm stroke necessitates the quality of
good shoulder flexibility. Mechanically effective body posi-
tion may only be achieved if the recovering arms are not
hindered by restrictive shoulder joints. Faulty body posi-
tion, as a result of inflexible shoulder joints, may eliminate
the horizontal streamlining effect, increase the level of
drag, therefore increase the swimmer's time for a particular
distance. The significance of composite flexibility in butter-

fly does not indicate the presence of a common factor among
the various joint movements. It simply indicates that the
high success group in butterfly, as compared to the middle
and low groups, demonstrated higher range of joint motion for
the items tested. The fact that ankle flexibility approached
significance contributed greatly to the significance of composite flexibility.

The similarity in the mechanics of the freestyle and
butterfly arm actions have been explained by Counsilman (5:77).
This similarity is, in a way, supported by this study. Shoulder
extension strength was significant in 100 meter freestyle and
very nearly significant (W_2 = 29.43 vs 28.89) in 100 meter
butterfly. Also, shoulder extension strength ranked first
in importance by both the regression analysis and the generality percentage ratings in both the 100 meter freestyle and
100 meter butterfly strokes.

The number of hours spent on training was not significant in terms of swimming performance. Therefore, the hypothesis that the number of hours spent on training will not
have a significant effect on the level of performance in any
one specific stroke was accepted. In individual sports,
especially those related to the ability to sustain prolonged
work, training becomes the most important factor in the
development of specific physiological parameters for successful performance. The swimming distances in this study were
of short duration or sprinting distances, where skill and
mechanical competency may be more decisive for successful

participation. Furthermore athletic ability during the growth period may be related more to genetic factors than to regimented training. Andrew, et al., (1) suggested that the relative contribution of swimming training to various physiological parameters is difficult to assess for young athletes. Some of the group differences in growth components may be due to the factor of endowment or possibly due to higher levels of physical activity in early childhood. Participants in the more strenuous events (200 freestyle, 100 butterfly, 200 individual medley) in this study spent more time on training than the participants in the other events (Table 19, p. 111). These events may be considered endurance events for younger competitors which suggests that more training hours may be necessary for successful participation.

Throughout the review of literature various studies stated that young athletes exhibited greater anthropometric and physiologic parameters than their non-athlete peers. Direct comparisons between other investigations and the present study are extremely difficult due to the differences in testing and control procedures and to the differences in the basic purposes which ultimately define the manner of presentation. The parameters most often reported and which often offer the easiest comparison are height, weight, vital capacity and skeletal age. Table 21 illustrates such comparison between the present investigation and other studies. The illustrated data of this study compares well with the other studies, however, cannot confidently support the contention

TABLE 21

COMPARISON OF CERTAIN MEAN GROWTH DATA FOR 12 YEAR OLD BOYS FROM DIFFERENT STUDIES

Growth Parameter	Bayley (2)	Wiley (20)	Day (11)	Docherty (12)	Santa Maria (19)	Present Study
Height	59.53	59.68* 58.64**	58.62	59.02	58.95	59.36
Weight	90.63	92.81* 89.14**	90.88	92.18	90.63	95.91
Vital Capacity		141.92	141.02		145.10	184.49
Skeletal Age		151.44* 142.80**	142.35	145.92	146.11	149.34

* Athletes (football, basketball, baseball, track and field).

** Non-athletes.

that young athletes exhibit greater physical profile than non-athletes. The differences which may be attributed to training, will perhaps be more outstanding in adult years. Andrew (1:245) suggested that one cannot say with confidence to what extent the differences are the consequence of training or to what extent they may be due to the athletes endowment. It is possible that differences are established by comparing trained athletes and untrained non-athletes. Andrew reported comparable heights, up to 12 years of age, for swimmers and non-athletic groups. Beyond 12 years, however, swimmers were taller than non-athletic children. Vital capacity was reported greater for swimmers at all ages. This observation is supported by this study for 12 year old boys.

More studies are required before conclusive evidence may be presented to determine the relative contribution of maturational determinants to competitive swimming success for young swimmers.

The apparent inconsistency of the results and the difficulty of assessment may be explained by the following. Within the realm of this investigation the swimmers who qualified for the provincial championship were already successful with respect to their chronological age group peers. The highly select nature of the group allowed little variation in the maturational determinants as reliable factors for successful performance. Younger competitive swimmers are apt to be more all-round swimmers and show very limited stroke specialization. Consequently certain parameters which may have been related to

one specific stroke more closely than to another were not evi-
dent. The possible onset of puberal spurt, during which cer-
tain physical parameters 'outgrow' one another thus limit
performance ability, may be a factor for consideration. It
is possible that a more varied ability level group may have
demonstrated, with greater difference, the relative importance
of the various maturational determinants for successful swimm-
ing competition.

REFERENCES

1. Andrew, G.M., et al., Heart and Lung Functions in Swimmers and Nonathletes During Growth, Journal of Applied Physiology, 32:249, 1972.

2. Bayley, Nancy, Growth Curves of Height and Weight by Age for Boys and Girls, Scaled According to Physical Maturity, Journal of Pediatrics, 48:187-194, 1956.

3. Bloomfield, J., Anatomical and Physiological Differences Between Three Groups of Swimmers of Varying Abilities, Microcarded Doctoral Dissertation, University of Oregon, 1967.

4. Clarke, H.H., K.H. Petersen, Contrast of Maturational, Structural, and Strength Characteristics of Athletes and Non-Athletes 10 to 15 Years of Age, Research Quarterly, 32:162-176, 1961.

5. Counsilman, J.E., The Science of Swimming, Englewood Cliffs: Prentice-Hall, Inc., p. 279, 1968.

6. Cureton, T.K., Physical Fitness of Champion Athletes, Urbana: University of Illinois Press, pp. 84-93, 1951.

7. Cureton, T.K., Mechanics and Kinesiology of Swimming, Research Quarterly, 1:112, 1930.

8. Cureton, T.K., Flexibility as an Aspect of Physical Fitness, Research Quarterly, 12:381-390, 1941.

9. Draper, N.R., H. Smith, Applied Regression Analysis, New York: John Wiley and Sons, Inc., p. 163, 1966.

10. Davis, J.F., Effects of Training and Conditioning, for Middle Distance Swimming Upon Measures of Cardiovascular Condition, General Physical Fitness, Gross Strength, Motor Fitness, and the Strength of the Involved Muscles, Microcarded Doctoral Dissertation, University of Oregon, 1955.

11. Day, J.A.P., Longitudinal Analysis of Maturity and Physical Growth of Boys Ages 7 through 12 Years, Microcarded Doctoral Dissertation, University of Oregon, 1967.

12. Docherty, D., Longitudinal Analysis of the Rate and
    Pattern of Growth of Selected Maturity, Structural,
    Strength, and Motor Ability Measures of Boys 10-16
    Years of Age, Microcarded Master Thesis, University
    of Oregon, 1967.

13. Hetherington, M.R., T.O. Maguire, Comparison of Genera-
    lity and Specificity Factors Estimated with Squared
    Correlation and Analysis of Variance Techniques,
    Research Quarterly, Accepted for publication,
    June, 1972.

14. Kindall, H., F. Kindall, Normal Flexibility According
    to Age Groups, Journal of Bone and Joint Surgery,
    30:690-694, 1948.

15. Kirk, R.E., Experimental Design: Procedures for Behavioral
    Sciences, Belmont California: Brooks-Cole Publishing
    Company, pp. 91-93, 1968.

16. Leighton, J.R., On the Significance of Flexibility for
    Physical Educators, JOHPER, 31:27-8, 1960.

17. Olson, A.L., Characteristics of Fifteen Year Old Boys
    Classified as Outstanding Athletes, Scientists,
    Fine Artists, Leaders, Scholars or as Poor Students
    or Delinquents, Microcarded Doctoral Dissertation,
    University of Oregon, 1961.

18. Rarick, L.G., Motor Development During Infancy and Child-
    hood, Madison: College Printing and Typing Co.,
    Inc., p. 74, 1961.

19. Santa Maria, D.L., Longitudinal Analysis of Maturity and
    Physical Growth for Boys Ages 12 through 17 Years,
    Microcarded Doctoral Dissertation, University of
    Oregon, 1968.

20. Wiley, R.C., Single Year and Longitudinal Comparisons
    of Maturity, Physique, Structural, Strength and
    Motor Characteristics of Twelve-Year-Old Elementary
    Athletes and Non-Participants, Microcarded Doctoral
    Dissertation, University of Oregon, 1963.

21. Winer, B.J., Statistical Principles in Experimental
    Design, Toronto, Ontario: McGraw-Hill Book Company,
    pp. 105-131, 1962.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The purpose of this investigation was to evaluate the relationship between swimming speed and selected maturational determinants. Fifteen independent variables (maturational determinants) were evaluated against six dependent variables (swimming speed).

The independent variables included were:

        Chronological Age

        Skeletal Age

        Height

        Weight

        Vital Capacity

        Training

        Shoulder Flexibility

        Trunk Flexibility

        Ankle Flexibility

        Composite Flexibility

        Shoulder Extension

        Knee Extension

        Trunk Extension

        Ankle Extension

        Composite Strength

The dependent variables included were:

Freestyle (100 and 200 meters) speed

Back Stroke (100 meters) speed

Breast Stroke (100 meters) speed

Butterfly (100 meters) speed

Individual Medley (200 meters) speed

The 36 subjects involved in the investigation were from twelve competitive swimming clubs who qualified to participate in the 1970 Alberta Age Group Provincial Championships. The subjects were all in the 11-12 year age group as defined by the competitive swimming regulations. Each subject was tested once, on all of the independent variables, during the time period of the championships. For computational purposes the average scores of the three trials, where applicable, were utilized. All test items were administered to the left side of the body.

The dependency of competitive swimming on maturational determinants was evaluated by the stepwise regression analysis procedure. The maturational factors were chosen into the regression model on their relative predictive strength. For each stepwise regression analysis a prediction equation was recommended. The precision of the regression equation was based on the 'squared multiple correlation' or R^2 and the 'standard error of predicted Y' statistics. It must be noted, however, that these equations do not predict any particular level of achievement in competitive swimming.

The generality percentages of the maturational determinants were calculated in an effort to provide a hierarchical

order of importance of the independent variables.

The high, middle and low success groups, based on swimming speed, were evaluated by a one-way analysis of variance method.

The reliability estimates were carried out by a one-way analysis of variance with repeated measures model. Exception to this is the reliability and the objectivity estimates for skeletal age. These estimates were based on the coefficient of correlation by the product-movement method.

Relatively close agreement was shown to exist between the stepwise regression selection and the hierarchical order of importance based on generality percentages. Both methods of analyses emphasized the importance of strength in competitive swimming. Contrary to popular belief the flexibility characteristics of swimmers in this study were found to be relatively less important in relation to competitive swimming. Other popular growth and maturational factors as height, vital capacity and skeletal age were also indicated as less important. Weight on the other hand rated highly among the maturational determinants.

Large differences were found to exist among the different achievement groups. The differences were significant ($P < 0.05$) for shoulder extension strength in 100 meter freestyle; for knee extension strength in 100 meter breast stroke; for shoulder flexibility and composite flexibility in 100 meter butterfly stroke.

The number of hours spent on training was not signifi-

cantly different among the three different ability groups.
The higher ranked groups, however, spent more hours on train-
ing than their lower ranked peers.

Conclusions

The following remarks appear to be pertinent for the
competitive swimmers who participated in this study.

1. Based on the recommended prediction equations and
on the order of selection the following maturational determin-
ants may be important for the 11 and 12 year old provincial
caliber boy swimming competitors.

(a) 100 meter freestyle - shoulder extension, training,
knee extension, ankle extension, composite flexibi-
lity, trunk extension, weight, height, chronological
age.

(b) 200 meter freestyle - training, shoulder extension,
chronological age, weight, knee extension, trunk
extension, composite strength, trunk flexibility,
ankle extension.

(c) 100 meter back stroke - trunk extension, ankle ex-
tension, weight, height, chronological age, ankle
flexibility, trunk flexibility.

(d) 100 meter breast stroke - knee extension, trunk
flexibility, weight, trunk extension, chronological
age, vital capacity.

(e) 100 meter butterfly stroke - shoulder extension,
ankle flexibility, trunk extension, vital capacity,

knee extension, training, weight, trunk flexibility.

(f) <u>200 meter individual medley</u> - training, shoulder extension, skeletal age, weight, ankle flexibility.

2. Shoulder extension strength was significantly greater for the high ability group in the 100 meter freestyle.

3. Knee extension strength was significantly greater for the high ability group in the 100 meter breast stroke.

4. Shoulder flexibility and composite flexibility were significantly greater for the high ability group in the 100 meter butterfly stroke.

5. Flexibility, contrary to what one may expect for swimmers, generally rated low among the maturational determinants. The desirability of specific flexibility qualities as related to specific joint movements was illustrated by its relatively high ranking in breast and butterfly strokes. It appeared that more successful swimmers possessed greater specific flexibility measures.

6. The various strength measurements were the most important contributors, among the maturational determinants, to successful swimming participation.

7. Body weight rated relatively high. The effect of body weight can be considered only with respect to gains in musculature and consequently strength.

8. Body height had no particular effect on swimming speed.

9. Maturity status in terms of skeletal age appeared to be irrelevant to competitive swimming speed, although the

participants exhibited a slight acceleration in skeletal maturation.

10. Vital capacity rated relatively low among the maturational determinants.

11. Training rated relatively high among the maturational determinants. The number of hours spent on training was not significant among the three ability groups for the various swimming strokes, although the high ability swimmers spent more time on training than their low ability peers.

12. It would seem reasonable that the development of specific strength and flexibility attributes may be profitable for young age group swimmers. It is possible that further evidence, similar to the present study, may eventually alter the contemporary philosophy of long and tedious hours of water training by adopting more effective training regimen based on the development of specific physical and/or physiological parameters.

The extreme homogeneous nature of the group allowed very little variability in the maturational determinants among the subjects, thus limiting the expression of strong conclusions and recommendations. This was evident by the limited number of significant differences among the independent variables as measured by swimming performance. Therefore the results derived from this study should be applied with extreme caution. Generalization of the observations may only be applicable to the population of swimming competitors who are comparable in ability and experience to the study sample. It

appears that the most efficient experience in terms of performance capacity development for young swimmers comparable to the study sample may not be water training alone. Consequently the contemporary philosophy of 'high pressure' water training may have to be closely examined and a more a-propriate methodology implemented. Perhaps the development of specific motor patterns, characterized by the different swimming strokes, which require specific strength and flexibility qualities, may be the avenue to a more successful but less stressful training regimen for young swimmers. It is recommended that swimming coaching within the realm of this investigation may be more effective by spending more time on the improvement of the mechanical efficiency of stroke patterns, by means of specific strength and flexibility exercises, than coaching to develop ability to endure long hours of water training. It is also recommended that further study be initiated to examine the developmental patterns of relevant maturational parameters which may enhance performance capacity.

BIBLIOGRAPHY

Acheson, R.M., Maturation of the Skeleton, in Falkner, F.,
     (ed.), Human Development, Philadelphia: W.B. Saunders,
     p. 465, 1966.

Acheson, R.M., et al., Studies in the Reliability of Skeletal
     Maturity from X-rays. Part I. Greulich-Pyle Atlas,
     Human Biology, 35:317-349, 1963.

Acheson, R.M., D. Hewitt, Oxford Child Health Survey, Stature
     and Skeletal Maturation in the Pre-School Child, British
     Journal of Preventive Social Medicine, 8:59-65, 1954.

Andrew, G.M., et al., Heart and Lung Functions in Swimmers
     and Nonathletes During Growth, Journal of Applied
     Physiology, 32:245-51, 1972.

Antonini, F.M., Why We Grow Old, World Health, p. 27, April,
     1972.

Baldwin, Bird T., The Physical Growth of Children from Birth
     to Maturity, University of Iowa Studies in Child Welfare,
     Iowa City: University of Iowa Press, 1:1, 1921.

Baldwin, A.L., Behavior and Development in Childhood, New
     York: Dryden Press, 1955.

Bardeen, C.R., The Relation of Ossification to Physiological
     Development, Journal of Radiology, 2:1-8, 1921.

Bayley, Nancy, Growth Curves of Height and Weight by Age for
     Boys and Girls, Scaled According to Physical Maturity,
     Journal of Pediatrics, 48:187-194, 1956.

Bayley, Nancy, Skeletal Maturing in Adolescence as a Basis for
     Determining Percentage of Completed Growth, Child
     Development, 14:47, 1944.

Bloomfield, J., Anatomical and Physiological Differences
     Between Three Groups of Swimmers of Varying Abilities,
     Microcarded Doctoral Dissertation, University of Oregon,
     1967.

Bogert, W.J., Nutrition and Physical Fitness, (6th ed.),
     Philadelphia: W.B. Saunders Company, 1954.

Breckenridge, Marian E., Margaret N. Murphy, Growth and
     Development of the Young Child, Toronto: W.B. Saunders,
     p. 8, 1969.

Burley, L.R., R.L. Anderson, Relation of Jump and Reach Measures of Power to Intelligence Scores and Athletic Performance, Research Quarterly, 26:28-35, 1955.

Canadian Amateur Swimming Association, Swimming Rules, pp. 67-72, 1972.

Carter, T.M., Techniques and Devices Used in Radiographic Study of the Wrist Bones of Children, Journal of Educational Psychology, 17:237-247, 1926.

Clarke, H.H., J.C.E. Harrison, Differences in Physical and Motor Traits Between Boys of Advanced, Normal, and Retarded Maturity, Research Quarterly, 33:13-25, 1962.

Clarke, H.H., K.H. Petersen, Contrast to Maturational, Structural, and Strength Characteristics of Athletes and Non-Athletes 10 to 15 Years of Age, Research Quarterly, 32:162-176, 1961.

Clarke, H.H., K.H. Petersen, Contrast to Maturational, Structural, and Strength Characteristics of Athletes and Non-Athletes 10 to 15 Years of Age, Research Quarterly, 32:162-176, 1961.

Clarke, H.H., A Manual - Cable-Tension Strength Tests, Springfield: Springfield College Press, 1953.

Clarke, H.H., T.G. Schopf, Construction of Muscular Strength Test for Boys in Grades 4, 5, and 6, Research Quarterly, 33:515-522, 1962.

Clarke, H.H., J.S. Wickens, Maturity, Structural, Muscular Strength, and Motor Ability Growth Curves of Boys 9 to 15 Years of Age, Research Quarterly, 33:26-39, 1962.

Cone, T.A., Jr., Secular Acceleration of Height and Biologic Maturation in Children During the Past Century, Journal of Pediatrics, 59:736-740, 1961.

Cook, C.D., J.F. Hamman, Relation of Lung Volume to Height in Healthy Persons Between the Ages of Five and Thirty Eight Years, Journal of Pediatrics, 59:710-718, 1961.

Counsilman, J.E., The Science of Swimming, Englewood Cliffs: Prentice-Hall, Inc., p. 279, 1968.

Crampton, C.W., Physiological Age - A Fundamental Principle, Child Development, 15:1-52, 1944.

Cureton, T.K., Analysis of Vital Capacity as a Test of Condition for High School Boys, Research Quarterly, 7:80-92, 1936.

Cureton, T.K., Physical Fitness of Champion Athletes, Urbana: University of Illinois Press, pp. 84-93, 1951.

Cureton, T.K., Mechanics and Kinesiology of Swimming, Research Quarterly, 1:112, 1930.

Cureton, T.K., Flexibility as an Aspect of Physical Fitness, Research Quarterly, 12:381-390, 1941.

Davis, J.F., Effects of Training and Conditioning, for Middle Distance Swimming Upon Measures of Cardiovascular Condition, General Physical Fitness, Gross Strength, Motor Fitness, and the Strength of the Involved Muscles, Microcarded Doctoral Dissertation, University of Oregon, 1955.

Day, J.A.P., Longitudinal Analysis of Maturity and Physical Growth of Boys Ages 7 through 12 Years, Microcarded Doctoral Dissertation, University of Oregon, 1967.

Deach, D.F., Genetic Development of Motor Skills of Children Two through Six Years of Age, Dissertation Abstract, University of Michigan, p. 376, 1950.

Dearborn, W.F., J.W.M. Rothney, Predicting the Child's Development, Cambridge, Mass.: Scientific Art Publishers, 1941.

Dickinson, R.B., The Specificity of Flexibility, Research Quarterly, 39:792-793, 1968.

Dimock, H.S., A Research in Adolescence, Child Development, 6:177-195, 1968.

Docherty, D., Longitudinal Analysis of the Rate and Pattern of Growth of Selected Maturity, Structural, Strength, and Motor Ability Measures of Boys 10-16 Years of Age, Microcarded Master Thesis, University of Oregon, 1967.

Draper, N.R., H. Smith, Applied Regression Analysis, New York: John Wiley and Sons, Inc., 1967.

Elgenmark, O., The Normal Development of Ossific Centers During Infancy and Childhood, A Clinical, Roentgenological, and Statistical Study, Acta Paediatrica, (Uppsala) 33, Suppl. No. 1, 1946.

Emerson, P.W., H. Green, Vital Capacity of the Lungs of Children, American Journal of Diseases of Children, 22:202-211, 1922.

Espenschade, A.S., Motor Performance in Adolescence, Monograph of the Society for Research in Child Development, 5:1-126, 1940.

Everett, P.W., The Prediction of Baseball Ability, <u>Research Quarterly</u>, 23:15-19, 1952.

Flory, C.D., Osseous Development of the Hand as an Index of Skeletal Development, <u>Monographs of the Society for Research in Child Development</u>, 1:1-141, 1936.

Garn, S.M., Research in Human Growth, <u>Human Biology</u>, 29:1-11, 1957.

Garrett, H.E., R.S. Woodworth, <u>Statistics in Psychology and Education</u>, New York: David McKay Co., pp. 139-142, 1958.

Gates, A.I., The Nature and Educational Significance of Physical Status and of Mental, Physiological, Social, and Emotional Maturity, <u>Journal of Educational Psychology</u>, 15:329-358, 1924.

Greulich, W.W., The Relationship of Skeletal Status to the Physical Growth and Development of Children, in Boell, E.J., (ed.), <u>Dynamics of Growth Processes</u>, New Jersey: Princeton University Press, p. 212, 1954.

Greulich, W.W., The Rationale of Assessing the Developmental Status of Children from Roentgenograms of the Hand and Wrist, <u>Child Development</u>, 21:33-44, 1950.

Greulich, W.W., S.I. Pyle, <u>Radiographic Atlas of Skeletal Development of the Hand and Wrist</u>, Stanford, California: Stanford University Press, 1959.

Hale, C.J., Physiological Maturity of Little League Baseball Players, <u>Research Quarterly</u>, 27:276-284, 1956.

Hale, C.J., What Research Says About Athletics for Pre-High School Age Children, <u>Journal of Health, Physical Education, and Recreation</u>, 30:19-21, 1959.

Harding, Vernette S.V., A Method of Evaluating Osseous Development from Birth to 14 Years, <u>Child Development</u>, 23:247-272, 1952.

Harrison, J.C.E., The Relationship Between Selected Physical and Motor Factors and the Skeletal Maturity of 9, 12, and 15 Year Old Boys, Microcarded Doctoral Dissertation, University of Oregon, 1959.

Hayman, N.R., Reduction of the Number of Bone Assessments Necessary for Skeletal Age Determination of Adolescent Boys, Microcarded Doctoral Dissertation, University of Oregon, 1959.

Heaton, K.L., Physical Development of Children of High and
    Low Mental Ability Groups, American Physical Education
    Review, 30:127-130, 1925.

Henry, F.M., 'Best Versus Average' Individual Scores, Research
    Quarterly, 38:317-320, 1967.

Hetherington, M.R., Trainability and Generality/Specificity
    Ratios of the Ability of Grade Five Boys to Develop
    Torque, Doctoral Dissertation, The University of Alberta,
    pp. 60-65, 1971.

Hetherington, M.R., T.O. Maguire, Comparison of Generality
    and Specificity Factors Estimated with Squared Correla-
    tion and Analysis of Variance Techniques, Research
    Quarterly, Accepted for publication, June, 1972.

Hindmarch, R.G., Significance of Physique, Maturational, Body
    Size, Strength, Motor Ability and Reaction Time Char-
    acteristics of Eight Year Old Boys, Microcarded Doctoral
    Dissertation, University of Oregon, 1962.

Hooks, G.E., Prediction of Baseball Ability Through an Analysis
    of Measures of Strength and Structure, Research Quarterly,
    30:38-43, 1959.

House, R.W., Stage of Bodily Maturation Found in 318 First
    Grade Pupils, Journal of Educational Research, 37:214-
    217, 1943.

Howell, M.L., et al., Strength of Edmonton School Children,
    Unpublished Study, University of Alberta, 1966.

Hupprich, Florence, L., P.O. Sigerseth, The Specificity of
    Flexibility of Girls, Research Quarterly, 21:25-33, 1950.

Johnston, F.E., The Concept of Skeletal Age, Clinical Pedia-
    trics, 1:133-144, 1962.

Johnston, F.E., The Relationship of Certain Growth Variables
    to Chronological and Skeletal Age, Human Biology,
    36:16-27, 1964.

Jones, H.E., Motor Performance and Growth: A Developmental
    Study of Static Dynamometrical Strength, Berkeley:
    University of California Press, pp. 53-79, 1949.

Kindall, H., F. Kindall, Normal Flexibility According to Age
    Groups, Journal of Bone and Joint Surgery, 30:690-694,
    1948.

Kiphuth, R.J.H., Swimming, New York: A.S. Barnes and Co.,
    p. 110, 1942.

Kirk, R.E., Experimental Design: Procedures for Behavioral
    Sciences, Belmont California: Brooks-Cole Publishing
    Company, pp. 91-93, 1968.

Koski, K.J., et al., Skeletal Development of Hand and Wrist
    in Finnish Children, American Journal of Physical
    Anthropology, 19:379-382, 1961.

Krogman, W.M., Factors in Physical Growth of Children as They
    May Apply to Physical Education, AAHPER Proceedings,
    p. 60, 1954.

Krogman, W.M., The Concept of Maturity from a Morphological
    Viewpoint, Child Development, 21:25-32, 1950.

Krogman, W.M., Maturation Age of 55 Boys in the Little League
    World Series, 1957, Research Quarterly, 30:54-56, 1959.

Kroll, W., Reliability Theory and Research Decision in Selec-
    tion of a Criterion Score, Research Quarterly, 38:412-
    419, 1967.

Kurimoto, E., Longitudinal Analysis of Maturity, Structural,
    Strength, and Motor Developments of Boys Fifteen Through
    Eighteen Years of Age, Microcarded Doctoral Dissertation,
    University of Oregon, 1963.

Leighton, R.J., Flexibility Characteristics of Four Specialized
    Skill Groups of College Athletes, Archives of Physical
    Medicine and Rehabilitation, 38:24-28, 1957.

Leighton, R.J., Flexibility Characteristics of Three Specia-
    lized Skill Groups of Champion Athletes, Archives of
    Physical Medicine and Rehabilitation, 38:580-583, 1957.

Leighton, R.J., Simple Objective and Reliable Measure of
    Flexibility, Research Quarterly, 13:205-216, 1942.

Leighton, R.J., An Instrument and Technic for the Measurement
    of Range of Joint Motion, Archives of Physical Medicine
    and Rehabilitation, 36:571-578, 1955.

Leighton, R.J., On the Significance of Flexibility for Physi-
    cal Educators, JOHPER, 31:27-8, 1960.

Leighton, R.J., Flexibility Characteristics of Males Ten to
    Eighteen Years of Age, Archives of Physical Medicine
    and Rehabilitation, 37:494-499, 1956.

Mainland, D., Evaluation of the Skeletal Age Method of Estimating Children's Development. I. Systematic Errors in the Assessment of Roentgenograms, _Pediatrics_, 12: 114-129, 1953.

Mainland, D., Evaluation of the Skeletal Age Method of Estimating Children's Development. II. Variable Errors in the Assessment of Roentgenograms, _Pediatrics_, 13:165-173, 1954.

McCloy, C.H., Norma D. Young, _Tests and Measurements in Health and Physical Education_, New York: Appleton-Century-Crofts, Inc., 1954, p. 55.

Metheny, E., The Present Status of Strength Testing for Children of Elementary School and Pre-school Age, _Research Quarterly_, 12:115, 1941.

Metheny, E., Breathing Capacity and Grip Strength of Pre-School Children, _University of Iowa Studies in Child Welfare_, 18:1-207, 1941.

Meredith, H.V., The Rhythm of Physical Growth: A Study of 18 Anthropometric Measures on Iowa City Males Ranging in Age Between Birth and Eighteen Years, _University of Iowa Studies in Child Welfare_, 11:128, 1936.

Morse, M., _et al._, The Lung Volume and Its Subdivisions in Boys 10-17 Years of Age, _Journal of Clinical Investigations_, 31:380-391, 1952.

Olson, A.L., Characteristics of Fifteen Year Old Boys Classified as Outstanding Athletes, Scientists, Fine Artists, Leaders, Scholars or as Poor Students or Delinquents, Microcarded Doctoral Dissertation, University of Oregon, 1961.

Oyster, Nancy, The Relationship Between Skeletal Age and Measures of Motor Performance and Muscle Strength Second Grade Girls and Boys, Microcarded M.S. Thesis, University of Wisconsin (Madison), 1961.

Pickens, W.L., A Study of Flexibility in Swimmers, Microcarded Master Thesis, University of Oregon, 1950.

Pointu, R., Age is No Barrier, _World Health_, p. 25, April, 1972.

Pryor, J.W., Time of Ossification of the Bones of the Hand of the Male and Female and Union of Epophyses with the Diaphyses, _American Journal of Physical Anthropology_, 8: 401-410, 1925.

Pyle, S.I., Camille Manino, Observations on Estimating Skeletal Age from the Todd and Flory Bone Atlases, <u>Child Development</u>, 10:27-34, 1939.

Pyle, S.I., L.W. Sontag, Variability in Onset of Ossification in Epiphyses and Short Bones of the Extremities, <u>American Journal of Roentgenology</u>, 49:795-798, 1943.

Rarick, G.L., N. Oyster, Physical Maturity, Muscular Strength and Motor Performance of Young School Age Boys, <u>Research Quarterly</u>, 35:522-528, 1964.

Rarick. L.G., <u>Motor Development During Infancy and Childhood</u>, Madison: College Printing and Typing Co. Inc., p. 74, 1961.

Ratch, T.M., The Development of the Bones in Childhood Studies by the Roentgen Method, with a View of Establishing a Developmental Index for the Grading and Protection of Early Life, <u>Transactions of the Association of American Physicians</u>, 24:603, 1909.

Reynolds, E.L., T. Asakawa, Skeletal Development in Infancy, <u>The American Journal of Roentgenology and Radium Therapy</u>, 65:403-410, 1951.

Richey, H.G., The Relation of Accelerated, Normal and Retarded Puberty to the Height and Weight of School Children, <u>Monographs of the Society for Research in Child Development</u>, 2:1-67, 1937.

Rogers, F.R., <u>Physical Capacity Tests in the Administration of Physical Education</u>, (Contributions to Education No. 173) New York: Bureau of Publications, Teachers College, Columbia University, 1925.

Santa Maria, D.L., Longitudinal Analysis of Maturity and Physical Growth for Boys Ages 12 through 17 Years, Microcarded Doctoral Dissertation, University of Oregon, 1968.

Sargent, D.A., Intercollegiate Strength Tests, <u>American Physical Education Review</u>, 2:108, 1897.

Sawtell, Ruth O., Ossification and Growth of Children from One to Eight Years of Age, <u>American Journal of Diseases of Children</u>, 37:61-87, 1929.

Seils, L.G., The Relationship Between Measures of Physical Growth and Gross Motor Performance of Primary School Children, <u>Research Quarterly</u>, 22:244-260, 1951.

Shay, C.T., The Relationship Between Selected Anthropometric Measurements and Loss of Strength in Selected Muscle Groups, Microcarded Doctoral Dissertation, Springfield College, 1954.

Shelley, M.E., Maturity, Structure, Strength, Motor Ability, and Intelligence Test Profiles of Outstanding Elementary School and Junior High School Athletes, Microcarded Master Thesis, University of Oregon, 1960.

Shuttleworth, F.L., The Physical and Mental Growth of Girls and Boys Age Six to Nineteen in Relation to Age at Maximum Growth, Monograph of the Society for Research in Child Development, 4:1-191, 1939.

Simmons, Katherine, The Brush Foundation Study of Child Growth and Development, II. Physical Growth and Development, Monographs of the Society for Research in Child Development, 9:49-54, 1944.

Singh, M., et al., The Strength and Physical Work Capacity of the Native Indian Children of Alberta, A Paper Presented at the XVLL World Congress of Sports Medicine, Mexico City, October, 1968.

Stolz, H.H., L.M. Stolz, Somatic Development of Adolescent Boys, New York: The Macmillan Company, pp. 137-138, 1951.

Stucliffe, A., J.W. Canhan, The Heights and Weights of Boys and Girls, London: John Murray, 1950.

Tanner, J.M., Education and Physical Growth, London: University of London Press, p. 36, 1961.

Tanner, J.M., Growth at Adolescence, Oxford: Blackwell Scientific Publications, p. 1, 1962.

Tihanyi, J., The Effects of an Accelerated Physical Education Programme on Certain Physical and Motor Traits of Children in Grades One, Three, and Four, Unpublished Master Thesis, University of British Columbia, 1966.

Todd, W.T., Atlas of Skeletal Maturation (Hand), St. Louis: C.V. Mosby Co., 1937.

Todd, W.T., The Roentgenographic Appraisement of Skeletal Differentiation, Child Development, 1:309, 1930.

Tomaras, W.A., The Relationship of Anthropometric and Strength Measures of Junior High School Boys to Various Arm Strength Criteria, Microcarded Doctoral Dissertation, University of Oregon, 1957.

Watt, N.S., Maturity, Structural, Strength, and Motor Conver-
gence Growth Analysis of Boys Seven Through Seventeen
Years of Age, Microcarded Doctoral Dissertation, Univer-
sity of Oregon, 1963.

Whittenberger, J.L., L.R. Gallagher, Maximum Breathing Capacity
and Vital Capacity of Male Children and Adolescents,
Pediatrics, 9:659-670, 1952.

Whittle, H.D., Effects of Elementary School Physical Education
Upon Some Aspects of Physical, Motor, and Personality
Development of Boys Twelve Years of Age, Microcarded
Doctoral Dissertation, University of Oregon, 1956.

Wickens, J.S., Maturity, Structural, Muscular Strength, and
Motor Ability Growth Curves of Boys Nine to Fifteen Years
of Age, Microcarded Doctoral Dissertation, University of
Oregon, 1958.

Wiley, R.C., Single Year and Longitudinal Comparisons of
Maturity, Physique, Structural, Strength, and Motor
Characteristics of Twelve-Year-Old Elementary Athletes
and Non-Participants, Microcarded Doctoral Dissertation,
University of Oregon, 1963.

Winer, B.J., Statistical Principles in Experimental Design,
Toronto: McGraw-Hill Book Company, Inc., pp. 105-132,
1962.

Zankel, H.T., A New Method of Measurement of Range of Motion
of Joints, Archives of Physical Medicine, 32:227, 1951.

Zimmerli, E., Studies of Unusual Physical Fitness Indices,
Research Quarterly, 6:244-249, 1935.

APPENDIX A

COMMUNICATION: 1. ALBERTA SWIMMING FEDERATION

2. PARTICIPATING CLUB-COACHES

April 29, 1970.

Mr. J.S. Kennedy,
Secretary, CASA Alberta Section,
4616 - 109 Avenue,
Edmonton, Alberta.

Dear Mr. Kennedy:

A study is being organized to investigate what physical maturation aspects of children contribute most to their success in competitive swimming. The purpose of this letter is to ask the Canadian Amateur Swimming Association Alberta Section for permission to conduct this study during the 1970 Age Group Provincial Championships.

The study involves testing each boy entry in the following tests:

1. Strength of one shoulder, one arm, one ankle, and the trunk. It involves an exertion against a harness, for 2 seconds, which is attached to a strength measuring instrument.

2. Flexibility of the neck, one shoulder, one ankle, and the trunk. This item measures the range of movement of the joint and body segments involved.

3. Single x-ray of the left hand. The x-ray will be taken by the Radiology Department of the University of Alberta Hospital.

4. Breathing capacity. This measures the amount of air an individual is able to inhale and exhale.

All testing will be carried out at the Coronation Park Swimming Pool. I would like to assure all concerned that the testing procedure will not interfere with the swimming program, nor will it jeopardize the swimming performance of the boys involved.

I personally discussed this project with many of the coaches, both Calgarians and Edmontonians, who indicated a keen interest and support for the study. A similar letter, outlining the proposed procedures, will be sent to all participating clubs.

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It is hoped that this study will contribute to the
development of better training practices by expending our
understanding of some of the mysteries why some children are
more successful than others.

Your kind cooperation will be greatly appreciated.

Respectfully,

Jeno Tihanyi,
Principal Investigator.

May 19, 1970.

Dear Coach:

Perhaps you recall that some time ago I approached you and solicited your permission to involve your male swimmers in a study I will conduct during the 1970 Age Group Provincial Swimming Championships. Should I have missed speaking to you, I apologize and ask you now if I may involve your swimmers in this study. The coaches with whom I discussed this study indicated enthusiasm and full support. The details of the study have been now outlined and this letter is sent to you with the purpose of familiarizing you with these procedures.

First of all I would like to assure you that the testing procedures will not in any way interfere with the swimming program, nor will it jeoparidize the swimming performance of the boys involved. All testing will be carried out at the new Coronation Park Swimming Pool. Would you please brief your age group boys of the testing procedures so they will know what to expect, thereby speed up our efforts. The testing team will be at the pool one hour before the commencement of the meet each day. You may want to mention this to your swimmers so any one who could come earlier would be tested before the meet began.

Each boy will be tested on the following items:

1. Strength (2 second force against a harness):

   a. knee extension
   b. shoulder extension
   c. trunk extension
   d. ankle extension.

2. Flexibility (measures range of joint movement):

   a. shoulder
   b. trunk
   c. ankle.

3. Lung Capacity: the amount of expired air will be measured by blowing in a measuring container.

4. X-ray of the hand: this will determine the extent of bone development.

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It is my belief that the outcomes of studies such as this will contribute to the development of better training methods, and will hopefully provide tentative explanations of why some children are more successful than others in competitive swimming. Should you wish to have more information, please do not hesitate to contact me.

Thank you very much for your cooperation and I am looking forward to seeing you at the Championships.

Sincerely yours,

Jeno Tihanyi,
Principal Investigator.

APPENDIX B

PERSONAL INFORMATION AND PERFORMANCE DATA

PERSONAL INFORMATION AND PERFORMANCE DATA

Name _____ Club _____ City _____

Birth Date _____ Skeletal Age _____

Height _____ Weight _____ Lung Capacity _____

Average _____

Hours spent on training:

    Hours per day   _____

    Days per week   _____

    Weeks per year   _____

    Approximate total number of hours _____

Strength: Average

    Trunk extension   _____ _____ _____ _____

    Knee extension   _____ _____ _____ _____

    Shoulder extension   _____ _____ _____ _____

    Ankle plantar flexion _____ _____ _____ _____

                                     Composite _____

Flexibility: Average

    Shoulder   _____ _____ _____ _____

    Trunk (Trunk-Hip)   _____ _____ _____ _____

    Hip   _____ _____ _____ _____

    Ankle   _____ _____ _____ _____

                                     Composite _____

APPENDIX C

SAMPLE ROENTGENOGRAPH AND EVALUATION FORM

SKELETAL AGE OF INDIVIDUAL BONES

Distal End of Radius _____

Distal End of Ulna _____

Capitate _____
Hamate _____
Triquetral _____
Lunate _____
Scaphoid _____
Trapezium _____
Trapezoid _____

Metacarpal I _____
Metacarpal II _____
Metacarpal III _____
Metacarpal IV _____
Metacarpal V _____

Proximal Phalanx I _____
Proximal Phalanx II _____
Proximal Phalanx III _____
Proximal Phalanx IV _____
Proximal Phalanx V _____

Middle Phalanx II _____
Middle Phalanx III _____
Middle Phalanx IV _____
Middle Phalanx V _____

Distal Phalanx I _____
Distal Phalanx II _____
Distal Phalanx III _____
Distal Phalanx IV _____
Distal Phalanx V _____

Pisiform _____
Adductor Sesamoid of Thumb _____
Flexor Sesamoid of Thumb _____

NAME: MEAN AGE:

X-RAY NO:

FIGURE 17

Sample Roentgenograph

FIGURE 17

Sample Roentgenograph

APPENDIX D
RAW DATA

Name	100 Free	200 Free	100 Back	100 Breast	100 Fly	200 I.M.
Lofvendahl	1.08.7	2.35.4	1.17.0		1.14.4	2.48.4
McNeil	1.08.9	2.30.8	1.21.4		1.16.2	2.48.0
Emerson		2.28.6			1.21.1	2.51.2
Armstrong	1.09.0	2.26.5	1.16.5	1.36.9	1.18.5	2.42.4
Cathro	1.11.3	2.33.1	1.21.4	1.27.8	1.16.8	2.46.9
Armstrong	1.12.0	2.36.0	1.23.4	1.33.8	1.18.4	2.48.8
Lowe	1.11.9	2.44.3	1.20.2		1.21.3	2.54.8
Campbell	1.12.7					
Smith	1.11.7	2.38.9		1.25.7	1.17.5	2.54.6
New	1.12.1	2.38.2			1.28.9	2.59.2
Glass	1.12.5	2.35.2	1.20.8		1.22.9	
Sondergaard		2.37.9			1.19.0	3.03.9
Fung	1.12.6		1.25.8	1.35.0	1.21.3	
Campbell	1.14.1	2.36.9	1.27.5		1.21.4	2.58.6
Smart	1.11.4	2.40.0	1.26.4	1.39.6	1.23.3	2.57.0
Fester	1.13.0	2.46.2	1.25.6	1.31.4	1.26.0	2.55.9
Scarth	1.14.4	2.41.8	1.25.6		1.28.2	2.59.8
Bokstein			1.27.5	1.38.0		
Ross	1.17.1			1.40.9		
Dixon				1.36.8		
Seright	1.19.5	2.50.1			1.27.6	3.06.4

Name	100 Free	200 Free	100 Back	100 Breast	100 Fly	200 I.M.
Lofvendahl	1.20.9		1.33.5		1.29.0	
Allen					1.24.9	
Ballendine	1.16.4	2.46.5		1.38.8		3.09.0
Marney	1.16.4					
Smith	1.17.2	2.52.5	1.29.0			3.06.3
Lillijord	1.13.2					
Van Egtren	1.12.6					
McLeod				1.35.0		
Hogg				1.31.7		
Roskey				1.36.8		
Bokstein				1.39.6		
Henning			1.23.5	1.37.7		
Allen			1.29.9	1.44.0		
Chow			1.25.0			
Noble			1.24.4			

Name	Chronological Age	Skeletal Age	Height	Weight	Hours Trained	Lung Capacity 1	2	3
Lofvendahl	155	167.62	63.25	114.50	345	223	207	225
McNeil	145	136.21	59.00	82.25	345	182	186	190
Emerson	148	148.33	56.50	74.00	516	183	167	176
Armstrong	145	160.29	60.00	102.50	564	177	175	186
Cathro	144	136.93	58.50	94.00	564	157	178	163
Armstrong	145	162.63	60.25	104.50	564	204	200	203
Lowe	138	156.80	60.00	90.50	414	152	160	150
Campbell	155	155.03	62.00	98.50	360	205	203	204
Smith	145	142.30	57.50	86.50	385	187	186	180
New	151	153.00	63.00	111.00	385	221	228	230
Glass	141	141.29	55.75	80.00	332	162	163	160
Sondergaard	148	157.21	60.75	97.00	414	197	198	200
Fung	152	163.90	63.00	110.50	414	182	200	198
Campbell	145	136.39	58.00	95.50	564	163	161	174
Smart	156	161.87	61.50	92.50	423	208	210	208
Fester	139	155.05	58.00	88.50	300	195	196	199
Scarth	135	147.23	61.25	111.50	564	180	165	185
Bokstein	143	149.04	61.50	121.00	264	242	240	248
Ross	152	145.02	57.50	73.00	396	170	166	176
Dixon	149	136.80	57.75	80.00	414	154	156	155
Seright	154	136.76	56.00	78.75	345	177	162	182

Name	Chronological Age	Skeletal Age	Height	Weight	Hours Trained	Lung Capacity 1	2	3
Lofvendahl	143	150.48	57.00	102.00	345	156	157	159
Allen	132	150.38	56.50	96.00	352.50	168	173	160
Ballendine	132	129.79	56.00	82.00	423	155	150	165
Marney	150	134.76	59.00	82.00	312	158	172	167
Smith	136	155.93	63.75	135.50	322.50	229	217	241
Lillijord	142	112.63	54.00	81.00	462	139	162	162
Van Egtren	153	165.41	65.00	105.00	504	199	219	207
McLeod	151	152.80	58.00	78.50	300	157	142	160
Hogg	133	134.92	58.25	71.00	345	150	146	152
Roskey	141	130.69	58.00	99.25	277.50	148	176	173
Bokstein	132	127.58	56.25	86.50	240	142	156	160
Henning	156	165.52	61.00	122.00	258	184	190	191
Allen	154	163.55	57.50	101.50	414	178	175	183
Chow	144	151.10	57.25	82.00	360	165	162	162
Noble	147	147.11	57.75	82.00	235	175	188	190

Name	Trunk Extension 1	2	3	Knee Extension 1	2	3	Shoulder Extension 1	2	3	Ankle Extension 1	2	3
Lofvendahl	130	116	93	162	151	149	69	69	63	173	173	199
McNeil	57	59	60	111	108	107	153	173	158	215	181	192
Emerson	33	30	34	103	101	103	53	48	45	114	132	129
Armstrong	85	73	80	102	90	103	62	57	49	152	144	152
Cathro	47	50	50	123	127	134	63	53	48	142	157	131
Armstrong	75	77	56	115	130	125	46	53	43	174	158	185
Lowe	50	58	41	85	77	81	44	37	38	117	125	153
Campbell	36	40	41	84	93	121	51	51	57	121	128	139
Smith	77	79	78	105	110	130	66	73	75	155	153	174
New	87	92	91	144	150	136	49	65	73	134	189	163
Glass	43	49	54	107	107	113	50	51	50	124	145	125
Sondergaard	82	67	65	122	147	154	53	58	46	190	170	191
Fung	57	65	65	160	145	153	78	72	83	185	184	175
Campbell	46	38	45	85	69	58	57	42	36	104	124	116
Smart	42	39	40	136	124	146	49	54	56	155	191	167
Fester	14	13	13	110	118	115	74	50	64	73	83	97
Scarth	82	78	78	78	62	86	53	52	52	170	178	173
Bokstein	74	82	53	125	157	129	79	61	66	187	183	199
Ross	21	20	23	63	79	88	33	33	40	128	130	126
Dixon	51	38	35	94	90	94	34	38	37	141	129	142
Seright	64	57	60	103	97	95	54	38	39	136	138	133

Name	Trunk Extension 1	2	3	Knee Extension 1	2	3	Shoulder Extension 1	2	3	Ankle Extension 1	2	3
Lofvendahl	48	35	29	110	105	113	47	47	55	172	184	185
Allen	41	38	36	90	91	98	38	36	32	143	138	148
Ballendine	30	24	31	75	75	83	35	34	29	115	123	124
Marney	40	30	41	73	75	80	42	35	47	121	117	117
Smith	73	81	77	124	153	141	63	60	64	160	187	185
Lillijord	42	39	32	83	91	89	39	36	44	140	144	139
Van Egtren	32	26	30	130	146	169	67	49	51	181	197	194
McLeod	49	50	44	65	87	69	44	43	43	153	157	160
Hogg	51	55	46	45	43	39	29	35	37	104	126	136
Roskey	41	39	43	75	79	83	48	47	52	127	131	139
Bokstein	12	13	14	57	85	94	52	43	48	110	95	104
Henning	37	30	26	102	101	106	60	41	51	129	180	182
Allen	28	27	29	62	67	70	51	44	47	136	152	132
Chow	65	64	66	101	96	112	42	46	45	162	165	184
Noble	72	69	77	101	99	98	52	61	54	153	155	158

Name	Shoulder Flexibility 1	2	3	Trunk Flexibility 1	2	3	Hip Flexibility 1	2	3	Ankle Flexibility 1	2	3
Lofvendahl	220	218	219	233	227	225	109	114	110	92	80	87
McNeil	224	215	220	180	178	179	114	115	113	96	100	98
Emerson	209	210	215	181	182	180	117	117	117	94	99	101
Armstrong	219	204	215	173	177	179	115	115	115	97	97	97
Cathro	209	210	211	175	176	174	123	127	131	95	98	99
Armstrong	245	239	235	187	180	181	130	130	130	104	102	103
Lowe	204	200	210	177	178	179	125	125	125	86	87	85
Campbell	226	222	222	185	180	183	82	84	84	85	84	87
Smith	219	215	220	187	195	195	115	114	113	93	94	95
New	210	210	210	185	183	184	124	128	125	74	74	74
Glass	211	200	200	192	180	185	103	105	108	90	95	95
Sondergaard	215	214	216	164	170	175	112	111	113	96	100	99
Fung	215	212	214	172	178	176	117	115	116	90	84	84
Campbell	206	204	205	200	198	199	120	119	121	84	82	83
Smart	182	170	186	205	201	204	118	115	116	99	100	101
Fester	168	166	167	184	185	183	115	115	115	104	102	103
Scarth	209	204	202	170	176	177	110	105	107	88	90	89
Bokstein	216	209	217	170	156	157	46	46	46	74	70	71
Ross	205	205	205	177	176	175	97	104	105	71	80	81
Dixon	230	220	226	175	172	177	92	85	90	70	75	75
Seright	195	210	215	171	168	171	120	115	120	85	90	85

Name	Shoulder Flexibility			Trunk Flexibility			Hip Flexibility			Ankle Flexibility		
	1	2	3	1	2	3	1	2	3	1	2	3
Lofvendahl	210	200	199	225	225	225	125	130	130	90	86	85
Allen	210	214	211	175	171	170	105	101	108	86	88	87
Ballendine	216	215	214	185	178	176	100	105	100	81	91	85
Marney	260	230	235	206	200	201	106	106	106	104	100	97
Smith	215	205	204	190	192	191	107	103	115	101	111	105
Lillijord	202	219	211	171	171	171	129	139	138	84	80	84
Van Egtren	215	215	215	210	211	211	115	115	115	89	89	89
McLeod	222	213	218	180	197	198	84	85	83	95	85	92
Hogg	180	180	180	150	154	157	80	84	85	90	90	90
Roskey	216	215	215	175	179	182	83	85	87	58	65	59
Bokstein	219	228	217	162	180	171	109	105	100	88	84	82
Henning	202	196	199	165	175	165	110	109	111	95	94	93
Allen	210	211	209	140	145	155	79	74	80	69	68	67
Chow	225	210	217	190	195	198	115	116	114	87	86	85
Noble	210	200	204	172	184	185	113	120	121	85	93	85