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A BATTERY OF SKILL TESTS: ITS VALUE TO PREDICT PERFORMANCE OF 8 YEAR OLD BOYS IN ICE HOCKEY

by

JEAN JOBIN ©

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "A Battery of Skill Tests: Its Value to Predict Performance of 8 Year Old Boys in Ice Hockey", submitted by Jean Jobin in partial fulfilment of the requirements for the degree of Master of Science in Physical Education.

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Date Sept. 26, 1975

ABSTRACT

The purpose of this study was to evaluate the effectiveness of a battery of Hockey Skill Tests (proposed by Hockey Canada, 1970) in predicting performance in playing hockey for a homogeneous group of eight year old boys and, to compare it to two other batteries of tests that were not directly related to hockey.

Fourteen boys (mean age 105.6 months), all members of the same team, were given three test batteries near the end of their hockey season (30-40 games). The test batteries were identified as Hockey Skill Tests, Laboratory Tests and Field Tests of fitness performance.

Multiple regression equations were computed for each battery of tests and elements from each battery were mixed to produce the best prediction equation for the performance criterion of this group to play hockey. The performance criterion to play hockey was evaluated by the coaches of the team, who ranked the players from one to fourteen, one being the best score.

None of the three batteries was found to produce a significant ($p < .10$) multiple R. No significant difference ($p < .10$) was found between the multiple R's from the three batteries, but the Hockey Skill Tests battery produced the lowest multiple R. Only one equation gave a multiple R significantly different from zero ($p < .10$). This equation was composed of the best single predictors from the three batteries.

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CHAPTER I

INTRODUCTION

Ice-hockey is our national sport and Canadians are proud to be identified with it. Unfortunately, Canadians have not devoted much effort to a detailed study of the sport. Scientific research on hockey (in Canada) has never been encouraged by professional and semi-professional players and organizations. Canada had such a large pool of hockey talent that scientific teaching as well as study and analysis hardly seemed necessary. This method persisted as long as other nations knew little of the sport and were unable to compete on an equal level. Recently however, other nations have equalled or perhaps surpassed the ability of Canadians in the sport. This situation has brought up a new consciousness of the problem and some research teams are now working to recuperate the loss of many years of over confidence in natural endowment. It was as Gaston Marcotte called it a "réveil brutal" (Marcotte) (46) in an article dealing with the need for research in hockey in which he summarized the actual situation as follows:

> "La défaite de 9 à 0 des Petes de Peterborough de la ligue Junior Majeure de l'Ontario aux mains des Russes et une troisième position au championnat junior du monde, démontrent clairement que la suprématie incontestée du Canada est maintenant chose du passé. Si nos juniors ne sont pas à la hauteur aujourd'hui, qu'en sera-t-il de nos séniors ~~et de~~ nos professionnels dans dix ans? Mais tout n'est pas perdu. Le

> Canada peut espérer continuer à rivaliser avec la Russie, la Tchecoslovaquie et les autres pays d'Europe qui ne cessent de progresser. Mais pour ce faire, les Canadiens, et tout particulièrement les dirigeants et les entraîneurs du hockey amateur et professionnel, devront changer d'attitude vis-a-vis la recherche, l'enseignement, l'apprentissage du hockey et les "hommes-ponts".

This awakening has been characterized for a few years by the multiplication of hockey schools for children and adolescents. As in any educational organization, evaluation became more and more important to justify the programs and to measure the progress of the "student". The standardization of tests specific to hockey began to take on more importance with the aim of comparing and classifying children as to their ability in the sport.

This has led to an interest in what Bouchard (7, p.96) calls the "déterminants variables specifiques de la performance sportive" which are the specific physical fitness of the athlete, his technical ability (effectiveness) and his strategic intelligence. The aspect which has attracted the greatest attention of physical educators involved in teaching ice-hockey is the technical ability of the student. For this purpose, many tests and batteries of tests (21,23,25,33,48) have been designed and are currently used by teachers in different schools. Unfortunately, many of them do not contain enough elements to evaluate the different qualities needed to be a well skilled hockey player. Some on the other hand, were not well tested for validity or were not applied to groups large enough to obtain good statistical evaluation (Larivière, 1974) (44).

Hockey Canada, in 1970, suggested a battery of tests and an investigation was undertaken under the responsibility of Professor Hal Hansen from the University of Ottawa to select and validate the tests. These tests as suggested were not related to the "in vivo" situation and no attempt was made to see how good the battery would predict the performance of young hockey players in the game. The present study was undertaken to try to answer at least partially the following recommendation of Larivière (1974) (44):

> ...Il serait intéressant de mesurer le rapprochement entre les résultats des tests "in vitro" avec la performance ou le rendement du joueur "in vivo".

The tests suggested by Hockey Canada were correlated to the overall performance of a group of young hockey players and compared to other tests which would belong to the category concerning the general physical fitness of the athlete.

STATEMENT OF THE PROBLEM

The purpose of this study was to examine the effectiveness of a battery of hockey skill tests to estimate or predict the performance of a group of 14 eight year old hockey players. The principal objectives of the study were as follows:

1. To test the effectiveness of the battery of hockey skill tests suggested by Hockey Canada (34) to predict the performance of a group of young hockey players.

2. To compare the prediction value of this specific

battery of tests to two other series of tests frequently used as a measure of performance, but which are not specific to hockey.

3. To find the best series of predictors using the three batteries of tests as source.

The two series of predictors used, besides the hockey skill tests, were classified as laboratory tests and field tests of physical performance.

A) Laboratory Tests

1. Maximum oxygen consumption
2. Strength (static)
    a) of the elbow extensors
    b) of the elbow flexors
    c) of the knee extensors
    d) of the hand grip
3. Skeletal Age

B) Field Tests

1. The CAHPER Fitness Performance Tests (10):
    a) 50 yard run
    b) 300 yard run
    c) Shuttle run
    d) One minute speed sit-ups
    e) Standing broad jump
    f) Flexed arm hang

C) Hockey Tests

The Hockey Canada Skill Test (34) contained the following elements:
a) forward skating 60', 90' and 120'
b) backward skating 60', 90' and 120'

c) an agility skating test

d) a puck control test

JUSTIFICATION OF THE STUDY

Performance has always been the center of interest of coaches and many physical educators. One of the problems in the area of measurement and evaluation in physical education is to build tests that really estimate or evaluate what they were designed for. Within a battery of skill tests for a given sport each element is usually a good measure of one of the abilities that is considered important to perform well in the sport. But unfortunately it is always difficult to evaluate the athlete, either young or old, for his overall ability to perform in a sport.

For the past few years the study of hockey has increased and many tests have been suggested to evaluate young hockey players. A particularly interesting battery of tests was proposed by Hockey Canada for different age groups. But to the knowledge of the author, no study has been done to investigate the effectiveness of this battery in predicting the overall performance of young hockey players.

This study was done to look at the effectiveness of the battery of tests suggested for boys of 8 years of age, to predict the overall performance of a particular group of young hockey players and to explore the possibility of using a combination of some of these tests with other performance tests to increase the power of prediction of the battery.

LIMITATIONS OF THE STUDY

An inherent limitation of the present study is the fact that only a small number of subjects were observed and a reasonably great number of tests were used as predictors. Another is the subjectivity of determining what represents good performance in hockey, especially when the number of people being involved in the task of estimating the level of performance of the players was small. The performance criterion was indeed marked by the philosophy of the evaluators and their conception of performance in hockey. The group used was very homogeneous and of particular capabilities as they were runners-up in the city of Edmonton for their age group. The fourteen boys represented the best of a group of 35 eight year olds who played hockey in the Edmonton Community of Malmo.

DELIMITATIONS OF THE STUDY

The fourteen subjects involved in the study were all members of the same team and even though they were playing in the same age group, most of them had attended many hockey schools and clinics. The two coaches of the team were used as evaluators as they were the persons who knew the capability of each boy and his contribution to the team. The team played in the Little Richard League of Edmonton.

This study did not attempt to select the physiological factors important in playing hockey or the physical qualities necessary to be a good hockey player. The tests other than the hockey tests were selected for their frequent use as predictor of physical performance and because some of them were estimated as being related to some of the qualities of a hockey player (subjective estimation) without being specific to hockey.

DEFINITION OF TERMS

Skeletal Age: Maturation level of the bones of the wrist and the hand as measured by roentgenography.

Maximum Oxygen Consumption ($M\dot{V}O_2$): the highest oxygen uptake an individual can attain during physical work at sea level.

Predictors: Variables used to predict the criterion, composed of laboratory tests, field tests or hockey skill tests.

Criterion: The value expressing the relative performance level of the subjects to play hockey, as judged by the team coaches.

Laboratory Tests: Measurements performed in the Exercise Physiology Laboratory and the Radiology Department of the University of Alberta and the University of Alberta Hospital.

Field Tests: A Fitness Performance Test suggested by the Canadian Association for Health, Physical Education and Recreation (1966).

Hockey Skill Tests: The battery of hockey skill tests suggested by Hockey Canada (1970) to measure speed skating forward and backward, puck control and agility.

Little Richard: Competitive hockey league for young boys aged eight and under in the City of Edmonton.

Roentgenogram: An X-ray film used in this study to estimate the skeletal age of the subjects.

Forward Players: A boy playing in any position other than goal tender.

STPD: Standard temperature and pressure, dry (0°C., 760 mmHg., dry).

CHAPTER II

REVIEW OF THE RELATED LITERATURE

SKELETAL AGE AND MOTOR PERFORMANCE

Maturity was and is still considered a very important factor influencing the physical performance of children. More specifically biological maturity (as measured by bone age) is thought to be closely related to motor performance in the young as it was shown in many studies (11,12,31,36, 37,56,59) on the other hand, Rarick (55), Balász (4) and Tihanyi (58) have shown that bone age is not an important factor in prediction of performance. Most of these studies have used the Greulich and Pyle (30) method for the assessment of the level of maturation of the bones of the wrist and the hand which was also the technique used in the present study. A few papers have reported the use of the Tanner-Whitehouse technique.

Bouchard et al. (6) showed large discrepancies in bone maturation (using Greulich) in children of the same chronological age. The range at the age of 8 years, for example, was from 7 to 9.25 years in their cross-sectional study on German children from 8 to 18. They also found high correlations between bone age and anthropometric measurements such as height, weight, bi-acromial and bi-iliac widths, and volume of the heart.

Most of the studies considering the correlation between maturity and motor performance have been done on children near the pubescent period, i.e., between 10 and 15 years old. The majority agree that the level of performance in sports is related to the level of maturity of the children. Hale (31) in an investigation of the physiological maturity of 112 children (10,11 and 12 year olds) playing in the 1955 little league world series found that the ability to play baseball was affected by the growth spurt at puberty. Although all of the boys were prepubescent chronologically, he found that 17% of the participants were pubescent, 45.5% post pubescent and 37.5% prepubescent. The technique used to evaluate maturity was the Crompton pubic air index.

Clarke and Petersen (12) compared maturational, structural and motor traits of upper elementary and junior high school boys (10 to 15 years old) with different levels of athletic ability in interschool competitive teams and with non athletes. At both school levels, they found that the outstanding athletes exhibited higher bone age (Greulich and Pyle) than non athletes and other athletes. The sports investigated were: tackle football, basketball, baseball, track and field, wrestling, tennis and golf. The general conclusion was that the superior athletes were definitely superior in maturity, body size, and build and relative (to weight and age) muscular strength and explosive muscular power.

Following the same line of thought Clark and Harrison

(11) compared the physical and motor traits of boys of advanced, normal and retarded maturity. The subjects were 273 boys of 9, 12 and 15 years of age. They concluded that the more mature group had higher means in tests. Normal and retarded subjects were significantly different in the cable tension strength test of shoulder flexion. The biggest difference occurred at 15 years for strength and at 9 for group strength, strength index and elbow flexion. The normal and advanced groups were found to be significantly different in grip strength at 15. The biggest differences were found in order between advanced and retarded, retarded and normal and normal and advanced subjects. Also the 15 year old boys showed the largest differences, followed by the 12 year olds and the 9 year olds, respectively.

Rarick and Oyster (55) in a study on 48 second grade boys found that skeletal maturity was of little consequence in explaining individual differences in strength and motor proficiency. The variables observed were the strength of 8 muscle groups, standing broad jump, 30 yard dash and the overarm throw.

Hollmann and Bouchard (36) in their Cologne study on 275 boys aged 8 to 18 studied the correlation between chronological and biological age (Greulich and Pyle technique) with anthropometric measurements, spiroergometric values, the volume of the heart and the strength of the skeletal muscle. They found higher correlations between biological age and anthropometric values than between chronological age and the anthropometric values. The heart in accelerated groups had greater diameters than in the retarded groups ($p=0.01$). Accelerated groups had larger heart volumes than the retarded ones ($p=0.001$), but this difference was not found to be significant if the heart volume was divided by body weight. At a work load of 7 kpm/sec the accelerated group was significantly different than the retarded group ($p < 0.01$) for oxygen pulse(greater in advanced), for respiratory frequency (greater in advanced) and pulse frequency (lower in advanced) at the chronological age of 8 years old. The accelerated group (chronological age 8) had significantly higher ($M\dot{V}O_2$ and $M\dot{V}O_2$/kg) maximum oxygen consumption than the retarded group for the same chronological age. The correlation coefficient between biological age and $M\dot{V}O_2$ was higher than between chronological age and $M\dot{V}O_2$ for the whole group of subjects (275). The accelerated group (chronological age 8) performed significantly better for the Physical Work Capacity 130 Test than the retarded subjects. They also found that the accelerated groups at all ages showed a more progressive development of strength within all examined muscle groups ($p= 0.001$).

Cumming (18), in a study of 68 girls and 103 boys, found a higher correlation between bone age (Greulich and Pyle technique) and performance than between chronological age and performance. However, no correlation exceeded 0.58 which was the correlation between the 100 yard run and bone age. The performances were drawn from the results obtained in a decathlon. The average chronological age of the boys was 14.9 and their skeletal age 15.2. He also considered the partial correlations of bone age to performance eliminating height and weight. The correlations were low ($< .50$) but all were significant at $p < 0.01$. These measurements were taken from children participating at a track camp and the events of the decathlon were high jump, broad jump, shot put, javelin, 100 yard dash and an 880 yard run.

Halliwell (32), in attempt to look at the relationship between growth and the level of participation of young hockey players found no significant correlation between height, weight, experience and classification in minor hockey. In 39 players of 7-8 years of age the correlations were lower than 0.33 and in the 9-10 year old boys the highest correlation was obtained between weight and classification ($r = 0.16$). The classification was based on the fact that the child was playing either in class 'A', class 'B', house league, recreation or novice category for his age level.

Tihanyi (58), in his study on the relationship of maturation to competitive swimming ability found that bone age was not an important factor in performance during swimming. He studied 36 boys (11-12 years old) participating at a provincial competition so that they were all high class swimmers for their age level. The highest rating for bone age (Greulich and Pyle technique) in the stepwise regression equation was third. This occurred for the 200 meter medley.

A general conclusion from this review is that performance on sports is different when considering retarded and advanced children of the same chronological age, especially when considering the period of puberty. It seems also that this relationship of maturity and performance tends to diminish, the greater the number of years before pubescence, i.e., the correlations are much lower at 9 years of age than at 12 and 15. However, no extensive study has been undertaken on children younger than 9 years and involved in a particular sport.

MAXIMUM OXYGEN CONSUMPTION AND PERFORMANCE

Maximum oxygen consumption ($M\dot{V}O_2$) is considered by exercise physiologists as being the best single measure of fitness (3,42,50). $M\dot{V}O_2$ is often referred to as a good index of one's performance level in a particular sport:

> "...the capacity of an individual to undergo prolonged physical work depends ultimately on his ability to utilize oxygen and expired energy. This measurement of the maximum rate at which the cardiorespiratory system can transport and the working muscles can utilize oxygen ($M\dot{V}O_2$) forms a useful guide to a person's exercise capacity".
>
> (C.T.M. Davies) (20)

However, not many studies have related $M\dot{V}O_2$ and performance in children especially under the age of 12. The relationship between performance in specific complex sports and $M\dot{V}O_2$ is not very well documented. However, Cumming et al. (18) investigated the correlation between $M\dot{V}O_2$ and performance in adolescents and Bouchard et al. (7) compared $M\dot{V}O_2$ and performance in adult ice hockey players.

Nevertheless, many investigations have been conducted to measure $M\dot{V}O_2$ and the work capacity of pubescent and prepubescent children (2,17,19,28,29,43) and a few studies looked at the $M\dot{V}O_2$ of adult hockey players (7,28,52).

G. R. Cumming and W. Friesen (17) measured the $M\dot{V}O_2$ of children while working on a bicycle ergometer. They did 7 to 15 tests on 20 boys ranging from 11 to 15 years of age. The average age of the subjects was 13.6 years. The subjects warmed up at a work load corresponding to 170 beats per minute (work load attained in a PWC_{170} previously performed) for 6 minutes. The work load was then increased progressively until the subject could not ride for more than 3 minutes. They obtained a mean maximum heart rate of 202 beats per minute and a mean $M\dot{V}O_2$ of 53.8 ml/kg.min. They estimated that the work load that the subjects were able to complete was such that a mean predicted pulse rate of 247 beats/minute would have resulted. A true plateau in O_2 uptake being difficult to obtain by exercising untrained children on a bicycle they obtained an O_2 value very close to the maximum with a single test by constructing a pulse rate curve from two submaximum tests and then exercising the subjects at a super maximum load that would produce a theoretical heart rate of 250 beats or greater.

Astrand (2) in a study on physical work capacity and its relation to sex versus age reported an average $M\dot{V}O_2$ of

56.9 ml/kg•min. for boys between the age of 7 and 9. The average height of the 12 children tested was 135 cm. and the average weight 30 kg. The children were from Sweden and the tests were performed on the treadmill. The test was done with the treadmill horizontal at a speed of 7.8 km/hr. for the first work load and an increase of 1.2 km/hr. was imposed on successive days until the subject reached exhaustion in 4 to 6 minutes.

Mirwald (49) performed a longitudinal investigation of maximal aerobic power in boys from 8 to 15 years old. The mean $M\dot{V}O_2$ was 58.45 ml/kg•min. for the eight year old age group. Twenty boys were tested in this age bracket and their average weight and height were 25.7 kg. and 127.7 cm. respectively. All tests were done on a treadmill. The subjects began the test walking for 3 minutes at 3 mph., ran for 3 minutes at 6 mph., 3 minutes at 9 mph., and for as long as the subject was able to continue at 12 mph.

Massicotte and Macnab (47) performed a study on the cardiorespiratory adaptations to training at different intensities in 36 boys aged 11 to 13 (average age 12.5 yrs). The testing was performed by means of a discontinuous test consisting of periods of 4 minutes of exercise separated by rest intervals of 5 minutes. They obtained the following $M\dot{V}O_2$ results before the training period (6 weeks) for their four groups: 46.7 ml/kg•min., 47.4 ml/kg•min., 46.6 ml/kg•min., and 45.7 ml/kg•min. for the high intensity group, medium intensity, low intensity group and the control group, respectively. It was found that only the subjects in the high intensity group increased their $M\dot{V}O_2$ significantly over the 6 week training period (mean 51.8 ml/kg·min.).

Ishiko (40) compared performance on the Harvard Step Test to performance in many sports. The subjects were candidates for the Tokyo Olympic Games, track and field athletes and oarsmen. He tested 17 intercollegiate track athletes on a bicycle ergometer. The athletes were divided into two groups, 8 long distance runners and 9 non-distance runners including jumpers and throwers. The following results were obtained: $M\dot{V}O_2$ of 2.5 l/min. or 45.3 ml/kg·min. and 2.0 l/min. or 34.4 ml/kg·min. for long distance runners and non distance runners, respectively, the difference between both groups was found to be significant ($p < .01$). He also compared the best time of several 5000 meter runners with $M\dot{V}O_2$. An r of -0.423 was obtained for $M\dot{V}O_2$ in l/min. and an r of -0.668 for $M\dot{V}O_2$ in ml/kg.min. The Harvard Step Test produced an r of -0.909. He concluded that $M\dot{V}O_2$ could be used as an external criterion of performance in endurance events.

Cumming et al. (18) reported the results from an investigation at a summer track camp. A correlational study was carried out between the maximal oxygen consumption of 20 boys aged 12 to 18 and their performance in a 880 yard run as well as in a 440 yard run. They found no correlation between the 440 yard run time and the $M\dot{V}O_2$ and a low correlation of 0.49 between the 880 yard run time and the $M\dot{V}O_2$.

However, the lowest times were associated with MVO_2's greater than 60 ml/kg·min. The attempt to find a correlation between the broad jump and MVO_2 gave an expected zero correlation. To compute the correlation coefficients MVO_2 was expressed in ml/kg·min. they reported an average MVO_2 for 14 boys of 3.92 l/min. The procedure used to measure the maximal oxygen consumption consisted of 2 submaximal loads of 6 minutes followed by a supermaximal load of 2-3 minutes in which expired air was collected for the final 30 seconds.

Corbin (14) studied the relationship of PWC to running performance of young boys. Sixty-four school boys from a pool of volunteers were selected from grades 3 through 6 (16 from each grade). They ran 200, 400, 600 and 800 yards and were tested on a bicycle ergometer to determine the PWC_{170} according to Adams (1) recommendations. The heart rate was telemetered during the runs. A latin square design was used to control for the order of running. They ran inside an airconditioned arena around a 100 yard square. The subjects performed all runs before the PWC_{170} test. Corbin did not find any r to be significant. The highest correlation was found with the 400 yard run for the grade 4 boys (r= -0.424).

In 1968 Nagai and Ogawa (51) tested all the candidates for the Olympic ice hockey team of Japan including measurements of body structure and physical fitness. In December of the same year the authors also measured the USSR good-will ice hockey team then visiting Japan, as well as members of other teams from Poland, Yugoslavia and Norway. The Japanese players scored lower than any other in all variables (height, weight, girth of the upper arm, of the chest, of the buttock and the thigh). In 1970 they measured $M\dot{V}O_2$ and O_2 debt of hockey players on the bicycle ergometer. The maximal oxygen consumption of 5 Japanese players was comparable to the $M\dot{V}O_2$ of Canadian players reported by Ferguson, 53.64 ml/kg·min and 55.70 ml/kg·min., respectively. It should be noted that Ferguson's test took place on an ice rink as mentioned later, and Ogawa's test was performed on a bicycle ergometer.

Ferguson et al (27) measured the MVO_2 of hockey players. The purpose of this study was to develop a test of $M\dot{V}O_2$ during ice skating and to determine its reproducibility by the test-retest procedure. Seventeen hockey players were tested at the end of their competitive season. The work loads were skating for 3 minutes on a 140 meter oval course around the rink. Velocities of 350, 382, 401, 421 and 443 meters per minute gave lap times of 24.22, 21.20 and 19 seconds/lap, respectively, in order to obtain increases in $\dot{V}O_2$ of 300 ml/min. for a one second decrease in lap time. A 5 minute rest was allowed between loads. Work loads were increased until the maximum voluntary work capacity was attained (decrease in speed within the three minutes). The subject was paced by a whistle signal recorded on a tape. Oxygen uptake was measured by an open-circuit gas collection apparatus carried by the subject. Expired gas was collected during the third minute of skating at each work load. Heart rate was recorded by telemetry. The subjects were wearing full hockey equipment plus the apparatus (10 kg). They concluded that the relationship between $M\dot{V}O_2$ and skating velocity was linear. At a velocity of 382 m/min. the mean $\dot{V}O_2$ was 46.7 ml/kg.min (40.1-54.7). The cost of skating at this velocity was related to the $M\dot{V}O_2$ of the subject (r = 0.64). The reproducibility of the test appeared comparable to other MVO_2 tests (r = .94). The mean MVO_2's were 4.04 and 4.08 l/min. or 54.8 ml/kg·min. and 55.3 ml/kg·min. for both tests, respectively. The values ranged from 44.9 to 68.5 ml/kg·min. with no significant difference between defensemen and forward players. An inter-individual variability of ±15% in $\dot{V}O_2$ was explained by differences in skill of skating.

Bouchard et al. (7) conducted a study in which the authors identified some of the physical and physiological characteristics of hockey players and their relationship with performance. They measured 24 junior players and 12 professional players for analysis of these characteristics. But only 12 junior and 11 professional players were retained for the correlational studies, as only forwards were studied. They divided the parameters studied into 10 subdivisions: a) weight, height, diameters; b) girth; c) adiposity; d) tissues composition; e) somatotype; f) reaction time; g) muscular strength; h) pulmonary indices; i) reactions to sub-maximum exercise; j) reactions to maximum exercise. The performance criterion was the ratio of goals scored and assists per game played. They obtained $\dot{M}VO_2$ measures of 54.1 ml/kg·min. as the average for the professionals and 58.4 ml/kg·min. for the juniors. The correlations between $\dot{M}VO_2$ and performance were 0.251 for the professionals and -0.309 for the juniors. The multiple R's computed for each sub-division and the criterion variable is not reported here because of some irregularities in the statistical procedures.

To conclude this section, a commentary by Macnab (45) about the use of $\dot{M}VO_2$ as an external criterion of performance seems very appropriate.

> "...Aerobic capacity also fails to take into account other factors involved in performance of physical work (i.e. specificity of task, motivation, strength, anaerobic capacity). The item which best correlates with the time required to run two miles as the time required to run two miles. Thus, in predicting performances, aerobic capacity, at best, only imitates specific tests.
>
> ...Variance characteristics of the sample and the relative contribution of aerobic capacity to a given type of performance should thus be seriously considered in any studies of the relationship of aerobic capacity to external criteria of performance".

FITNESS PERFORMANCE TESTS

Fitness performance tests are usually used to evaluate the general physical fitness of a population. They are relatively simple to administer and can be easily used in the field. There is a multitude of these batteries of tests.

Almost every state of the United States has its own battery of tests, the American Association for Health Physical Education and Recreation (AAHPER) has suggested one and the Canadian Association for Health Physical Education and Recreation (CAPHER) created one in 1966. There is a scarcity of literature on the use of these tests as they are rarely used for research purposes. Their application is more to sensitize the population to its fitness level and to allow the individual to compare himself to the rest of the country from the norms developed for different age groups.

In 1966, the Canadian Association for Health Physical Education and Recreation (CAHPER) under the direction of Yuhasz and Hayden (10) conducted a study on ten thousand boys and girls, aged between seven and seventeen on a battery of fitness performance items including: 50 yard dash, 300 yard run, shuttle run, flexed arm hang, standing broad jump and speed sit-ups. The mean values obtained for the boys of eight years old were: 50 yard run, 9.6 seconds; 300 yard run, 81 seconds; shuttle run, 13.5 seconds; standing broad jump, 47 inches; flexed arm hang, 27 seconds; one minute speed sit-ups, 24. These results and the results of all other age groups served to establish the Canadian norms which appear in the booklet edited by CAHPER in 1966.

As mentioned previously, these tests are used to assess the fitness level of populations, and are not very often used to measure the effect of training or are never related to performance in sports.

Cumming and Keynes (19) have used the CAHPER fitness performance test on seven hundred Winnipeg school children. Four hundred and ninety - seven children of the original seven hundred were tested. The battery contained: speed sit-ups, standing broad jump, shuttle run, flexed arm hang, 50 yard run and a 300 yard run. Students were not randomly selected, but were students from two classes of each grade from 1 to 12 chosen by the principals of the schools. The eight year old boys (n=39) obtained the following mean results: sit-ups, 27/min.; broad jump, 51 inches; arm hang, 27 seconds; shuttle run, 13 seconds; 50 yard run, 9.3 seconds; and 300 yard run, 77 seconds. The correlation coefficients between the test items vary from a low -0.37 between the flexed arm hang and the 50 yard run to a high of -0.76 between the shuttle run and broad jump and the 300 yard run and broad jump. Comparing every variable to $M\dot{V}O_2$ and PWC_{170}, they found the correlation coefficients presented in Table I. They concluded that height and weight are better predictors of PWC_{170} and $M\dot{V}O_2$ than any of the test items.

These studies reported the use of fitness tests to evaluate the level of fitness of the individual compared to norms or compared these tests to other performance tests, but none compared them to performance in a sport activity as it is the case in the present study.

MUSCULAR STRENGTH AND PERFORMANCE

Strength is probably the oldest measurement taken to

TABLE 1

CORRELATION COEFFICIENTS BETWEEN CAHPER FITNESS TESTS AND PWC_{170} AND MVO_2 FOR BOYS

Test Item	PWC_{170}	MVO_2
Sit-ups	.58	.42
Broad Jump	.76	.69
Shuttle Run	.54	.50
Arm Hang	.53	.43
50 Yard Run	.55	.60
300 Yard Run	.68	.65
Multiple R	.76	.75
$p < .001$		

*Adapted from Cumming and Keynes (19)

evaluate the physical capacity of athletes. This muscular quality was shown by many researchers to be related to physical performance and to motor performance (5,12,13,22,36, 58,60) and basic to athletic performance.

Digiovanna (22), in a study on 836 students (17 to 24 year olds), including 102 university athletes plus another 95 athletes, compared structural and functional measurements to success in sports (the other 639 students involved in the study were considered as non-athletes. The sports studied were baseball, basketball, football, gymnastics and track and field. In each sport it was found that functional qualities (strength and power) were related to success in sport but not for tennis. Comparing the whole athletic group to average individuals, it was found that they were characterized by higher strength and power measures as well as different structural characteristics. Digiovanna concluded that body structures, muscular strength and explosive power are associated with athletic success; these factors being of varying importance to performance indifferent sports.

Wilhelm (60) attempted to measure the traits that contribute to success in football. In this study Wilhelm employed 65 freshmen football players and 65 freshmen nonplayers. The author administered 44 tests of mental, physical, and visual ability. The football players were classified as successful or unsuccessful by the coaches. The football players were found to be characterized by better strength, structure, power, agility, speed, kinesthesis, depth perception, visual acuity compared to the non-football players. The successful football players were stronger faster, more agile and found to have larger girth and speed than the unsuccessful players.

Hooks (37) studied the predictability of baseball ability by analyzing measures of strength with success in baseball. Low correlations were found between structural measurements and the criteria (hitting and throwing ability). Strength and the criteria were highly correlated. Hooks obtained an r of 0.79 between left shoulder flexion strength and hitting ability, and r of 0.72 between right shoulder flexion strength and throwing ability and an r of 0.62 between left shoulder flexion strength and the total ability to play baseball. Hooks completed the study employing 56 men and over all ability was evaluated from the average of the scores of the different criteria.

Barry and Cureton (5) utilized factor analysis in a study on physique and performance in prepubescent boys. The subjects were 95 boys aged 7 to 11. The subjects performed a total of 37 tests. Performance was evaluated from 10 measurements: total strength, chins, dips, curler hips, standing broad jump, 440 yard run, running broad jump, high jump, drop off, agility run. It was found that power, endurance and dynamic shoulder strength were related to motor performance and that the morphological measurements did not relate to performance.

Clarke and Petersen (12), in a study (reported earlier) on contrast of maturational, structural and strength characteristics of athletes and non-athletes 10 to 15 years of age concluded that strength was a consistent differentiator of athletic ability.

Tihanyi (58) (reported earlier) studied the relation of maturation to performance in swimming. His study involved 36 boys aged 11 and 12 participating at the provincial finals for this category for the Province of Alberta. One of the important points of his conclusions was that the results illustrated well that strength is basic to athletic performance. The regression equations included maturation, flexibility, strength and vital capacity.

From these studies it is clear that strength is an important factor in the performance of most sports. But its influence on athletic success is relative to the sport considered. It is of less importance in sports based on high coordination and strategy compared to contact sports.

Bouchard et al. (7) in the study reported earlier obtained the following results for muscular strength of hockey players. For the professionals they found 33 kg., 28.8 kg., and 57.7 kg. for elbow flexion, elbow extension and knee extension, respectively. The juniors had values of 34.8 kg., 33.2 kg., and 64.1 kg. for elbow flexion, elbow extension and knee extension. The professionals completed 44.6 sit-ups in one minute while the juniors performed 47.3. The simple correlation between strength and performance were as follows: elbow flexion, professionals r=0.128; juniors r = 0.110; elbow extension, professionals r = 0.078, juniors r = -0.304; knee extension, professionals r = 0.064, juniors r = 0.0271. These results will be discussed later.

HOCKEY SKILL TESTS AND PERFORMANCE

A few attempts have been made to develop hockey skill tests (Brown 1935, Sabasteanski, 1949, Dewitt, 1953, Percival 1956, Tower, 1959, DeVincenzo, 1960, Doroschuck and Marcotte 1965, Hache, 1967, Merrifield and Walford, 1969, Fédération Svédoise de Hockey sur Glace, 1971, Hockey Canada, 1970, and Enos, 1973)*. Some of these tests are single tests to measure one simple skill (Doroschuck and Marcotte, 1965, Sabasteanski, 1949, Tower, 1959). Others contain more than one test but with no attempt made to study their value as a battery (Hockey Canada, 1970, Brown, 1935, Percival, 1956). Other studies have looked at the interrelation between certain tests and at the ability of the battery to predict or evaluate the overall performance of a player (DeVincenzo et al., 1960, Hache, 1967, Merrifield and Walford, 1969 and Enos, 1973).

Larivière (44), in an article on performance tests to measure the technical ability and the specific fitness of hockey players reviewed the skill tests existing in hockey. The content of each battery or test appears in Table . Some of these tests will be reviewed here to indicate the characteristics of these tests in general, according to the

*Reported by Larivière (44)

TABLE 2

AVAILABLE TESTS MEASURING TECHNICAL ABILITY OF HOCKEY PLAYERS

Author	Elements of the Tests					
	Speed Skating Forward	Speed Skating Backward	Puck Control	Agility	Shooting	Passing
Brown (1935)	x		x		x	
Sabasteanski (1949)				x		
Dewitt (1953)	x		x		x	
Percival (1956)	x		x	x	x	
Tower (1959)	x					
DeVincenzo (1960)	x		x	x	x	
Doroschuck & Marcotte (1965)				x		
Hache (1967)	x	x	x	x		
Merrifield & Walford (1969)	x	x	x	x	x	x
Sweden Ice-Hockey Federation (1971)	x	x	x	x		
Hockey Canada (1970)	x	x		x		
Enos (1973)	x		x	x	x	x

*From Larivière (44)

three categories mentioned earlier (single test, independent tests battery, related tests battery).

Dewitt (21) mentioned three tests to evaluate what was estimated to be extremely valuable to the successful hockey player: shooting, stick handling, speed. Unfortunately, Dewitt did not mention any statistical analysis and the procedure was not very precise.

Doroschuck and Marcotte (23) created an agility test for hockey. The test consisted of an adaptation of the Illinois agility run to hockey. The validity of the test was tested against the evaluation of the coach (r=.83) and the reliability by a test-retest procedure (r=.93). The authors reported that in the selection of 15 players for a hockey team, the top 13 in the test were also selected by the coach.

Larivière (44) reported that DeVincenzo, Kelly [illegible]n (1960) suggested a battery of four tests: speed [illegible]uck movement, skating agility and accuracy of [illegible]as a measure of the potential of high school play-e[illegible]e four tests were well standardized but the validity co[illegible]cients (correlation between tests results before the se[illegible] and classification by the coach at the end of the se[illegible]n) were, for some reason, very low, ranging from 0.11 to[illegible].74.

Merrifield and Walford (48) proposed the use of forward skating speed (120 feet), backward skating speed (120 feet), skating agility, puck carry, shooting and passing as tests of hockey ability. They tested the battery by administering it to 15 male college students playing for the same club, but of various levels of ability in hockey. To validate their tests the authors compared the results to a ranking made by the coach. All tests correlated significantly to the ranking of the coach. In the intercorrelation analysis, Merrifield and Walford found four tests significantly related to each other (3 at $p < .01$ and 1 at $p < .05$). Skating agility and backward speed gave an $r = .91$. Puck carry correlated significantly to the three other tests and was found to be the best single item for measuring the overall ability to play hockey. The authors concluded that forward skating speed, puck carry and either backward speed skating or skating agility may be used to measure ice hockey skills. Shooting and passing tests were rejected because of low reliability (respectively, 0.62 and 0.37).

Hockey Canada, in 1970, engaged Hansen, Moore and Mahoney (34) from the University of Ottawa to validate a hockey skill test battery. The investigators designed, refined and administered 16 tests in the hockey skills areas of skating, passing, shooting and puck control. The study was performed on 200 subjects of the following caliber: Mosquito, PeeWee, Bantam and Junior A (Mosquitos under 10 years, Pee Wees under 12 years, Bantams under 15 years). The tests on passing and shooting were rejected as they did not meet the statistical requirements and were recommended for further investigations. Hansen et al. recommended that a battery of hockey skill tests should be prepared containing the best test in each of the four areas of hockey skills. Of these tests (sixteen) eight were used in the present study as they were recommended for boys under 10 years of age. They are: the Hansen modified-3 agility test, the Marcotte modified puck control test, and six skating tests (60, 90 and 120 feet forward and backward). Only the results on the tests recommended by Hansen (33) will be reported here. It is of interest to note that the correlations between many of these tests were high. These correlation coefficients were calculated for the whole population (173 out of the 200 original subjects).

The results for the recommended tests can be summarized as follows:

Forward skating: for this test the boys under 10 years gave larger t values on the 90 feet test. Boys over 10 yielded better t values for the 120 ft. test. The 90' predicted the 120' with a correlation coefficient of 0.81. The 0.01 level of significance was obtained and the reliability coefficients were 0.71 for both tests (N=173)(the first 60' was rejected being considered a warm-up phase).

Backward skating: as for the forward skating tests, younger boys (under 10) yielded better results on the 90' test. The 90' test was a good predictor of the 120' test. Furthermore the 120' test predicted the agility and puck control tests. The t values were significant at the 0.01 level. The reliability coefficients were, respectively, 0.79 and 0.84 for the 90 and 120' tests (N = 173).

Agility: all the t values were significant in this area (five tests were tried). The last one on such final modification occurred (Hansen modified-3) was used on the junior players (N = 15). This test predicted both forward and backward skating. This test yielded the best validity results. The reliability coefficients for this agility test were 0.58 (junior players, N=15) and 0.48 (Bantam players N=28). On 14 physical education majors and 14 visiting players the authors reported a reliability value of 0.87.

Puck control: four puck control tests were studied. The Modified Marcotte and the Hansen tests were the two that met the criteria. The Modified Marcotte (used in the present study) obtained a reliability coefficient of 0.74 and it was a predictor of tests in other categories of skills (Hansen puck control r = 0.84). The correlation coefficients with forward skating (the 90' and 120' tests) were, respectively, 0.64 and 0.53. Backward skating (90' and 120' tests) yielded correlations of 0.61 and 0.55. Puck control correlated with agility (r = 0.57). The t values were significant and the test (Modified Marcotte) was suggested for boys under 10 years of age.

The Hansen puck control test predicted more tests in other areas than any other test. The t values were significant at the 0.01 level when the groups were compared to the junior players (criterion). This test tended to have lower correlations with other tests, indicating a measure of puck control to a better extent than other tests. The reliability coefficients for different groups were as follows: Juniors r = 0.74 (N=15), Bantams r = 0.51 (N=54), Pee Wee r = 0.66 (N=32).

The validity coefficients, as obtained from correlations between ranking of experts and actual measurements, for each test were as follows: forward skating 90 and 120 feet, 0.58; backward skating 90 feet, 0.66 and 120 feet 0.62; agility, 0.58; Modified Marcotte puck control 0.63 and Hansen puck control 0.51.

Enos (25) developed and evaluated a battery of tests to measure selected hockey skills. The results of the battery were compared with ranks assigned by a panel of coaches based on the subjects' abilities in five intrasquad games. The battery was administered to 126 subjects on seven teams representing four levels of hockey proficiency; bantam, senior high school, college and professional. Reliability was determined by test-retest method. The validity of the battery was tested by an analysis of its ability to discriminate the ascending order among the levels of hockey proficiency and by comparison with ranking of coaches (7 experienced men from the four levels of proficiency). The final battery consisted of seven tests which were weighted, being based on a 10 point scale. The battery was comprised of four skill areas: skating, stick handling, shooting and passing. The skating area was composed of skating agility, starts-stops-turns, and forward skating speed. The stick handling consisted of only one test. Shooting was composed of the wrist shot and the slap shot. Passing was tested by a forehand passing test. The weight for each test was as follows:

Skating agility	1
Start-stop-turn	1
Forward skating speed	1
Stick handling	2
Wrist shot	1-1/2
Slap shot	1-1/2
Forehand passing	2

As a conclusion to this section, the Larivière's statement* is appropriate:

> "...these different trials show the complexity of ice hockey and experts in this discipline do not agree on the relative importance of the different technical elements as well as on their essential characteristics".(44)

It is also of importance to note that too often the tests did not undergo proper statistical analyses and that not many batteries were tested for their capacity to predict the overall ability of hockey players. However, many of these tests can be useful to the teacher or the coach who wishes to follow the evolution of his players, and to evaluate his teaching methods for single skills.

*Translation by the writer

CHAPTER III

METHODS AND PROCEDURES

SAMPLE

The subjects for this study were all from the community of Malmo in Edmonton, Alberta. The group included fourteen boys, members of a hockey team participating in the Edmonton Little Richard League for the community of Malmo. All players were 8 years of age as of December 31, 1973. They were highly trained and the team finished second in the City of Edmonton for that age group. Some characteristics of the subjects appear in Table 3 (Chapter IV).

TESTING

The three batteries of tests used were a hockey skill test battery, a laboratory group of measurements and the CAHPER fitness performance test as described in Chapter I.

All physical performance tests were done in the main gymnasium and in the Exercise Physiology Laboratory of the University of Alberta, and at the University of Alberta Hospital for the X-Ray of the wrist. The hockey test was done on the outdoor rink of the community of Malmo during the second week of February and all the other measurements were taken within a month of that time.

TESTING PROCEDURE

The Hockey Tests

Near the end of the hockey season (ie. after 30-40 games) on February 13th, 1974, the fourteen boys were evaluated for their skills. The test was performed at 5 p.m. and at a temperature of 15 degrees Fahreinheit above zero. The test used was the one suggested by Hockey Canada which was developed by Hansen et al. (33,34). The battery of tests includes four items: forward skating, backward skating, agility and puck control. The backward and forward skating was measured at 60, 90 and 120 feet with the start on the goal line and the first mark at the first blue line, the second mark at the center red line and the third mark at the far blue line. The time was recorded in seconds to one tenth of a second at each distance. The subjects were sent two at a time to increase the motivation, but only one was timed each time. The signal was given verbally by the starter to the performer who started about 10 feet behind the goal line and a visual signal given to the timers when he crossed the line, eliminating the problems of readiness and false starts.

The agility test consisted of a speed skating following the pattern presented in Figure 1. Starting at the midpoint between the blue and the central (red) lines the subject skated backward to a pylon behind the blue line and pivot turned forward. He jumped over the blue line and skated forward to the stick lying on the ice. He then ran along the length of the stick and did a figure eight pattern around cones on the red line. The finish was at the blue line, 15 feet farther than the starting point. If the on February, 13th, 1974, the fourteen boys were evaluated for their skills. The test was performed at 5 p.m. and at a temperature of 15 degrees Fahreinheit above zero. The test used was the one suggested by Hockey Canada which was developed by Hansen et al. (33,34). The battery of tests includes four items: forward skating, backward skating, agility and puck control. The backward and forward skating was measured on 60, 90 and 120 feet with the start on the goal line and the first mark at the first blue line, the second mark at the center red line and the third mark at the far blue line. The time was recorded in seconds with one digit after the decimal point, each time the subject went across the three testing points. The subjects were sent two at a time to increase the motivation, but only one was timed each time. The signal was given verbally by the starter to the performer who started about 10 feet behind the goal line and a visual signal given to the timers when he crossed the line, eliminating the problems of readiness and false starts.

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Diagramatic Representation of Agility Test

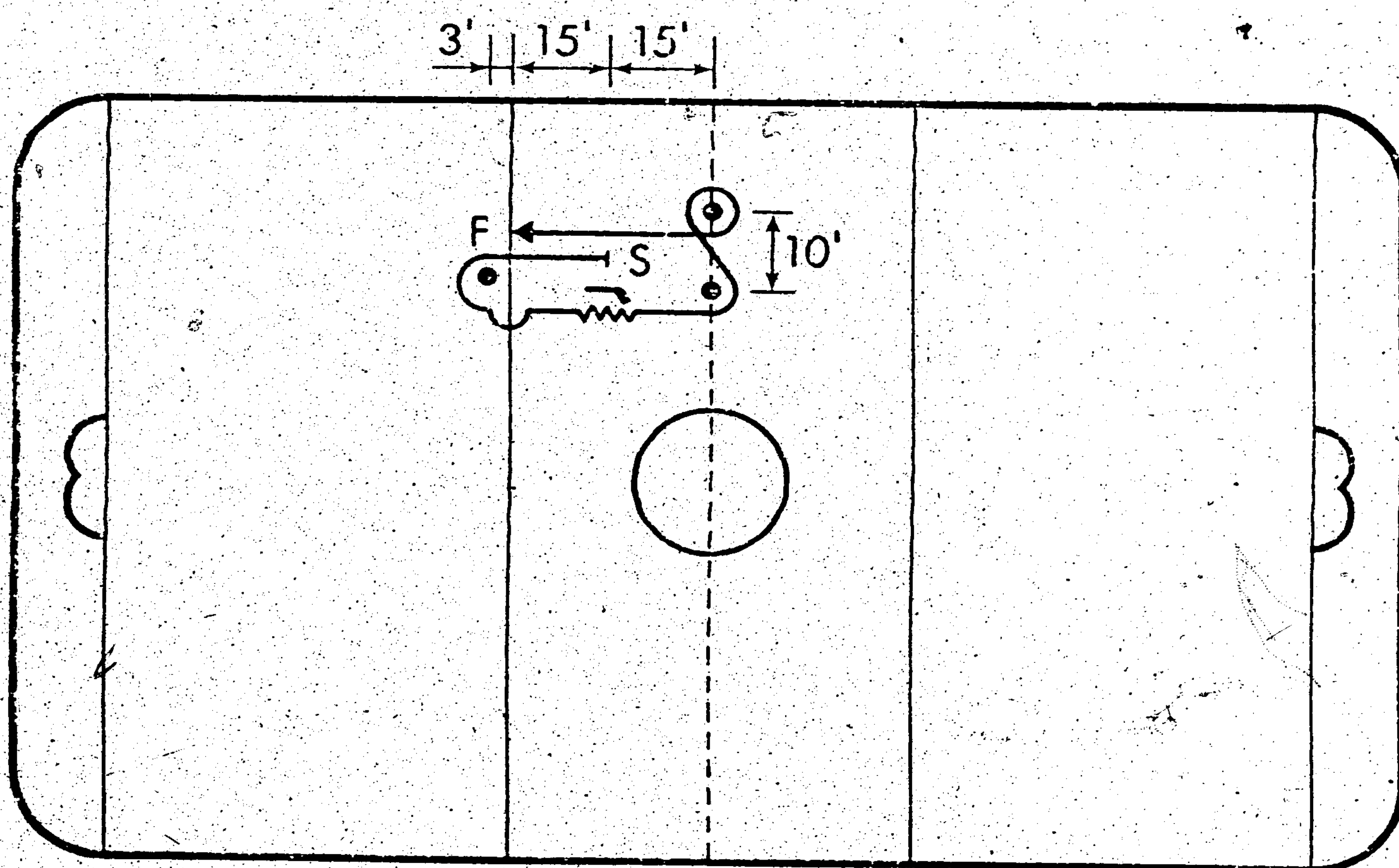

Figure 1

participant fell during the test, he was given a repeat trial.

The puck control test was the Marcotte modified puck control test. A representation of the pattern of the test appears on Figure 2. From a standing start with both skates touching the goal line and with a puck at his stick, the subject skated to point A, stopped, changed direction, (still skating forward) skated to cone #1 and then weaved through cones 1,2,3 and 4 (as indicated on the Figure 2), then skated directly to the finish line. For this test, an incorrect execution was followed by a repeat trial after the other subjects had completed the test. The watch was stopped as the subject skated across the finish line.

Both puck control and agility tests were performed by each player individually and a clear explanation and demonstration was given prior to the beginning. All battery tests were performed with the players wearing their whole hockey equipment.

MAXIMUM OXYGEN CONSUMPTION TEST

During the last week of March, all subjects were tested for their maximum oxygen consumption on a Monark bicycle ergometer modified at the University of Alberta for the testing of young children. The test used was a graded discontinuous test. After a 5 minute rest period (sitting on the bike), each subject performed two workloads of four minutes each, separated by a five minute rest period. Expired air was collected in a Douglas Bag during the last minute of each

Diagramatic Representation of Marcotte's Puck Control Test

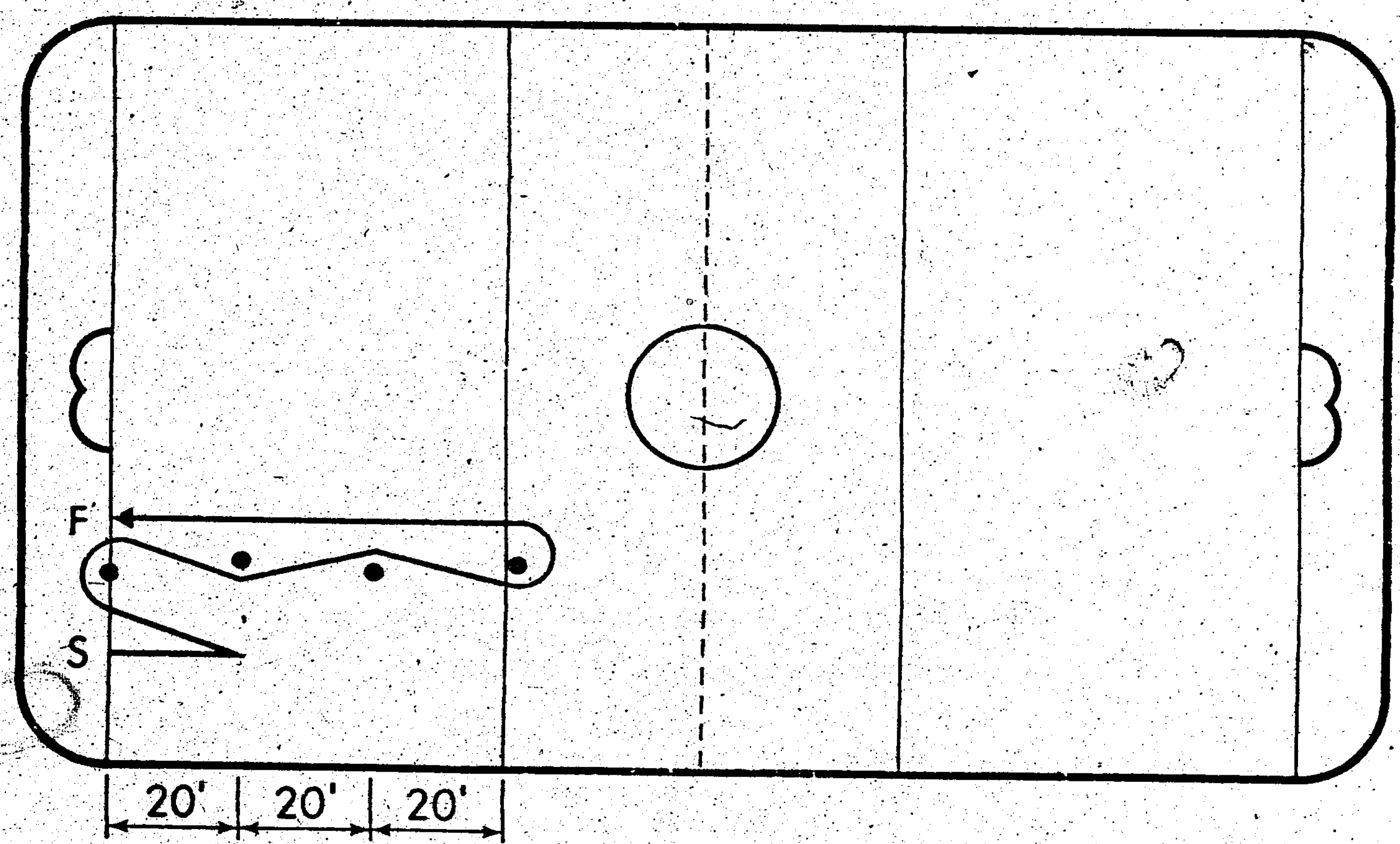

Figure 2

workload and was analyzed for O_2 and CO_2 content by means of a Beckman paramagnetic O_2 analyzer (Type E2) and a Godart infrared CO_2 analyzer. The pedalling rate was set at 60 revolutions per minute. Maximum oxygen consumption was expressed in ml/kg.

The initial workload was determined from a PWC_{170} test that the subjects had taken a few weeks before. This workload corresponded to the intensity at which they attained a heart rate of 170 beats per minute. The second workload was chosen arbitrarily to get a maximum oxygen consumption from the subject during the last minute of this second bout. The subject was asked to pedal as fast as he could during the last minute of the second workload to attain a maximum O_2 consumption. The procedure was adopted after experience in testing children for maximum O_2 consumption. At that age children are impatient and as the time goes by they lose interest and it is really difficult to obtain a true maximal value of O_2 intake if a large number of workloads are used. This method makes it possible to complete the test in about twenty minutes, including the rest period.

All the gas measurements were corrected to STPD. The room temperature varied between 22° and 24°C and the relative humidity did not vary more than 15% (43-58%). The barometric pressure was between 700 and 711 mmHg. The ECG of the subject was recorded on a Sanborn 500 visocardiette, from a three lead position; two on the chest and a third fixed just below the right scapula, and the heart rate calculated from the distance between three adjacent QRS peaks with the paper running at 25 mm/sec.

Prior to being tested, the subjects were weighed in pounds and measured in inches on a Detecto-medic scale. The pounds were converted to kilograms to give the MVO_2 in ml. per kilogram of body weight.

CAHPER FITNESS PERFORMANCE TESTS (10)

a) The 50 yard dash was a timed straight-away sprint run in pairs;

b) The 300 yard run was a timed (six times 50 yards) straight-away, back and forth around markers. It was also run in pairs;

c) The shuttle run was a back and forth run between two lines, thirty feet apart. The subjects had to pick up a small block from the far line, bring it and put it on the starting line, run back, pick a second block and run across the starting line. The subjects had to start lying on the floor, face down. The time was recorded in seconds;

d) The one-minute speed sit-up test in which the subject started from a back-lying position, knees flexed, feet flat on the floor. The subjects' feet and flexed knees were supported by the test administrator. He sat up touched both elbows to his knees, then returned to the starting position. The number of times was recorded;

e) The standing broad jump in which a distance from a take-off line to the nearest point of landing from that line was measured in inches;

f) The flexed arm hang in which the subject tried to hang as long as possible from a horizontal bar. The time was recorded in seconds.

STREN[illegible]TS

[illegible]easures were taken in the strength laboratory. A gri[illegible] test was performed using a Stoelting adjus[illegible]le [illegible]amometer. The results of two contractions [illegible] re[illegible]ed. The best result was retained (Hetherington, 3[illegible]

[illegible]g a modified model of the new Hettinger chair, bui[illegible] the machine shop of the University of Alberta by the [illegible]hnical Services Department, and equipped with a spec[illegible] seat for children, measures were taken on arm extensi[illegible] and flexion (elbow extension and flexion) and knee extens[illegible]. Measures were made using a Cable Tensiometer Model T5, Serial Number 10945 (Pacific Scientific Company), and cal[illegible]ted before each session of testing. Conversion tables [illegible]unds from the tensiometer units are found in Append[illegible] E. Two trials were performed for each test and the best was recorded (39). The starting angle was 90 for all tests, with the forearm parallel to the floor and the leg perpendicular to the floor. All strength measures were taken on the left limb.

The CAHPER tests and the strength tests were performed during the same testing period, but several days after the maximum oxygen consumption tests.

SKELETAL AGE

Skeletal age was estimated by the hand-wrist roentgenographic technique outlined by Greulich and Pyle (30). Hand wrist roentgenographs were taken by a registered X-Ray technician from the University of Alberta Hospital in Edmonton. The roengenographs were interpreted by Dr. C. Stuart Houston, professor and assistant director of the Department of Diagnostic Radiology and consultant to the Saskatchewan Growth and Development Study.

The specifications of the roentgenogram, materials and procedure were as follows:

1. The left hand was placed palm downwards in contact with the film, and the axis of the middle finger was in direct line with the axis of the forearm. The fingers were slightly apart and the thumb placed in the comfortable, natural degree of rotation with its axis making an angle of about 30 with the first finger. The palm was pressed lightly downwards on the film.

2. The tube was centered above the head of the third metacarpal at a tube-film distance of 30 inches.

3. The type of films used were; Kodak x-o-matic cassettes with five intensifying screens and Kodak x-o-matic "G" films.

4. The films were identified in the dark room and processed through a Kodak M6A processor.

5. The exposure used was 200 MA (milliampere) at 0.1 second and 54 kilovolts.

THE PERFORMANCE CRITERION

The hockey players were evaluated and ranked from 1 to 14 by their two coaches (Table 14). All 14 players were forward players, the goal tending position being held in rotation by four of them throughout the season. It should be noted that 1 was the highest rating and 14 the lowest. Hence, some correlation coefficients are negative when the performance criterion is involved.

STATISTICAL PROCEDURES

A correlation matrix was computed from the results of the three different groups of tests and the performance criterion value. The calculations were performed by the computer IBM 360 of the University of Alberta using the program for correlation from the statistical package for Social Sciences (SPSS) (52,p.181).

A regression equation was computed for each group of tests versus the performance criterion. This gave the original regression equations. From the considerations of the multiple R's obtained for each group of data, and the correlations inter-variables and the correlation of variables with the performance criterion, multiple additional regression equations were tested in an attempt to find the best predictors of performance using as many hockey tests as possible.

The small number of subjects did not allow the use of the stepwise regression equation (52,61) and the different steps (introduction of a new variable or displacement of one) were done by consideration of the increment of R^2 due to that variable and its correlation with the other predictors and the criterion.

The generalized equation of the model is:

$$\hat{y} = B_o + B_1X_1 + B_2X_2 + \ldots\ldots\ldots + B_nX_n$$

where $\hat{y}$ = predicted y (y = criterion)

B_o = constant term

B_n = regression weight

X_n = predictor variable

The variation percentages (r^2x 100) were calculated from the coefficients of regression between the predictor and criterion variables.

The regression equations were determined using the regression program of the SPSS on the IBM 360 computer of the University of Alberta.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS

1. The Tests

The raw scores for all tests are presented in Appendices A and B. Table 3 gives the means and standard deviations for the antrhopometric characteristics of the subjects. The means were 105.6 months, 108.5 months, 52.8 inches and 62.9 pounds for chronological age, skeletal age, height, and weight, respectively. The means and standard deviations for static strength tests are presented in Table 4 along with the means and standard deviations for hockey skills tests. On the hand grip strength, arm extension strength, arm flexion strength, and knee extension strength tests the 14 young hockey players obtained means of 43.3, 16.9, 20.9, and 42.5 pounds, respectively. The group of subjects scored 3.6, 5.0 and 6.5 seconds in front skating 60, 90 and 120 feet in order. For the back skating the means were 5.4 seconds on the 60 feet, 7.7 seconds on the 90 feet and 10.2 seconds on the 120 feet. The hockey agility and puck control tests yielded means of 12.7 and 18.5 seconds, respectively. For the CAHPER Fitness Performance Tests (Table 5) the 14 boys involved in the study averaged 8.9 seconds for the 50 yard dash, 68.5 seconds for the 300 yard run and 11.8 seconds for the shuttle run. On the flexed arm hang test they maintained the position for an average of 57.7 seconds. They jumped 55.7 inches on the average for the standing broad jump and completed an average of 30 sit-ups in one minute. The average pre-exercise heart rate and maximum heart rate were respectively, 97.07 and 198.85 beats per minute (Table 5). The average $M\dot{V}O_2$ for the group was 41.0 ml/kg.min (Table 5).

TABLE 3

ANTHROPOMETRIC CHARACTERISTICS OF THE SUBJECTS (MEANS AND S.D.)

CHRONOL. AGE (MONTHS)	SKELETAL AGE (MONTHS)	HEIGHT (INCHES)	WEIGHT (POUNDS)
105.6	108.5	52.79	62.9
± 2.8	±12.58	±1.79	±7.3

TABLE 4

MEANS AND STANDARD DEVIATIONS FOR STATIC STRENGTH TESTS AND HOCKEY SKILLS TESTS OF 14 EIGHT YEAR OLD HOCKEY PLAYERS

HAND GRIP STRENGTH (lbs)	ARM EXTENSION STRENGTH (lbs)	ARM FLEXION STRENGTH (lbs)	KNEE EXTENSION STRENGTH (lbs)	FRONT SKATING (sec.)			BACK SKATING (sec.)			HOCKEY AGILITY (sec)	PUCK CONTROL (sec)
				60'	90'	120'	60'	90'	120'		
43.3	16.9	20.9	42.5	3.6	5.0	6.5	5.4	7.7	10.2	12.7	18.5
±7.4	±4.9	±3.9	±9.7	±0.2	±0.2	±0.3	±0.3	±0.6	±0.6	±0.6	±1.1

TABLE 5

MEANS AND STANDARD DEVIATIONS FOR THE CAHPER FITNESS TESTS, $\dot{M}VO_2$, RESTING AND MAXIMUM HEART RATE OF 14 EIGHT YEAR OLD HOCKEY PLAYERS

50 YARD DASH (sec.)	300 YARD RUN (sec.)	SHUTTLE RUN (sec.)	FLEXED ARM HANG (sec.)	STANDING BROAD JUMP (inches)	ONE MINUTE SPEED SIT-UPS	PRE-EXERCISE HEART RATE (beats/min)	MAXIMUM HEART RATE (beats/min)	$\dot{M}VO_2$ (ml/kg.min)
8.9	68.5	11.8	57.7	55.7	30.0	97.07	198.85	41.0
±0.5	±3.0	±0.5	±19.1	±4.25	±9.0	±12.79	±5.92	±7.2

2. Correlation Coefficients and Regression Equations

Correlation matrices for all variables are found in Appendix C. The detailed regression equations are found in Appendix D along with the summary of analysis of variance of each of them.

The level of significance for the rejection of H_o and the acceptance of H_1 was fixed at .05 and 0.10 for the pearson product moment correlation coefficients and the multiple R, respectively.

CORRELATIONS

Significant correlations were found between the following variables ($p < .05$):

1) Skeletal Age and arm extension strength, arm flexion strength, hand grip strength, and puck control; respectively, 0.54, 0.51, 0.73 and 0.68.

2) Arm extension strength and hand grip strength, skating forward 120', skating backward 60', skating backward 120' and puck control; respectively, 0.56, -0.46, -0.51, -0.54, and 0.46.

3) Arm flexion strength and arm extension strength, skating forward 60', skating forward 90', skating forward 120'; respectively, 0.48, -0.75, -0.68 and -0.46.

4) Maximum oxygen consumption and the performance criterion -0.548.

5) 50 yard run and sit-ups per minute, arm flexion strength, skating forward 60' and skating forward 90'; respectively, -0.51, -0.65, 0.53 and 0.51.

6) Hand grip strength and sit-ups, 300 yard run, agility skating, puck control; respectively, -0.49, -0.55, 0.50 and 0.76.

7) 300 yard run and 50 yard run, with an r = 0.55.

8) Shuttle run and skating backward 60' and skating backward 120'; respectively, r = 0.70 and 0.56.

9) Flexed arm hang and 50 yard run, sit ups, and standing broad jump respectively, -0.48, 0.48 and 0.48.

10) Skating backward 60' and skating forward 120', skating backward 90' and skating backward 120'; respectively, r = 0.47, 0.72 and 0.94.

11) Skating backward 90' and standing broad jump, r = -0.57.

12) Skating backward 120' and skating forward 120' and skating backward 90', r = 0.46, and 0.80.

13) Puck control and sit-ups per minute and agility, respectively, r = -0.63 and 0.46.

MULTIPLE REGRESSION

The first step consisted of finding the multiple correlation coefficient of each of the three batteries of tests with the performance criterion. This was to determine which of the series of tests were the best predictor of performance as evaluated by the coaches. The next steps consisted of attempting to find the best predictor using the best arrangement of tests from the three batteries. This procedure could not be done by usual stepwise regression because of the small number of subjects and the number of tests. It was thus done by hand, retaining the best correlated factors with the criterion and eliminating factors having high (.40) intercorrelations. Thus if the correlation coefficient between factor "a" and the criterion was 0.54, the correlation coefficient between factor b and the criterion 0.52 and the correlation coefficient between the two factors was 0.50 then factor b was rejected from the predictor list and "a" retained.

For all regression equations, the level of significance considered minimum was 0.10.

LABORATORY TESTS

The highest multiple correlation from the first three blocks of tests was found using the laboratory tests as predictors. The multiple R in that instance was 0.79 with an R^2 of 0.62. Thus, 62% of the variability of the criterion with this series of measurements can be explained. The F test showed non significance at 0.10 level.

The regression equation obtained reads as follows:

$$* \hat{y} = 13.22 - 0.286X_1 + 0.013X_2 - 0.527X_3 + 0.484X_4 + 0.038X_5 + 0.098X_6$$

(X_1 being MVO_2, X_2 = skeletal age, X_3 = arm extension, X_4 = arm flexion, X_5 = leg extension and X_6 = hand grip).

*the regression coefficients are those obtained from raw data

THE FIELD TESTS

The second best predictor of hockey (performance criteria) was the field test series (CAHPER fitness performance tests). The multiple R computed using that group of predictors was 0.68. The R^2 was equal to 0.46 allowing one to explain about 45.8% of the variability of the criterion using this series of tests. The F test showed no significance at the 0.10 level.

The regression equation for this set of measurements was as follows:

$$\hat{Y} = 111.53 - 4.436X_1 + 0.014X_2 - 2.850X_3 - 0.032X_4 - 0.440X_5 - 0.192X_6$$

(X_1 = 50 yard run, X_2 = 300 yard run, X_3 = shuttle run, X_4 = flexed arm hang, X_5 = standing broad jump and X_6 = sit-ups per minute).

THE HOCKEY SKILL TESTS

The hockey skill tests produced the worse prediction with a multiple R equal to 0.44 and a R^2 of 0.19 explaining as less as 19% of the variability of the criterion. The F test showed no significance again at the 0.10 level.

The regression equation in this instance was as follows:

$$\hat{Y} = 10.8 - 9.237X_1 + 7.152X_2 - 1.389X_3 + 2.473X_4 - 3.964X_5 + 3.027X_6 - 0.178X_7 - 0.418X_8$$

(X_1 = skating forward 60', X_2 = skating forward 90', X_3 =

skating forward 120', X_4 = skating backward 60', X_5 = skating backward 90', X_6 = skating backward 120', X_7 = agility, X_8 = puck control).

THE SEARCH OF THE BEST EQUATION

In this second step, 10 regression equations were developed using different arrangements of variables. Two of them (Regression Equations 6 and 7) will not be considered here because of their weakness to predict performance. These two equations produced a multiple R of 0.51 and 0.30, respectively. The eight other series gave multiple R higher than 0.60.

Even though most of these equations had multiple R's higher than the Field Test and the Hockey Skill Test, only one of them appeared to be significantly different from 0 at the 0.10 level. This series of variables (regression equation 5) produced a multiple R equal to 0.81, allowing an explanation for 66.0% of the variability of the criterion. This equation was composed of the following variables: $M\dot{V}O_2$, arm extension strength, standing broad jump, skating forward 60' and skating backward 120'. This equation contained the highest simple correlation coefficient between predictors and the criterion as well as the variables among which the inter-correlation coefficients were as low as possible ($r < .40$). If we examine this equation closer, we can see that the variable which produced the greatest change in the multiple R was $M\dot{V}O_2$ contributing 30% of the 66% of variability explained by the whole equation. Skating forward 60' accounted for 22.4% of the 66% and arm extension for 10.3%. The other two variables contributed less than 2% each. (Skating backward 120'; 1.9% and standing broad jump for 1.4%).

This equation would be expressed as follows:

$$\hat{Y} = 45.255 - 0.378X_1 - 0.362X_2 + 0.02X_3 - 8.18X_4 + 1.192X_5$$

(where X_1 = $M\dot{V}O_2$, X_2 = arm extension, X_3 = standing broad jump, X_4 = skating forward 60', X_5 = skating backward 120').

All the other equations produced non significant R's. In order, the best prediction after the one mentioned above was given by equation number 8 with a R of 0.72, equation number 11 with a R = 0.71, equation number 9 with a R = 0.71, equation number 4 with a R = 0.69, equation number 10 with R = 0.68, equation number 12 with R = 0.65 and equation number 13 with R = 0.64. It is of interest to note that $M\dot{V}O_2$ was a variable in all of the best predicting equations and that the only two equations in which it did not appear are the two that were rejected at the beginning for having low multiple R's (equations 6 and 7).

DISCUSSION

The aim of this study was to analyze the possibility of using the Hockey Canada battery of hockey skill tests to predict the overall performance of young hockey players of eight years of age. No comparable study has previously been done on a group of this age. However, for the non-hockey variables, comparisons can be made using results obtained for similar measurements from other studies. The results from the correlations and regression equations can be compared with the results from different age groups on which similar studies were performed.

The height and weight of the group studied 52.8 inches and 62.0 pounds, are comparable to normal children of the same age group, as Adams (1), Cumming (19) and Howell (38) reported. These studies reported weights of 66, 66 and 61.82 pounds and heights of 52.4, 52.8 and 51.12 inches, respectively.

However, the maturity of the hockey players in the present study appears to be slightly advanced, as their skeletal age was somewhat higher than their chronological age. This difference could not be considered significant as the variation in bone age was very wide. Their chronological age was 105.6 months (S.D. 2.8) and their bone age was 108.5 (S.D. 12.58).

For the hockey skill tests, the subjects in the present study appear to be better performers than the 41 children (8 to 9-1/2 years) tested by Hansen (33). Hansen obtained means of 14.09, 23.15, 5.70 and 9.84

seconds for the agility test, the puck control test, and the 90' speed skating forward and backward, respectively. The children in the present study obtained the following results for the same tests; 12.7, 18.5, 5.0 and 7.7 seconds. The high performance level of the present sample seems to be confirmed here. It should be recalled that the team finished second in the city of Edmonton for their age group.

The results obtained in the present study for the maximum oxygen consumption however, were lower than the ones reported in the literature for that age group as the mean MVO_2 was 40.1 ml/kg.min. Astrand (2) reported MVO_2 of 56.9 ml/kg.min. for boys 7-9 years of age. Mirwald (49) obtained 58.45 ml/kg.min. (on treadmill) for boys of 8 years, as Cumming and Friesen (17) obtained an average MVO_2 of 53.8 ml/kg.min. in boys aged seven to fifteen. The possibility that not a true MVO_2 was obtained could be considered, but the heart rate for the last minute of testing was sufficiently high to consider it as maximum heart rate. The average maximum heart rate in the present study was 198.85, while Cumming (17) reported 202 beats per minute, so that a true MVO_2 is expected. The differences in procedure for the testing could account for some of the differences observed.

The data from Astrand as well as from Mirwald are hard to compare because they did the testing on the treadmill (MVO_2 being about 8% higher on a treadmill (3)).

In the CAHPER Fitness Performance tests the hockey players involved in this study performed better than boys of the same age as reported by Cumming (19) and CAHPER (10). Cumming reports the following results: 50 yards, 9.3 seconds; 300 yards, 77 seconds; shuttle run, 13.0 seconds; flexed arm hang, 27.0 seconds; standing broad jump, 51 in. and one minute speed sit-ups, 27. The CAHPER means for that age group are: 50 yard, 9.5 sec.; 300 yard, 78.0 sec.; shuttle run, 13.3 sec.; flexed arm hang, 23.0 sec.; standing broad jump, 47 inches and one minute speed sit-ups, 24. In the same order the group in this study obtained 8.9 sec., 68.5 sec., 11.8 sec., 57.7 sec., 55.70 inches and 30.0. For every test the subjects of this study were high in the CAHPER percentile scale. They were above the 90th percentile for the 300 yards, the 85th percentile for the standing broad jump and speed sit-ups and the 75th percentile for the flexed arm hang and the 50 yards.

The strength measurement can be compared to Howell's study (38) on young Albertans. Howell reported measures of 31.37 pounds, for the grip strength of the left hand of boys of 8 years of age, 28.07 pounds for the elbow flexion strength of the left arm, 24.63 pounds for the elbow extension of the left arm and 50.84 pounds for the knee extension of the left leg. The hockey players appeared to be stronger only in hand grip strength, where they obtained a mean of 43.3 pounds. The results for elbow flexion, elbow extension and knee extension were respectively, 20.4 pounds, 16.9 pounds and 42.5 pounds.

To summarize, the subjects in this study were somewhat better than most of the values found in the literature for the CAHPER Fitness Performance test, one strength measurement out of four and for the hockey skill tests for which some values have been published. However, they were comparable to other Canadian samples for height and weight, but below the average value for that age group for the maximum oxygen consumption measurements.

The correlation between the criterion and the variables in each series of tests will be discussed by comparison with similar studies reported in the related literature in a general way, as there is nothing similar on hockey. However, the correlations and regressions obtained between the laboratory tests and the criterion will be compared with the study of Bouchard et al. (7). The correlation and regression carried out from the skill tests and the performance criterion, as well as the correlation between all tests, will be compared with the results of Merrifield and Walford (48) and those obtained by Hansen on the same tests.

It is appropriate to stress at this point the inherent danger of making cross study comparisons of correlation, reliability and validity coefficients. Such coefficients are strongly influenced by the homogeneity or heterogeneity of the sample being used to determine the coefficient. The following example demonstrates this danger. Any of the hockey tests, i.e., agility, may be shown to be highly reliable, or valid if the coefficient is calculated from a sample comprised of an international hockey star, an average intramural player and a non-skater. The same test may be shown to be completely unreliable and not valid as the coefficient is calculated from a sample of three international hockey stars. Thus correlation, reliability and validity coefficients are only meaningful for the sample from which they were calculated, unless all previous influences can be eliminated.

SKELETAL AGE AND THE PERFORMANCE CRITERION

The correlation coefficient obtained between bone age and the criterion of performance in hockey playing agrees with the trends shown by some of the researchers whohave considered this parameter in youngsters below the age of 9. Rarick (55) and Balász (4) have shown that bone age is not an important factor in prediction of performance in children younger than 9 years. Their performance criterion was the results obtained in fitness and strength tests. The only study which could be compared to the one discussed here is Tihanyi's research (58). In this study, even though the children were 11 and 12 years old, he compared the variables measured with the actual performance in swimming. In this study, bone age was the third most important contributing variable. Clarke and Harrison (11) found that the difference between normal, advanced and retarded children for strength diminished for children under 15 years of age.

The correlation coefficient of -0.04 (non significant) found here on this group of children aged 8, is in agreement with the results reported in the literature. However, it is of interest to note that bone age was significantly correlated to grip strength of the left hand (r = 0.73). This result is comparable to the study of Clarke and Harrison (11), who reported the biggest difference in grip strength between retarded, normal and advanced boys at the age of 9. The correlation between bone age and $M\dot{V}O_2$ (r = 0.12), on the otherhand, is in disagreement with the results by Hollmann and Bouchard (36), who found better correlations between biological age and $M\dot{V}O_2$ than between chronological age and $M\dot{V}O_2$ (r = 0.89 and 0.86, respectively). However, their high correlations were to be expected due to the fact that they were investigating an age group from 8 to 18 years of age.

MUSCULAR STRENGTH AND THE PERFORMANCE CRITERION

None of the strength measurements were found to be in significant correlation with the performance criterion here. The highest (non significant) correlation coefficient was obtained between arm extension and the criterion (-0.39). These results do not agree with the concept that strength is basic to physical and sport performance as stated by Digiovanna (22), Wilhelm (60), Barry and Cureton (5), Clarke and Petersen (12), Clarke and Wickens (13), Hooks (37) and Tihanyi (58) and demonstrated in their studies. However, it should be kept in mind that only Tihanyi (58) compared strength measurements to actual performances in a competition. Wilhelm (60) in his study on football success, also found that strength was a very important factor.

On the other hand, the results of this study agree with the correlation coefficients published by Bouchard et al. (7). In the latter study on junior and professional hockey players, they found no correlation higher than -0.304 (arm extension strength and criterion for the juniors). They obtained multiple R's of 0.596 and 0.464 (juniors and professionals, respectively) using the strength measurements (arm extension, arm flexion, leg extension, sum of strength measures and total strength per unit of body weight).

It is of interest to mention that some measures of strength were found to be correlated to some of the hockey skill tests in the present study. The two which are of any significance in the theoretical approach are arm extension strength, which correlates significantly ($p < .05$) ($r = 0.46$) with puck control and hand grip and puck control ($r = 0.76$). Any further implication is beyond the scope of this study, in which no attempt was made to investigate the implication of particular physical qualities in playing hockey. These coefficients are probably another example of the "distortion" due to the homogeneity of the sample as one would have expected a negative correlation, if any for these parameters.

MAXIMUM OXYGEN CONSUMPTION AND THE PERFORMANCE CRITERION

Maximum oxygen consumption is the parameter which gave the highest correlation with the performance criterion ($r = -0.54$). This correlation coefficient, though it is the highest, cannot be considered to represent a strong relationship. Many studies have reported low correlation between $\dot{M}VO_2$ and the critical performance. T. Ishiko (40) compared the best time of several 5000 meter runners with $\dot{M}VO_2$ and obtained a correlation coefficient of -0.668. It is of interest to stress the fact that the long distance runners in this experiment averaged a low $\dot{M}VO_2$ per kg of body weight. This was partly accountable from the heterogenous nature of their sample. But it is amazing that they found a r of -0.909 with the Harvard fitness test. He also obtained 0.425 for the correlation between the performance of crews of oarsmen and the $\dot{M}VO_2$ of these oarsmen. Corbin (14) reported -.424 as correlation between 400 yard run and PWC_{170} in grade four boys. Bouchard (7) reported r's of 0.251 and -0.309 between $\dot{M}VO_2$ and performance in hockey for junior and professional players respectively. The multiple R's obtained for this subdivision of parameters (reaction to maximal and submaximal exercise) is questionable (junior: 0.998 and 0.96, pro: 0.980 and 0.96) and cannot be used to estimate the percent variation of the performance explained by these parameters. This problem will be discussed later.

It seems then, that the commentary of Macnab (45)(quotation p. 22, Chapter II) justified here and seems to be particularly applicable to complex sports such as hockey.

CAHPER FITNESS PERFORMANCE TESTS AND THE PERFORMANCE CRITERION

None of the items of the battery of tests were found significantly related to the performance criterion. The highest correlation coefficient appeared to be between the criterion and the number of sit-ups per minute ($r = -.30$). No study (to the knowledge of the author) has been done to relate the results of CAHPER Test and performance in athletics. It is then impossible to compare the present results with those in the literature. The low correlations obtained between the items of the CAHPER test and the performance in $\dot{M}VO_2$ is in no way comparable to those of Cumming and Keynes (19) and Olree et al. (53). This difference is hard to explain, although the cited studies were performed on much larger more heterogeneous groups with respect to physical abilities and age. It is of importance also, to mention that for the young hockey players tested here, the values for the $\dot{M}VO_2$ were below values reported in the literature for this age bracket and that on the otherhand, the results on the CAHPER Test were above previously reported results.

THE HOCKEY SKILL TESTS AND THE PERFORMANCE CRITERION

The correlations between the skill tests and the performance criterion were remarkably low for the group studied here. None of the correlation coefficients showed significance for this group of variables. It is difficult to compare these results to those possibly available in the literature because the tests are different from one study to another and very often the authors omitted to give values for correlation between tests and the overall ability to play hockey. But the tests used in the present study were tested for reliability and validity by Hansen et al. (34) and these results can be compared to what could be found in the literature for similar tests. Hansen reported (33) the reliability coefficients and validity coefficients appearing in Table 6 for the tests used in this study. It is interesting to note that the highest reliability coefficient was found for the Agility test (r = .87). Compared to Merrifield's results (48) these coefficients are low as Merrifield found reliability coefficient of .74, .80, .94 and .93 for skating forward, backward, agility and puck control. It is remarkable how the validity coefficients are low in Hansen's study as the highest coefficient is .66. Merrifield reported validity coefficients of .83, .79, .75 and .96 in his study. Merrifield related his tests to two different ratings by coaches, one about the performance on the tests and one about the overall ability of the players. Unfortunately, he did not report the results for the overall evaluation. However, he stated that the puck control test and either the backward skating or the forward skating may be used to measure hockey skills and that the puck control test was the best single item test for determining overall ice hockey ability.

Enos (25) reports very few statistical results, unfortunately, a more complete report was inaccessible to the author. Although he compared his battery to overall performance, and weighted the different elements of the battery so

TABLE 6

RELIABILITY AND VALIDITY
COEFFICIENTS OF HOCKEY SKILL TESTS*

TEST		RELIABILITY	VALIDITY
Forward Skating	90'	.71	.58
	120'	.71	.53
Backward Skating	90'	.79	.66
	120'	.84	.62
Agility		.87	.58
Modified Marcotte Puck Control		.71	.63

*as reported by Hansen (33)

as to estimate the overall ability from the results in each test. He reported high reliability, ranging from 0.898 to 0.978. He validated his battery by comparing the subjects' battery ranks and the subjects' panel of coaches' rank, r ranged from 0.817 to 0.922. These latter figures are far more impressive than the one found in the present study for the correlation between the coaches' ranks and the results from the battery of tests (r = 0.44) although the results in Enos study were not multiple R's, but simple correlations between the rank on the total score in the skill tests and the coaches' rank.

The correlations among tests can be found in Table 7, where the correlations from this study are compared to those found by Hansen with the same tests and to the inter-correlations reported by Merrifield (48) for his tests.

This leads to the consideration of the multiple regression equations. The low multiple R obtained with the performance criterion may lead to three fundamental questions in evaluation of sport skills. Are the tests as a group an estimation of the ability to perform in hockey? Does the variability of each test cover a substantial part of the variability of the criterion? Is the criterion representative of the performance in hockey? The first question can be answered by means of the change in the multiple R due to each of the tests of the battery. And the response here appears to be no. In no instance did one of the skill tests affect R by more than [illegible]8% in the case of backward skating

TABLE 7

INTERCORRELATIONS BETWEEN BATTERY TESTS OF HOCKEY ABILITY

	FORWARD SKATING 60' 1	90' 2	120' 3	BACKWARD SKATING 60' 4	90' 5	120' 6	AGILITY 7	PUCK CONTROL 8
1H		.82*	.65*				.36	.63**
J				.23	.08	.19	-.11	-0.15*
M								
H			.69				.48	.48**
2J				.13	.07	.15	-.13	-.12**
M								
H							.40	.48**
3J				.47	.16	.46	.11	.22**
M						.44***	.38***	.78***
H					.98*	.94*	.62	.62**
4J					.72	.94	.27	.01**
M								
H							.65	.69**
5J						.80	-.06	-.06**
M								
H							.64	.72**
6J							.29	.05**
M							.91***	.71***
H								.57**
7J								.46**
M								.74
H								
8J								
M								

H = Hansen 1970 — *From total group (Hansen)(8 to 18 yrs)
J = Jobin — **Modified Marcotte
M = Merrifield — ***Merrifield speed skating

NOTE: Figures with no star for Hansen are from Mosquitos (9,10) and Peewee (11,12) players. Merrifield's tests were done on college students.

90'. Although the multiple correlation coefficient for the totality of the hockey skill tests to predict performance is higher than the multiple R found using only the best 6 predictors. It should be kept in mind that the difference between these two coefficients is affected not only by the capacity of each test to explain a certain percentage of the variation of the criterion. The fact that the number of subjects was relatively low here and furthermore, the fact that the number of variables was fairly high compared to the sample size, and thus every multiple R obtained from more than four of five variables is questionable as the sample size, as well as the number of predictors affect it. This in reality, explains the "high" R's found even though the r's were low in many cases. This is an example of saturation due to a great number of variables. It could be shown that when the saturation is complete, i.e., as many variables as observations the R will always be equal to 1 (24,26). The results obtained by Bouchard et al. (7) are a good example of this phenomenon. The measures of reactions to submaximal exercise for instance, produced a R of .96 in the case of the junior players, when no correlation between the criterion and the variables was higher than .214 and seven of them were smaller than .10. In this case, the number of observations was 12 and the equation contained 10 variables.

The multiple correlation coefficients obtained with this group of hockey players of eight year olds could not be compared to any other results found in the literature. It appears that the battery of hockey skill tests is not a better predictor of performance than general fitness tests.

The lack of significance of many correlation coefficients with hockey performance and of the multiple correlation coefficients have to be expected from this kind of study. Hockey is a most complex and unnatural activity. The skill of skating is one of the least natural movements involved in any sport. Moving from a point to another in balance on two steel blades could not be compared to any common movement in everyday activity. Furthermore, the handling of a stick, displacement on every direction, conservation of balance and consideration of teammates, as well as opponents must be considered. One or a few simple tests or measurements cannot be expected to give an accurate estimation of the capacity to perform so complex a set of movements.

It seems important to again stress that the criterion of performance in hockey was indeed characterized by the personal philosophy and perception of thetwo coaches as to what is a good hockey player. The results as well as the conclusion presented in this study were to a certain extent biased in this direction and the reader should keep this fact in mind in interpreting the results. Considerable care should be exercised in generalizing from this study as it is unlikely that other groups would yield comparable regression equations.

CHAPTER V

SUMMARY AND CONCLUSION

The hockey skill battery proposed by Hockey Canada and validated by Hansen et al. (33) was tested as predictor of overall performance in young hockey players, and its prediction capacity was compared to the prediction value of two other battery of fitness tests not specifically related to hockey.

Fourteen eight year old boys playing in a competitive hockey league were measured on 20 variables divided into three batteries of tests, hockey skill tests, laboratory measurements and field tests. The laboratory measurements were composed of a $\dot{M}VO_2$ test, four strength tests and bone age. The field tests consisted of the CAHPER Fitness Performance test items. The fourteen players were ranked by their coaches on their performance within the team. These ranks became the performance criterion used in the building of regression equations. Variables from the two other batteries were added to the hockey skill tests to improve the prediction value of these tests. The best multiple correlation was obtained using $\dot{M}VO_2$, elbow extension strength, standing broad jump, skating forward 60' and skating backward 120' as predictors. It was the only R significant at $p < .10$ ($R = 0.81$). The hockey skill tests used alone gave the lowest multiple correlation (R = 0.44). Of the three batteries, laboratory measurement came first with a R of 0.79 and field tests second (R = 0.68). Inter-correlations, validity and reliability of the hockey skill battery were discussed and compared to similar studies.

CONCLUSIONS

From the results presented and discussed, it can be concluded that the battery of tests proposed by Hockey Canada (1970) is not an effective method of estimating hockey performance for 8 year old boys, whose ability is very homogeneous in nature.

Laboratory measurements such as $\dot{M}VO_2$, Bone age, muscular strength are better predictors of hockey performance than the CAHPER fitness performance tests and the hockey skill tests in eight year old boys whose ability is very homogeneous in nature. However, it should be noted that the multiple R's obtains in this study, i.e., .79 for laboratory tests, .68 for field tests and .44 for the hockey tests were not significantly different from each other.

Approximately 2/3 of the variation in performance in hockey can be explained using the following parameters as predictors: $\dot{M}VO_2$/kg, arm extension strength, standing broad jump, skating forward 60' and skating backward 120' in boys of 8 years of age whose ability is very homogeneous in nature.

The best single predictor of performance in hockey of the 20 variables studied appeared to be $\dot{M}VO_2$/kg.

Compared to other similar studies, Hockey Canada skill battery shows a lack of validity for boys of 8 years of age whose ability is quite homogeneous.

RECOMMENDATIONS FOR FURTHER STUDIES

Similar studies should be done on much larger groups and using many batteries of skill tests as to find the best predictors of "in vivo" performance.

Several studies should be initiated to study the effectiveness of hockey skill tests in predicting hockey performance on groups whose ability is much more heterogeneous.

A standard procedure of evaluation of performance "in vivo" should be encouraged and a study of specificity and generality of skill tests or skills in hockey should be conducted.

A new battery of tests should be developed that would respect the following two points: high specificity between tests and high generality between test and the criterion of performance.

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APPENDIX A

THE SUBJECTS AND THEIR CHARACTERISTICS

TABLE 8

SUBJECTS

NAME	DATE OF BIRTH (DAY, MONTH, YEAR)
1 Antoniuk M.	12-01-65
2 Carlson R.	11-06-65
3 Donadt R.	26-03-65
4 Donald S.	24-06-65
5 Holgate B.	16-12-65
6 Jones B	06-09-65
7 Leisen B	13-07-65
8 Lund G.	13-07-65
9 Lund T.	12-07-65
10 Macnab B.	16-07-65
11 Milligan P.	21-04-65
12 Roberge D.	15-02-65
13 Tkachuk S.	25-02-65
14 Wozniak L.	03-09-65

TABLE 9

ANTHROPOMETRIC CHARACTERISTICS OF THE SUBJECTS

NO.	CHRONOL. AGE (months)	SKELETAL AGE (months)	HEIGHT (inches)	WEIGHT (pounds)
1	110.5	129	56.00	77.5
2	105.5	102	52.50	59.0
3	108.0	108	53.00	61.0
4	106.0	138	55.25	75.0
5	99.5	99	52.75	57.0
6	103.5	114	52.75	61.5
7	104.5	112	56.25	74.0
8	104.5	111	51.50	56.4
9	104.5	102	51.00	53.5
10	104.5	90	52.25	58.0
11	107.0	108	51.75	59.0
12	109.5	114	50.50	57.0
13	109.0	93	50.50	58.0
14	103.0	99	52.75	61.5
MEANS	105.6	108.5	52.79	62.0
S.D.	2.8	12.58	1.79	7.3

APPENDIX B

RAW SCORES

TABLE 10

HOCKEY SKILLS TESTS
(sec.)

NO.	FRONT SKATING 60'	90'	120'	BACK SKATING 60'	90'	120'	AGILITY	PUCK CONTROL
1	3.7	5.1	6.6	5.0	6.9	9.0	13.2	20.6
2	4.0	5.3	7.0	5.6	7.3	10.4	12.7	18.4
3	3.4	5.0	6.5	5.2	7.6	10.2	13.0	18.5
4	3.2	4.5	6.3	5.5	7.6	10.3	13.5	20.1
5	3.5	5.0	6.7	5.8	7.4	10.9	13.9	19.3
6	3.5	4.7	6.6	6.0	8.7	11.3	12.8	18.9
7	3.9	5.3	6.8	5.2	7.2	9.5	11.5	17.7
8	3.5	4.6	6.1	5.2	7.1	9.6	12.5	17.1
9	3.7	4.9	6.8	5.3	7.4	10.0	12.8	18.7
10	4.0	5.4	6.9	6.0	8.4	11.2	12.7	17.0
11	4.0	5.4	6.9	5.5	9.1	10.8	12.7	19.5
12	3.2	4.7	6.4	5.4	7.6	10.1	11.7	18.9
13	3.4	4.9	6.0	5.2	8.0	9.8	12.0	18.0
14	3.4	4.9	6.1	5.1	7.2	9.4	12.8	16.9
MEANS	3.6	5.0	6.5	5.4	7.7	10.2	12.7	18.5
S.D.	0.2	0.2	0.3	0.3	0.6	0.6	0.6	1.1

TABLE 11

HEART RATE AND MAXIMUM O_2 CONSUMPTION

NO.	SUBJECT	RESTING* HEART RATE (beats/min)	MAXIMUM HEART RATE (beats/min)	MAXIMUM O_2 CONSUMPTION (ml/kg.min)
1	Antoniuk M.	99	204	39.41
2	Carlson R.	107	195	34.20
3	Donadt R.	92	195	48.50
4	Donald S.	93	204	38.78
5	Holgate B.	87	198	42.19
6	Jones B.	98	187	41.47
7	Leisen B.	106	195	33.09
8	Lund G.	--	195	47.84
9	Lund T.	83	195	48.68
10	Macnab B.	115	204	39.89
11	Milligan P.	85	204	42.94
12	Roberge D.	74	195	53.96
13	Tkachuk S.	115	209	38.72
14	Wozniak L.	108	204	24.40
MEANS		97.07	198.85	41.0
S.D.		$\pm$12.79	$\pm$5.92	$\pm$7.2

*These values represent pre-exercise H.R. as the subject was sitting on the bike.

TABLE 12

CAHPER FITNESS PERFORMANCE TEST ITEMS

NO.	50 YARD (sec)	300 YARD (sec)	SHUTTLE RUN (sec)	FLEX ARM H. (sec)	STAND BROAD JUMP (in)	ONE MINUTE SPEED SIT-UPS
1	9.0	65.5	12.2	63	58.15	26
2	8.6	65.5	11.9	60	59.50	29
3	8.5	65.5	11.4	61	52.25	36
4	8.4	66.0	11.5	64	56.60	17
5	8.8	66.4	12.4	80	56.15	22
6	8.5	70.0	12.4	25	49.75	26
7	8.8	71.5	11.6	33	58.00	29
8	8.9	71.5	11.8	74	60.00	35
9	9.0	71.0	11.2	68	60.25	39
10	8.8	66.0	12.8	72	54.00	39
11	10.5	73.0	11.8	13	48.50	10
12	8.3	65.4	11.4	60	62.80	42
13	8.9	74.0	11.6	75	53.75	31
14	8.9	67.5	11.2	60	50.15	40
MEANS	8.9	68.5	11.8	57.7	55.70	30.0
S.D.	0.5	3.0	0.5	19.1	4.25	9.0

TABLE 13
STATIC STRENGTH

NO.	GRIP LEFT	ARM EXT.	ARM FLEX.	KNEE EXT.
1	60.5	26.9	19.7	49.6
2	44.0	12.5	17.3	53.2
3	45.1	17.3	19.7	56.8
4	58.3	22.1	26.9	46.0
5	45.1	11.3	19.7	29.3
6	37.4	12.5	24.5	43.6
7	39.6	14.9	19.7	50.8
8	35.2	14.9	19.7	34.1
9	35.2	13.7	14.9	24.5
10	38.5	12.5	18.5	30.5
11	45.1	14.9	14.9	36.4
12	42.9	24.5	29.3	53.2
13	37.4	23.3	19.7	43.6
14	41.8	14.9	20.9	43.6
MEANS	43.3	16.9	20.4	42.5
S.D.	7.4	4.9	3.9	9.7

N.B. All measures in pounds

TABLE 14

PERFORMANCE RATING

NO.	SUBJECTS	RATING*
1	Antoniuk M.	1
2	Carlson R.	9
3	Donadt R.	7
4	Donald S.	10
5	Holgate B.	13
6	Jones B.	11
7	Leisen B.	12
8	Lund G.	3
9	Lund T.	4
10	Macnab B.	2
11	Milligan P.	8
12	Roberge D.	5
13	Tkachuk S.	6
14	Wozniak L.	14

*The best score being 1

APPENDIX C

CORRELATION MATRICES

CORRELATION MATRIX I

	MVO_2	BONE AGE	ARM EXTENSION	ARM FLEXION	LEG EXTENSION
MVO_2	1.0000	0.1231	0.1370	0.1566	-0.1449
Bone Age		1.0000	0.5350*	0.5090*	0.4009
Arm Extension			1.0000	0.4755*	0.4195
Arm Flexion				1.0000	0.4482
Leg Extension					1.0000
Hand Grip	-0.1315	0.7273*	0.5564*	0.2662	-0.3921
50 Yards	-0.0645	-0.1685	-0.1282	-0.6514*	-0.3860
300 Yards	-0.0070	-0.2462	-0.1007	-0.3866	-0.3508
Shuttle Run	-0.0328	-0.1473	-0.2484	-0.0928	-0.2839
Flexed Arm Hang	0.1202	-0.2209	0.1632	0.0528	-0.2238

*Significant at $p < .05$

CORRELATION MATRIX II

	MVO_2	BONE AGE	ARM EXTENSION	ARM FLEXION	LEG EXTENSION
Standing Broad Jump	0.3779	0.2178	0.3081	0.1930	0.0549
Sit-up Per Minute	0.1373	-0.4151	-0.0247	0.1176	0.0351
Skating Forward 60'	-0.2517	-0.3402	-0.4431	-0.7468*	-0.2268
Skating Forward 90'	-0.3055	-0.4479	-0.3236	-0.6737*	-0.0302
Skating Forward 120'	0.0370	-0.1249	-0.4569*	-0.4570*	-0.1404
Skating Backward 60'	0.0866	-0.2322	-0.5068*	0.1037	-0.3407
Skating Backward 90'	0.1472	-0.2644	-0.2309	0.1114	-0.1833
Skating Backward 120'	0.2146	-0.2699	-0.5411*	0.0188	-0.3223
Agility	-0.0473	0.1997	-0.1972	-0.1089	-0.3138
Puck Control	0.2690	0.6789*	0.4632*	0.1878	0.1677
Performance Criterion	-0.5484*	-0.0359	-0.3919	0.1627	0.1517

*Significant at $p < .05$

CORRELATION MATRIX III

	HAND GRIP	50 YARDS	300 YARDS	SHUTTLE RUN	FLEXED ARM HANG
Hand Grip	1.0000	-0.0261	-0.5480*	0.0472	0.0234
50 Yards		1.0000	0.5474*	0.0360	-0.4750*
300 Yards			1.0000	-0.1869	-0.3586
Shuttle Run				1.0000	0.0014
Flexed Arm Hang					1.0000
Standing Broad Jump	0.0453	-0.43.4	-0.2447	-0.1728	0.4804*
Sit-up Per Minute	-0.4908*	-0.5111*	-0.2055	-0.2462	0.4785*
Skating Forward 60'	-0.1616	0.5326*	0.1823	0.4192	-0.3480
Skating Forward 90'	-0.0408	0.5049	0.0270	0.3426	-0.2879
Skating Forward 120'	0.0285	0.2657	-0.1730	0.4186	-0.3082

*Significant at $p < .05$

CORRELATION MATRIX IV

	SKATING BACKWARD 60'	SKATING BACKWARD 90'	SKATING BACKWARD 120'	AGILITY	PUCK CONTROL
Hand Grip	-0.1959	-0.3210	-0.2202	0.5002*	0.7598*
50 Yards	-0.0999	0.0974	0.0455	0.0227	0.1088
300 Yards	-0.1719	0.2205	-0.0827	-0.4337	-0.2421
Shuttle Run	0.6992*	0.4227	0.5569*	0.3124	0.0712
Flexed Arm Hang	-0.1415	-0.3737	-0.2327	0.2718	-0.1807
Standing Broad Jump	-0.2320	-0.5717*	-0.3757	-0.2321	0.0813
Sit-up Per Minute	-0.2103	-0.1590	-0.2777	-0.3978	-0.6318*
Skating Forward 60'	0.2262	0.0781	0.1904	-0.1128	-0.1454
Skating Forward 90'	0.1289	0.0668	0.1485	-0.1257	-0.1243
Skating Forward 120'	0.4739*	0.1566	0.4623*	0.1092	0.2161

*Significant at $p < .05$

CORRELATION MATRIX V

	SKATING BACKWARD 60'	SKATING BACKWARD 90'	SKATING BACKWARD 120'	AGILITY	PUCK CONTROL
Skating Backward 60'	1.0000	0.7225*	0.9439*	0.2737	0.0092
Skating Backward 90'		1.0000	0.7996*	-0.0551	-0.0582
Skating Backward 120'			1.0000	0.2870	0.0524
Agility				1.0000	0.4617*
Puck Control					1.0000
Performance Criterion	0.1713	0.0251	0.1791	0.1395	-0.0634

*Significant at $p < .05$

CORRELATION MATRIX VI

	PERFORMANCE CRITERION
Hand Grip	-0.0223
50 Yards	-0.0717
300 Yards	0.0243
Shuttle Run	-0.1694
Flexed Arm Hang	-0.3207
Standing Broad Jump	-0.3946
Sit-up per min.	-0.3021
Skating Forward 60'	-0.1545
Skating Forward 90'	-0.0469
Skating Forward 120'	-0.0252

APPENDIX D

REGRESSION EQUATIONS AND SUMMARY OF ANALYSIS OF VARIANCE

MULTIPLE REGRESSION I

LAB TESTS VERSUS PERFORMANCE CRITERION

	PREDICTOR	B* FACTOR	MULTIPLE R	R^2	R^2 CHANGE	SIMPLE R	B*
X_1	MVO_2	-0.51370	0.54838	0.30073	0.30073	-0.54838	-0.28606
X_2	Bone Age	0.04019	0.54931	0.30174	0.00101	-0.03590	0.01287
X_3	Arm Extension	-0.65002	0.67723	0.45864	0.15690	-0.39192	-0.52734
X_4	Arm Flexion	0.46899	0.78409	0.61480	0.15616	0.16270	0.48371
X_5	Leg Extension	0.09147	0.78807	0.62105	0.00625	0.15169	0.03796
X_6	Hand Grip	0.08189	0.78953	0.62336	0.00232	-0.02232	0.09786

*B Factor = Regression coefficient for normalized data

B = Regression coefficient for raw data

SUMMARY OF THE ANALYSIS OF VARIANCE FOR MULTIPLE REGRESSION I

		SOURCE OF VARIATION	DF	SUM OF SOURCES	MEAN SQUARE	F
Multiple R	0.78953	Regression	6	141.81521	23.63587	1.93093
R^2	0.62336	Residual	7	85.68479	12.24068	
S.D.	3.49867					

Critical F = 2.83

DF 6,7

$(1-\alpha) = .90$

MULTIPLE REGRESSION II

FITNESS TEST VERSUS PERFORMANCE CRITERION

	PREDICTOR	B FACTOR	MULTIPLE R	R^2	R^2 CHANGE	SIMPLE R	B
X_1	50 Yards	-0.55762	0.07168	0.00514	0.00514	-0.07168	-4.43590
X_2	300 Yards	0.01099	0.10444	0.01091	0.00577	0.02428	0.01445
X_3	Shuttle Run	-0.33267	0.18522	0.03431	0.02340	-0.16945	-2.84990
X_4	Flexed Arm Hang	-0.15339	0.43943	0.19310	0.15879	-0.32074	-0.03226
X_5	Standing Broad Jump	-0.46389	0.58900	0.34692	0.15382	-0.39463	-0.43990
X_6	Sit-up Per Min.	-0.42817	0.67692	0.45822	0.11130	-0.30209	-0.19170
	Multiple R		0.67692		Constant		111.52719

SUMMARY OF THE ANALYSIS OF VARIANCE
FOR MULTIPLE REGRESSION II

		SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F
Multiple R	0.67962	Regression	6	104.24517	17.37420	0.98673
R^2	0.45822	Residual	7	123.25483	17.60783	
S.D.	4.19617					

Critical F = 2.83

DF 6,7

$(1-\alpha) = .90$

MULTIPLE REGRESSION III

HOCKEY TESTS VERSUS PERFORMANCE CRITERION

	PREDICTOR	B FACTOR	MULTIPLE R	R^2	R^2 CHANGE	SIMPLE R	B
X_1	Skating Forward 60'	-0.63054	0.15455	0.02389	0.002389	-0.15455	-9.23742
X_2	Skating Forward 90'	0.50261	0.24277	0.05896	0.03505	-0.04691	7.15196
X_3	Skating Forward 120'	-0.10880	0.28028	0.07856	0.01962	-0.02526	-1.38945
X_4	Skating Backward 60'	0.19038	0.34365	0.11810	0.03954	0.17127	2.47268
X_5	Skating Backward 90'	-0.49096	0.40763	0.16612	0.04807	0.02307	-3.96435
X_6	Skating Backward 120'	0.50154	0.42513	0.18074	0.01457	0.17910	3.02749
X_7	Agility	-0.02750	0.43144	0.18614	0.00540	0.13954	-0.17814
X_8	Puck Control	-0.11302	0.43710	0.19106	0.00492	-0.06344	-0.41822
	Multiple R		0.43710		Constant		10.18509

SUMMARY OF THE ANALYSIS OF VARIANCE FOR MULTIPLE REGRESSION III

		SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F
Multiple R	0.43710	Regression	8	43.46609	5.43326	0.14762
R^2	0.10106	Residual	5	184.03391	36.80678	
S.D.	6.06686					

Critical F = 3.34

DF 8,5

$(1-\alpha) = .90$

MULTIPLE REGRESSION IV
(BEST) LAB TESTS AND FITNESS TESTS VERSUS PERFORMANCE CRITERION

	PREDICTOR	B FACTOR	MULTIPLE R	R^2	R^2 CHANGE	SIMPLE R	B
X_1	MVO_2	-0.46673	0.54838	0.30073	0.30073	-0.54838	-0.25991
X_2	Arm Extension	-0.31377	0.63483	0.40301	0.10229	-0.39192	-0.25455
X_3	Flexed Arm Hang	-0.12672	0.66909	0.44768	0.04466	-0.32074	-0.02665
X_4	Standing Broad Jump	0.00598	0.66953	0.44826	0.00059	-0.39463	0.00567
X_5	Sit-up per Minute	-0.18724	0.68831	0.47377	0.02550	-0.30209	-0.08383
X_6	--	--	--	--	--	--	--
	Multiple R		0.68831		Constant		26.14026

SUMMARY OF THE ANALYSIS OF VARIANCE FOR MULTIPLE REGRESSION IV

		SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F
Multiple R	0.68831	Regression	5	107.78178	21.55636	1.44047
R^2	0.47377	Residual	8	119.71822	14.96478	
S.D.	3.86843					

Critical F = 2.73

DF 5,8

$(1-\alpha) = .90$

MULTIPLE REGRESSION IV

LAB TESTS AND (SOME) HOCKEY TESTS VERSUS PERFORMANCE CRITERION

	PREDICTOR	B FACTOR	MULTIPLE R	R^2	R^2 CHANGE	SIMPLE R	B
X_1	MVO_2	-0.62144	0.54838	0.30073	0.30073	-0.54838	-0.34606
X_2	Arm Extension	-0.50801	0.63483	0.40301	0.10229	-0.39192	-0.41313
X_3	Skating Backward 120'	0.07563	0.65068	0.42338	0.02037	0.17910	0.45653
X_4	Agility	-0.21144	0.65097	0.42376	0.00037	0.13954	-1.36983
X_5	Puck Control	0.43271	0.70461	0.49648	0.07272	-0.06344	1.60120
X_6	--	--	--	--	--	--	--
	Multiple R		0.70461		Constant		11.61378

MULTIPLE REGRESSION V
(BEST) LAB TESTS AND FITNESS TESTS AND HOCKEY TESTS VERSUS PERFORMANCE CRITERION

	PREDICTOR	B FACTOR	MULTIPLE R	R^2	R^2 CHANGE	SIMPLE R	B
X_1	MVO_2	-0.67816	0.54838	0.30073	0.30073	-0.54383	-0.37764
X_2	Arm Extension	-0.44619	0.63483	0.40301	0.10229	-0.39192	-0.36198
X_3	Standing Broad Jump	0.02074	0.64565	0.41686	0.01385	-0.39463	0.01967
X_4	Skating Forward 60'	-0.55869	0.80051	0.64082	0.22396	-0.15455	-8.18483
X_5	Skating Backward 120'	0.19740	0.81257	0.66027	0.01946	0.17910	1.19159
X_6	--	--	--	--	--	--	--
Multiple R			0.81257		Constant		45.25542

SUMMARY OF THE ANALYSIS OF VARIANCE FOR
MULTIPLE REGRESSION V

		SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F
Multiple R	0.81257	Regression	5	150.21250	30.04250	3.10969
R^2	0.66027	Residual	8	77.28750	9.66094	
S.D.	3.10820					

Critical F = 2.73

DF 5,8

$(1-\alpha) = .90$

MULTIPLE REGRESSION VI

(SOME) LAB TESTS AND FITNESS TESTS AND HOCKEY TESTS VS PERFORMANCE CRITERION

	PREDICTOR	B FACTOR	MULTIPLE R	R^2	R^2 CHANGE	SIMPLE R	B
X_1	Arm Extension	-0.78809	0.39192	0.15360	0.15360	-0.39192	-0.63936
X_2	Hand Grip	0.63751	0.45727	0.20910	0.05550	-0.02232	0.76184
X_3	300 Yards	0.18473	0.48298	0.23327	0.02417	0.02428	0.24296
X_4	Skating Backward 120'	-0.02022	0.48544	0.23565	0.00238	0.17910	-0.12206
X_5	Agility	0.24896	0.51064	0.26076	0.02511	0.13954	-1.61296
X_6	--	--	--	--	--	--	--
	Multiple R		0.51064		Constant		8.24496

SUMMARY OF THE ANALYSIS OF VARIANCE FOR MULTIPLE REGRESSION VI

		SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F
Multiple R	0.51064	Regression	5	59.32232	11.86446	0.56438
R^2	0.26076	Residual	8	168.17768	21.02221	
S.D.	4.58500					

Critical F = 2.73

DF 5,8

$(1-\alpha) = .90$

MULTIPLE REGRESSION VII
(SOME) HOCKEY TESTS VERSUS PERFORMANCE CRITERION

	PREDICTOR	B FACTOR	MULTIPLE R	R^2	R^2 CHANGE	SIMPLE R	B
X_1	Skating Forward 90'	0.15791	0.04691	0.00220	0.00220	-0.04691	2.24705
X_2	Skating Forward 120'	-0.34409	0.04855	0.00236	0.00016	-0.02526	-4.39410
X_3	Skating Backward 60'	0.53234	0.21233	0.04508	0.04273	0.17127	6.91426
X_4	Skating Backward 90'	-0.31674	0.30056	0.09033	0.04526	0.02307	0.25024
X_5	Agility	0.03862	0.30193	0.09116	0.00083	0.13954	0.25024
X_6	Puck Control	-0.01060	0.30202	0.09122	0.00005	-0.06344	-0.03923
	Multiple R		0.30202		Constant		4.56471

SUMMARY OF THE ANALYSIS OF VARIANCE FOR
MULTIPLE REGRESSION VII

		SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F
Multiple R	0.30202	Regression	6	20.75157	3.45860	0.11710
R^2	0.09122	Residual	7	206.74843	29.53549	
S.D.	5.43466					

Critical F = 2.83

DF 4,7

$(1-\alpha) = .90$

MULTIPLE REGRESSION VIII

(SOME) LAB TESTS AND HOCKEY TESTS VERSUS PERFORMANCE CRITERION

	PREDICTOR	B FACTOR	MULTIPLE R	R^2	R^2 CHANGE	SIMPLE R	B
X_1	MVO_2	-0.61855	0.54838	0.30073	0.30073	-0.54838	-0.34445
X_2	Bone Age	0.18457	0.54931	0.30174	0.00101	-0.03590	0.05912
X_3	Arm Extension	-0.52606	0.67723	0.47851	0.15690	-0.39192	-0.42677
X_4	Skating Backward 120'	0.12059	0.69175	0.47851	0.01987	0.17910	0.72793
X_5	Agility	-0.20862	0.69586	0.48423	0.00572	0.13954	-1.35158
X_6	Puck Control	0.31134	0.71518	0.51148	0.02726	-0.06344	1.15210
X_7	--	--	--	--	--	--	--
X_8	--	--	--	--	--	--	--
	Multiple R		0.71518		Constant		10.71078

SUMMARY OF THE ANALYSIS OF VARIANCE FOR MULTIPLE REGRESSION VIII

		SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F
Multiple R	0.71518	Regression	6	116.36282	19.39380	1.22152
R^2	0.51148	Residual	7	111.13718	15.87674	
S.D.	3.9456					

Critical F = 2.83

DF 6,7

$(1-\alpha)$ = .[illegible]

SUMMARY OF THE ANALYSIS OF VARIANCE FOR MULTIPLE REGRESSION IX

		SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F
Multiple R	0.70461	Regression	5	112.94850	22.58970	1.57761
R^2	0.49648	Residual	8	114.55150	14.31894	
S.D.	3.78404					

Critical F = 2.73

DF 5,8

$(1-\alpha) = .90$

MULTIPLE REGRESSION X

LAB TESTS AND FITNESS TESTS AND HOCKEY TESTS VERSUS PERFORMANCE CRITERION

	PREDICTOR	B FACTOR	MULTIPLE R	R^2	R^2 CHANGE	SIMPLE R	B
X_1	MVO_2	-0.48941	0.54838	0.30073	0.30073	-0.54838	-0.27253
X_2	Arm Extension	-0.30721	0.63483	0.40301	0.10229	-0.39192	-0.24923
X_3	Sit-up per minute	-0.24871	0.67988	0.46224	0.05923	-0.30209	-0.11135
X_4	Skating Backward 120'	0.06669	0.68125	0.46411	0.00186	0.17910	0.40256
X_5	Agility	-0.06224	0.68350	0.46718	0.00307	0.13954	-0.40327
X_6	--	--	--	--	--	--	--
	Multiple R		0.68350		Constant		27.19896

SUMMARY OF THE ANALYSIS OF VARIANCE FOR
MULTIPLE REGRESSION X

		SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F
Multiple R	0.68350	Regression	5	106.28242	21.25648	1.40286
R^2	0.46718	Residual	8	121.21758	15.15220	
S.D.	3.89258					

Critical F = 2.73

DF 5,8

$(1-\alpha) = .90$

MULTIPLE REGRESSION XI

LAB TESTS AND FITNESS TESTS AND HOCKEY TESTS VERSUS PERFORMANCE CRITERION

	PREDICTOR	B FACTOR	MULTIPLE R	R^2	R^2 CHANGE	SIMPLE R	B
X_1	MVO_2	-0.81939	0.54838	0.30073	0.30073	-0.54838	-0.45629
X_2	Arm Extension	-0.15592	0.63483	0.40301	0.10229	-0.39192	-0.12649
X_3	Flexed Arm Hang	-0.18282	0.66909	0.44768	0.04466	-0.32074	-0.03844
X_4	Standing Broad Jump	0.31003	0.66953	0.44826	0.00059	-0.39463	0.29399
X_5	Skating Backward 60'	-1.06177	0.67062	0.44973	0.00146	0.17127	-13.79067
X_6	Skating Backward 120'	1.34659	0.71138	0.50606	0.05633	0.17910	8.12850
	Multiple R		0.71138		Constant		6.28645

SUMMARY OF THE ANALYSIS OF VARIANCE FOR MULTIPLE REGRESSION XI

		SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F
Multiple R	0.71138	Regression	6	115.12867	19.18811	1.19529
R^2	0.50606	Residual	7	112.37183	16.05305	
S.D.	4.00663					

Critical F = 2.83

DF 6,7

$(1-\alpha) = .90$

MULTIPLE REGRESSION XII

LAB TESTS AND HOCKEY TESTS VERSUS PERFORMANCE CRITERION

	PREDICTOR	B FACTOR	MULTIPLE R	R^2	R^2 CHANGE	SIMPLE R	B
X_1	MVO_2	-0.55520	0.54838	0.30073	0.30073	-0.54838	-0.30917
X_2	Arm Extension	-0.21725	0.63483	0.40301	0.10229	-0.38192	-0.17625
X_3	Skating Backward 120'	0.17487	0.65068	0.42338	0.02037	0.17910	1.05561
X_4	Agility	0.02027	0.065097	0.42376	0.00037	0.13954	0.13134
X_5	--	--	--	--	--	--	--
X_6	--	--	--	--	--	--	--
	Multiple R		0.065097		Constant		10.70061

SUMMARY OF THE ANALYSIS OF VARIANCE FOR MULTIPLE REGRESSION XII

		SOURCE OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
Multiple R	0.65097	Regression	4	96.40436	24.10109	1.05459
R^2	0.42376	Residual	9	131.09564	14.56618	
S.D.	3.81657					

Critical F = 3.63

DF 4,9

$(1-\alpha) = .90$

SUMMARY OF THE ANALYSIS OF VARIANCE FOR MULTIPLE REGRESSION XII

		SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F
Multiple R	0.65097	Regression	4	96.40436	24.10109	1.05459
R^2	0.42376	Residual	9	131.09564	14.56618	
S.D.	3.81657					

Critical F = 3.63

DF 4,9

$(1-\alpha) = .90$

MULTIPLE REGRESSION XIII

LAB TESTS AND HOCKEY TESTS VERSUS PERFORMANCE CRITERION

	PREDICTOR	B FACTOR	MULTIPLE R	R^2	R^2 CHANGE	SIMPLE R	B
X_1	MVO_2	-0.51287	0.54838	0.30073	0.30073	-0.54838	-0.28560
X_2	Arm Extension	-0.28252	0.63483	0.40301	0.10229	-0.39192	-0.22920
X_3	Skating Backward 60'	0.06036	0.63767	0.40662	0.00361	0.17127	0.78398
X_4	Agility	0.04308	0.63900	0.40833	0.00170	0.13954	0.27910
X_5	--	--	--	--	--	--	--
X_6	--	--	--	--	--	--	--
	Multiple R		0.63900		Constant		15.22827

SUMMARY OF THE ANALYSIS OF VARIANCE FOR
MULTIPLE REGRESSION XIII

		SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F
Multiple R	0.63900	Regression	4	92.89423	23.22356	1.55277
R^2	0.40833	Residual	9	134.60577	14.95620	
S.D.	3.86732					

Critical F = 3.63

DF 4,9

$(1-\alpha) = .90$

APPENDIX E

CONVERSION TABLE FOR THE CABLE TENSIOMETER

CONVERSION TABLE FOR THE CABLE TENSIOMETER

TENSIOMETER UNIT	POUNDS
1	2.949
2	5.341
3	7.734
4	10.127
5	12.519
6	14.912
7	17.305
8	19.697
9	22.090
10	24.483
11	26.875
12	29.268
13	31.661
14	34.053
15	36.446
16	38.839
17	41.231
18	43.624
19	46.017
20	48.409
21	50.802
22	53.195
23	55.588
24	57.980
25	60.373