CHAPTER 3

METHODOLOGY

3.1. Subjects

Twenty-six male ice-hockey players voluntarily participated in the study. With the help of coaches and various contacts, subjects were recruited from different clubs approximately six weeks before the start of the ice-hockey competitive season. The subjects were frequent and experienced ice-hockey players participating at club, elite or collegiate level in Montréal (Quebec, Canada). Subjects were proficient skaters, but had a wide variety of fitness levels, some having trained relatively regularly during the summer and some had just returned to Montreal after their summer holiday, having done no training (Figure 3.1 and 3.2).

Figure 3.1: Two Subject Participants and the Researcher

To be recruited and included in the study, subjects had to fulfil the following criteria:

1. be aged between 18 and 50,
2. be in good health and successfully complete the PAR-Q (Physical activity Readiness Questionnaire) of the Canadian Society of Exercise Physiology (Appendix E),
3. be proficient skaters (with good agility), that had mastered their skating skills (start, stop, forward acceleration, skating turns), and
4. be willing to participate and give their informed consent.

Exclusion criteria were as follows:

1. goalies were excluded from the study,
2. failure to meet inclusion criteria described above,
3. injury sustained during the testing period, or
4. any contraindications to participation as indicated by his medical doctor.

Figure 3.2: Subject Participants After the Running 20 MST

3.2. Ethical Considerations

The rights and privacy of subjects was adhered to. This study was approved after institutional review by the relevant Ethics committees of both the University of Pretoria and the University of Montreal (Appendix F). To participate in the study, each subject was required to read and sign an informed consent form (Appendix G). This was done after meeting the subject and before the administration of the first test.

All the tests were done in the Centre d'education physique et des sports de l'UdeM (CEPSUM, University of Montreal) where an emergency procedure was in place. The head of the human performance laboratory was a qualified CPR instructor, and the primary researcher administering the tests was CPR and AED certified.

3.3. Study Design

In accordance with the aim of this study a repeated measures design was adopted to:

1. compare the MS20MST(2003) (Modified Skating 20 MST, Kuisis, 2003), SMAT (Skating Multistage Aerobic Test, Leone, Léger, & Comtois, 2002, unpublished), and FAST (Faught Aerobic Skating Test; Petrella *et al.*, 2007) ice-skating tests to determine which one is better suited for the evaluation of maximal aerobic power of ice hockey players,
2. assess the external and relative validity of the three new practical ice-skating tests to predict maximal aerobic power ($\dot{V}O_2$ max), using direct treadmill $\dot{V}O_2$ max as the "gold standard" criterion variable,
3. determine which test is subjectively rated by the players as being the best suited and most functional test for ice-hockey, and

4. determine if these on-ice skating tests are better than the established over-ground 20 MST (20 m shuttle running test, Léger *et al.,* 1988).

Twenty-nine subjects thus performed five maximal multistage aerobic tests on separate days. The subjects were not permitted to participate in more than one test per day on any two consecutive days, where after a minimum period of 24 hours rest was required before the next test. All five tests were however completed within three weeks. Due to the fact that there were up to four subjects participating in the field tests at the same time, test order could not be totally randomized. However, tests were done in mixed order (refer to Appendix H) to avoid any systematic ordering of the tests. Field tests were done in small groups (less than or equal to four subjects), to stimulate competitive spirit, to avoid high cost of ice-time and for better monitoring and control over pacing. All ice-tests were done on resurfaced ice.

3.4. Procedures and Instrumentation

Subjects were instructed not to engage in heavy physical activity 24 hours before the test, to arrive for the tests approximately three hours postprandial, after a light meal. An attempt was made to test each subject at the same time of day for each different test (to avoid diurnal biological variation), but owing to the fact that participants had to return for testing on five separate occasions, this was logistically (availability of ice and subject) not possible and thus tests took place at approximately the same time of day.

Biographic Data

The following biographical data was collected during the first meeting with each subject before the first test was completed (refer to Appendix I):

- name and surname,
- date of birth,

- age,
- position of play,
- right or left shoot,
- years of ice-hockey experience;
- level of best play,
- age of best play, and
- date and time of the test.

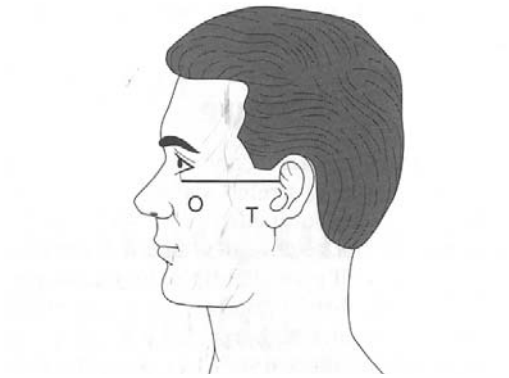
Physical Data

The following physical data was collected on the day of treadmill testing, before the test:

Stature

A Steel measuring tape was mounted against the wall. Stature was recorded as the maximal distance between the soles of the feet (measured in cm) to the vertex of the head, when an imaginary line between the lower margin of the orbital and the upper margin of the zygomatic bone is parallel to the ground (the Frankfort plane) (Figure 3.3). The subject stood barefoot with the arms hanging at the sides. The heels, buttocks, upper back and head were in contact with the wall. Prior to measurement the subject was instructed to look ahead and take a deep breath, without lifting the heels. The measurement was recorded to the nearest mm (Norton *et al.,* 2000).

Figure 3.3: The Frankfort Plane



Mass

Body mass was recorded on a calibrated balance scale (Detecto, Webb City, Mo, USA) and recorded to the nearest 100g. The subject was weighed in running shorts and without shoes, approximately three to four hours postprandial (Norton *et al.,* 2000). Subjects were also weighed in full kit, skates and stick on a balance scale, in the ice arena, prior to performing the MS20MST or SMAT (Figure 3.4). A small sub sample of four subjects were also weighed wearing a tracksuit, helmet, stick, and gloves, as required for the FAST.

Environment

Temperature (°C) was measured from a wall mounted mercury thermometer; humidity (%) was measured from a wall mounted hygrometer, and barometric pressure (mmHg) was measured from a wall mounted barometer, all in the human performance laboratory.

Figure 3.4: A subject Being Weighed With Full Kit

Warm-up and Recovery Procedures

Warm-up before running tests consisted of four to five minutes low intensity jogging (6-8 km h^{-1}), followed by five minutes of stretching. Upon completing the running tests, subjects recovered actively for four to five minutes by walking on the treadmill or in the vicinity of the testing area (for the running 20 MST).

Warm-up procedures for all ice protocols consisted of five minutes of submaximal skating around the outer perimeter of the ice (alternating direction), followed by a few easy stop and go drills, for the modified skating 20 MST and SMAT. Finally four to five minutes of stretching was performed. Upon completing the skating tests, subjects recovered actively for four to five minutes by skating slowly and gliding around the ice. Before any of the field tests were begun, the compact disc of the specific test was played, consisting of a brief explanation of the test, leading to a countdown of the start itself. The following data was collected during all of the tests:

Heart Rate

HR was measured with a Polar pulse monitor (Polar Electro Oy, Kempele, Finland). HR measurement was continuous. Submaximal HR values were recorded at 15 s intervals to establish a HR-Speed curve of each test and to compare how quickly the degree of difficulty evolved/progressed in each test. HR_{max} value was recorded at the end of each test as an indication of the overall difficulty or intensity of each test.

Blood Lactate

Finger prick (capillary) blood samples using a Lactate Pro (Arkray, Inc, Kyoto, Japan) for the determination of blood lactate concentration were obtained between five and eight minutes of recovery, and at the end of a five minute

active recovery period. The finger tip was cleaned with alcohol, dried, and pricked with a lancet. Blood lactate was considered another indication of the overall intensity of the tests, indicating the gross anaerobic contribution of the test.

Oxygen Consumption ($\dot{V}O_2$)

$\dot{V}O_2$ was measured every 30 s with the open circuit method (Moxus Modular $\dot{V}O_2$ System, AEI Technologies, Pittsburgh, Etats-Unis; Figure 3.5). The $\dot{V}O_2$ system was calibrated with standard reference gases and for volume approximately five min prior to each treadmill test. Direct oxygen uptake was measured during the treadmill running test, where $\dot{V}O_2$ values were recorded every 30 s. Sub maximal values of HR and $\dot{V}O_2$ were used to establish an individual calibration curve in order to estimate the energy requirement at sub maximal level of the other field tests. $\dot{V}O_2$ max values for field tests were estimated by applying the specific regression equation for each test, and were used as dependant variable as a function of maximal speed in each field test to assess their respective validity.

Figure 3.5: Moxus Modular $\dot{V}O_2$ System

Rating of Perceived Exertion

The Borg Rating of Perceived Exertion (RPE) (Borg, 1970) (refer to Appendix J) was established on a 6 to 20 point scale from "very very easy" to "very very difficult" and was used as a subjective indicator of the overall difficulty of each test. The Borg RPE scale was used for every test upon termination of the test to determine the final perceived intensity of the tests.

Likert Resemblance Score

A Likert resemblance score (Likert, 1932) (refer to Appendix K) was obtained on a subjective seven point scale. This measurement was done after the completion of each test, recovery and lactate measurement. Each of the tests performed by the subjects was evaluated at five levels:

1. the similarity of the technical skating skills (not stick/puck handling) of the test with those of the hockey game,
2. the resemblance between the maximal intensity of the test and maximal intensity of the hockey game,
3. how the test is suited to evaluate aerobic fitness of the hockey players,
4. how the test is suited to evaluate overall fitness (including cardiovascular and muscular fatigue) of the hockey players, and
5. how the test is suited to evaluate overall hockey ability (fitness and technical skating skills) of the hockey players

3.5. Maximal Multistage Laboratory Treadmill Running Test

All maximal treadmill running tests were conducted in the human performance laboratory of the Kinesiology Department of the University of Montréal located in the CEPSUM (see Figure 3.6). Mean temperature in the laboratory was 20.7±0.6˚C, mean humidity was 62.4±7.9%, and mean barometric pressure was 747.7±21.7 mmHg. Subjects performed the maximal treadmill running test on a Quinton 65 (Series 90) treadmill (Figure 3.7). The Moxus Modular $\dot{V}O_2$ system was calibrated before the start of each test. Subjects performed the test wearing shorts, running shoes and socks. The HR monitor was attached to the subject and adjusted before the warm-up. Subject information was entered into the system while the subject warmed-up.

Figure 3.6: Human Performance Laboratory

Figure 3.7: Quinton 65 Treadmill

Before the test started, test procedures were recapped, as well as the starting position on treadmill and breathing technique (through the mouth, as a nose clip was placed on the subject's nose and worn throughout the test to prevent air from escaping). Subjects were unable to talk during the test due to the mouthpiece (Figure 3.8 and Figure 3.9), and thus, hand signals were confirmed to indicate all OK, what the subject thought would be the last 30 s of the test, and, when the subject indicated he wished to stop). Lastly, the subject was briefed on what he needed to do in the event of an emergency stop.

Figure 3.8: Mouthpiece Components

Figure 3.9: Mouthpiece Assembly

A fan was placed behind the treadmill at a low speed for subject comfort. A headset (Figure 3.10) and mouthpiece was positioned on the subject's head and adjusted for good fit. The subject was then connected to the Moxus Modular $\dot{V}O_2$ system, which analyzed the expired air for volume, as well as oxygen and carbon dioxide content. $\dot{V}O_2$ was measured every 30 s. The subject then stood on the treadmill with feet on either side of the belt, and was given the final instructions.

Treadmill Protocol

The belt was started and the subject initially started walking, then running, while the speed of the treadmill was slowly increased and when a speed of 10 km h^{-1} was reached, the test was started and recordings begun. The test was a continuous multistage test with initial speed set at 10 km·h^{-1} with 1 km h^{-1} increment per stage thereafter. Stage duration was two minutes. The researcher communicated with the subject at regular intervals to monitor the subject's progress. Subjects were urged to run until completely fatigued and to give a maximal effort. The subject ran until volitional exhaustion, and the highest $\dot{V}O_2$ achieved ($\dot{V}O_2$ peak) was considered $\dot{V}O_2$ max. Similar procedures were used by Dreger & Quinney (1999).

At the end of the test, the treadmill belt was stopped; the subject was instructed to continue breathing for an additional 30 s while still connected to the machine. The head set was then removed and the treadmill restarted at a low speed (walking), and a recovery period of five minutes began. The Borg RPE scale was then administered. After four minutes of active recovery the treadmill was stopped, the subject was seated and prepared for lactate measurement. While lactate was being analyzed by the Lactate Pro, the Likert resemblance scale was administered. Maximal speed was the performance score of each test, and was recorded as the speed of the last completed stage. Finally, a follow-up appointment for next test was arranged before the subject was dismissed from the session. Preparation, participant information

and participation in each test required approximately 45 minutes (see Figure 3.11).

Figure 3.10: Headset

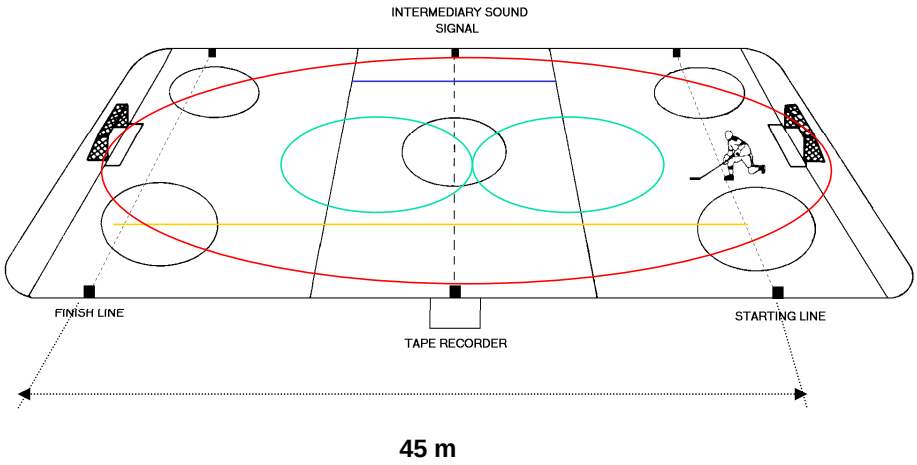
Figure 3.11: Subject Participant during a Maximal Treadmill Test

3.6. Field Tests

All ice tests took place in the ice arena (55 m x 26 m) at the CEPSUM (Figure 3.12 and 3.13).

Figure 3.12: Ice Arena in the CEPSUM

Figure 3.13: Ice Layout for Field Tests



Note 1: The red line indicates the FAST, the yellow line indicates the SMAT, and the blue line indicates the MS20MST.

3.6.1. Modified (Skating) 20 MST (MS20MST, Kuisis, 2003)

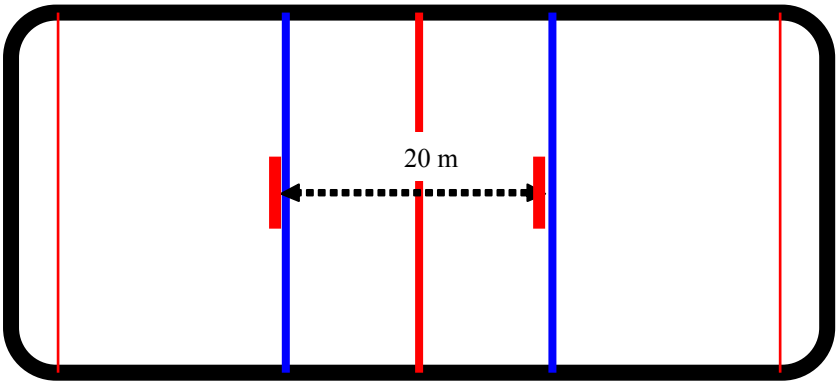
The nature of this test was continuous, multistage and linear with frequent stop and go. Subjects were required to wear full ice-hockey kit (shoulder, elbow, and shin pads, hockey jersey, gloves, socks and pants and helmet) and were required to hold the hockey stick in one hand. The HR monitor was attached to the subjects and adjusted before the warm-up. Before the test started, test procedures were recapped. The subjects were instructed to skate until completely fatigued and to give a maximal effort. The test involved skating back and forth consecutively between two cones placed on the ice, 20 m apart. The subjects started at one cone and were given a signal to start. The subjects were required to reach the cone at the other end of the 20 m course within a certain time (7.1 s for the first stage), indicated by an audio signal emitted by a pre-recorded compact disc. The subjects were then required to stop, turn and return to the cone at the other end of the 20 m course. The initial velocity was 2.82 m s^{-1} or 10.14 km h^{-1}, increasing by ~0.5 km h^{-1} every minute (thus decreasing the time interval between the bleeps) and the subjects were required to adjust their skating velocity when necessary. The recording indicated the end of each length (shuttle), as well as each level.

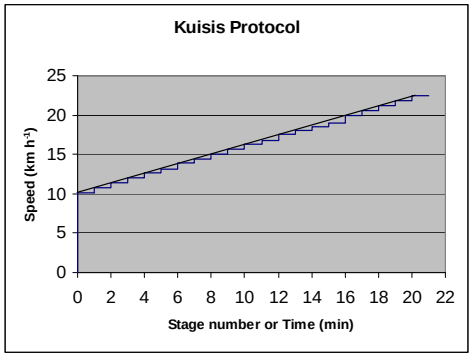
The test was terminated when the subject voluntarily stopped or could no longer follow the set pace. The last fully completed stage number was recorded, the HR monitor was stopped and a recovery period of five minutes began. The Borg RPE Scale was then administered. After approximately four minutes of active recovery, the subject was prepared for lactate measurement. Lactate was measured between five and eight minutes after the end of the test depending on the number of subjects who performed the test at the same time. While lactate was being analyzed by the Lactate Pro, the Likert Resemblance Scale was administered. Finally, a follow-up appointment for next test was arranged before the subjects were dismissed

from the session. Preparation, participant information and participation in this test required approximately 30 minutes. See Figure 3.14 and 3.15.

Figure 3.14: Subject Performing the MS20MST

Figure 3.15: Ice Layout of the Modified (Skating) 20 MST





The predicted $\dot{V}O_2$ max was calculated by using the following equation (developed in this study, reported in Chapter 4):

$\dot{V}O_2$ max = -33.337 + 6.24*Speed

Where:

a) $\dot{V}O_2$ max is expressed in ml kg^{-1} min^{-1},

b) Speed is the final speed reached during the tests and is in km h^{-1}.

3.6.2. Skating Multistage Aerobic Test (SMAT) (Leone, Léger, & Comtois, 2002, unpublished)

The nature of this ice-skating filed test is linear (over a distance of 45 m with stop-and-go), maximal, and multistage, but intermittent (1 minute:0.5 minute work:rest ratio). Subjects were required to wear full ice hockey equipment (shoulder, elbow, and shin pads, hockey jersey, gloves, socks and pants, and helmet) and required to hold the hockey stick in one hand. The HR monitor was attached to the subject and adjusted before the warm-up. Before the test started, the pre-recorded audio compact disc containing test procedures and instructions were played and then recapped by the researcher. The subjects were instructed to skate until completely fatigued, and give a maximal effort.

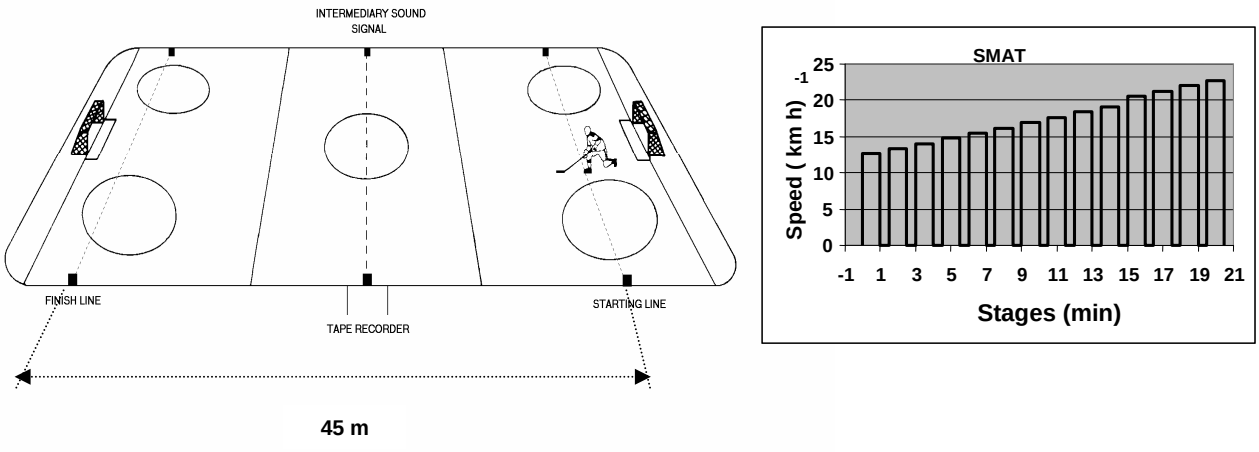
Two cones were placed on the ice, 45 m apart. The subjects were required to skate back and forth over a distance of 45 m (stop and go) while following the pace fixed by an audible signal. At the start of each stage, the subjects rested upright with the front skate parallel to the starting line of the 45 m shuttle course. At the sound of the first signal the subjects began skating, without stopping, and if necessary adjusting the skating velocity, the subjects continued skating to reach the end of the course and where he then stopped abruptly in time with the auditory signal. The subjects would immediately turn and start skating in the opposite direction (stop and go), and so on till the end of the one minute stage. At the end of the one minute stage, the subjects skated slowly to the closest end of the 45 m shuttle course for a 30 s rest before the start of next stage (Figure 3.16).

The original test required a cone at the halfway mark (22.5 m) as well as a half-length audio signal with the intent of helping subjects to pace themselves and adjust the skating velocity to meet the mid-point of the course in synchrony with the second audible signal. After experimentation with this test, researchers decided to remove the halfway marker and audio signal as it proved to be of little value in helping subjects keep to a set pace; in fact it

was confusing to the subjects. Leone *et al.* (2007) showed the half stage difference between the pre- and post-test values not to be significant.

The initial velocity was 12.6 km h^{-1} (3.5 $m \cdot s^{-1}$) with increments of 0.72 km h^{-1} (0.2 $m \cdot s^{-1}$) at every stage. The subjects were required to adjust their skating velocity when necessary. The test was terminated when the subject voluntarily stopped or could no longer follow the pace set by the audible signal and was not within three metres of the line after the sound signal, on two consecutive occasions. The last fully completed stage number was recorded, the HR monitor was stopped and a recovery period of five minutes began. The Borg RPE scale was administered. After approximately four minutes of active recovery, the subjects were prepared for lactate measurement. Lactate was measured between five and eight minutes after the end of the test depending on the number of subjects who performed the test at the same time. While lactate was being analyzed, the Likert Resemblance Scale was administered. Finally, a follow-up appointment for next test was arranged before the subjects were dismissed from the session. Preparation, participant information and participation in each test required approximately 30 minutes. The entire test procedure would last approximately 15 minutes (including the 30 second rest periods).

Figure 3.16: Ice Layout of the Skating Multistage Aerobic Test



The $\dot{V}O_2$ max was calculated by using the following equation (for adult males, aged 17 years and older):

$\dot{V}O_2$ max = 16.151(maximal skating velocity)-29.375.

Where:

a) $\dot{V}O_2$ max is expressed in ml kg^{-1} min^{-1},

b) skating velocity is in m s^{-1}.

In practice, Table 2.1 may be used for rapid estimating $\dot{V}O_2$ max values.

Table 2.1: The Skating Multistage Aerobic Test (SMAT) Maximal Oxygen Consumption Prediction Table for Adult Male Professional Hockey Players.

Stage	$\dot{V}O_2$ max (ml kg^{-1} min^{-1})	Time (min)	Velocity (m s^{-1})	Velocity (km h^{-1})
1	27.2	1.5	3.5	12.6
2	30.4	3.0	3.7	13.3
3	33.6	4.5	3.9	14.0
4	36.8	6.0	4.1	14.8
5	40.1	7.5	4.3	15.5
6	43.3	9.0	4.5	16.2
7	46.5	10.5	4.7	16.9
8	49.8	12.0	4.9	17.6
9	53.0	13.5	5.1	18.4
10	56.2	15.0	5.3	19.1
11	59.5	16.5	5.5	19.8
12	62.7	18.0	5.7	20.5
13	65.9	19.5	5.9	21.2
14	69.1	21.0	6.1	22.0
15	72.4	22.5	6.3	22.7

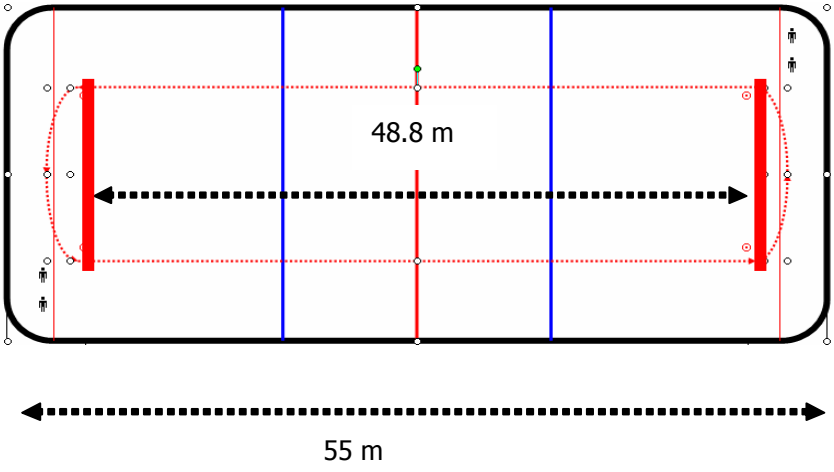
***Based on the following regression equation: $\dot{V}O_2$ max = 16.151 x (velocity) – 29.375; r = 0.969; SEE = 2.06 ml kg^{-1} min^{-1}; n = 37**

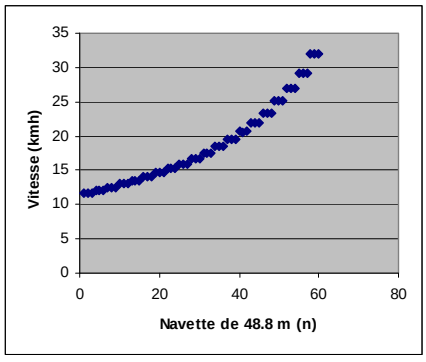
3.6.3. Faught Aerobic Skating Test (FAST) (Petrella, 2007)

The nature of this ice-skating filed test is maximal, multistage, continuous and curvilinear, over a distance of 48.8 m. When performing the FAST each subject was instructed to wear skates, gloves, helmet, and carry a stick. A Polar HR monitor was attached to the subject and adjusted before the warm-up. Before the test started, test procedures and instructions were played off the compact disc and then recapped by the researcher. The subject was instructed to skate until completely fatigued, and give a maximal effort.

The procedure consisted of skating a 48.8 m distance from one end of the ice to the other, making a wide turn around the cone on the ice, in the allotted stage time indicated by a fixed audible signal. The duration of the first stage (first three lengths) is 15 s. Stage duration then decreased by 0.5 seconds after every third length (one stage). The initial velocity is 11.7 km h^{-1} (3.25 $m \cdot s^{-1}$) with increments of 0.72 km h^{-1} (0.2 $m \cdot s^{-1}$) at every stage (three lengths). The subjects were required to adjust their skating velocity when necessary. Figure 3.17.

Figure 3.17: Ice Layout of the Faught Aerobic Skating Test (FAST)





The test was terminated when the subject voluntarily stopped; or could no longer follow the pace set by the audible signal. The last fully completed stage number was then recorded (F-stage), the HR monitor was stopped and a recovery period of five minutes began. The Borg RPE scale was administered. After approximately four minutes of active recovery, the subject was prepared for lactate measurement. Lactate was measured between five and eight minutes after the end of the test depending on the number of subjects who performed the test at the same time. While lactate was being analyzed, the Likert Resemblance Scale was administered. Finally, a follow-up appointment for next test was arranged before the subject was dismissed from the session. Preparation, participant information and participation in each test required approximately 30 minutes.

The following equations are used to calculate $\dot{V}O_2$ max:

$\dot{V}O_2$ max ={0.428(F-length)} - {0.348(weight)} + {25.434(height)} - {11.09(gender)} +27.196 (Petrella *et al.,* 2007)

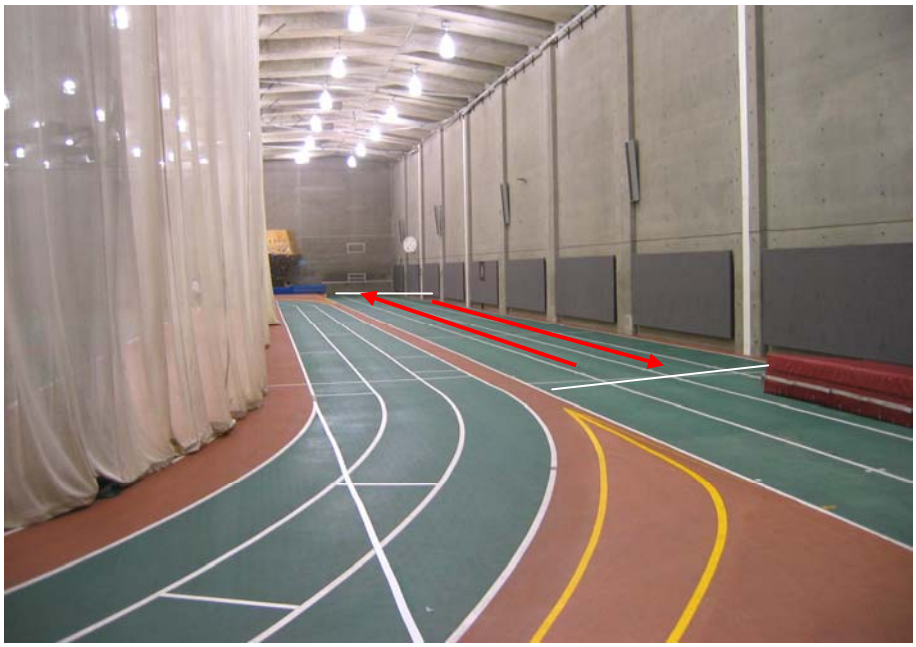
Where:

a) $\dot{V}O_2$ max is expressed in ml kg^{-1} min^{-1};
b) F-stage is the final stage, i.e. the number of lengths completed
c) Weight is in kg
d) Height is in m
e) In the second equation: 1= male, and 2= female (1 in this study, as all subjects were males)

3.6.4. 20 Metre Multistage Shuttle Run Test (20 MST) (Léger *et al.*, 1988)

All running 20 MST tests were conducted on the indoor running track at the CEPSUM (Figure 3.18). The nature of this test was continuous and linear with frequent stop and go. The test is maximal and progressive. Subjects performed the 20 MST wearing running shorts, running shoes and socks. The HR monitor was attached to the subject and adjusted before the warm-up. Subjects were instructed to run until completely fatigued, giving a maximal effort, and to attempt to reach as high a level as possible, until they could no longer keep up with the required pace.

Figure 3.18: Indoor Running Track at the CEPSUM



The test involved running back and forth along a 20 m course consecutively between two cones placed 20 m apart. The subjects started at one cone after a signal to start. The subjects were required to reach the cone at the other end of the 20 m course within a certain time, indicated by an audio signal emitted by a pre-recorded compact disc. The subjects were then required to stop, turn and return to the cone at the other end of the 20 m course by the time the next signal was emitted (subjects were not permitted to run wide circles). Subjects were instructed to always place one foot either on or behind

the 20 m mark at the end of each shuttle. If subjects arrived at the end of a shuttle before the bleep sound, they would turn around and wait for the bleep, then resume running and adjust their speed. The initial velocity was 8.5 km h^{-1} (2.38 m s^{-1}) allowing 8.4 s in which to run each 20 m shuttle, increasing by 0.5 km h^{-1} every minute. The subjects were required to adjust this running velocity when necessary. The first running speed was referred to as "Level 1", the second speed as "Level 2", and so on. The end of each shuttle was denoted by a single bleep; the end of each level was denoted by a triple bleep and was announced by the recording on the compact disc.

The test was terminated when the subjects voluntarily stopped or it became apparent that the subjects were dropping behind the required pace, and failed to reach the end of the shuttle before the bleep. The last fully completed stage number was then recorded, the HR monitor was stopped and a recovery period of five minutes began. The Borg RPE scale was administered. After approximately 4 minutes of active recovery, the subjects were prepared for lactate measurement. While lactate was being analyzed, the Likert Resemblance Scale was administered. Finally, a follow-up appointment for next test was arranged before the subjects were dismissed from the session. Preparation, participant information and participation in each test required approximately 30 minutes.

The $\dot{V}O_2$ max was calculated by using the following equation (for subjects 18 years or older):

$\dot{V}O_2$ max = 31.025 + 3.238(running speed) – 3.248(18) + 0.1536(18)(running speed) (Léger *et al.,* 1988)

Where:

a) $\dot{V}O_2$ max is expressed in ml kg^{-1} min^{-1}; and
b) running speed is the speed at the last completed stage expressed in km h^{-1}

3.7. Statistical Analysis and Treatment of Data

Statistical analyses were performed using SPSS software package (Version 15.0). Descriptive statistics (mean ± SD) were conducted for all variables.

1. Multiple regression analysis was employed to construct an equation to predict $\dot{V}O_2$ max from the MS20MST. Direct $\dot{V}O_2$ max from the treadmill test was used as the dependant variable and, maximal MS20MST speed, height and weight, as the independent variables.
2. Comparisons of maximal values of different variables ($\dot{V}O_2$ max, HR_{max}, speed max, $lactate_{max}$, test duration, Borg RPE max, and Likert scores) were done using a repeated one-way ANOVA to assess the similarity in physiological difficulty of each test (HR_{max}, speed max, $lactate_{max}$, Likert scores, Borg RPE scores). A posteriori test (Tukey) was used to determine exactly where the differences are (as ANOVA only determines whether or not differences exist).
3. Pearson correlation coefficients were also estimated for each of the following values obtained from each test
    1. Heart rate
    2. $\dot{V}O_2$ max
    3. Speed
    4. $Lactate_{max}$ values
    5. Test duration
    6. Rating of perceived exertion
4. Regression analysis (scatter plot, Pearson correlation and SEE) was applied between direct treadmill $\dot{V}O_2$ max and maximal speed for each of the four tests to establish a predictive model, to determine the external validity (vs. literature model) and to compare validity of each field test in a pair design. Statistical validation will consist of a complete residual analysis as well as testing for co-linearity between the independent variables in the model.