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THE EFFECTS OF HOCKEY PROTECTIVE EQUIPMENT ON AEROBIC AND ANAEROBIC PERFORMANCE

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ABSTRACT

THE EFFECTS OF HOCKEY PROTECTIVE EQUIPMENT

ON AEROBIC AND ANAEROBIC PERFORMANCE

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Ten experienced hockey players age 13 to 15 performed a maximum aerobic capacity treadmill test and the Wingate anaerobic capacity test once wearing shorts and once wearing hockey equipment, except skates. Wearing the equipment significantly: (a) decreased the subjects' run time, peak power, and mean power, (b) increased the heart rate at one exercise level, two rest periods, and after five minutes of recovery, (c) increased the ventilation and absolute oxygen consumption at three levels of submaximal exercise and three rest periods, and (d) increased the blood lactate concentration following two levels of exercise. No significant differences were found in oxygen uptake relative to total test weight, maximum oxygen uptake, peak lactate concentration, lactate concentration after the Wingate test, blood pressure, oxygen consumption during recovery, and lactate concentration during recovery. The significant changes observed are attributed to the excess weight of the equipment, particularly that on the legs.

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Chapter I - The Problem

Over the past decades, protective equipment for ice hockey players has undergone an evolution in design. A greater awareness of the injuries of the game led initially to development of improved head and face protection (Love, 1963, Pashby, et al, 1975). As the game changed to include more checking by bigger and faster players, the manufacturers strengthened other equipment as well. For example, the elbow pads were lengthened to cover the full gap between the gloves and the shoulder pads. The perfunctory chest protection of the shoulder pads was thickened and extended downwards. More recently, the distinctive baggy short pants are being replaced by a close fitting girdle of space age padding (Kalchman, 1981).

Appropriately, it is the youth hockey players who are among the best protected. The Amateur Hockey Association of the United States (AHAUS) now requires that each player wear a helmet and full face mask approved by the AHAUS Hockey Equipment Certification Council (HECC) (AHAUS, 1983). The Canadian Amateur Hockey Association has similar requirements.

In addition to helmet and face mask, the well-dressed youth hockey player wears shoulder pads, elbow pads, gloves, cup, pants or girdle, shinpads, and a mouthguard. The total weight can easily exceed four kilograms for older players, without including the player's skates and stick.

Excess weight has been shown to interfere with skating (Montgomery, 1981) and running (e.g., Cureton, et al, 1978) performance. Weight carried artificially above the legs can be considered the same as natural obesity (Goldman and Iampietro, 1962), while weight added to the feet or legs incurs a greater increase in energy cost due to the additional movement of the weight during running and walking (Soule and Goldman, 1969).

Maximum oxygen uptake values found by Ferguson, Marcotte, and Montpettit (1969) in an on-ice skating test are comparable to values found in treadmill tests. Treadmill running appears to be a reasonable approximation of skating for determining maximal aerobic capacity.

Bouchard, Taylor, and Dulac (1982) indicate that laboratory measures of anaerobic capacity correlate well (r=-.74) with at least one running field test. Considering the similarities in stroke between cycling and skating, the Wingate cycling test of anaerobic capacity (Bar-Or, Dotan, and Inbar, 1977) is assumed here to provide a reasonable approximation of skating anaerobic capacity. However, since cycling is not a weight bearing activity, as is skating, the approximation may not be as close as the one mentioned above for aerobic capacity.

Hockey players require both aerobic and anaerobic conditioning. During a game, a player typically will play in shifts of thirty to ninety seconds with a rest interval between shifts of one to three times that, depending on the number of players on the team, the coach's philosophy, and the game situation. Many youth hockey teams, particularly in the younger age groups, select only enough players to have two lines who alternate shifts.

During a shift, a player may perform brief bursts of acceleration, 60 yard dashes, or fairly continuous skating, interspersed with coasting, easy skating, or standing still. Sound anaerobic conditioning is crucial to the player's tactical play during a shift, while his aerobic training allows him to maintain peak performance throughout the game.

This study will use treadmill running and stationary cycling to examine the aerobic and anaerobic capacities of elite youth hockey players, and the effects of wearing their protective equipment on their performance on these laboratory tests.

Need for the Study

This study seeks to determine if there are significant detrimental effects of hockey protective equipment on aerobic and anaerobic performance in a laboratory situation. The areas in which performance may be affected may deserve further study either in on-ice tests or in new designs in the equipment worn during the tests.

Purpose of the Study

The study will examine the performance of experienced youth hockey players on an aerobic treadmill test and an anaerobic cycling test. The players will be tested once dressed in running shorts and once dressed in full hockey protective equipment, though without skates. The study was designed to look at the effects of the equipment on oxygen uptake, blood lactate concentration, heart rate and blood pressure during primarily aerobic exercise, and on blood lactate concentration and power output during primarily anaerobic exercise.

Research Hypotheses

The research hypotheses are that performing the tests while wearing hockey protective equipment will:

a) decrease the total run time,

b) increase the heart rate and blood pressure during exercise, rest, and recovery,

c) decrease the peak heart rate,

d) increase the ventilation and oxygen uptake relative to body weight at each level of submaximal exercise, but show no change relative to the total test weight,

e) decrease the maximum oxygen consumption relative to body weight,

f) increase the oxygen consumption during the 1.5 minute rest period following each level of exercise, and the oxygen consumption for five and ten minutes following exercise,

g) increase the blood lactate concentration at each level of exercise,

h) decrease the peak blood lactate concentration,

i) decrease the percent recovery of blood lactate concentration at 5, 10, and 60 minutes following exercise,

j) show no decrease in anaerobic peak power, mean power, and percent of peak power produced after thirty seconds, and

k) show no increase in the blood lactate concentration following anaerobic exercise.

Research Plan

The Michigan State University Center fo the Study of Human Performance has developed a treadmill test protocol involving alternating periods of exercise at increasing intensity and rest. Oxygen uptake and ventilation data are recorded using a gas bag system, while the rest periods provide opportunities to obtain blood samples and blood pressure readings. For a representative study, see VanHuss, Stephens, Vogel, et al, 1986.

The Wingate Bicycle Test is a frequently used test of anaerobic capacity (Bar-Or, Dotan, and Inbar, 1977). The test records the total work output of the subject over thirty seconds and the peak power in a five second segment. Blood samples for lactate concentration are taken before and after the test.

Delimitations

Wearing uniforms or protective equipment when working or exercising involves thermal effects on the wearer (Duncan, Gardner, and Barnard, 1979; Fox, et al, 1966; Mathews, Fox, and Tanzi, 1969). Since it is not possible to reproduce in this laboratory the usual environment of an active ice hockey player, the thermal effects are beyond the scope of this study.

Limitations

The results of this study are limited in application to experienced youth hockey players age 13 to 15. They are further limited to the laboratory setting of an aerobic treadmill test and an anaerobic bicycle test.

Chapter II - Related Literature

The available literature on the effects of protective equipment on athletic performance is very limited, with the exception of running shoe design. Most of the information reviewed here covers the effects of excess weight in general, with the more specific equipment studies grouped at the end. The majority of the literature is concerned with aerobic capacity and heart rate. Very little data have been reported on effects on anaerobic capacity.

Excess Weight - Obesity

The following two studies investigated the relationship between obesity and oxygen uptake, one by weight reduction and one by induced weight gain.

Sprynarova and Parizkova (1965) tested seven obese boys, with an average age of 11.5 years, before and after the boys attended a weight loss camp. In each test, the boys ran a progressive maximal treadmill test. During the weight loss camp, the boys lost an average of 14% of their post-camp body weight. The loss of the excess weight significantly ($p<.01$) increased their treadmill run time. During the second test, the absolute oxygen consumption was lower than the pre-camp test level at every speed. The maximum absolute oxygen consumption increased significantly, but both the increase per unit of body weight and the decrease per unit of lean body mass were not significant. The correlation between body weight and absolute oxygen uptake increased from r=0.75 to r=0.93 when the subjects lost weight.

In the second study, Hanson (1973) had four twenty-five year old subjects alter their diet to produce an average 19% weight gain. The subjects were tested on a treadmill (walking at three grades) and on a bicycle ergometer (at three loads) prior to the weight gain, after an average 15% weight gain, after the average 19% gain, and five months later after the loss of most of the gained weight, but with a backpack load used to return each subject's total weight to that of the third test. Significant changes ($p<.05$) were observed in ventilation and absolute oxygen uptake at the higher grades of the treadmill test, with increases occurring at all levels. The percentage increases in oxygen consumption were approximately the same as the corresponding percentage increase in weight gain. Tests when carrying the backpack on the treadmill showed no significant differences from tests with the natural weight. The subjects showed no increase in the energy cost of bicycle ergometry due to the increase in body weight. The authors point out that stationary cycling is not a weight bearing activity.

Excess Weight - Carried Weight

Goldman and Iampietro (1962) studied the energy cost of walking on a treadmill with three standard backpack loads of 10, 20, and 30 kilograms. Five men, average age 22, were tested at each of 22 combinations of load, grade (3%, 6%, and 9%), and speed (1.5, 2.5, 3.5, and 4.0 mph). For each combination of speed and grade, the energy cost, in kilocalories per kilogram of body weight per minute, clearly increases with each increase in load. When the energy cost is computed per kilogram of total weight (body weight plus load), it is virtually constant for each combination of speed and grade. The authors concluded that the energy cost of walking is independent of what portion of the weight is body weight and what portion in a backpack.

Soule and Goldman (1969) investigated the effects of carrying excess weight on the head or hands. In separate tests, the ten male subjects, average age 22, carried no weight, 4 kg on each hand, 7 kg on each hand, and 14 kg on their heads at speeds of 4.0, 4.8, and 5.6 kph. the authors found only slight increases in energy cost over the value expected if the load was carried in a backpack. They suggested some or all of the additional energy cost arises from efforts to stabilize the load, particularly that on the head.

Cureton, Sparling, Evans, et al, (1978) examined the effects of excess weight on aerobic capacity and distance running performance. Six trained runners (four male, two female, ages 20 to 30) performed a maximal, multi-stage, progressive treadmill test and a twelve minute run four times over a four week period with no added weight or 5, 10, or 15 percent of their body weight carried on a harness around the waist and shoulders. The authors found highly significant ($p<.01$) decreases in the distance run during twelve minutes and the time run on the treadmill, and in maximum oxygen uptake per unit of total weight (body weight plus weight carried). No significant differences were found in ventilation, oxygen uptake per unit of body weight or lean body mass, or heart rate during the maximal stress test. The authors also investigated the energy cost of running during submaximal exercise. At seven miles per hour, significant ($p<.05$ or less) changes occurred in ventilation, heart rate, and oxygen uptake per unit of body weight and per unit of lean body mass, while changes in oxygen uptake per unit of total weight were not significant. They concluded that the effects of the additional weight are due almost entirely to the increased energy cost of submaximal exercise.

Cureton and Sparling (1980) used a harness to add weight to ten male subjects, average age 26, to equate their excess weight (added weight plus body fat) to that of arbitrarily paired female subjects. Again, the added weight significantly ($p<.05$) reduced the males' treadmill run time and twelve minute run performance. At a submaximal work rate, the added weight increased the heart rate and oxygen uptake, both absolute and per unit of lean body mass, while decreasing the oxygen uptake per unit of total weight. On the maximal treadmill run, the added weight decreased their oxygen uptake per unit of total weight and the respiratory quotient, but did not significantly affect the other measures.

Excess Weight - Weight on Feet

Soule and Goldman (1969), cited earlier, included the additional condition of a load of 6 kilograms on each foot in the form of double wall boots filled with mercury. In this case, the increased energy cost over the no load condition was significant ($p<.01$) and the increased cost with each increase in speed was highly significant ($p<.001$). The authors suggest some of the increase in energy cost is due the reduced mobility of the ankle joint from the heavy boots, but the major part of the increase comes from the effort of moving those weights with each step.

Catlin and Dressendorfer (1979) considered the effect of shoe weight on running energy costs of seven marathoners. The heavier training shoe (0.87 kg) increased the energy cost of running 0.51 kilocalories per minute over running with a racing shoe (0.52 kg) ($p<.05$).

Jones, et al, (1984) investigated the effects of walking (at 2.5, 3.5, and 4.5 mph) and running (at 5.5, 6.5, and 7.5 mph) in shoes, boots, and shoes plus weight added to equal the weight of the boots. The subjects' shoes had an average weight of 0.6 kilograms and the boots 1.8 kilograms. The maximum oxygen uptake for each subject, wearing shoes, had been obtained in a previous test. The subjects were six trained and eight untrained males with an average age of 30. The oxygen consumption when wearing boots instead of shoes was significantly higher ($p<.05$) at all speeds except the lowest. The increase averaged 8%, while the boots increased each subject's weight by an average of only 1.4%. The subjects' heart rate was higher, though not significantly, when wearing boots instead shoes. Oxygen consumption when wearing shoes plus the added weight was significantly higher ($p<.05$) at the three running speeds. When compared to the boots, weight by itself accounted for up to 70% of the difference between shoes and boots.

Excess Weight - Skating

Montgomery (1981) investigated the effects of excess weight on the mostly anaerobic task of six repetitions of skating 100 yards. A repetition was started every thirty seconds. The subjects were twelve males with an average age of 21. Each carried, during separate tests over a two week period, no excess weight, and 5, 10, and 15 percent of their body weight in a vest. The results showed a significant ($p<.05$) decrease in speed and increase in both total performance time and the drop-off index, an indicator of anaerobic endurance. There were no significant effects on heart rate after three and five minutes of recovery.

Excess Weight - Uniforms

Duncan, Gardner, and Barnard (1979) studied eleven firefighters, average age 29, in street clothes and protective uniforms at submaximal work rates on a treadmill. The uniforms, including rubber lined clothes, boots, and breathing apparatus, added an average of 21.82 kilograms to each subject's total weight. The subjects walked on a treadmill at four kilometers per hour and ten percent grade for fifteen minutes. Heart rate, oxygen uptake, and breathing rate were measured for every fifth minute of exercise, and heart rate at each minute of recovery. The mean heart rate of uniformed subjects showed significant ($p<.01$) increases at all points, including recovery. The average oxygen consumption and breathing rate after fifteen minutes of exercise both increased significantly ($p<.01$).

Fox and Mathews at Ohio State University conducted two studies investigating the causes of heatstroke deaths in football players. In the first (Fox, Mathews, Kaufman, et al, 1966), five high school players ran on a treadmill at six miles per hour for twenty minutes dressed in a hospital scrub suit and their football uniform. Heart rates were recorded for twenty minutes of exercise and thirty minutes of recovery. Ventilation and oxygen consumption were recorded every fifth minute of exercise. The mean heart rate increased steadily, with a significant difference of fifteen beats per minute at the end of exercise ($p<.01$), uniform over scrub suit. The difference remained throughout the half hour recovery and was still significant ($p<.05$) at the end. There was no difference in the heart rate per kilogram of total weight during exercise. Oxygen consumption was reported per kilogram of total weight, including the average 14.7 pounds of football uniform. No differences were reported in oxygen consumption (ml/kg/min), total ventilation (ml/kg/min), ventilation equivalent, or oxygen pulse (ml/min/beat). However, the authors mention, without reporting significance, that, in uniform, oxygen consumption, ventilation, and heart rate increased when the weight carried was not included in the calculation. The authors attribute the reported changes to the weight and thermal effects of the football equipment. They also reported significant differences in core temperature elevation during exercise and temperature after thirty minutes of recovery.

Mathews, Fox, and Tanzi (1969) continued this line of investigation with nine male graduate students running on a treadmill (9.6 km/hr, 0% grade) in shorts, football uniform, and shorts plus a backpack weighing the same as the football uniform (6.2 kg). Besides extensive data on skin and rectal temperature, they recorded heart rate, ventilation, and oxygen consumption every fifth minute for thirty minutes of exercise. This paper provided little useful analysis of the oxygen consumption and ventilation data; the authors' interest was in the temperatures. Average oxygen consumption was consistently higher with the backpack than with either shorts or uniform, and higher with the uniform than the shorts, though apparently not significantly. The authors suggest the energy cost is greater for a concentrated weight than for the same weight distributed evenly over the body. At the end of recovery, the oxygen consumption was still significantly increased over the pre-exercise levels, with the mean difference for the uniform trial ($p<.02$) about twice that of the other two ($p<.05$ for shorts, $p<.10$ for backpack). Ventilation increased during exercise for all three tests, with the uniform and backpack conditions noticeably above the shorts-only condition at each point (no significance was mentioned). The only significant difference between pre-exercise and end of recovery ventilation occurred with the uniform on ($p<.05$). The heart rate increased faster and longer during exercise with a backpack or uniform than with shorts, and remained similarly elevated throughout recovery.

Summary

Excess weight seems to have the same effects on aerobic performance whether it is natural obesity or artificially added. There are some additional energy costs associated with stabilizing heavy concentrated loads on one part of the body. At submaximal exercise levels, the weighted performer operates at a higher percentage of his maximum heart rate and oxygen consumption. Peak capacity is reached more quickly, decreasing the duration of the performance. Excess weight carried on the feet has effects out of proportion to the weight carried due to the extra movement of the weight required.

Added weight shows no effect on anaerobic power or capacity as measured by a stationary bicycle test, but does decrease performance in the weight-bearing activity of skating. Uniforms and protective clothing also have thermal effects on the wearer during exercise.

Chapter III - Research Methods

Subjects and Sample

The ten subjects were volunteers from the sixteen players of the Bantam AA youth hockey team of the Greater Lansing Amateur Hockey Association. Eight turned fourteen during 1984; two were one year younger. All were experienced hockey players. The team had won the Michigan State Championship in its class. The team continued its normal training through the National Tournament. The testing sessions were scheduled for the two weekends immediately following the tournament, while the players were still at or near peak condition.

Each subject was assigned randomly to a starting time to be used for both test sessions. Although each subject was at the laboratory for about two hours, the starting times were about forty five minutes apart. The subjects further were divided randomly into two groups. One group tested first in full hockey equipment, except skates and stick, and second in running shorts. The other half tested first in shorts and second in equipment to control the effects of familiarization with the testing and any detraining that might occur. Samples of the test schedule and other descriptive items that were presented to the subjects are located in Appendix A.

Test Protocols

Each subject performed an intermittent maximal aerobic capacity treadmill test and the Wingate anaerobic capacity bicycle test once in shorts and once in hockey equipment. During one test session, the subject's percentage of body fat was determined by hydrostatic weighing.

On arrival at the laboratory, each subject was weighed wearing shorts only. Electrodes were attached for the three-lead electrocardiogram (CM-5), and the subject sent to dress for running. Those wearing their hockey equipment were instructed to dress as they would for a game, including a game jersey. The subject was weighed again to determine the weight of the equipment. The equipment was dry before the test began. The shinpads were weighed separately before the subject dressed. Pre-exercise heart rate and blood pressure were taken, as was a blood sample, from a finger tip, for blood lactate concentration analysis.

The treadmill run consisted of alternating three-minute runs and minute-and-a-half rest periods, repeated to exhaustion and followed by a ten-minute recovery period. The initial exercise level was at six miles per hour and zero percent grade. The second exercise level was at six miles per hour and five percent grade. Each subsequent exercise level was at an increase of one mile per hour and one percent grade. During rest and recovery, the subject sat on a table placed over the treadmill.

Expired air was collected in a Douglas bag system for each minute of exercise and each half-minute of rest. During recovery, expired air was collected in five one-minute bags, one two-minute bag, and one three-minute bag. The subject's heart rate was recorded at the end of each bag time. Immediately after each exercise level and at five and ten minutes of recovery, the subject's blood pressure was recorded and a finger tip blood sample was taken. Additional blood samples were taken after fifteen and sixty minutes of recovery. The subjects were free to move about the room during the forty five minutes before the final blood sample.

The Wingate bicycle test was administered immediately after the sixty minute blood sample was taken. The subject rode for eight seconds at the highest rpm he could manage to determine his maximum anaerobic power for five seconds. After a two minute rest, the subject pedaled at his maximum rpm for thirty seconds. The pedal revolutions were recorded on a chart recorder. The test load was 0.045 kilograms per kilogram of body weight, rounded to the nearest half kilogram, and was the same for both tests. A blood sample was taken after one minute of seated rest.

Dependent Variables Collected

The following dependent variables were collected during the treadmill run:

a) pre-exercise heart rate and heart rate during exercise, rest, and recovery,

b) pre-exercise blood pressure, blood pressure following each level of exercise, and blood pressure during recovery,

c) blood lactate concentration before exercise, following each level of exercise, and during recovery,

d) ventilation and percentage of oxygen and carbon dioxide in the expired air during exercise, rest, and recovery, and

e) total running time.

The following dependent variables were computed from data collected during the treadmill run:

f) oxygen consumption in both liters per minute and milliliters per kilogram per minute during exercise, rest, and recovery, and

g) percent recovery of blood lactate concentration at five, ten, fifteen, and sixty minutes of recovery.

The following dependent variables were collected during the Wingate anaerobic test:

h) blood lactate concentration after the test, and

i) pedal revolutions for the last five seconds of the eight-second test and each five seconds of the thirty-second test.

The following dependent variables were computed from the data collected during the Wingate test:

j) peak power during any five second segment of either test,

k) mean power all six segments of the thirty second test, and

l) percent drop-off from the first to last segments of the thirty second test.

Statistical Analysis

The statistical analysis of the data utilized one-tail t-tests of the significance of the difference between the means of two normal dependent samples. The variables being tested were assumed to be normally distributed for the population of experienced Bantam youth hockey players. Nothing was known, or required to be known, about the variance of the population or samples.

Alpha was set at 0.05 and beta at 0.20. A difference of one-half of a standard deviation was to be considered significant. The necessary and sufficient sample size was 51. Due to financial and time limitations, it was not possible to test that many subjects at this time.

Chapter IV - Results and Discussion

The use of a maximum aerobic capacity treadmill test and the Wingate anaerobic capacity bicycle test proved satisfactory for determining changes in the subjects' performances caused by their wearing hockey protective equipment. The test sessions proceeded as planned. All subjects completed the test sequences without incident. The results of the test sessions are presented in Tables 2 through 10. Column A in each pair of columns contains the data from the subjects' tests with their hockey equipment, the experimental condition. Column B contains the data from the standard tests in running shorts, the control condition.

The results are presented below and discussed in relation to the expected increases in heart rate, blood pressure, ventilation, oxygen consumption, and blood lactate concentration for submaximal exercise and corresponding decreases for the subjects' maximum performance.

Initial Conditions

Table 1 presents the ten subjects' initial conditions. The weight of each subject's hockey equipment is listed as a percentage of the his body weight, and the weight of his shinpads as a percentage of his total equipment weight. Each player's equipment weighs from 8 to 12 percent of his body

Table 1: Physical Characteristics

Subject	Age (yr)	Height (cm)	Weight (kg)	% Fat
1	15.1	180	68.2	12.1
2	14.8	188	75.3	9.3
3	14.1	163	51.2	16.9
4	14.9	180	63.5	12.6
5	15.2	182	66.9	5.6
6	14.5	167	57.9	17.4
7	14.3	157	48.0	15.5
8	13.5	160	48.7	17.6
9	13.9	160	47.9	19.0
10	15.3	168	57.6	13.4
Mean (s.d.)	15.3 (0.6)	168 (11)	48.0 (10.3)	8.2 (4.6)

Subject	Eqp Wt (kg)	% BW	SP Wt (kg)	% EQP Wt
1	5.5	8.1	.76	13.8
2	6.2	8.2	.72	11.6
3	5.0	9.8	.74	14.8
4	7.7	12.1	1.04	13.5
5	6.4	9.6	.64	10.0
6	6.1	10.5	.84	13.8
7	5.6	11.7	1.04	18.6
8	4.6	9.4	.60	13.0
9	3.9	8.1	.64	16.4
10	3.8	7.9	.76	20.0
Mean (s.d.)	3.8 (1.2)	9.5 (1.5)	.78 (.16)	14.6 (3.0)

weight, with the shin pads accounting for 10 to 20 percent of that weight.

There were no significant differences in the pre-test measures of heart rate, blood pressure, and blood lactate concentration, as shown in Table 2. These t-tests were done as two-tail tests since there was no reason to expect a difference in a specific direction. The blood lactate concentration was nearly significant, although there is no known reason why this should be so. Seven of the subjects had higher lactate concentrations prior to testing without their hockey equipment and two registered higher prior to testing with their equipment. One subject had the same concentration both days. Possibly the subjects were more active on the days they did not wear their equipment.

Maximum Aerobic Capacity Characteristics

Wearing their hockey equipment significantly decreased the subjects' mean total run time over 22 percent (Table 3). Seven of them ran into Level 4 (minutes 10, 11, and 12), while three could manage only Level 3. Without their equipment, six subjects ran into Level 5; four into Level 4. Two subjects were in the lower level for both tests. There was a significant decrease in the peak heart rate. However, the difference was less than half a standard deviation. The difference also was close to the limit of resolution of the heart rate monitoring device at high heart rates. The decrease may be significant but not relevant. There were no

Table 2: Pre-Test Heart Rate, Blood Pressure, and Blood Lactate Concentration

Subject	Heart Rate (bpm) A	B	Systolic B.P. (mmHg) A	B
1	63	72	112	122
2	75	72	138	130
3	72	88	128	124
4	87	75	120	120
5	66	71	108	122
6	88	84	108	118
7	96	80	116	110
8	107	95	112	110
9	85	96	108	112
10	97	63	118	118
Mean	84	80	117	119
(s.d.)	(14)	(11)	(10)	(6)

	N	T	P Value
Pre-Test Heart Rate	10	0.84	0.42
Pre-Test Systolic B.P.	10	-0.76	0.46

Subject	Diastolic B.P. (mmHg) A	B	Blood Lactate (mmol/l) A	B
1	72	68	1.65	1.65
2	70	65	1.80	3.00
3	82	60	2.70	2.30
4	80	90	2.05	1.70
5	76	78	1.60	2.05
6	80	78	1.55	1.80
7	70	72	1.40	1.85
8	74	72	1.45	2.10
9	68	62	1.10	1.85
10	62	60	1.95	2.30
Mean	74	71	1.73	2.06
(s.d.)	(6)	(10)	(.44)	(.40)

	N	T	P Value
Pre-Test Diastolic B.P.	10	1.13	0.29
Pre-Test Lactate Conc.	10	-2.15	0.06

Significance: * $p<.05$; ** $p<.01$

Table 3: Maximum Aerobic Characteristics

Subject	Total Run Time (mm:ss) A	B	Maximum VO_2 (ml/kg/min) A	B
1	10:00	11:31	57.6	55.2
2	11:00	13:17	60.2	59.0
3	9:56	10:42	60.8	59.4
4	10:02	13:10	57.9	61.0
5	11:30	13:53	56.1	60.2
6	7:57	11:00	52.5	57.5
7	7:12	10:37	52.0	54.0
8	9:36	13:00	62.1	59.3
9	8:44	12:53	59.6	58.5
10	9:55	13:28	58.9	62.3
Mean	9:35	12:21	57.8	58.7
(s.d.)	(1:18)	(1:15)	(3.4)	(2.5)

	N	T	P Value
Total Run Time	10	-8.51	0.00 **
Maximum VO_2	10	-0.94	0.19

Subject	Peak Heart Rate (mm:ss) A	B	Peak Lactate (ml/kg/min) A	B
1	206	203	10.20	11.95
2	183	200	12.95	14.50
3	207	204	12.15	9.65
4	200	210	13.75	12.75
5	210	209	18.30	15.15
6	210	210	10.60	10.80
7	210	210	10.80	11.85
8	220	240	9.20	12.65
9	230	240	11.10	18.55
10	205	210	9.85	13.25
Mean	208	213	11.89	13.11
(s.d.)	(12)	(14)	(2.66)	(2.50)

	N	T	P Value
Peak Heart Rate	10	-2.08	0.03 *
Peak Lactate	10	-1.23	0.12

Significance: * $p<.05$; ** $p<.01$

significant decrease in maximum oxygen uptake relative to body weight or peak lactate concentration.

Heart Rate

The maximum heart rate during each level of exercise showed no major changes due to the hockey equipment (Table 4). While statistically significant at Level 2, the difference was less than one half of one standard deviation. Since the other levels showed heart rates with no significant differences, this result may be anomalous. A larger sample size would be needed to resolve this question.

The minimum heart rate during each rest period showed greater effects of the hockey equipment (Table 5). The difference was significant following the first and second exercise levels. Occasional difficulties with the heart rate monitor and three subjects who could not complete Level 3 when wearing equipment reduced the sample size for Levels 1 and 3. Following exercise, the heart rate may recover less quickly when wearing the hockey equipment. There was a substantial amount of extra oxygen consumed during each of the three rest periods (Table 6). The increased heart rate would be involved in mobilizing this extra oxygen to replenish the muscles.

There does not appear to be any difference in heart rate immediately following the subjects' maximal efforts. The heart rate was significantly elevated after five minutes of recovery and nearly so after ten minutes. These elevated

Table 4: Heart Rate and Blood Pressure During Exercise

Level 1:	Heart Rate (bpm)		Systolic BP (mmHg)		Diastolic BP (mmHg)	
Subject	A	B	A	B	A	B
1	162	145	170	168	72	70
2	132	154	180	180	72	90
3	178	178	182	174	86	80
4	168	170	188	192	90	80
5	164	160	162	170	76	75
6	190	178	172	162	90	90
7	197	175	152	150	76	80
8	200	195	144	152	82	72
9	205	195	180	168	80	78
10	175	160	182	160	82	74
Mean	177	171	171	168	81	79
(s.d.)	(22)	(17)	(14)	(13)	(7)	(7)

	N	T	P Value
Level 1 Heart Rate	10	1.55	0.08
Systolic Blood Pressure	10	1.20	0.13
Diastolic Blood Pressure	10	0.65	0.27

Level 2:	Heart Rate (bpm)		Systolic BP (mmHg)		Diastolic BP (mmHg)	
Subject	A	B	A	B	A	B
1	188	176	198	194	76	70
2	172	176	198	192	80	85
3	195	185	190	190	88	70
4	190	192	188	190	80	70
5	183	177	164	170	70	65
6	205	205	162	180	80	90
7	205	205	*	158	*	82
8	210	204	152	166	88	78
9	210	207	182	192	80	78
10	200	185	208	158	92	80
Mean	196	191	182	179	82	77
(s.d.)	(13)	(13)	(19)	(15)	(7)	(8)

	N	T	P Value
Level 2 Heart Rate	10	2.31	0.02 *
Systolic Blood Pressure	9	0.17	0.44
Diastolic Blood Pressure	9	1.84	0.05

Significance: * $p<.05$; ** $p<.01$

Table 4: (continued)

Level 3: Subject	Heart Rate (bpm) A	B	Systolic BP (mmHg) A	B	Diastolic BP (mmHg) A	B
1	205	192	208	190	80	70
2	183	186	192	190	80	90
3	204	193	198	198	90	80
4	200	201	170	178	80	80
5	205	205	166	200	80	70
6	210	205	158	182	85	82
7	205	210	152	170	70	90
8	215	215	160	172	98	78
9	230	230	170	198	84	80
10	205	200	210	172	92	90
Mean	206	204	178	185	84	81
(s.d.)	(12)	(13)	(22)	(12)	(8)	(7)

	N	T	P Value
Level 3 Heart Rate	10	1.34	0.11
Systolic Blood Pressure	10	-0.95	0.82
Diastolic Blood Pressure	10	0.81	0.22

Level 4: Subject	Heart Rate (bpm) A	B	Systolic BP (mmHg) A	B	Diastolic BP (mmHg) A	B
1	206	199	210	188	88	68
2	169	195	168	185	70	80
3	207	204	180	200	82	74
4	190	210	142	185	60	65
5	210	205	132	170	70	60
6	*	210	*	170	*	78
7	*	210	*	148	*	70
8	220	240	160	158	90	92
9	*	230	*	182	*	80
10	205	210	204	168	92	80
Mean	201	211	171	175	79	75
(s.d.)	(17)	(14)	(29)	(15)	(12)	(9)

	N	T	P Value
Level 4 Heart Rate	7	-1.54	0.91
Systolic Blood Pressure	7	-0.74	0.76
Diastolic Blood Pressure	7	1.17	0.14

Significance: * p<.05; ** p<.01

Table 5: Heart Rate and Blood Pressure in Rest and Recovery

	Rest 1 HR (bpm)		Rest 2 HR (bpm)		Rest 3 HR (bpm)	
Subject	A	B	A	B	A	B
1	86	77	113	87	129	130
2	98	108	122	123	145	130
3	118	116	148	125	164	140
4	108	100	122	111	130	134
5	107	95	127	118	140	143
6	139	130	150	130	*	129
7	139	125	160	135	*	150
8	128	*	150	153	155	*
9	150	*	175	147	*	173
10	*	87	147	90	*	135
Mean (s.d.)	119 (21)	105 (18)	141 (20)	122 (22)	144 (14)	140 (14)

	N	T	P Value
Rest Period 1 Heart Rate	7	2.05	0.04 *
Rest Period 2 Heart Rate	10	3.58	0.00 **
Rest Period 3 Heart Rate	5	1.10	0.17

	Rec.+1 HR (bpm)		Rec.+2 HR (bpm)		Rec.+3 HR (bpm)	
Subject	A	B	A	B	A	B
1	132	160	119	112	112	110
2	163	155	129	127	120	115
3	170	163	145	137	132	126
4	143	142	120	124	118	114
5	160	168	147	139	133	130
6	180	177	145	153	139	138
7	170	160	141	135	137	120
8	170	180	145	151	135	147
9	175	197	160	170	148	160
10	140	168	132	138	124	118
Mean (s.d.)	160 (16)	167 (15)	138 (13)	139 (16)	130 (11)	128 (16)

	N	T	P Value
Recovery + 1 Min. Heart Rate	10	-1.42	0.91
Recovery + 2 Min. Heart Rate	10	-0.13	0.55
Recovery + 3 Min. Heart Rate	10	0.74	0.24

Significance: * $p<.05$; ** $p<.01$

Table 5: (continued)

Subject	Rec.+4 HR (bpm) A	B	Rec.+5 HR (bpm) A	B	Rec.+10 HR (bpm) A	B
1	113	112	113	108	114	112
2	116	113	117	116	111	112
3	126	124	126	129	129	123
4	117	115	120	115	130	118
5	127	119	125	125	126	113
6	137	122	131	117	132	122
7	129	120	135	122	139	120
8	135	147	140	135	135	139
9	145	151	148	150	140	149
10	131	120	128	128	139	138
Mean	128	124	128	125	130	125
(s.d.)	(10)	(14)	(11)	(12)	(10)	(13)

	N	T	P Value
Recovery + 4 Min. Heart Rate	10	1.30	0.11
Recovery + 5 Min. Heart Rate	10	2.05	0.03 *
Recovery +10 Min. Heart Rate	10	1.79	0.05

Subject	Rec.+5 SBP (mmHg) A	B	Rec.+5 DBP (mmHg) A	B
1	142	124	80	60
2	140	130	72	70
3	142	148	80	70
4	118	135	68	60
5	128	135	70	60
6	128	132	82	64
7	132	117	64	64
8	124	142	84	72
9	132	158	66	78
10	152	136	78	82
Mean	134	136	74	68
(s.d.)	(10)	(12)	(7)	(8)

	N	T	P Value
Rec. + 5 Min. Systolic BP	10	-0.38	0.64
Rec. + 5 Min. Diastolic BP	10	2.04	0.03 *

Significance: * p<.05; ** p<.01

Table 5: (continued)

Subject	Rec.+5 SBP (mmHg) A	B	Rec.+5 DBP (mmHg) A	B
1	135	118	80	60
2	108	110	62	75
3	128	128	80	68
4	100	120	60	75
5	94	120	60	65
6	120	128	80	70
7	128	118	70	64
8	118	110	78	76
9	128	122	74	76
10	140	115	90	78
Mean	120	119	73	71
(s.d.)	(15)	(6)	(10)	(6)

	N	T	P Value
Rec. + 10 Min. Systolic BP	10	0.20	0.42
Rec. + 10 Min. Diastolic BP	10	0.75	0.24

Significance: * $p<.05$; ** $p<.01$

Table 6: Ventilation and Oxygen Uptake During Submaximal Exercise

Level 1: Subject	Ventilation (liters/min) A	B	Oxygen Uptake (liters/min) A	B	Oxygen Uptake (ml/kg/min) A	B	A-TW
1	64.7	57.2	2.81	2.51	41.2	36.8	38.1
2	60.4	48.4	3.08	2.68	40.9	35.6	37.8
3	58.6	52.0	2.48	2.17	48.4	42.4	44.1
4	59.9	50.1	2.64	2.58	41.6	40.6	37.1
5	60.8	59.0	2.66	2.59	39.8	38.7	36.3
6	60.8	47.2	2.48	2.26	42.8	39.0	38.8
7	53.4	40.9	2.25	1.89	46.9	39.4	42.0
8	42.3	42.0	2.13	1.92	43.7	39.4	40.0
9	47.6	44.9	2.15	2.09	44.9	43.6	41.5
10	47.9	40.9	2.15	1.98	44.8	41.3	41.5
Mean	55.6	48.2	2.48	2.27	43.5	39.7	39.7
(s.d.)	(7.4)	(6.4)	(.32)	(.30)	(2.8)	(2.4)	(2.5)

	N	T	P Value
Level 1 Ventilation	10	5.00	0.00 **
Oxygen Consumption per Minute	10	5.43	0.00 **
O_2 per Minute per Body Weight	10	5.54	0.00 **
O_2 per Minute per Test Weight	10	-0.06	0.95

Level 2: Subject	Ventilation (liters/min) A	B	Oxygen Uptake (liters/min) A	B	Oxygen Uptake (ml/kg/min) A	B	A-TW
1	86.4	76.0	3.51	3.11	51.5	45.6	47.6
2	75.7	61.8	3.63	3.34	48.2	44.4	44.5
3	72.3	61.8	2.88	2.51	56.3	49.0	51.2
4	82.5	65.4	3.19	3.16	50.2	49.8	44.8
5	86.4	69.1	3.29	3.04	49.2	45.4	44.9
6	81.0	61.8	2.88	2.69	49.7	46.5	45.0
7	74.5	57.7	2.48	2.36	51.7	49.2	46.3
8	55.6	54.5	2.47	2.31	50.7	47.4	46.3
9	62.0	52.6	2.62	2.35	54.7	49.1	50.6
10	61.4	48.9	2.54	2.29	52.9	47.7	49.0
Mean	73.8	61.0	2.95	2.72	51.5	47.4	47.0
(s.d.)	(10.9)	(8.0)	(.43)	(.41)	(2.5)	(1.9)	(2.5)

	N	T	P Value
Level 2 Ventilation	10	7.59	0.00 **
Oxygen Consumption per Minute	10	6.58	0.00 **
O_2 per Minute per Body Weight	10	6.59	0.00 **
O_2 per Minute per Test Weight	10	0.53	0.61

Significance: * $p<.05$; ** $p<.01$

Table 6: (continued)

Level 3: Subject	Ventilation (liters/min) A	B	Oxygen Uptake (liters/min) A	B	Oxygen Uptake (ml/kg/min) A	B	A-TW
1	116.5	97.6	3.93	3.64	57.6	53.4	53.3
2	92.2	80.6	4.15	3.98	55.1	52.9	50.9
3	88.9	83.2	3.11	2.85	60.7	55.7	55.3
4	100.4	86.2	3.67	3.57	57.8	56.2	51.5
5	112.2	88.7	3.75	3.69	56.1	55.2	51.2
6	*	78.1	*	3.09	*	53.4	*
7	*	70.1	*	2.51	*	52.3	*
8	71.5	67.6	2.86	2.66	58.7	54.6	53.7
9	*	64.4	*	2.68	*	55.9	*
10	77.1	56.9	2.83	2.55	59.0	53.1	54.6
Mean	94.1	77.3	3.47	3.12	57.9	54.3	53.0
(s.d.)	(16.8)	(12.5)	(.53)	(.55)	(1.9)	(1.4)	(1.7)

	N	T	P Value
Level 3 Ventilation	7	5.00	0.00 **
Oxygen Consumption per Minute	7	5.72	0.00 **
O_2 per Minute per Body Weight	7	4.84	0.00 **
O_2 per Minute per Test Weight	7	1.81	0.12

Significance: * p<.05; ** p<.01

heart rates may be related to thermal effects as the subjects, when wearing full equipment, may have had more difficulty dissipating heat following maximal exercise.

Blood Pressure

The blood pressure measurements taken immediately following each exercise level showed no statistical significance (Table 4). Those taken five and ten minutes after the subject stopped running were significant only in the diastolic blood pressure after five minutes (Table 5). The blood pressure values appear stable enough that any potential differences were not significant with this small sample size.

Ventilation and Oxygen Consumption

The increase in ventilation due to the hockey equipment was highly significant at each of the three levels of submaximal exercise (Table 6). (The three subjects who reached maximum oxygen uptake in Level 3 while wearing their equipment were not included in the t-test for Level 3.) Oxygen consumption, in both liters per minute and milliliters per kilogram of body weight per minute, was similarly significant. However, when the oxygen consumption was adjusted for the total test weight - body weight in one case and body weight plus equipment weight in the other - there were no significant differences. At Level 3 the difference was nearly one standard deviation, but with only seven subjects, was not statistically significant.

At each level, the weight of the hockey equipment caused the subjects to operate at a higher percentage of their maximum oxygen uptake. Thus peak performance was reached sooner, decreasing the total run time. The oxygen consumption relative to total test weight remained steady, indicating that the energy cost to move the weight was the same whether the weight was artificial or natural. There was an increasing effect on the oxygen consumption relative to total test weight as the subject approaches maximum effort. This most likely was due to the extra work involved in moving the shinpads with each stride.

The total volume of oxygen consumed during each of the three rest periods increased significantly when the subjects were wearing their equipment, although the increase in oxygen uptake relative to body weight was significant only for two, possibly due to the reduced sample size (Table 7). The subjects were running a substantially increased oxygen debt when wearing their equipment. In a test without rest periods, the total running time likely would be shortened even more drastically.

Neither oxygen uptake nor total oxygen consumed differed significantly during the post-exercise recovery period. The recovery period was preceded by a run to exhaustion in both tests; one just took longer.

Table 7: Total Oxygen Uptake During Rest and Recovery

Subject	Rest 1 VO_2 (liters) A	B	Rest 2 VO_2 (liters) A	B	Rest 3 VO_2 (liters) A	B
1	2.11	1.69	2.60	2.01	3.15	2.65
2	2.15	1.93	2.55	2.32	3.14	2.69
3	1.72	1.56	2.06	1.89	4.24	2.25
4	1.86	1.82	2.36	2.09	2.82	2.43
5	2.08	2.02	2.50	2.44	2.94	2.80
6	1.83	1.73	2.17	1.94	*	2.23
7	1.58	1.32	1.89	1.60	*	1.95
8	1.50	1.23	1.67	1.41	2.14	1.65
9	1.65	1.50	1.97	1.58	*	1.99
10	1.53	1.12	1.83	1.64	1.92	1.87
Mean	1.80	1.59	2.16	1.89	2.91	2.25
(s.d.)	(.24)	(.30)	(.33)	(.34)	(.76)	(.39)

	N	T	P Value
Rest Period 1 Oxygen Used	10	4.96	0.00 **
Rest Period 2 Oxygen Used	10	5.98	0.00 **
Rest Period 3 Oxygen Used	7	2.33	0.03 *

Subject	Rec. + 5 VO_2 (liters) A	B	Rec. +10 VO_2 (liters) A	B
1	5.60	4.86	8.35	7.65
2	6.52	5.76	9.53	8.65
3	4.52	4.27	6.64	6.21
4	4.33	5.28	6.87	7.87
5	6.39	6.53	9.72	9.66
6	4.35	4.84	6.76	7.22
7	3.77	3.83	6.16	5.86
8	3.92	4.08	5.91	6.10
9	3.81	3.82	5.93	6.48
10	3.91	4.06	5.87	6.15
Mean	4.71	4.73	7.17	7.19
(s.d.)	(1.06)	(0.90)	(1.49)	(1.27)

	N	T	P Value
5 Min. Recovery Oxygen Used	10	-0.13	0.55
10 Min. Recovery Oxygen Used	10	-0.06	0.52

Significance: * $p<.05$; ** $p<.01$

Table 7: (continued)

Subject	Rest 1 RVO_2 (ml/kg/min) A	Rest 1 RVO_2 (ml/kg/min) B	Rest 2 RVO_2 (ml/kg/min) A	Rest 2 RVO_2 (ml/kg/min) B	Rest 3 RVO_2 (ml/kg/min) A	Rest 3 RVO_2 (ml/kg/min) B
1	13.3	9.3	15.5	12.5	20.2	16.9
2	11.5	13.0	12.8	14.1	18.3	15.4
3	15.1	12.5	16.4	15.4	20.1	18.3
4	13.1	13.6	14.7	14.8	14.8	17.6
5	13.8	14.3	14.9	16.7	21.7	18.9
6	13.1	12.8	17.8	14.6	*	17.3
7	14.1	11.9	17.5	14.4	*	18.2
8	13.2	11.6	15.3	12.0	18.3	13.5
9	16.0	14.4	18.3	15.1	*	18.8
10	15.3	11.0	16.6	15.6	17.5	18.1
Mean	13.9	12.4	16.0	14.5	18.7	17.3
(s.d.)	(1.3)	(1.6)	(1.7)	(1.4)	(2.2)	(1.7)

	N	T	P Value
Rest Period 1 Oxygen Uptake	10	2.29	0.02 *
Rest Period 2 Oxygen Uptake	10	2.32	0.02 *
Rest Period 3 Oxygen Uptake	7	1.78	0.06

Subject	Rec. + 5 RVO_2 (ml/kg/min) A	Rec. + 5 RVO_2 (ml/kg/min) B	Rec. +10 RVO_2 (ml/kg/min) A	Rec. +10 RVO_2 (ml/kg/min) B
1	9.1	9.7	7.8	7.7
2	10.0	9.2	7.1	7.4
3	8.7	9.4	8.2	7.3
4	9.0	8.8	7.3	7.7
5	13.8	10.9	9.5	8.9
6	8.1	9.2	7.7	7.5
7	8.9	9.3	11.0	8.2
8	9.8	9.6	7.3	8.2
9	9.7	10.0	8.5	12.3
10	8.5	11.0	7.7	8.2
Mean	9.6	9.7	8.2	8.3
(s.d.)	(1.6)	(0.7)	(1.2)	(1.5)

	N	T	P Value
Recovery + 5 Min. O_2 Uptake	10	-0.34	0.63
Recovery + 10 Min. O_2 Uptake	10	-0.25	0.60

Significance: * $p<.05$; ** $p<.01$

Blood Lactate Concentration

The increase in blood lactate concentration following each exercise period was statistically significant after the second and third levels, but not after the first (Table 8). The excess weight, particularly on the legs, may have caused fatigue problems at higher levels of exercise. The decrease in peak lactate concentration, most likely caused by the sharply decreased total run time, was not significant.

The lactate levels remained lower all through recovery, although they showed no significant differences up to 60 minutes following maximal exercise. The percentage of the increase in blood lactate concentration that was removed during recovery showed no differences up to 60 minutes following exercise (Table 9). The hockey equipment did not change the rate of elimination of the lactate.

Anaerobic Characteristics

The anaerobic tests showed significant differences due to the hockey equipment in peak power generated and mean power generated over thirty seconds (Table 10). There was no change in the percentage of the peak power being produced at the end of thirty seconds or in the post-test blood lactate concentration. The differences likely were due, once again, to the weight of the shinpads. Since the subject was seated, the remainder of the equipment should have had little effect.

Table 8: Blood Lactate Concentration

Subject	Pre-Test (mmol/l) A	Pre-Test (mmol/l) B	Level 1 (mmol/l) A	Level 1 (mmol/l) B	Level 2 (mmol/l) A	Level 2 (mmol/l) B
1	1.65	1.65	3.40	3.25	5.20	3.75
2	1.80	3.00	4.45	4.15	4.55	4.75
3	2.70	2.30	3.80	3.15	5.90	4.25
4	2.05	1.70	4.10	3.30	5.85	4.65
5	1.60	2.05	3.75	3.95	5.60	4.50
6	1.55	1.80	4.65	3.20	7.55	4.10
7	1.40	1.85	6.35	4.25	10.15	6.00
8	1.45	2.10	2.55	3.50	4.25	4.25
9	1.10	1.95	3.50	4.65	5.90	5.35
10	1.95	2.30	4.45	4.40	6.55	5.25
Mean	1.73	2.07	4.10	3.78	6.15	4.69
(s.d.)	(.44)	(.40)	(1.00)	(.56)	(1.69)	(.68)

	N	T	P Value
Pre-Test Lactate Conc.	10	-2.17	0.06
Level 1 Lactate Conc.	10	1.02	0.17
Level 2 Lactate Conc.	10	3.35	0.00 **

Subject	Level 3 (mmol/l) A	Level 3 (mmol/l) B	Peak Conc. (mmol/l) A	Peak Conc. (mmol/l) B	Rec.+ 5 Min. (mmol/l) A	Rec.+ 5 Min. (mmol/l) B
1	8.90	7.10	10.20	11.95	8.70	10.05
2	8.75	6.55	12.95	14.50	12.15	12.45
3	10.45	7.60	12.15	9.65	10.25	8.90
4	11.25	6.80	13.75	12.75	12.80	11.75
5	10.00	6.40	18.30	15.15	18.30	15.15
6	*	7.20	10.60	10.80	9.90	10.10
7	*	9.50	10.80	11.85	9.70	10.05
8	8.55	6.95	9.20	12.65	7.35	11.30
9	*	8.40	11.10	18.55	9.95	16.35
10	9.50	6.75	9.85	13.25	7.70	11.20
Mean	9.63	7.33	11.89	13.11	10.68	11.73
(s.d.)	(.99)	(.96)	(2.66)	(2.50)	(3.18)	(2.37)

	N	T	P Value
Level 3 Lactate Conc.	7	7.19	0.00 **
Peak Lactate Concentration	10	-1.23	0.12
Recovery + 5 Min. Conc.	10	-1.17	0.13

Significance: * $p<.05$; ** $p<.01$

Table 8: (continued)

Subject	Rec.+ 10 Min. (mmol/l)		Rec.+ 15 Min. (mmol/l)		Rec.+ 60 Min (mmol/l)	
	A	B	A	B	A	B
1	7.10	8.75	6.00	7.25	2.80	1.80
2	10.70	10.30	8.45	8.45	2.55	3.15
3	8.70	7.35	7.25	5.55	3.60	2.00
4	10.55	10.10	9.55	7.65	2.75	2.95
5	16.20	13.65	14.85	10.50	3.75	2.85
6	8.00	8.90	6.55	7.55	3.70	2.90
7	7.85	8.70	6.45	7.35	2.20	2.20
8	5.75	9.50	4.50	7.95	2.45	2.80
9	8.95	14.85	6.75	13.10	1.55	4.45
10	5.90	9.95	4.70	8.15	1.85	2.85
Mean	8.97	10.21	7.51	8.35	2.72	2.80
(s.d.)	(3.04)	(2.32)	(3.00)	(2.07)	(.77)	(.74)

	N	T	P Value
Recovery + 10 Min. Conc.	10	-1.48	0.08
Recovery + 15 Min. Conc.	10	-0.87	0.20
Recovery + 60 Min. Conc.	10	-0.18	0.43

Significance: * $p<.05$; ** $p<.01$

Table 9: Blood Lactate Concentration Recovery Percentage

Subject	Rec.+ 5 Min. (percent) A	B	Rec.+ 10 Min. (percent) A	B
1	17.5	18.5	36.3	31.1
2	7.2	17.8	20.2	36.5
3	20.1	10.2	36.5	31.3
4	8.1	9.0	27.4	24.0
5	0.0	0.0	12.6	11.4
6	7.7	7.8	28.7	21.1
7	11.7	18.0	31.4	31.5
8	23.9	12.8	44.5	29.9
9	11.5	13.3	21.5	22.3
10	27.2	18.7	50.0	30.1
Mean	13.5	12.6	30.9	26.9
(s.d.)	(8.5)	(6.1)	(11.4)	(7.2)

	N	T	P Value
Percent Recovery at 5 Min.	10	0.40	0.65
Percent Recovery at 10 Min.	10	1.30	0.89

Subject	Rec.+ 15 Min. (percent) A	B	Rec.+ 60 Min. (percent) A	B
1	49.1	45.6	86.6	98.5
2	40.4	52.6	93.3	98.7
3	51.9	55.8	90.5	104.1
4	35.9	46.2	94.0	88.7
5	20.7	35.5	87.1	93.9
6	44.8	36.1	76.2	87.8
7	46.3	45.0	91.5	96.5
8	60.6	44.5	87.1	93.4
9	43.5	32.8	95.5	84.9
10	65.2	46.6	101.3	95.0
Mean	45.8	44.1	90.3	94.2
(s.d.)	(12.5)	(7.4)	(6.7)	(5.8)

	N	T	P Value
Percent Recovery at 15 Min.	10	0.47	0.67
Percent Recovery at 60 Min.	10	-1.45	0.09

Significance: * p<.05; ** p<.01

Table 10: Anaerobic Characteristics

Subject	Peak Power (watts/kg) A	Peak Power (watts/kg) B	Mean Power (watts/kg) A	Mean Power (watts/kg) B
1	7.24	7.24	6.12	6.42
2	7.93	7.65	6.56	6.33
3	7.75	8.61	5.69	6.22
4	8.06	8.33	6.76	6.71
5	7.91	8.44	6.97	7.16
6	7.11	6.85	5.75	5.75
7	6.61	6.86	5.23	5.56
8	7.00	7.49	5.55	5.96
9	6.38	6.87	5.60	5.48
10	7.11	7.11	6.12	6.25
Mean	7.31	7.55	6.04	6.18
(s.d.)	(.58)	(.69)	(.57)	(.52)

	N	T	P Value
Peak Power	10	-2.01	0.04 *
Mean Power	10	-1.91	0.04 *

Subject	% Power at 30 Sec A	% Power at 30 Sec B	Post-Test Lactate (mMol/l) A	Post-Test Lactate (mMol/l) B
1	71	82	9.15	9.80
2	66	68	12.20	10.50
3	56	50	10.15	8.90
4	72	71	12.35	12.10
5	80	77	13.55	14.35
6	64	67	11.00	10.40
7	72	73	11.20	9.80
8	62	67	11.30	11.90
9	80	76	8.60	9.80
10	81	89	11.05	10.95
Mean	70	72	11.06	10.85
(s.d.)	(8)	(10)	(1.48)	(1.58)

	N	T	P Value
% Power at 30 Seconds	10	-2.08	0.19
Post-Test Lactate	10	-1.23	0.27

Significance: * $p<.05$; ** $p<.01$

Summary

The acceptance and rejection of the research hypotheses are summarized in Table 11. No decision could be made on three of the hypotheses regarding the changes in heart rate. While there were instances of statistical significance during exercise, the differences are below the one-half of a standard deviation earlier required to be significant and also are at or below the limit of resolution of the heart rate monitor at high heart rates. The differences noted during recovery may be strongly influenced by thermal effects outside the scope of this study.

Table 11: Summary of Research Hypotheses and Judgements

Hypothesis	Judgement
Performing the tests while wearing hockey protective equipment will:	
a) decrease the total run time	Accepted
b) increase the heart rate during	
exercise,	No Decision
rest,	Accepted
and recovery	No Decision
increase the blood pressure during	
exercise,	Rejected
and recovery	Rejected
c) decrease the peak heart rate	No Decision
d) increase the ventilation	Accepted
and oxygen uptake per body weight	Accepted
but show no change relative to test weight	Accepted
e) decrease the maximum oxygen uptake	Rejected
f) increase the oxygen consumption	
during rest	Accepted
and recovery	Rejected
g) increase the blood lactate concentration	Accepted
h) decrease the peak lactate concentration	Rejected
i) decrease the percent recovery of blood lactate concentration	Rejected
j) show no decrease in anaerobic	
peak power,	Rejected
mean power,	Rejected
and percent power at 30 seconds,	Accepted
k) show no increase in post-test blood lactate concentration	Accepted

Chapter V - Conclusions and Recommendations

The results of this study indicate that wearing hockey protective equipment had substantial detrimental effects on the subjects' maximum performance on the treadmill test as determined by the external factor of total running time. When the criteria involve internal factors, for example, maximum oxygen consumption and peak blood lactate concentration, there was no difference in the maximum effort involved. At submaximal levels of exercise, the weight of the hockey equipment caused each subject to operate at a higher percentage of his maximum capacity, thus decreasing the duration of the performance.

The part of the excess weight attached to the legs - the player's shinpads - has an effect out of proportion to the remaining weight. While not strictly isolated in this study, this effect is most noticeable in the anaerobic bicycle tests, and likely accounts for most of the rapid divergence in the blood lactate concentrations between the experimental and control condition. Further studies should plan to test subjects with and without shinpads, or with shinpads and an equivalent weight attached to the upper body.

While the thermal effects of the hockey equipment were not within the scope of this study, they are deserving of study. The equipment and garments worn by the players were intended to insulate them from the cold environment in which they normally practice and compete. Particularly during recovery, the players indicated they were warm, and most removed part of their equipment while waiting the forty five minutes until the bicycle test.

Recommendations Relating to the Study

The pre-test heart rate and blood pressure measures showed no differences. The pre-test blood lactate concentration, however, showed a difference of well over half of a standard deviation. While not statistically significant with only ten subjects, there may be an effect there. Possibly the subjects were more active while waiting for their tests to begin on the day they did not wear their equipment. A future study may need to include restrictions on the subjects' pre-test activities.

The heart rate monitor had difficulty discriminating heart beats when the rate was over 200 beats per minute, with the result that the displayed number would fluctuate, sometimes wildly, around the presumably true value. Unfortunately, it is at this point of maximum or near maximum effort that the most accurate data is needed. Future studies in this area should address the problem of resolution at maximum heart rates.

Although the Wingate anaerobic capacity test had statistically significant findings, it may not be the most appropriate test for this type of study. In particular, the non-weight bearing character of a bicycle test limits application of these findings to an on-ice situation. Further studies should consider replacing it with a second treadmill test of shorter duration, higher speed, and higher grade. This would more accurately reflect the bursts of high intensity effort frequently required of hockey players.

Recommendations Relating to the Hockey Protective Equipment

The obvious recommendation is to make the protective equipment as lightweight as possible while still allowing the equipment to perform its function. However, each marginal improvement in the weight of the equipment comes at an increasing marginal cost in development and production, and therefore in purchase price. There soon comes a time when the next step is so expensive that no one could afford to make the equipment, or to purchase it if it was made. Sufficient information on the energy cost of the equipment would help manufacturers balance the economic cost against the added benefit of the lighter product. More specifically, there may be a relationship between maximum oxygen consumption relative to body weight and equipment weight such that an optimum equipment weight could be determined to allow a player to perform at, for example, 80 percent of his unweighted maximum.

The distribution of the weight also plays a role in the effects on performance. Weight attached to the legs -

shinpads and, though not covered in this study, ice skates - acts disproportionately to decrease a player's performance. A manufacturer should spend correspondingly more weight reduction efforts on these pieces of equipment than on others. Further study may establish a second relationship between performance and weight on the legs that would determine an optimum weight of shinpads and skates to achieve a given level of performance.

Recommendations Relating to the Hockey Players

Players could also use this information to make decisions on the protection versus performance trade-off of new equipment. For example, subject number seven was the smallest player yet wore one of the heaviest pairs of shinpads. He most likely could have found adequate protection in lighter equipment and increased his performance and endurance on the ice. Similarly, subject number five was one of the larger players yet wore one of the lighter pair of pads. He perhaps could have gotten some additional protection without seriously impairing his performance.

Hockey players also should consider training wearing a weight vest and/or ankle weights to simulate their equipment. Most wear their equipment for on-ice training. Some wear extra weight for their off-ice training. However, the training, and hence the adaptations, could be made specific to the weight the player would be carrying.

Summary

The effects of protective equipment deserves continuing study to monitor the costs - in energy and economics - and benefits - in performance and protection - that it provides to the athletes it is protecting. In the sophisticated world of professional and international competition, seemingly minor changes may mean the difference between success and failure. The evolution of the sport, modern technology, and new ideas ensure that those changes come quickly.

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