THE EXERCISE CAPACITY OF OCCUPATIONAL THERAPY PATIENTS, THE HEART RATE RESPONSE OF PATIENTS TO OCCUPATIONAL THERAPY ACTIVITIES AND THE CONDITIONING VALUE OF OCCUPATIONAL THERAPY FOR NON-TRAUMATIC AMPUTEES

A thesis
presented to
the University of Manitoba

In partial fulfillment
of the requirements for
the Degree of Master of Science

by

Marte E.M. Cole Bachynski

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ABSTRACT

Non-traumatic amputees, traumatic amputees, subjects with hemiplegia, and subjects with back problems performed a voluntary maximum exercise test at the approximate time they were referred for occupational therapy. All four experimental groups, but particularly the non-traumatic amputees and hemiplegics, were found to tolerate lower maximum workloads and obtain lower maximum oxygen uptake values than are anticipated for healthy able-bodied subjects.

Subsequently, subjects were monitored during occupational therapy with the 'Holter' monitor. The subjects without underlying cardiopulmonary disease were found to work at higher intensities as measured by their heart rates.

The non-traumatic amputees participated in a conditioning program for an approximate five week period. The control subjects attended physical therapy and were independently mobile within the hospital. The experimental subjects participated in the above, and in addition attended occupational therapy 30-60 minutes daily. Prior to discharge or after six weeks, subjects performed a second exercise test. The decreased mean submaximal heart rate at 200 kpm/min was significant ($p < .05$) for the control group. The increased mean maximum workload, decreased mean submaximum heart rates at 200 kpm/min and 300 kpm/min, and decreased mean pre-exercise blood pressure were found to be significant ($p < .05$) for the experimental group who attended occupational therapy.

The electrocardiographic findings at rest, during exercise and recovery, and during Holter monitoring have been described for all groups of subjects.

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STATEMENT OF THE PROBLEM

An objective evaluation of the cardiopulmonary status and of the exercise capacity of patients attending occupational therapy has not been documented in the literature. This should be of concern for many of these patients have multiple system disease involving the heart or peripheral circulation. The cardiopulmonary demands of occupational therapy activities are not usually monitored, even though this information is relevant to treatment. The possible value of occupational therapy for improving the cardiopulmonary condition of patients with multiple system disease involving the heart or peripheral circulation had not been investigated.

These problems have been addressed by three partly connected experiments. The objective and hypothesis for each are as follows:

Experiment I

Objective:

To evaluate the cardiopulmonary status and exercise capacity for groups of patients attending occupational therapy.

Hypothesis:

Patients with multiple system disease involving the heart or peripheral circulation will have a low exercise capacity.

Experiment II

Objective:

To evaluate the heart rate and electrocardiographic (ECG) response to occupational therapy activities.

Hypothesis:

Occupational therapy will increase the heart rates of patients with multiple system disease involving the heart or peripheral circulation sufficiently to have a cardiovascular training effect.

Experiment III

Objective:

To investigate the value of occupational therapy for improving the cardiopulmonary condition of non-traumatic amputees with multiple system disease.

Hypothesis:

Occupational therapy activities do have a potential conditioning value for non-traumatic amputee patients with multiple system disease.

INTRODUCTION AND REVIEW OF THE LITERATURE

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The background information for Experiments I and II, involving an evaluation of the cardiopulmonary status of occupational therapy patients and an investigation of their heart rate response to treatment activities, is reviewed in Sections I and II of this chapter. Further background regarding the patients with multiple system disease involving the heart or peripheral circulation is reviewed in section IV. Section V reviews occupational therapy treatment for these patients.

The background information for Experiment III, involving an investigation of the conditioning or training value of occupational therapy activities, is reviewed in Section III. The content of the sections on exercise testing and training are closely related and they have been ordered consecutively.

I. The Parameters of the Cardiopulmonary Response to Exercise

The following are non-invasive parameters of the cardiopulmonary response to exercise: oxygen uptake, heart rate, respiratory quotient, blood pressure, electrocardiogram and blood lactate.

Oxygen Uptake

Oxygen uptake is a functional measure of aerobic capacity, and is equal to the product of the cardiac output (CO) and the arteriovenous oxygen difference (a-vO_2 diff). The oxygen uptake ($\dot{V}_{O_2}$) at rest is approximately 3.5 ml/kg and rises during exercise in a linear relationship to workload to approximately 3-3.5 l/min in the fit subject. The highest recorded $\dot{V}_{O_2}$ of 7.4 l/min was obtained by a competitive male cross-country skier (Åstrand and Rodahl, 1977).

Oxygen uptake during submaximal exercise is a measure of mechanical efficiency. Mechanical efficiency is expressed as a percent and is calculated as follows:

$$\text{mechanical efficiency} = \frac{\text{rate of work (kpm/min)}}{\dot{V}_{O_2}\ \text{exercise(l/min)} - \dot{V}_{O_2}\ \text{rest(l/min)} \times 5.0 \times 427} \times 100$$

where 5.0 is the caloric equivalent of a litre of oxygen assuming the respiratory exchange ratio of 1.0 and is expressed in kilocalories (kcal)

427 is the equivalent of 1 kcal expressed in kpm/min

(Morehouse, 1972)

Mechanical efficiency is relatively constant for a given method of exercise at a given workload, for example 23% for bicycle ergometry work with male subjects (Sidney and Shephard, 1977). Higher than expected submaximal $\dot{V}_{O_2}$ values therefore indicate a decreased efficiency for that method of exercise. A decrease of 1.5% in the mechanical efficiency of cycling for older subjects (approximately 65 years of age) has been discussed by Shephard (1978). Lack of recent experience with exercise and stiff joints are among the possible explanations for the decreased efficiency.

Maximum $\dot{V}_{O_2}$ is in part determined by heredity, but can be increased approximately 15-20% with fitness training (Astrand and Rodahl, 1977). The possible mechanisms for this increase have been considered in Section III, Training.

Heart Rate

The linear relationship between heart rate (HR) and $\dot{V}_{O_2}$ for the range from 50% maximal heart rate (HR max) to near HR max was determined by Åstrand and Ryhming (1954). This finding was based on healthy subjects 18 to 30 years of age and was later verified for other age groups (Åstrand, 1960).

The resting HR is 60-100 beats/minute. For a given cardiac output, a lower heart rate suggests that cardiac diastole is longer and that the heart is a more efficient pump (Evans, 1918).

Maximum heart rate is a reproducible constant for each individual at a given age. The decline in HR max with age was demonstrated by Åstrand (1952) and Åstrand et al. (1959) and can be predicted by the formula 220 - age $\pm$ 10 beats/minute (Amsterdam, 1977). Sidney and Shephard (1977) obtained HR max values 10 to 15 beats/minute higher than Åstrand when exercising elderly sedentary subjects via treadmill walking. These investigators noted an average HR max of 172 beats/minute for 19 men aged 63.7 $\pm$ 2.6 years, and an average HR max of 161 beats/minute for 20 women 63.4 ± 3.6 years of age. The discrepancy may be related to the initial fitness level of Sidney and Shephard's subjects, to their use of a treadmill rather than bicycle testing protocol, and to the possible incomplete stressing of Åstrand's subjects.

Heart rate is usually determined from the electrocardiograph. Pulse rate is also used as a measure of HR, but may be less accurate because rhythm disturbances are not taken into account. Pulse rate is correctly determined by a 10 second count during or immediately following exercise/activity, with zero being the first count.

Respiratory Quotient

The respiratory quotient (RQ) or respiratory exchange ratio (R) is the ratio of the volume expired carbon dioxide to the volume of consumed oxygen for a given time interval. The respiratory quotient is diet dependent. A resting R value of .85 is characteristic of a mixed diet. The resting R value is lower if the diet is rich in fat (.71) or protein (.80) and is higher if the diet is carbohydrate (1.0). The respiratory quotient increases in the exercising subject from approximately .82 to 1.50 (Mathews and Fox, 1976; Consolazio, 1963).

Issekutz et al. (1962) exercised 24 untrained men 20-65 years of age and eight untrained women 55-65 years of age with bicycle ergometry, to investigate the logarithmic relationship between the change in R (ΔR) and $\dot{V}_{O_2}$. These investigators noted that $\dot{V}_{O_2}$ max was consistently obtained at ΔR values of .40 and suggest that ΔR be used as a criteria for achieving $\dot{V}_{O_2}$ max. Consolazio (1963) argues that although R is a reliable indicator of the combustion of food-stuffs and other oxidative processes at rest, the rise during exercise occurs in part because of the blowing off of CO_2 which occurs as the rate of respiration increases. An R value of 1.10 is however, an accepted index of maximal exercise.

Blood Pressure

The brachial artery pressure is determined by auscultation and is monitored during exercise as a measure of the central and peripheral circulatory responses. The average resting brachial artery pressure is 120/80 mmHg.

Erikssen et al. (1980) published blood pressure (BP) values for subjects exercised with bicycle ergometry.

Subjects with resting systolic BP $\geq$ 160 mmHg or resting diastolic pressure $\geq$ 95 were not considered normal and were excluded from the study. The blood pressure response at the maximum tolerated workloads have been presented in Section II, Table 2 for 1,678 normal male subjects aged 40-60 years.

The Electrocardiograph

The electrocardiograph (ECG) is a visual display of the electrical activity of the heart. It is normally characterized by a repeating pattern in which a P wave representing atrial depolarization, followed by a QRS complex representing ventricular depolarization, is followed by a T wave representing ventricular repolarization (Dubin, 1970).

Exercise testing protocols usually recommend that all subjects over 35 - 40 years of age and all those having possible heart disease be given a 12 lead resting ECG prior to exercise testing in order to detect prior heart damage that might contraindicate exercise, and to check the heart rhythm (Lea and Febiger, 1975). As well, the ECG is monitored during exercise.

There are several lead systems that can be used in exercise electrocardiography. A single bipolar lead reduces the data analysis and is simplest to use during exercise testing. Lead CM_5 was used for this study because it has been reported to be better in terms of specificity and sensitivity in the patient with atypical chest pain than any of the other 14 ECG leads (Chaitman, 1978).

Electrocardiographic recordings outside the exercise laboratory can be obtained by 'Holter' monitor or by radiotelemetry (Morris and Dotson, 1978).

The Holter monitor is a portable electrocardiographic recorder, first developed by Holter (1957). An electrocardiographic tape records the electrical activity of the heart for up to 24 hours. A graphic display can be viewed as fast as 60 times real time, and selected portions of the display can be recorded.

Artifacts are a problem for ECG recording by the Holter monitor because the electrodes must remain in place for long periods and because the subject's activities may interfere with the leads.

With radiotelemetry, a small radio transmits the cardiac electric impulses to a receiver-recorder. The instantaneous display is advantageous in that it provides immediate feedback from the exercising subject. Another advantage of radiotelemetry is that a unit may receive from more than one transmitter. However, selected portions of the display will not be recorded in the technician's absence, unless a programmed computer has been incorporated into the unit.

Irregularities of cardiac rhythm are frequently found in asymptomatic, young subjects with no evident heart disease. Despite the criteria of a normal resting 12 lead ECG for inclusion in the study, Brodsky et al. (1977) observed a 50% occurrence of premature ventricular contractions

(PVCs) in 50 male medical students during 24 hour Holter monitoring.

Clarke et al. (1977) observed PVCs in 63 (73%) of 86 clinically normal subjects, aged 16-65 years via 24 hour Holter recording. Rhythm disturbances believed to be of serious prognostic significance were found for 12% of this study population. Hinkle et al. (1969) observed 62.2% of 301 subjects, median age 55 years with ventricular arrhythmias, 76% with supraventricular arrhythmias and 6.7% with various degrees of heart block. Their data were obtained by six hour ECG recordings during daytime activity.

Blood Lactate

The concentration of lactate (La) in the blood is used to indicate whether or not a subject has made a reasonable effort to work to the point of physical fatigue. High blood lactate values are associated with anaerobic work and may in fact limit the anaerobic working capacity by slowing enzyme action (Åsmussen et al., 1974).

Blood lactate (Bl La) is usually determined from a one ml sample of blood taken from the right brachial artery within a two minute period following exercise. The value of 8 mol/l is accepted as an indication of near maximal effort for young men, although values as high as 30 mol/ml have been observed for exhausted athletic subjects. The lower lactate values observed at a given submaximal workload for fit subjects suggests the greater capacity of the fit individual to meet his/her energy requirements by aerobic means. Sidney and Shephard (1977) found lower blood lactate values at maximum effort for older men and women aged 60-83 years (10.3 ± 3.6 mmol/l, n=26 and 8.1 ± 2.9 mmol/l, n=29) than for young men and women (15.0 ± 5.5 mmol/l and 11.0 ± 2.5 mmol/l). The mean age of these controls was 23.5 ± 2.7 years (n=8) and 25.0 ± 2.8 years (n=5) respectively.

The authors suggest that lack of motivation and the smaller ratio of muscle mass to total blood volume may explain the lower blood lactate values observed for the elderly and for women.

Although maximal release of lactate from exercising muscle in the order of 5 mmol/min (Jorfeldt et. al.,1978) causes increased blood lactate values at maximum effort, the heart, kidney, exercising and non-exercising muscle take up significant amounts of lactate and invalidate the blood lactate value as early as five minutes following maximal exercise (Poortman et al., 1978).

II. Exercise Testing

Introduction to Exercise Testing

Exercise testing involves working at standard loads for the purpose of eliciting a cardiopulmonary response. The exercise test is usually graded by workload increments at fixed intervals. Shephard and Lavallée (1978) suggest that a 3-4 minute interval is practical to achieve a steady state in which O_2 uptake is equal to O_2 utilization.

The graded exercise test may require continuous or discontinuous work, the work periods for the latter being punctuated by rest periods. Discontinuous work is sometimes necessary, for example, to determine brachial artery blood pressure during arm exercise.

Although the end-point for testing may be a target heart rate (usually a percentage value of the age-predicted maximal HR), testing the subjects to voluntary fatigue has become widely accepted. Cumming (1972) noted that 46% of ischemic responders would have been overlooked if exercise testing had been terminated at less than 86% of the age-predicted HR max. His paper demonstrated that near maximal testing was of value for diagnostic purposes.

Methods for Exercise Testing

Standard workloads are routinely applied by treadmill work, one- or two-legged cycling on a bicycle ergometer or arm cranking.

Treadmill

Treadmill work is the preferred method of exercise testing in North America, as it is a familiar activity requiring little skill. A number of protocols, or specific guidelines for testing, have been developed and standardized for normal subjects (Elliot, 1974; Ellestad, 1975).

Bicycle ergometry

Bicycle ergometry is the preferred method for exercise testing in Europe. The bicycle ergometer is felt to be less frightening and facilitates monitoring of blood pressure during the more intense levels of exercise. However, cycling is weight independent and involves a lesser muscle mass as compared to treadmill exercise. Consequently, the $\dot{V}_{O_2}$ max values obtained are approximately 6.6% lower than those obtained by treadmill walking (Shephard et al., 1968). Local muscle fatigue, rather than cardiopulmonary stress, may limit performance on the bicycle.

Standard protocols for exercise testing via bicycle ergometry are recommended by three separate organizations which are the International Committee for Physical Fitness Research (I.C.F.R.), the International Biological Program (I.B.P.) and the World Health Organization (W.H.O.). Their recommended protocols for healthy young subjects have been summarized in Table 1.

Table 1

Protocols for exercise testing recommended by international organizations for bicycle ergometry

Organization	Initial Load	Increments	Stage Duration
I.C.F.R.	1 watt/kg body wt (1 watt = 6.12 kpm/min)	1/3 w/kg	-
I.B.P.	70% predicted $\dot{V}_{O_2}$ max	200 kg/min	-
W.H.O.	-	-	4 min

(Shephard and Lavallée, 1978)

Values for mean maximal workload and mean maximum heart rate obtained by two-legged cycling (Erikssen et al., 1980) have been presented in Table 2.

Pernow, Wahren and Zetterquist (1965); Freyschuss and Strandell (1968) have demonstrated work capacities as high as 1000 kpm for normal men tested by one-legged cycling. Bäcklund and James (James and Nordgren, 1973) compared the work capacity of 21 normal men for one- and two-legged cycling and for treadmill walking. Local fatigue was found to limit the work capacity of one-leg work at about 80% of the maximum capacity of both legs. These investigators believe the limiting factor to be the inability of the muscle vasculature to accept a higher blood flow.

Bassey and Goldsmith (1975) compared one- and two-legged pedalling for 21 healthy untrained subjects, mean age 34 years, at 1 kg and 2 kg loads. The $\dot{V}_{O_2}$ and CO_2 production were significantly higher during one-legged cycling at 2 kg as compared to two-legged cycling at 2 kg. There was no significant difference in HR at either load. These results suggest that the proportion of anaerobic work is higher in one-legged pedalling.

Arm crank ergometry

Protocols for exercise testing by arm cranking

Arm crank ergometry may be performed by a reciprocal cranking of two handles, or alternatively, by operating a single crank. A greater muscle mass is used with the single crank method because it involves the shoulder girdle and trunk muscles. However, the two-handled crank is less awkward. A comparison of the two methods of arm cranking has not been reported in the literature.

Table 2

The mean systolic blood pressure, mean maximum workload and mean maximum heart rate obtained by normal males during bicycle ergometry

Age (Years)	Number of subjects a b	Systolic pressure at maximum (mmHg)	Maximum workload* kpm	Maximal heart rate
40-44 a	244	215(range 175-290)	1456 range 539-3598	178
b	111	206	1296	
45-49 a	385	215(range 155-270)	1285 range 360-2519	171
b	133	209	1031	
50-54 a	386	217(range 160-290)	1112 range 2519-3809	165
b	64	212	951	
55-59 a	294	220(range 160-300)	914 range 300-2219	160
b	59	214	735	
TOTAL a	1309	217	1192	
b	369	209	1050	

a - subjects who achieved 90% of their age-predicted maximum heart rate
b - subjects who did not achieve 90% of their age-predicted maximum heart rate
* - 1 joule = 0.10197 kpm. Maximum workloads were documented in kj and have been converted to kpm by this investigator.

(Erikssen et al., 1980)

The subject may be exercised in a sitting or a standing position, however, because arm cranking is not the exercise method of choice, subjects who are able to stand are usually exercised by other means.

The crank axis is usually at heart or shoulder level for a given protocol. Arm cranking is more difficult when the crank axis is above heart level because of the increased hydrostatic pressure.

A standardized protocol for exercise testing by arm cranking has not been developed. Young healthy subjects have been tested by demanding protocols such as that used by Bar-Or and Zwiren (1975). By comparison, older adults, women and disabled subjects have been tested by less demanding protocols (Shaw et al., 1974; Freyschuss, 1975; Kavanagh and Shephard, 1973). Table 3 summarizes the arm crank protocols used by several investigators.

<u>The mechanical efficiency of arm cranking</u>

Oxygen uptake values at submaximal workloads were obtained by Vokac et al. (1975) for seven male subjects, mean age 23.5 years, during arm cranking in sitting and standing positions, and during cycling. The mean mechanical efficiency for each workload has been illustrated in Table 4. The net mechanical efficiency for arm cranking was significantly lower ($p < 0.001$) than for cycling at 600 kpm and 900 kpm workloads. Stenberg et al. (1967) and Åsmussen and Hemmingsen (1958) also report a decreased mechanical efficiency for arm cranking. However in the former study, the protocols for arm cranking and cycling were not sufficiently similar to compare observed $\dot{V}_{O_2}$ values. Åsmussen and Hemmingsen (1958) present their data graphically and actual values are not available.

Table 3

The protocols used by investigators for exercise testing by arm cranking

nvestigator	Date of publication	Subjects No.	Sex	Mean age or range	Initial load (kpm)	Increments (kpm)	Stage duration	rpm	Axis position	Crank Type	Date collected
ar-Or and Zwiren	1975	59	M	28.2 yr	450-750	450	2 min	50	shoulder	-	$\dot{V}_{O_2}$, HR, V_E
eybrouck et al.	1975	3	M	35 yr	0	184, 275, 367	4 min ex 5 min rest	60	shoulder	-	$\dot{V}_{O_2}$, Q, ECG, CO_2 V_I, V_T, V_E
okac et al.	1975	7	M	23.5 yr	300	300	6 min	50	shoulder	single crank	$\dot{V}_{O_2}$, V_E, HR
reyschuss	1975	16 14	M F	31 yr 30 yr	200 100	200 100	6 min	-	-	-	$\dot{V}_{O_2}$, HR, V_E
haw et al.	1974	40 7	M) F)	57 yr	200	100	3 min	40	shoulder	single crank	ECG, HR, BP, serum enzym
ollock et al.	1974	11 8	M M disabled	) 38 yr	variable values not given	100	3 min	60-70	-	two handles	$\dot{V}_{O_2}$, CO_2, HR, ECG
avanagh nd Shephard	1973	18 9	M amputee F amputee	42-79 yr 58-74 yr	90-240	not stated 300-450 peak workload	3 min	60	-	two handles	HR, ECG, La

$_I$ - breathing frequency

$_T$ - tidal volume

Table 4

The mean mechancial efficiency for arm cranking and bicycle ergometry at submaximal workloads

Workload	Arm Crank Sitting	Arm Crank Standing	Bicycle Ergometry
300	22.5 ± 0.8	24.3 ± 1.8	25.0 ± 1.5
600	19.1 ± 1.8	20.7 ± 1.6	27.1 ± 0.8
900	17.2 ± 1.8	17.9 ± 1.1	26.7 ± 1.7

(Vokac et al., 1975)

The value of arm cranking for obtaining maximum oxygen uptake, stroke volume and heart rate

The literature reports general agreement among investigators that $\dot{V}_{O_2}$ max values obtained by arm cranking are 60-70% of those obtained by bicycle ergometry or treadmill walking. The $\dot{V}_{O_2}$ max values obtained by arm cranking for three males, mean age 35 years, were 68% of those obtained for bicycle ergometry and 60% of those obtained for combined arm-leg ergometry (Reybrouck et al., 1975).

Stenberg et al. (1967) observed $\dot{V}_{O_2}$ max values of 2.55 l/min (65.9% of 3.87 l/min) and 3.87 l/min for arm cranking and bicycle ergometry respectively for five male subjects, mean age 23.5 years. The average maximum workloads achieved by these subjects, of 705 kpm/min for arm cranking and 1,800 kpm/min for bicycle ergometry, illustrate the discrepancy between the physical working capacity of the arms and legs.

The cardiac output and stroke volume response to arm cranking, bicycle ergometry and combined arm-leg ergometry was investigated via cardiac catheterization of six healthy males, mean age 24 ± 1.3 years by Bevegard et al. (1966). An insignificant change in the stroke volume from rest to exercise (76.17 ml to 84.16 ml) was observed during arm cranking in a sitting position, whereas the increase was significant for bicycle or combined arm-leg ergometry (76.17 ml to 118.67 ml and 76.17 ml to 123.83 ml respectively). Despite the minor change in stroke volume, diastolic and mean aortic pressures were notably increased during arm cranking. Bevegard et al. suggest that increased sympathetic tone in the vessels of the non-exercising muscle explains the finding. Åstrand et al. (1968), who observed varied blood pressure and heart rate responses during arm work in different positions, also attributed their findings to increased sympathetic vasoconstrictor tone. The smaller increase in stroke volume may otherwise be related to the smaller exercising muscle mass in arm work (Åstrand and Saltin, 1961).

Although the linear relationship of heart rate to workload and $\dot{V}_{O_2}$ holds true for arm cranking (Åsmussen and Hemmingsen, 1958), higher heart rates at given submaximal workloads have been found for arm cranking as compared to leg work (Bevegard et al., 1966; Pollock et al., 1974; Freyschuss, 1975).

Voluntary maximum heart rates have been obtained by arm cranking consistently. The absolute values for mean voluntary maximum heart rate, and the relationship to age-predicted maximum heart rate stated as a percentage have been illustrated in Table 5.

Shaw et al. (1974) exercised 27 subjects, mean age 57 years, who had suspected coronary artery disease by both arm cranking and treadmill walking. The mean voluntary maximum heart rate expressed as a percentage of the age-predicted heart rate was only slightly lower for arm cranking (81 $\pm$ 4%) than for treadmill walking (85 $\pm$ 3%). Absolute HR max values were not documented by these investigators.

Table 5

The mean voluntary maximum heart rates and the percentage of age-predicted maximum heart rate obtained by investigators during arm cranking

Investigator	Subjects	Mean Voluntary HR max	% Age-Predicted HR max	Mean Maximum Workload
Bar-Or & Zwiren(1975)	41 M 28.2 yr	173 $\pm$ 10.2	90%	not given
Vokac et al. (1975)	7 M 23.5 yr	180	92%	1125 kpm
Shaw et al. (1974)	27 M&F) 26 M&F) 57 yr	not given	81 $\pm$ 4% 73.2 $\pm$ 1.9%	not given not given
Stenberg et al.(1967)	5 M 24.1 yr	178	91%	705 kpm

The reliability of exercise testing by arm cranking

Bar-Or and Zwiren (1975) exercised 41 males, 28.2 $\pm$ 8.8 years, by arm crank ergometry to obtain voluntary maximum values for $\dot{V}_{O_2}$, HR, and V_E. The same protocol was repeated for each subject approximately two weeks later. The test-retest reliability coefficients for $\dot{V}_{O_2}$ max, V_E max and HR max were 0.94, 0.98 and 0.76 respectively. Table 6 presents the actual values.

Table 6

The test-retest reliability coefficients for maximum oxygen uptake, pulmonary ventilation and heart rate

	Test 1 n=41	Test 2 n=41	test-retest r value
$\dot{V}_{O_2}$ max ml/kg/min	30.37 $\pm$ 9.05	31.04 $\pm$ 9.01	0.94
V_E max l/min	76.5 $\pm$ 22.1	83 $\pm$ 22.0	0.98
HR max beats/min	174 $\pm$ 12.6	174 $\pm$ 14.3	0.76

(Bar-Or and Zwiren, 1975)

Bar-Or and Zwiren note the small coefficient of variation HR max (7-8%) as compared to 29% for $\dot{V}_{O_2}$ max, and suggest that the lower reliability coefficient for HR max may reflect this small dispersion of HR max values among individual subjects.

The specificity of arm work

A varied exercise response to two methods of arm work was demonstrated by Glaser et al. (1980). They compared the exercise response of six wheelchair and ten able-bodied subjects for wheelchair and arm crank ergometry. The Monark bicycle ergometer was modified in both instances and has been described in Glaser et al. (1979) and Glaser et al. (1980) respectively. Lower values for PWC (by 36%), HR max (by 7%) and La max (by 26%) for wheelchair ergometry were obtained. Values for $\dot{V}_{O_2}$ max (1.73 $\pm$ .14 l/min and 1.77 $\pm$ .14 l/min) and V_E max (71.5 $\pm$ 6.5 l/min and 71.8 $\pm$ 5.7 l/min) were similar for wheelchair and arm crank ergometry respectively.

III. Training

The Training Prescription

The elements of the training prescription are intensity, frequency, duration and type of exercise.

Intensity

The degree of effort or energy expended per unit of training time and stated in terms of $\dot{V}_{O_2}$ or HR is known as the training intensity. There is general agreement among investigators that intensity is the most critical element in the exercise prescription. The method for calculating the training intensity was investigated by Davis and Convertino (1975). The $\dot{V}_{O_2}$ and HR indices of intensity compared favourably when HR was determined as a percentage of the heart rate reserve (HR max - resting HR). The determination of intensity as a percentage of HR max yielded significant over-predictions of 29%, 22%, 16% and 8% at workloads representing approximately 25%, 45%, 65% and 85% of $\dot{V}_{O_2}$ max respectively.

Changes which occur as a result of training constitute the training effect. The minimum threshold above which a training effect would occur was first investigated by Karvonen et al. (1957) who noted the intensity to be approximately 60% of the heart rate reserve (HR max - resting HR). That training does not occur in young persons at efforts less than 50% $\dot{V}_{O_2}$ max has found general agreement among investigators (Shephard, 1968, 1969; Pollock, 1973; Kavanagh, 1976).

De Vries (1970) however presents evidence that programs of light intensity produced significant training effects in older subjects.

He trained seven males 51-87 years of age by cycling. The work intensity was limited to a maximum HR of 120 beats/min because of mild myocardial ischemia or arrythmias. After six weeks he observed a 14.3% increase in 0_2 pulse at HR_{120} ($p < .05$) and an increased PWC_{120} of 34.5%. Three subjects showed evidence of myocardial ischemia after six weeks training, which had not been observed before the program. One of the subjects subsequently followed more modified program and obtained an improvement in 0_2 $pulse_{120}$ and PWC_{120} of 11.5% and 48% respectively. De Vries suggests that the normal program was an inappropriate challenge to the subject's cardiovascular system.

Faria (1970) observed that the relationship between training intensity and the training effect is not necessarily linear. Whereas a training intensity of 50% circulatory strain may be sufficient to produce an effect, training can be optimally obtained in young subjects with an intensity of 70-85% circulatory strain (Åstrand and Rodahl, 1977).

Duration and frequency

Åstrand and Rodahl (1977) report the following relationships between intensity, duration and training effect:

a) intense activity of a few seconds duration may develop musculoskeletal strength.

b) intense activity of one minute duration may develop anaerobic power if repeated following intermittent rest periods.

c) moderately intense activity of three to five minutes duration which involves large muscle groups may develop aerobic power.

d) moderately intense activity of 30 minutes duration may develop the capacity to sustain aerobic power.

Saltin et al. (1968) consider a training protocol in which the training intensity is sustained for 20-40 minutes to be optimal for developing aerobic power and endurance. However, because stroke volume is greater during recovery than during exercise (Cumming, 1972) training protocols frequently demand intermittent workloads.

Pollock et al. (1975) summarized their investigations over a seven year period. In total, 148 healthy sedentary men aged 28-64 years (mean 41 years) had been divided into separate groups and trained by fast walking or running 30-45 minutes two, three or four times weekly for a 20 week period. Although $\dot{V}_{O_2}$ max was significantly increased for all groups compared to normals, the subjects who trained four days weekly improved significantly over the subjects training two or three days.

Pollock et al. suggest that the total work time, considering the duration of daily training periods and the total number of training days, is the appropriate measure of duration. Pollock refers to the thesis study by Hill (1969) in which two groups of men aged 20-44 years were trained three to five days per week (method of training not documented by Pollock et al.). At the end of eight weeks training, the $\dot{V}_{O_2}$ max values were improved for both groups, but the five day training group had improved significantly more. The three day training group attained an equally significant training response after training an additional five weeks. The total number of training days were 40 and 39 days for the five day and three day training groups respectively.

Type of exercise

For purposes of demonstrating a training effect, the method of training is usually the same as the method of testing. The training effect obtained by cycling is therefore evaluated by testing before and after training on the bicycle ergometer. The training effect obtained by arm cranking is evaluated by arm crank ergometry. Magel et al. (1978) illustrated the specificity of training. They trained nine subjects by arm cranking and tested these subjects by both arm cranking and treadmill running. The aerobic capacity when tested by arm cranking had improved by 438 ml (16.3%), but no significant increase (8 ml) was noted for treadmill running.

The Training Effects Obtained by Arm Cranking

Training by arm crank ergometry has been undertaken with small groups of young healthy subjects. The training protocols are summarized in Table 7 and the findings presented in Table 8.

Heart rate

The most consistent finding following training by arm cranking has been a decrease in HR for a given submaximal workload. Clausen et al. (1973) and Clausen et al. (1970) have demonstrated that this reduction in HR is greater as the submaximal workload is increased. In their 1973 study, a 29 $\pm$ 8 beats/min decrease was noted for workloads which achieved a pre-training HR of 170 beats/min as compared to a 19 $\pm$ 2.84 beats/min decrease for workloads which achieved a pre-training HR of 130 beats/min. The 1970 study reports a 34 $\pm$ 5.5 beat/min decrease in HR at 80-90% of the pre-training maximum. Simmons and Shephard (1971) report a combined mean

Table 7

The protocols used by investigators for training by arm cranking

Investigator	Date of publication				Training period	Work period	Work intensity	Frequency
Magel et al.	1978	9	M	college students	10 wk	6 - 4 min work	4 sub max, 5th max	3 days/wk
						5 min rest interval	6th supramax	
Clausen et al.	1973	5	M	23 yr	5 wk	4 - 5 min work 5 min rest interval	15 min warmup average > 170 beat/min	5 days/wk
Simmons & Shephard	1971	10	M	24.6	4 wk	30 min continuous	80% V_{O_2} max	2 days/wk
Clausen et al.	1970	4	M	32	4 wk	3 - 5 min work 3 min rest interval	max workload tolerated for 5 min	2 x daily

Table 8

The actual values, percentage change and level of significance of the changes observed following arm crank training

Investigator	Maximum Workload (kgm/min)	Duration of work (min)	Submaximum HR (beats/min)	$\dot{V}_{O_2}$ max (l/min)	Maximum a-vO_2 diff. (ml/l)	Q max (l/min)	Stroke volume (ml)
Magel et al. 1978 n=9	609-816 ↑ 34% *	24.2 $\pm$ 3.5 -33.4 $\pm$ 3.5 ↑ 38% *	134.9 $\pm$ 14.4 -118.9 $\pm$ 6.0 ↓ 12% *	2.689 $\pm$ 0.393 -3.127 $\pm$ 0.438 ↑ 16% *	146.9 $\pm$ 14.7 -167.7 $\pm$ 10.8 ↑ 14% *	18.3 $\pm$ 2.5 -18.6 $\pm$ 1.0 ↑ 1.6% NS	105.1 $\pm$ 15.0 -103.3 $\pm$ 4.7 ↓ 17% at max NS
Clausen et al. 1973 n=5	-	-	pretraining HR 130 (I) 137 $\pm$ 8.2 - 118 $\pm$ 6.0 ↓ 13.8% pretraining HR 170 (II) 170 $\pm$ 6.0 - 141 $\pm$ 6.7 ↓ 17% *	-	-	-	(I).97 $\pm$ 6.4 - 100 $\pm$ 6.4 ↑ 3% NS (II)100 $\pm$ 5.0 - 109 $\pm$ 6.3 ↑ 9% X
Simmons and Shephard, 1971 n=10	-		no actual values ↓ 5.9% X	2.76 - 2.99 ↑ 8.1%	no actual values no change	17.8 - 19.3 ↑ 8.4% X	no actual values ↑ 8.3% at max
Clausen et at. 1970			load 50-60% pretraining HR max = mean 277 kpm/min 114 - 105 ↓ 7.9% load 80-90% pretraining HR max = mean 510 kpm/min 160 - 126 ↓ 21.2% $p < 0.013$	1.713 - 1.661 ↓ 3% NS			

X significance at 0.05 level

* Significance at 0.01 level

NS not significant

decrease HR of 5.9% following training by arm cranking.

Similarly, reductions for resting heart rate values in the order of 7 $\pm$ 7.6 beats/min and 5% are noted by Clausen et al. (1973) and Simmons and Shephard (1971) respectively.

A possible mechanism for the early response of HR to training is reduced sympathetic tone (Frick et al., 1967). The specificity of arm training suggests that feedback from the trained muscle to the central nervous system is part of this mechanism. It is also possible that because leg training reduced HR almost equally during arm and leg exercise, the enhanced stroke volume/myocardial contractility associated with training may also provide feedback contributing to reduced sympathetic drive.

Oxygen uptake

Oxygen uptake at submaximal workloads is taken as a measure of mechanical efficiency. It follows that the lower submaximal $\dot{V}_{O_2}$ values obtained by Simmons and Shephard (1971) following training are attributed to a 4% increase in mechanical efficiency.

Maximum $\dot{V}_{O_2}$ was determined by Magel et al. (1978) and Simmons and Shephard (1971), who noted increased $\dot{V}_{O_2}$ max values following arm training. The increases were 6.94% and 8.1% for these respective studies. Clausen et al. (1970) reports discrepant results in which $\dot{V}_{O_2}$ max was not altered following four weeks of arm training. This latter finding may be related to the short four week training period. Maximum $\dot{V}_{O_2}$ has been consistently improved with training by other methods (Saltin et al., 1968; Ekblom et al., 1968; Pollock, 1973).

Maximum $\dot{V}_{O_2}$ is increased as a result of greater O_2 utilization by the tissues. The tissue changes which may allow greater utilization of O_2 have been reviewed by Holloszy and Booth (1976). They are as follows:

a) an increase in the size and number of mitochondria

b) a possible increased rate of O_2 diffusion through the cytoplasm to the mitochondria

c) an increased mitochondrial capacity to oxidize fat and carbohydrate

d) a less rapid depletion of muscle glycogen stores.

Evidence has been presented via the electron microscope studies of Hoppeler et al. (1973) and Morgan et al. (1971), demonstrating an increase in the size and number of mitochondria in human muscle following training. As well, the mitochondrial capacities to oxidize fat and carbohydrates are increased. This appears to occur because of increased levels of the enzymes involved in the activation, transport and oxidation of long chain fatty acids (Holloszy et al., 1973; Molé et al., 1971) and ketones (Winder et al., 1974; Winder et al., 1975). The levels of enzymes involved in the tricarboxylic acid cycle are also increased (Gollnick et al., 1973; Holloszy et al., 1970). It is suspected that the increased capacity of trained muscle for fatty acid oxidation, in particular, results in the less rapid depletion of muscle glycogen stores (Pattengale and Holloszy, 1967). Holloszy and Booth (1976) suggest that this greater muscle glycogen store is associated with an increase in the rate of diffusion of O_2 through the cytoplasm to the mitochondria.

Increased O_2 utilization/extraction by the tissues may result in a greater a-vO_2 difference following training. With respect to arm training, a significantly greater a-vO_2 difference was observed during maximal work following training by Magel et al. (1978) and by Clausen et al. (1973) during submaximal and 'supramaximal' arm work. No change in a-vO_2 difference during maximal leg work was noted following arm training.

Maximum workload and duration of work

An increased ability to do a given type of work following training is apparent if a subject is able to sustain a maximal workload for a longer period, or to progress to a higher workload. Clausen et al. (1973) report a marked 47% increase in the workload which could be sustained five minutes following a daily arm crank training program five weeks long. Magel et al. (1978) report an increased work time of 9.2 minutes (24.2 $\pm$ 3.5 to 33.4 $\pm$ 3.3 min) following ten week training by arm cranking as compared to a less than one minute increase noted for controls. The trained subjects performed a total work load of 18,768 kpm per session in the last week of their training program as compared to a workload of 14,007 kpm per session during the first week of training, the minutes per session (23 minutes) and training heart rate being constant values.

Blood pressure

Clausen et al. (1973) observed consistently lower systolic and diastolic aortic blood pressures at two submaximal workloads following a ten week training program in their catheterization study. Blood pressure data has not been reported by others investigating cardiovascular responses to arm training.

Blood lactate

Blood lactate values for a given exercise load have been found to decrease with training by Åstrand (1956); Saltin and Karlsson (1971) for cycling and treadmill running respectively. Holloszy and Booth (1976) attribute the lower blood lactate levels to a lesser reliance on carbohydrate and note further that the lower respiratory quotient also reflects the greater utilization of fats following training. These findings have not been verified for training by arm cranking.

IV. The Cardiopulmonary Status of Amputees and Hemiplegics

Literature pertaining to the ECG findings and exercise responses of amputees and hemiplegics has been reviewed.

Amputees

Electrocardiographic findings

Kavanagh and Shephard (1973) studied 62 non-traumatic amputees, 40 males, 42-87 years of age (mean 65.4 $\pm$ 11.5) and 18 females, 38-81 years of age (mean 67.2 $\pm$ 11.9). Twelve-lead ECGs had been obtained for 60 of 62 patients prior to the study. Twenty-eight of these showed evidence of myocardial infarction (M.I.), T-wave changes, arrhythmias, and various degrees of heart block. Twenty-seven subjects performed an exercise test. A horizontal or downward sloping ST segment greater than 1 mm was noted for 18 of 27 (66%) of the exercise subjects. Nine subjects (33%) who had been accepted as free of cardiac involvement on the basis of the resting ECG showed significant ST segment depressions (2.9 $\pm$ 1.6 mm range 1.1 to 6.0) at very moderate workloads (244 $\pm$ 52 kpm range 150 to 300 kpm).

Kavanagh's work is the only documentation of ECG findings for amputees. Electrocardiographic abnormalities have been documented for diabetes mellitus and peripheral arterial occlusive disease (also called peripheral vascular disease). Because these conditions are known to result in non-traumatic amputation, the literature pertaining to the ECG findings has been reviewed.

Cardiovascular disease and overt diabetes mellitus have been associated for over 50 years. The Framingham study, which is based on a series of 957 subjects, 45 to 75 years of age, and conducted over a 20 year period reports a 2-fold risk of cardiovascular disease in males and a 3-fold risk in females for diabetics as compared to non-diabetics (Kannel and McGee, 1979).

The Whitehall study investigated 18,403 male London civil servants, 40-64 years of age over a five year period. Coronary heart disease mortality was approximately doubled for subjects whose blood glucose after a 50 gm oral glucose load was above the 95th centile. The age-adjusted prevalence rates per 1,000 for diabetics and normoglycaemic subjects of ECG findings are listed in Table 9.

Table 9

The Whitehall Study. The age-adjusted prevalence of electrocardiographic findings per 1,000 for diabetics and normoglycaemic subjects

ECG finding	Diabetics	Normoglycaemic subjects
major Q wave	9.5	7.0
small Q wave	15.2	12.7
ST depression	27.9	12.6
T-wave depression	46.1	40.5
1^{o} AV block	31.1	24.3
L.BBB	14.8	4.6
PVC	5.6	14.2
heart rate > 100/min	47.2	21.3
heart rate < 50/min	0	14.0

(Fuller, 1980)

Abenavoli et al. (1981) reported that 7 of 12 (58.3%) diabetics without overt cardiac disease have an abnormal exercise ECG or a myocardial perfusion defect. These authors exercised 16 diabetic males, 32-60 years of age (mean 48.7 $\pm$ 8.9 years) without clinical or electrocardiographic evidence of heart disease at rest. All subjects were recruited through the New York Veterans Administration Hospital. The response of these subjects to treadmill work using the Bruce protocol has been compared to 12 age-matched normal male volunteers, 34-65 years of age (mean 48.9 $\pm$ 8.8 years). Diabetic subjects obtained a significantly lower mean HR max (diabetics 163 $\pm$ 9.9 beats/min vs controls 174.5 $\pm$ 17.4 beats/min, $p < .05$) and a lower mean $\dot{V}_{O_2}$ max (diabetics 32.9 $\pm$ 7.1 mg/kg/min vs controls 40.6 $\pm$ 5.5 ml/kg/min, $p < .005$).

Tomatis et al. (1972) demonstrated significant coronary artery disease in 34 of 72 (47%) of subjects with arteriosclerosis obliterans by angiographic studies.

Silvestre et al. (1979) demonstrated the manifestation of ST segment responses at low workloads in subjects with peripheral vascular disease (PVD). They evaluated fifty subjects 27-88 years of age (mean age 63 years) for suspect PVD of the legs, by treadmill exercise. The test was symptom-limited or otherwise terminated when the subject had sustained exercise at a limiting grade of 10% at 2.5 miles/hour for five minutes. Subjects tolerated exercise for only a mean of 3.8 minutes and achieved a mean maximum heart rate of 106 beats/minute (63% of their age-predicted norm). Thirteen of 50 subjects (26%) experienced ST segment change or frequent PVCs despite this low exercise stimulus.

Exercise testing of amputees

Several methods have been used for exercise testing of healthy traumatic unilateral amputee subjects. James and Nordgren (1973) compared physical work capacity for one-legged cycling on a modified bicycle ergometer, to treadmill walking for 38 healthy male amputee subjects 21 to 62 years of age (mean age 43.3 years). The bicycle ergometer was modified with a mechanically controlled switch so that the workload was discontinued for approximately one-third of the pedalling revolution. This phasing of the revolution was further facilitated by weighting the unused pedal. The mean maximum work load of 605 kpm/min (range 300 to 1200 kpm/min) was achieved by progressive six minute stages. Fatigue in the exercising leg as opposed to general fatigue was the limiting factor to maximal voluntary work for 66% of the subjects. The treadmill protocol was performed wearing a well-fitted prosthesis. The protocol progressed the walking speed from 25 to 45 to 65 metres per minute at slopes of 0 and 5 degrees. Each stage was six minutes in duration as for cycling.

Heart rate and blood lactate were higher at a given oxygen uptake for one-legged cycling than for treadmill walking.

Older, non-traumatic amputees have been tested by Miller (1976) and as previously noted, by Kavanagh and Shephard (1973). Miller (1976) exercised several unilateral, above knee and below knee amputees, 53 to 79 years of age, who were known to have cardiac disease. Two subjects were tested by upper extremity pully exercises with increasing weights. The others were tested by one-legged bicycle ergometry in the supine position with an initial load of 153 kpm and 153 kpm increments every two minutes. These exercise tests were terminated in 5 of 7 cases because of single ECG abnormalities, which included heart block, supraventricular tachycardia, ventricular tachycardia and junctional ST depression (specific ECG findings not illustrated).

Cardiac output and pulmonary arterial pressure were monitored by Miller for two subjects by thermal dilution catheter. In both cases, mean pulmonary artery pressures approached edema levels during the maximum workload.

Subsequent to the exercise test, four subjects were trained by upper limb work (arm-cranking, pulleys or sanding) of sufficient intensity to produce a target heart rate of 75% of the age-predicted HR max for 13-40 days (mean 20.9 days). An average resting pulse decrease of 10.7 beats/minute was noted following training and, although improved work performance was reported, specific data were not given.

Kavanagh and Shephard (1973) exercised 27 non-traumatic amputees (eighteen males, 42-79 years of age and nine females, 58-74 years of age) by arm cranking. Their initial load of 90-240 kpm at 60 rpm was increased by three minute stages to peak loads of 300-450 kpm. Of the twenty-seven subjects, only eleven advanced to the second load and only three to the third load, indicating the low work capacity of the older amputee. Breathed air was not collected for O_2 analysis because of the intolerance of the subjects for the collection apparatus.

Table 10 summarizes the exercise protocols for exercise testing amputees, used by the above investigators.

Table 10

The protocols for exercise testing amputee subjects used by investigators

Author and Date	No., age and disability of subjects	Method	Initial Load	Stage Duration(min)	Peak Load	Data Collected
James and Nordgren, 1973	38 21-62 yr	one-legged cycling	300 kpm	6	1200 mean 605 kpm	$\dot{V}_{O_2}$, HR, lactate, ECG
	traumatic amputee	treadmill walking	25 m/min	6	65 m/m slope 5^o	$\dot{V}_{O_2}$, HR, lactate, ECG
Kavanagh and Shephard, 1973	27 58-74 yr non-traumatic amputee	arm-cranking	190-240 kpm	3	300-450 kpm n=3	HR, lactate, ECG
Miller, 1976	2 53-59 yr non-traumatic amputee	pulleys				HR, lactate, ECG, BP, CO, pulmonary arterial pressure. n=2
	5 63-79 yr non-traumatic amputee	supine, one-legged cycling	153 kpm	2	306 kpm (pre-training)	

Hemiplegics

Electrocardiographic findings

Electrocardiographic findings for hemiplegics during the rehabilitation phase of treatment have not been reported. Therefore, the ECG findings during the acute phase following stroke have been reviewed. The ECG status of subjects may change in the first few weeks, and a comparison of data obtained at such intervals is not necessarily valid.

A pattern characterized by QT prolongation, U waves and T wave changes has been associated with acute stroke (Burch et al., 1954).

Three possible relationships between ECG changes and acute stroke are as follows:

a) the ECG changes may have occurred as a secondary event to the stroke (Burch et al., 1954).

b) the ECG changes may be associated with myocardial infarction or arrhythmia. Cerebral vascular accident may have occurred as a secondary event by the mechanism of decreased cardiac output and reduced cerebral blood flow (Gormsen et al., 1961).

c) the occurrence of an abnormal ECG and stroke may be coincidental, relating to a common hypertensive atherosclerotic pathology.

Dimant and Grob (1977) studied 100 consecutive admissions with acute stroke during the first 3 days following hospitalization. They observed abnormal ECG's for 90 of 100 subjects (90%) as compared to 50 of 100 subjects (50%) hospitalized for carcinoma of the colen. Refer to Table 11. Britton et al. (1979) also studied the ECG findings for 100 subjects with stroke, mean age 73 years (range 51-94 years). Their data were obtained by 24 hour Holter recordings 1 to 12

Table 11

The electrocardiographic findings by investigators for subjects with acute stroke and controls

	Goldstein (1979) obtained by 12-lead ECG				Dimant and Grob (1977) obtained by 12-lead ECG				Britton et al. (1979) obtained by 24 hr Holter recording	
	Stroke		Control		Stroke		Carcinoma of the colon		Stroke	
total abnormal ECG	138/150	92%	97/150	65%	90/100	90%	50/100	50%	82/100	82%
MI					14 old, 5 recent		14 old, 0 recent		3 during recording	
prolonged QT	68	45%	18	12%	14		3			
T-wave inversion	43	29%	32	21%	31		9			
U waves	42	28%	14	9%						
increased heart rate	42	28%	12	8%					3	
ST depression	41	47%	15	10%	22		3			
left ventricular hypertrophy	39	26%	18	12%	23		8			
Q waves	30	20%	14	9%						
atrial fibrillation	21	14%	6	4%	21		2		23	
axis deviation	21	14%	20	13%						
PVCs	18	12%	8	5%	13		3		37	
1^{o} heart block	12	9%	4	3%					3	
decreased heart rate	12	9%	6	4%					2	
sinus arrhythmia	10	7%	0	0%					1 sinus arrest	
other arrhythmia	10	7%	4	3%			7		1 nodal rhythm	
PACs	10	7%	7	5%						
R.BBB	10	7%	8	5%					1	
ST elevation	9	6%	2	1%						
L A E	8	5%	3	2%						
L.BBB	3	2%	4	3%					3	
other	4	3%	0	0%	4 tall T-waves 22 non-specific ST-T change 14 various types of heart block		0 24		1 heart block 1 complete heart block 2 h. ant. hemi block	

days (mean 2.4 days) after the cerebrovascular event. The frequency of particular ECG findings has been compared in Table 11 to the findings of the above authors.

Goldstein (1979) reviewed the electrocardiographic records of 150 subjects with acute stroke. An abnormal admission ECG was noted for 138 of 150 subjects (92%) as compared to 97 of 150 (65%) age- and sex-matched controls (reason for hospital admission other than stroke, MI or pacemaker). Refer to Table 11.

ECG's taken prior to the stroke were available for 53 (35%) of the subjects with stroke and for 63 (42%) of the controls. New abnormalities appeared on the current ECG's of 39 (74%) of the subjects with stroke and 9 (14% $p < .001$) of the controls. Goldstein's data provides support for the occurrence of stroke subsequent to decreased cardiac output. However, Goldstein does note the presentation of QT prolongation following stroke as a new documented finding in almost one-third of stroke subjects with prior available tracings.

Exercise testing of hemiplegics

The literature regarding exercise testing of hemiplegics is also scant. Iseri et al. (1968) exercised 37 non-traumatic hemiplegics (no age documented) with heart disease who were hospitalized for rehabilitation. Subjects sustained a workload of 240 kpm for 10 minutes at 30 rpm on the bicycle ergometer. Blood lactate values of $2.25 \pm .085$ and 2.57 ± 0.88 were observed after five and ten minutes of exercise (HR max, $\dot{V}_{O_2}$ were not documented).

Bjuro et al. (1975) exercised nine hemiplegic women 54 to 65 years of age. The subjects were at least one year post-stroke, were ambulant without aids, and participated in the domestic work of their homes. A mean maximum workload of 224 kpm (150-300 kpm) was obtained on the bicycle ergometer. The mean HR max was 123 beats/min (range 85-164 beats/min) and the $\dot{V}_{O_2}$ max was 0.75 l/min (range 0.51-0.99 l/min). Blood lactate values were not reported.

Saltin and Landin (1975) evaluated the work capacity for each of the paretic and non-paretic legs of six hemiplegic subjects, 38-55 years of age and three controls, 36-67 years of age, by one-legged cycling. The tests were conducted 1.5 to 12 years (mean 4.6 years) following the stroke. All subjects had a moderate paresis, but were ambulant without aids. Four of the subjects were employed at least part-time. At an initial workload of 150 kpm, the peak heart rate, oxygen uptake and blood lactate, obtained by exercising the paretic leg were 134 beats/min (range 102-152 beats/min), 0.99 l/min (range .96-1.11 l/min) and 3.2 mmol/l (range 2.3-4.6) respectively. For the non-paretic leg, these values were 108 beats/min (range 82-132), 0.88 l/min (range 0.81-1.04 l/min) and 2.0 mmol/l (range 1.4-2.5 mmol/l). At the same workload, the controls performed at a lower heart rate (94 $\pm$ 14 beats/min) and a lower $\dot{V}_{O_2}$ (.67 $\pm$ 0.08 l/min) and similarly, maintained a lower blood lactate (1.6 $\pm$ 0.5) than the hemiplegic subjects using either leg.

A second exercise test was performed with an initial workload near maximum and subsequent 100 kpm increments every second minute. The maximal average workload achieved by hemiplegic subjects while exercising the paretic leg was only 220 kpm, whereas the maximum tolerated work was 630 kpm for the non-paretic leg. The HR max, $\dot{V}_{O_2}$ and blood lactates obtained by exercising the paretic leg were 145 beats/min (range 102-176 beats/min), 1.1 l/min (range 1.01-1.43 l/min)

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and 3.8 mmol/l (range 3.6-4.0 mmol/l). The values obtained for HR max (163 ± 10 beats/min) and $\dot{V}_{O_2}$ max (2.0 ± 0.8 l/min) by exercising the non-paretic leg were significantly higher ($p < .05$). The blood lactate value obtained with maximal exercise of the non-paretic leg at 4.2 mmol/l (range 3.2-5.6 mmol/l) was not significantly higher.

Landin et al. (1977) further investigated the muscle metabolism in hemiparetic patients. Eight male patients, 38 to 58 years of age (mean age 45 years) were tested by two-legged cycling at the highest workload each subject could sustain for 40 minutes. This was 306-397.8 kpm (50 to 65 W). From tracings of pedal force, it was estimated that the non-paretic performed 64 ± 2% of the total workload and received a blood flow during exercise which was 120% to 160% greater than the blood flow to the paretic leg. Oxygen uptake by the paretic leg was 55% and 40-45% of the $\dot{V}_{O_2}$ by the non-paretic leg during rest and exercise respectively. Blood lactate values were low for both legs although significantly lower for the paretic leg.

Subsequently, both legs were exercised by one-legged cycling at the same workload of 61.2 kpm (10 W). Blood flow to the paretic leg was 25% lower, the $\dot{V}_{O_2}$ 48% higher and the release of lactate significantly greater compared to the non-paretic leg. The actual values are presented in Table 12. These investigators suggest that the reduced blood flow to and augmented lactate release from paretic muscle indicates that the capacity to oxidize free fatty acids is diminished in paretic muscle.

Table 12

The exercise response of hemiparetic patients for two-legged and one-legged cycling

		Two-legged cycling		One-legged cycling	
		Rest	40 min exercise	Rest	40 min exercise
Workload (kpm)		0	306 - 397.8	0	61.2
Blood flow (l/min)	P	0.29 ± 0.03	1.14 ± 0.17	0.35 ± 0.03	1.49 ± 0.05
	NP	0.48 ± 0.04	2.46 ± 0.10	0.50 ± 0.09	2.02 ± 0.31
Leg V_{O_2} (ml/min)	P	15 ± 2	160 ± 14	18 ± 2	189 ± 14
	NP	28 ± 3	405 ± 30	26 ± 3	240 ± 45
Leg lactate (mmol/min)	P	0.05 ± 0.01	0.07 ± 0.06	0.03 ± 0.01	0.71 ± 0.20
	NP	0.03 ± 0.01	0.52 ± 0.20	0.04 ± 0.01	0.48 ± 0.18

P = paretic

NP = non-paretic

(Landin et al., 1977)

V. Occupational Therapy Treatment of Amputees and Hemiplegics for Underlying Cardiopulmonary Disease

The premise of occupational therapy is that activity has a healing function. Activities are selected for treatment because of their appropriateness for meeting treatment goals. The achievement of these goals is thought to be enhanced by the patient's pre-occupation with productive work.

Occupational therapy literature does not specifically address the treatment of disabled persons, such as amputees or hemiplegics, for underlying cardiopulmonary pathology. However, patients with known cardiac disorders have been treated by occupational therapists since the early 1950's. At that time, the selection of an appropriate activity to promote healing was based on the energy cost of the activity. It was supposed that cardiac work varied with energy cost, which was measured as a multiple of basal oxygen uptake.

The unit of energy cost was called the MET, an abbreviated form for metabolic equivalent, equal to 3.5 ml O_2 uptake/kg/min or 1.2 kcal/min. Initially, occupational therapists depended on the MET values obtained by exercise physiologists.

In the mid 1950's, physicians involved with the rehabilitation disciplines and occupational therapists themselves began to study the energy costs of the activities they used. Gordon and Haas (1955) determined oxygen uptake as a percent increase over basal for 39 male tuberculosis patients (no age documented) doing four therapeutic activities. Hellestein and Ford (1957) obtained MET values for light industrial activities similar to those used in the occupational therapy workshops for 36 subjects with coronary artery disease (age not documented) through their involvement in the Cleveland Work

Classification Clinic. Quiggle, Kottke and Magney (1954) determined the oxygen uptake as a percentage increase over basal oxygen uptake for 37 occupational therapy students and faculty doing chip carving, leather carving, table weaving and sewing activities. These MET values cannot be correctly applied to the elderly, disabled occupational therapy clientele because they relate to specific disabilities or to young able-bodied subjects, and have been determined using protocols and equipment which were specific to the respective studies. Refer to Table 13 for details regarding the origin of MET values listed by Trombly and Scott (1977) which are pertinent to this study.

The inappropriateness of using MET values determined for able-bodied subjects to estimate the energy expenditures for amputee subjects has been recently illustrated by Chi-Tsou Huang et al. (1979). Oxygen uptake values were determined per foot travelled for six unilateral below knee (B/K) amputees 25-56 years of age (mean 38.2 years), for six unilateral above knee (A/K) amputees 20-45 years of age (mean 30.83 years), for four bilateral A/K amputees 20-49 years of age (mean 33.5 years) and 25 controls 19-43 years of age. These values were found to be 9%, 49% and 280% higher for the respective amputee groups as compared to the controls. Subjects walked at their own speed.

Hirschberg (1965) observed that hemiplegic subjects used 40-50% more energy per step than controls, for comparable methods of stair climbing. He studied 10 hemiplegics aged 36-65 years (mean 56 years) who were more than one year post-stroke and who had been ambulant at least three months, and 10 controls aged 27-74 years (mean 56 years).

Table 13

Details pertaining to the origin of the MET values for activities pertinent to the study

Activity as listed	Calories per minute	Reference as listed	Original source	Further qualifications	Number	Sex	Age
standing	1.9	Passmore & Durin(1955)	Garry et al.(1955)	at ease	av. of 7 miners & clerks	M	38 yr.
walking 2.5 mph	3.6	Gordon(1958)	Sherman (1952)		not given		
wheelchair propulsion	2.4	Gordon(1958)			not given		
stair climbing	6-10.0	Passmore & Durin(1955)	Passmore et al. (1952)	vertical speed 14.8 m/min ht. of stair 15.2 cm.			
carpentry	6.8	Gordon(1958)			not given		
planing hard-wood	9.1	Passmore & Durin(1955)			1	M	31 yr.
hand sawing	3.3-3.4	Gordon(1958)			not given		
shovelling	8.5	Gordon(1958)			not given		
assembler	2.49	Hellerstein & Ford(1957)	Heller-stein & Ford un-published data				
cycling	4.5	Passmore & Durin(1955)			1	M	not given
Not listed							
ladder climbing	9.0	Passmore & Durin(1955)	Lehman (1953)	70° incline no load vertical speed 11.1 m/min	foreign text		
cross-cutting with bucksaw	9.0	Passmore & Durin(1955)	Lundgren (1946)		11 lumber workers	M	

Oxygen uptake was determined for a series of tests involving the ascent and descent of two stairs, using unilateral step-to and alternating stair gaits. The energy expenditure per minute was similar for hemiplegics and controls because of the slower rate of stair climbing observed for the hemiplegic subjects.

A more individualized approach to the selection and regulation of activity to achieve cardiopulmonary goals was undertaken in the early 1960's via the monitoring of pulse rate and careful observation of the patient's response. Technological developments such as telemetry ECG equipment and research findings in exercise physiology have since made a re-definition of this individualized treatment approach possible (Hendrickson et al., 1960).

The scope of the occupational therapist's involvement in cardiac rehabilitation varies markedly between settings. The coronary rehabilitation program at St. Mary's Hospital, Minneapolis is one of the few programs reported in the literature (Mesenbourg, 1970). St. Mary's offers a three stage program where self-care activities are monitored in the acute stage, light conditioning activities are assigned in a second or sub-acute stage and heavy activities with a subsequent vocational assessment are offered during the convalescent stage. A fourteen-step program has been set out by Grady Memorial Hospital, Atlanta which similarly assigns a significant role to the occupational therapist (Trombly and Scott, 1977).

The Occupational Therapy and Physical Therapy Departments of Ranch Los Amigos Hospital, California have developed a comprehensive task evaluation. The patient's cardiovascular response to each task sample is evaluated via the parameters of blood pressure, telemetry

ECG recording, heart rate and symptoms of cardiopulmonary distress (Dempster Ogden, 1979; Harrington et al., 1981). Procedure guidelines have recently been published (Dempster Ogden, 1980).

MATERIALS AND METHODS

Experiment I:

Evaluation of the Cardiopulmonary Status of Occupational Therapy Patients

Subjects

Four diagnostic groups of patients attending occupational therapy whose disability and length of hospitalization were compatible with the objectives of the experiment were identified. Thereafter, subjects were selected for study on the basis of their primary treatment diagnoses. Participation was subject to obtaining positive consent from the attending physician, to obtaining informed consent from the prospective subject, and to screening of the medical history for absolute contraindications. These were:

a) angina at rest or unstable clinical angina with exertion

b) myocardial infarction within six weeks

c) blood pressure at rest greater than 200/110 mmHg

d) aortic or other aneurism

e) fibrile state, uncontrolled infection or metabolic state

f) extreme mental or physical incapacity.

The following groups of subjects were recruited from October 1980 to May 1981:

a) 17 non-traumatic male amputees aged 54-78 years (mean 63.5 $\pm$ 5.7 years)

b) 4 traumatic male amputees aged 20-37 years (mean 29.5 $\pm$ 6.7 years), 1 traumatic female amputee aged 21 years

c) 8 male patients with hemiplegia aged 36-67 years (mean 52.4 $\pm$ 9.9 years) and 1 female patient with hemiplegia, aged 68 years

d) 9 male subjects with back problems, aged 22-70 years (mean 37.2 $\pm$ 11.8 years) and 1 female subject with lumbo-sacral sprain, aged 23 years.

The age, weight, primary and other diagnoses, employment, duration of inactivity and medications have been recorded for the respective groups of subjects in Tables 14 to 17 inclusive.

Protocol

An exercise test was scheduled for each subject. Protocols for exercise testing have been illustrated in Tables 19 to 22 inclusive, under RESULTS.

Non-traumatic amputees

The non-traumatic amputee subjects were tested by arm cranking using an electronically braked Elema-Schonander ergometer. All arm crank tests were performed with the subjects seated and the crank axis at heart level. The crank length was 18 cm. All but one test was performed with two handles. The one test was performed using a single crank propelled by both upper limbs.

The initial workload was 100 kpm/min for 14 of the 17 non-traumatic amputees. An initial load of 200 kpm/min was used for 3 of 17 subjects as their history suggested a higher working capacity. The workload was increased at three minute intervals by 100 kpm/min increments for 14 subjects. One subject was tested with an initial load of 200 kpm/min and subsequent 200 kpm increments because low workloads were not sufficient to cause fatigue in 12-15 minutes. Increments of 200 and then 100 kpm/min were used for one subject because it was apparent that 200 kpm would have been the appropriate initial load. One subject was unable to work at more than 100 kpm/min for three minutes. The cranking rate was kept constant at 60 rpm with the aid of a revolution meter.

Traumatic amputees

The traumatic amputee subjects were tested by arm cranking as above. Four of five subjects performed the test with two handles and the fifth used a single crank. The initial workloads and workload increments of 100, 200 or 300 kpm/min were selected according to the subject's work history.

Hemiplegic subjects

The Elema-Schonander ergometer was used as a bicycle ergometer for testing the hemiplegic subjects. A very low initial workload of 50 kpm/min was selected for five of eight subjects. Of these five subjects, one was unable to advance, three advanced at three minute intervals by 50 kpm/min increments, and one subject advanced by 100 kpm/min increments. An initial workload of 100 kpm/min was selected for three of eight subjects. Two of these subjects advanced by 100 kpm/min increments and third by 200 kpm/min increments. The cycling rate was kept constant at 60 rpm with the aid of a revolution meter.

Subjects with back problems

Nine of ten subjects with back problems were tested by bicycle ergometry. An initial workload of 300 kpm/min was selected for eight of nine subjects and advanced at three minute intervals by 200 kpm/min increments for seven of these eight. One subject who performed an initial workload of 300 kpm on the bicycle advanced by 300 kpm increments. One of the nine subjects who were tested on the bicycle was assigned an initial workload of 100 kpm and advanced by 150 kpm/min increments every three minutes. One of the ten subjects with back problems was tested by arm crank ergometry in a standing position. The test was performed using two handles with the crank axis at heart level. The initial workload of 300 kpm/min was increased by 200 kpm/min increments.

Measurements of Cardiopulmonary Status

A 12-lead resting ECG was obtained. During exercise, lead CM_5 of the ECG was monitored and recorded.

Heart rates were obtained from the ECG before exercise, at three intervals during exercise, during immediate recovery and at two and five minutes recovery.

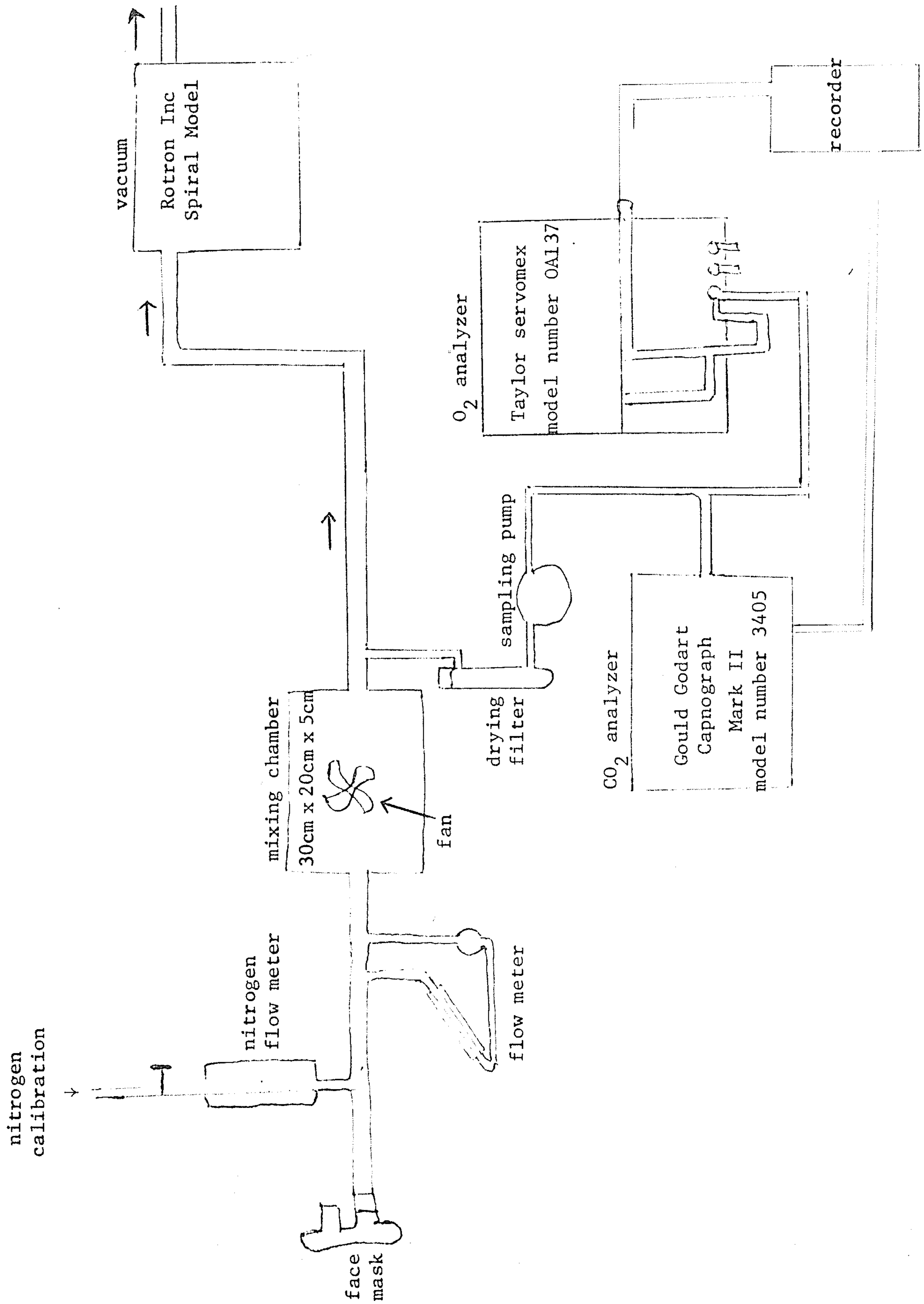
The subject's blood pressure was obtained by auscultation before exercise, at three minute intervals during exercise, during immediate recovery, and at two and five minutes recovery.

Oxygen uptake was determined using a face mask and Taylor Servomex continuous flow through system model number OA137. Figure 1 is an illustration of the O_2 uptake system. Room air was drawn through a valve in the face mask by the vacuum at 310 l/min. A sample of mixed air was passed through the silica gel drying agent and into each of the O_2 and CO_2 analyzers. The O_2 system was calibrated by adding 99.9% Nitrogen at 9.14 l/min to the moving air stream. The loss of O_2 from room air was recorded as a deflection on the recorder and was corrected to the standard-temperature-pressure of dry air (STPD).

The CO_2 system was calibrated by passing 2.44% CO_2 directly through the CO_2 analyzer. The CO_2 concentration in the air stream was also recorded as a deflection on the recorder. The respiratory quotient was determined from the O_2 uptake and CO_2 output values. For technical reasons, the CO_2 analyzer was not available February through May, 1981. Because the CO_2 output and respiratory quotient (RQ) were determined for only 8 of 41 subjects tested, the RQ was assumed to be 1.0 for all subjects. This assumption proved reasonable, as the actual mean RQ for the eight subjects was 1.014.

Figure 1

The oxygen uptake system



Experiment II:

The Heart Rate and Electrocardiographic Response to Occupational Therapy Activities

Subjects

All subjects who were recruited in Experiment I also participated in Experiment II, with the exception of five subjects who chose not to or were unable to participate.

Nine hemiplegic subjects who were unable to perform an exercise test were approached to request their participation in Experiment II. Five women, 60-67 years of age (mean 63 $\pm$ 2.0 years) and four men, 55-70 years of age (mean 62.8 $\pm$ 6.5 years) were recruited (see Table 18).

Protocol

All subjects were monitored by Holter recording during their regular occupational and physical therapy treatments for a daytime period of at least six hours.

Occupational therapy treatment encompassed light industrial, recreational mobility and personal care activities. Physical therapy treatment encompassed walking classes, general and specific exercises. In some instances, the subject was monitored during assessment, however the majority of treatment activities had been assigned by the treating therapists prior to the Holter recording. No effort was made to modify the activity or rate of work during the recording. An effort was made to structure the duration of the activity so that the subject worked continuously at a given activity for a minimum of three minutes. Subjects recorded the time and substance of their activities with the assistance of the therapists and nursing staff for the duration of the monitoring period.

Measurement of the Heart Rate and Electrocardiographic Response to Occupational Therapy Activities

The Holter tapes were scanned on a Phillips Holter-type instrument for cardiac research, Model Number 6003-C. The ECG was recorded as follows:

a) during designated activities

b) when distrubances of rhythm were present.

The peak heart rate for each treatment activity determined from the ECG recording is usually calcualted as a percentage of the heart rate reserve (HRR) as follows: HRR = HR max - resting HR

$$\%\ \text{HRR} = \frac{\text{HR during activity - resting HR}}{\text{HRR}}$$

The pre-exercise HR was found to be the more objective measure of resting HR. However, the pre-exercise HR was unreasonably high for four subjects, and an average of three morning pulse rates was used to calculate their HRR. The HR max obtained during the exercise test in Experiment I was used for the HRR calculations. The % HRR values for hemiplegic subjects who did not have exercise tests were calculated using the mean pre-exercise HR and the mean voluntary HR max obtained for hemiplegic subjects who were tested.

Experiment III:

The Conditioning Effect of an Occupational Therapy Program

Subjects

Fifteen of the seventeen non-traumatic amputee subjects who were recruited in Experiment I participated in Experiment III. The age range was 54-78 years (mean 62.4 $\pm$ 5.2 years). All subjects were males and all but one subject had vascular disease. The causes of amputation were diabetes

(5 subjects), peripheral arterial occlusive disease (PVD) (7 subjects), diabetes and PVD (1 subject), hypercoaguable state (1 subject) and frostbite (1 subject). All subjects were in the post-amputation, pre-prosthetic stage of treatment. The approximate time from amputation to the initial exercise test was 1.9 $\pm$ 1.1 months for 13 subjects. Two subjects had amputations one and three years prior to testing and had been hospitalized due to stump ulceration.

Subjects were designated to either the control or experimental groups. An attempt was made to match the groups for age and cause of the amputation. Seven subjects, aged 54-78 years (mean 64.6 $\pm$ 7.6 years), with PVD (4 subjects), diabetes (2 subjects) and frostbite (1 subject), were assigned to the control group. Eight subjects aged 54-69 years (mean 61.5 $\pm$ 4.3 years) with PVD (3 subjects), PVD and diabetes (1 subject), diabetes (3 subjects) and hypercoaguable state (1 subject) were assigned to the experimental group.

Protocol

Subjects in the control group participated in the physiotherapy program, which usually involved two 60 minute walking classes and a 30 minute exercise class daily. As well, these subjects were independently mobile within the Health Sciences complex via crutches and/or wheelchair.

Subjects in the experimental group similarly participated in the physical therapy program and were independently mobile. In addition, they attended the occupational therapy program.

The occupational therapy activities were selected for their conditioning value. Workshop projects involved sawing, planing, sanding and wood finishing. In addition, each subject pulled pulleys in the job simulation area. As for the Holter recording, the subjects were allowed to work at their own rate. The rationale for this lenience was first, that the ECG, blood pressure and heart rate responses to work were not adequately monitored. Second, the intensity of work was presumed to more closely approximate that of the routine treatment programs used in occupational therapy. The subjects chose to work steadily and vigorously on their respective projects. The subjects attended occupational therapy together at the same time each day, and worked in the same general area.

The duration and frequency of the occupational therapy program were 30-60 minutes 4-5 days weekly. The duration of the treatment period was six weeks. Ideally the patient was hospitalized eight weeks for recruitment, initial testing, treatment and re-testing.

The subjects's participation in the occupational therapy program remained voluntary throughout its duration. Subjects in either the control and experimental groups who were able to complete three or more weeks of the respective therapy programs performed a second exercise test prior to their discharge from hospital, or after six weeks of treatment. The re-tests were conducted using the same method and workloads as in the initial exercise test conducted in Experiment I.

Table 14

Non-traumatic amputee subjects

Subject	Sex	Age (Years)	Weight (kg)	Primary Treatment Diagnosis	Other Diagnoses	Employment	Approximate Period of Inactivity	Medications
Ass	M	60	63(with R. Prosthesis)	L.A/K amputation Oct. 1980	Two previous L. amputations R. B/K amputation May 1975 Diabetes since 1969	Construction worker Logger	6 years	Lente Insulin
Chom	M	68	72.2	R.B/K amputation Jan. 1981	Sympathectomy Dec. 1980 P.V.D. Diabetes	Steel worker	2 months	Chloropromide 125 mg Coumadin 7.5 mg Lasix 40 mg
Chor	M	62	92	R.B/K amputation Feb. 1981	One previous R. foot amputation on Mar. 1980. Two previous L. amputations Oct. 1979 Diabetes	Steelworker	16 months	Diabeta 5 mg
De R	M	62	63	L.B/K amputation Feb. 1981	Diabetes	Retired bus inspector	Retired 8 months	Chlorpropamide 250 mg Cloxacillin 500 mg Tylenol
Dyc	M	54	53	Symes amputation Jan. 1981	Alcoholism Neurosyphylis	Logger	1 month	Tylenol
Ewa	M	60	51	L.A/K amputation Apr. 1980	P.V.D.	Construction & Forestry worker	1 year	Dalmane Tylenol
Hen	M	71	58	L.B/K amputation Dec. 1980	Myocardial infarct July 1979 P.V.D.	Retired cook 6 years	2 years	Dalmane 30 mg Tylenol

Table 14 (cont'd)

Non-traumatic amputee subjects

Subject	Sex	Age (Years)	Weight (kg)	Primary Treatment Diagnosis	Other Diagnoses	Employment	Approximate Period of Inactivity	Medications
Jac	M	65	97.5	L.B/K amputation 1978 Recent ulceration	Diabetes since 1969	Semi-retired farmer	1 month	Insulin. Injections 4 years
Koz	M	55	75	L.B/K amputation Mar. 1980 Stump ulceration	Diabetes	Steelworker	1 year	Dalmane 30 mg Tylenol Hygroton 50 mg Chloropropamide 250 mg Slow K
McC	M	54	82.7	R.B/K amputation 1973 Revision Dec. 1980	Myocardial infarct 1963 P.V.D. claudication since 1979 R. ileofemoral bypass 1979 L. ileofemoral bypass Dec. 1980 R. hip pinning Feb. 1981	Chief security officer	6 months	Comadin 10 mg Dalmane 30 mg Tylenol with Codeine 30 mg
McL	M	71	74.8	L.B/K amputation	Diabetes Hypertension	Retired farmer		Dalmane 30 mg Digoxin 25 mg Hydralyzine 25 mg Lasix 20 mg Spiranolactone 25 mg
Mel	M	62	88.5	R.K/B amputation May 1980	P.V.D.	Cook	1 year	Dalmane 30 mg Tylenol plain
Ral	M	69	57	L.B/K amputation Jan. 1981	P.V.D. R.CVA ≦ Feb. 1980 Alcoholism	Retired engineer - not heavy work	1 year	Benzinal Dalmane Hydrochlorothiazide Thiamine Tylenol
Rob	M	67	63.2	R.B/K amuptation Nov. 1980	P.V.D. R. bypass Dec. 1980 unsuccessful L. bypass 1979 Bronchitis		2 months	Dalmane 30 mg Kondremul with Cascara 30 cc Tylenol

Table 14(cont'd)

Non-traumatic amputee subjects

Subject	Sex	Age (Years)	Weight (kg)	Primary Treatment Diagnosis	Other Diagnoses	Employment	Approximate Period of Inactivity	Medications
San	M	57	59.5	L.A/K amputation Feb. 1981	Hypercoaguable state bypass unsuccessful	Railway worker	2 months	Heparin 600 units Tylenol Valium 5 mg
Sei	M	65	65.8	L.B/K amputation Oct. 1979 Recent ulceration	P.V.D.		4 months	
Str	M	78	51	R.B/K amputation Sept. 1980	P.V.D.	Retired construction worker	5 months	Chloral hydrate 500 mg Surfak 240 mg Tylenol 15 mg with Codeine

Table 15

Traumatic amputee subjects

Subject	Sex	Age (Years)	Weight (kg)	Primary Treatment Diagnosis	Other Diagnoses	Employment	Approximate Period of Inactivity	Medications
Der	M	20	66.2	L.B/K amputation August 1980	Compound fracture of left femur Aug. 1980 with fraction by compression plate Sept. 1980	Construction labourer	4.5 months	Dalmane 15 mg Tylenol
Duc	M	29	58	R.A/K amputation October 1980	Head injury with memory impairment	Brick layer	6 months	Tylenol plain
Eag	M	32	74	R.B/K amputation 1972 stump ulceration		Factory worker - Fibre glass plant	2 weeks	Erythromycin 25 mg Dalmane 30 mg
Keno	M	37	66.8	R.B/K amputation 1975 Bursitis and stump swelling		Soap-stone carver	2 weeks	Dalmane 15 mg
Rof	F	21	56.8	R.B/K amputation June 1980	-	Dancer	7 months	Dalmane 30 mg Tylenol 2 mg Valium 2 mg

Table 16

Hemiplegic subjects

Subject	Sex	Age (Years)	Weight (kg)	Primary Treatment Diagnosis	Other Diagnoses	Employment	Approximate Period of Inactivity	Medications
Ash	M	66	85.8	L.CVA Jan. 1981	-	Administrator	1 month	Entrophen 650 mg
Ham	M	48	77	L.CVA July 1980	-	Plumber	8 months	-
Hoj	M	60	72	R. Lateral Medullary Infarction Jan. 1981	-	Steelworker	1 month	Digoxin suppository Ducolax suppository Probanthine 15 mg Tagamet 300 mg Tylenol - headache
Hol	M	41	67.2	R.CVA Oct. 1980	C.A.D. T.I.A.s. Alcoholism	Construction (Roofer)	3.5 months	Bradasol Dalmane-sleeping pill Glycerine suppository Surfak Thiamine 100 mg Tylenol
Mal	M	51	72.6	L.CVA Jan. 1981	-	Businessman	1 month	Dalmane 30 mg Entrophen 650 mg Metamucil
Mar	M	67	70.9	L.CVA Apr. 1981	Sympathectomy Oct. 1980 Diabetes 17 yrs.	Salesman	8 months	Insulin Toronto 8 u Insulin Lente 6 u Clindamycin 300 mg
Sha	F	58	71.8	R.CVA Jan. 1981	C.A.D.	Homemaker	2 weeks	Nitroglycerin Mylenta, Tylenol
Slo	M	50	106	R.CVA Aug. 1980	Gilat Phlebitis Gout Multiple Pulmonary embolis Alcohol abuse		4 months	Allopurinal 300 mg Delusil 15 mg Entrophen 650 mg Nitroglycerin .6 mg Surfak 240 mg
Ste	M	36	70.7	R.CVA Jan. 1981 following mitral/aortic valve replacement	Endocarditis Open heart surgery 4x Epilepsy - controlled after Nov. 1980	Truck driver and Farmer	2 years	Digoxin .25 mg Dilantin 200 mg Tylenol

Table 17

Subjects attending the workman's compensation board backs program

Subject	Sex	Age (Years)	Weight (kg)	Primary Treatment Diagnosis	Other Diagnoses	Employment	Approximate Period of Inactivity	Medications
Dre	M	36	96	Non-specific back injury	Old injury to left knee with loss of movement	Bus driver	1 month	
Fri	M	52	82	Cracked L_1 and L_2 vertebrae	-	Construction worker	4 months	-
Har	M	28	68	Lumbo-sacral sprain	-	Construction worker	1 month	-
Hil	M	34	89.8	Lumbo-sacral sprain	-	Butcher	1 month	-
Lis	F	23	52.2	Lumbo-sacral sprain	-	Licensed practical nurse	2 weeks	Antispasm medication
Lov	M	33	93.1	Probable L_{4-5} disc strain	Ulcer	Factory receiver	2 months	Tagamet
Rou	M	32	81.9	Lumbo-sacral sprain possible L_{4-5} root compression	-	Fireman	1 month	-
Ven	M	22	87.3	Lumbo-sacral sprain	-	Utility labourer	1 month	-
Wah	M	28	93.6	Cervical strain Lumbo-sacral disc prolapse	-	Utility labourer	2 months	-
Wil	M	70	83.2	Chronic low back pain S_1 root irritation	-	Retired administrator	1 month	Atarax 25 mg Dalmane 30 mg

Table 18

Hemiplegic subjects investigated by 'Holter' recording only

Subject	Sex	Age (Years)	Weight (kg)	Primary Treatment Diagnosis	Other Diagnoses	Employment	Approximate Period of Inactivity	Medications	Contraindication to Exercise Testing
Fen	F	62		R.CVA Dec. 1980		Homemaker	2 months	Cortisporin Digoxin .125 mg	Physical and mental inability
Han	F	62		R.CVA Jan. 1981	Brain stem infarct 2 subsequent T.I.A.s. R. ulnar n. lesion with claw hand deformity	Homemaker	8 years	Chloral Hydrate 500 mg Chlorothalidone 50 mg Tylenol	Physical and mental inability
Ken	M	55		L.CVA Oct. 1980	Chronic atrial fibrillation aphasia	Fishing guide unemployed	4 months	Hydrochlorothiazide Hydralazine Propranolol 20 mg	Physician refused
Kow	M	65		R.CVA Nov. 1980	-	Retired salesman	4 months	Entrophen 325 mg Chloral hydrate 500 mg Dyazide 25 mg	Unwilling and anxious
Lup	M	61		L.CVA Jan. 1981	L.A/K amputation 1978 Aphasia	Unemployed	2.5 years	Entrophen 325 mg Tylenol	Disability of R. arm and both legs
Ros	F	67		R. parietal lobe syndrome Feb. 1981	Myocardial infarct 1980	Homemaker	2 weeks	Dalmane Entrophen 650 mg Propranolol 80 mg Nitroglycerine .3 mg	Patient on inderol. Retrograde P wave; personal assn.
Szc	M	70		R.CVA Feb. 1981	Hypertension	Retired railway worker	1 month	Chloral hydrate 500 mg Entropheng 50 mg Glysennid Nitroglycerine 0.3 mg Tylenol plain	Unable to pedal unresisted bicyle due to flacid limbs

Table 18(cont'd)

Hemiplegic subjects investigated by 'Holter' recording only

Subject	Sex	Age (Years)	Weight (kg)	Primary Treatment Diagnosis	Other Diagnoses	Employment	Approximate Period of Inactivity	Medications	Contraindication to Exercise Testing
Wen	F	61		L.CVA Nov. 1980	Diabetes Aphasia	Homemaker	3 months	Lente Insulin 28 u Apresoline 25 mg Chlorthalidone 50 mg Nitroglycerine Seconal 100 mg Tylenol 15 mg with Codeine	Aphasic
Wur	F	63		R. CVA Oct. 1980	-	Homemaker	4 months	Chloral Hydrate Tylenol	Marked spasticity in affected leg

RESULTS

Experiment I

Seventeen non-traumatic male amputees, mean age 63.5 ± 5.7 years exercised by arm cranking 8.4 ± 1.5 minutes to obtain a mean maximum workload of 321 ± 81 kpm/min (range 100-400 kpm/min). The mean maximal heart rate was 138 ± 17 beats/min (range 106-163 beats/min) which was 87% (range 74-101%) of the age-predicted HR max for these subjects was obtained. The submaximal $\dot{V}_{O_2}$ values at 200 kpm and 300 kpm were .80 ± .05 l/min (n=14) and 1.05 ± .0 l/min (n=2) respectively. The $\dot{V}_{O_2}$ max was 1.09 ± .20 l/min (range .64 - 1.93 l/min, n=15). The mean post-exercise blood lactate value was 10.4 ± 2.8 mmol/l (range 5.2 - 16.0 mmol/l, n=14). The observed values are presented in Table 19.

A higher mean maximum workload of 540 ± 190 kpm/min (range 300-700 kpm/min) was obtained by the five younger traumatic amputees, mean age 27.8 ± 7.3 years who were exercised by arm cranking for the same approximate time (8.4 ± 0.7 minutes). The traumatic amputees obtained a comparable percentage of their age-predicted HR max of 85% (range 70-96%). The higher actual mean HR max of 164 ± 22 beats/min (range 129-192 beats/min) of the traumatic amputees was to be expected because they were 36 years younger than the non-traumatic amputees. The submaximal $\dot{V}_{O_2}$ values at 200 and 300 kpm/min of .81 ± .20 l/min (n=3) and 1.05 ± .16 l/min (n=3) for the young amputees were very similar to the figures observed for the older amputee subjects of .80 l/min and 1.05 l/min. It appears that the mechanical efficiency of arm cranking was similar for both groups. The $\dot{V}_{O_2}$ max of 1.79 ± .51 l/min (range 1.15 - 2.29 l/min) observed for the traumatic amputees was .70 l/min higher (64% of 1.09 l/min) than that observed for the non-traumatic amputees. The mean post-exercise blood lactate value of 12 $\pm$ 3.8 mol/l (range 7.8 - 15.2 mol/l) indicated that the traumatic amputees had made a near maximal effort. The individual values for the traumatic amputees are presented in Table 20.

Nine hemiplegic subjects, mean age 53 $\pm$ 9.8 years exercised by bicycle ergometer 8.5 $\pm$ 4.3 minutes to obtain a mean maximal workload of 269 $\pm$ 20 kpm/min (range 50 - 450 kpm/min). A mean HR max of 126 $\pm$ 15 beats/min (range 100-148 beats/min) was obtained which is 76% of the age-predicted HR max for these subjects (range 62 - 86%). The respective submaximal $\dot{V}_{O_2}$ values at 200 kpm and 300 kpm were .80 $\pm$ .09 l/min (n=4) and 1.10 $\pm$ .07 l/min (n=3). The $\dot{V}_{O_2}$ max was 1.11 $\pm$ .29 l/min (range .62 - 1.56 l/min, n=8). The mean post-exercise lactate concentration in blood sampled from the paretic arm was 3.4 $\pm$ 1.1 mmol/l (range 1.3 - 4.4 mmol/l, n=8). We developed some curiosity with respect to the low blood lactate values mid-experiment and subsequently collected post-exercise lactates from both the paretic and non-paretic arms of two subjects. The mean values obtained from the paretic arm (4.0 mmol/l, n=2) and non-paretic arm (3.7 mmol/l, n=2) for these subjects were not significantly different. One hemiplegic subject, Mal, obtained a maximum workload of 450 kpm/min, a HR max of 157 beats/min (93% of his age-predicted HR max) and a $\dot{V}_{O_2}$ max of 1.42 l/min. His post-exercise blood lactate (4.2 mmol/l) was obtained from the non-paretic arm. He attended a combined rehabilitation program for six weeks and was subsequently re-tested. He was able to increase his maximum workload to 700 kpm/min, his maximal HR to 170 beats/min (101% of his age-predicted HR max) and his $\dot{V}_{O_2}$ max to 2.00 l/min. The post-exercise blood lactate values from the paretic and non-paretic arms were 4.9 mmol/l and 6.7 mmol/l respectively.

Table 21 presents the observed values for the hemiplegic subjects.

Ten subjects with back problems, mean age 35.8 $\pm$ 10.1 years, obtained a mean maximum of 990 $\pm$ 213 kpm/min (range 700 - 1300 kpm/min) after cycling for 13.2 $\pm$ 2.5 minutes. The mean HR max of 169 $\pm$ 12 beats/min (range 144 - 183 beats/min) obtained by these subjects was 92% of their age-predicted HR max (range 86 - 98%). The mean submaximal $\dot{V}_{O_2}$ obtained at 300 kpm/min for seven subjects was 1.00 $\pm$ .08 l/min. This value appears to be notably increased by subject Dre who had a knee injury with decreased range of movement. The mean $\dot{V}_{O_2}$, excluding this subject, was 0.95 l/min, reasonably close to the anticipated value of 0.90 l/min (Åstrand, 1960). The mean $\dot{V}_{O_2}$ was 2.6 $\pm$ .31 l/min (range 1.53 - 3.20 l/min, n=8) and the mean blood lactate was 8.8 $\pm$ 2.1 mmol/l (range 3.9 - 15.2 mmol/l, n=7). See Table 22.

Experiment II

The mean % HRR values obtained by the non-traumatic amputees were 22.5% during occupational therapy (range 13% - 31% HRR, n=6 activities) and 23.5% during physical therapy (range 16% - 31% HRR, n=2 activities). The % HRR obtained by these subjects during wheelchair propulsion of 28% (n=2 subjects) was also recorded. The % HRR during physical therapy and other significant activities was pertinent to Experiment III and was recorded for the non-traumatic amputee group only. Table 23 lists the recorded HR and calculated % HRR for the non-traumatic amputee subjects. A wide variation in % HRR was observed for each activity, even though the age and disability of these subjects was similar. For example, the ranges of values recorded for lathe work, sawing, and walking class were 0% - 43% HRR, 9% - 50% HRR and 13% - 52% HRR respectively.

The traumatic amputees obtained a mean % HRR value of 55% (range 32% - 80% HRR) for occupational therapy activities. The % HRR values for the non-traumatic amputees and traumatic amputees performing the same activities were determined during pulley work, sanding, sawing and walking. These values, 25% HRR and 54% HRR, respectively provide further evidence that the younger amputee subjects without cardiovascular disease obtained a higher mean % HRR than did the non-traumatic amputees ($p > .05$). See Table 27. The variation between traumatic amputee subjects performing the same activity could not be determined as the number of subjects in this group was small.

The mean % HRR value obtained by the hemiplegic subjects during occupational therapy activities was 27% (range 9% - 49% HRR). The wide range in % HRR between subjects for a given activity was again remarkably. Hemiplegic subjects obtained a range of 2% HRR to 66% HRR during light upper limb activity performed in a sitting position, 10% HRR to 68% HRR during cycling of the electronic 'Oliver' bicycle, and 10% HRR to 62% HRR (excluding subjects Ken and Ros who were on propranolol) during walking. Two subjects, Lup and Ros, had very slow heart rates and were unable to obtain HR values greater than 58 beats/min for any activity. The failure of HR to increase in subject Ros was likely due to the propranolol, 20 mg.

The mean % HRR values obtained by the subjects with back problems was 55% (range 44% - 68% HRR). The intensity of work for the back patients and the traumatic amputees, during occupational therapy activities, appear to be comparable. However, these values were determined from activity samples which were not exactly similar.

Experiment III

Five control subjects and six experimental subjects participated in the experiment for 5 ± 1.5 weeks and 5.2 ± 1.3 weeks respectively. Two subjects were excluded from each group during the course of the experiment as noted in Table 28. The time each subject participated in the experiment

Table 19

Experiment I - The test protocol and exercise response - non-traumatic amputee subjects

Sub-ject	Method of Testing	Initial Workload kpm/min	Increments kpm/min	Maximum Workload kpm/min	Duration of Work min	Pre-Ex HR	Voluntary HR Max beats/min	H.R.R.	% Age Predicted HR Maximum	Pre-Ex BP mmHg	BP at Max mmHg	$\dot{V}_{O_2}$ at 200 kpm	$\dot{V}_{O_2}$ at 300 kpm	Max $\dot{V}_{O_2}$	Blood Lactate mmol/l	RQ
Ass	arm crank 2 handles sitting	100	100	300	8	79	120	41	75	130/80	176/96	.684	-	.958	-	
Chom	arm crank 2 handles sitting	100	100	200	5.5	83	123	40	81	110/68	130/74	-	-	.640	-	
Chor	arm crank 2 handles sitting	200	100	350	8	82	132	50	84	144/80	210/85	.764		1.113	10.7	
De R	arm crank 2 handles sitting	100	100	300	10	64	144	80	91	130/82	174/72	.859		1.134	-	
Dyc	arm crank 2 handles sitting	100	100	400	10	100	163	63	98	164/78	200/90	.837		1.172	16.0	1.1370
Ewa	arm crank 2 handles sitting	100	100	400	10.5	91	153	62	96	130/90	165/85	.726		.939	12.3	
Hen	arm crank 2 handles sitting	100	100	300	9	63	132	69	89	110/76	150/100	.790		.973	-	1.1003
Jac	arm crank 2 handles sitting	200	200	600	9	49	114	65	74	140/80	150/80	.751	1.055	1.932	11.4	.9984
Koz	arm crank 2 handles sitting	100	100	300	8.5	111	154	43	93	130/78	150/86	.831		.923	-	-

Table 19 (cont'd)

Experiment I - The test protocol and exercise response - non-traumatic amputee subjects

Subject	Method of Testing	Initial Workload kpm/min	Increments kpm/min	Maximum Workload kpm/min	Duration of Work min	Pre-Ex HR	Voluntary HR Max beats/min	H.R.R.	% Age Predicted HR Maximum	Pre-Ex BP mmHg	BP at Max mmHg	$\dot{V}_{O_2}$ at 200 kpm	$\dot{V}_{O_2}$ at 300 kpm	Max $\dot{V}_{O_2}$	Blood Lactate mmol/l	RQ
McC	arm crank 2 handles sitting	100	200 then 100	400	9	82	159	79	96	120/76	180/110	.861 extra-polated	1.054	1.265	8.5	
McL	arm crank 2 handles sitting	100	100	200	6	83	not useful		-	110/70	160/70	.896		.896	5.2	-
Mel	arm crank 2 handles sitting	100	100	300	9	87	120	33	76	140/68	190/80	.822		1.187	6.0	-
Ral	arm crank 2 handles sitting	100	100	250	9	85	153	68	96	150/88	190/90	.871	-	.971	13.1	
Rob	arm crank 2 handles sitting	100	100	400	11	77	129	52	84	124/72	160/85	-	-	-	12.1	-
San	arm crank 2 handles sitting	200	100	350	9	98	144	46	88	126/70	160/74	.758	-	1.047	7.7	
Sei	arm crank 2 handles sitting	100	100	300	9	83	157	74	101	140/72	142/94	.811		1.235	11.9	-
Str	arm crank single crank sitting	100	-	100	2	86	106	20	75	120/54	130/60	-	-	-	-	
Totals n=17 unless otherwise stated				320.6 ±80.9	8.4 ±1.5	82.5 ±10.2	137.6 ±16.7	55.3 ±15.6	87	130/75	166/84	.804 ±.054 n=14	1.054 ±.0 n=2	1.092 ±.199 n=15	10.4 ±2.8 n=14	

Table 20

Experiment I - The test protocol and exercise response - traumatic amputee subjects

Subject	Method of Testing	Initial Workload kpm/min	Increments kpm/min	Maximum Workload kpm/min	Duration of Work min	Pre-Ex HR	Voluntary HR Max beats/min	H.R.R.	% Age Predicted HR Maximum	Pre-Ex BP mmHg	BP at Max mmHg	$\dot{V}_{O_2}$ at 200 kpm	$\dot{V}_{O_2}$ at 300 kpm 1/min	Max $\dot{V}_{O_2}$	Blood Lactate mmol/1	RQ
Der	arm crank single crank sitting	300	200	700	9	83	192	109	96	106/62	140/58	-	.889	2.158	15.2	.9874
Duc	arm crank 2 handles sitting	100	100	300	9	100	155	55	81	110/74	120/80	.832		1.148	7.8	
Eag	arm crank 2 handles sitting	300	300 then 100	700	7	87	181	94	96	120/76	130/76	-	1.055	1.934	16.4	
Ken	arm crank 2 handles sitting	200	200	600	8.5	45	129	84	70	114/76	160/62	.762	-	2.294	10.9	
Rof	arm crank 2 handles sitting	200	100	400	8.5	82	165	83	83	100/64	130/50	.844	1.199	1.421	9.7	.8941
Totals n=5 unless otherwise stated				540 ±190	8.4 ±.7	79.4 ±17.2	164.4 ±22.4	85 ±16.5	85	110/70	136/65	.813 ±.204 n=3	1.048 ±.159 n=3	1.791 ±.506	12 ±3.8	

Table 21

Experiment I - The test protocol and exercise response - hemiplegic subjects

Subject	Method of Testing	Initial Workload kpm/min	Increments kpm/min	Maximum Workload kpm/min	Duration of Work min	Pre-Ex HR	Voluntary HR Max beats/min	H.R.R.	% Age Predicted HR Maximum	Pre-Ex BP mmHg	BP at Max mmHg	$\dot{V}_{O_2}$ at 200 kpm	$\dot{V}_{O_2}$ at 300 kpm l/min	Max $\dot{V}_{O_2}$	Blood Lactate mmol/l	RQ
Ash	bicycle ergometer	100	100	400	12	49	100	51	64	128/90	220/88	.853	1.199	1.152	4.4 aff. arm 3.1 unaf. arm	-
Ham	bicycle ergometer	100	100	500	15	95	148	53	86	140/90	164/100	.679	1.019	1.562	3.7 aff. arm	-
Hoj	bicycle ergometer	100	200	500	9	83	121	38	81	110/70	120/70	-	nasal catheter		5.1 aff. arm	
Hol	bicycle ergometer	50	50	100	6	84	129	45	72	110/60	125/70	-	-	1.220	2.5 aff. arm	.9908
Mal	bicycle ergometer	50	100	450	15	62	157	95	93	120/78	150/90	.872 extra-polated	1.086	1.424	4.2 aff. arm	1.0023
Mar	bicycle ergometer	100	100	300	9	77	129	52	84	110/56	192/80	.782	-	.989	3.5 aff. arm 4.3 unaf. arm	-
Sha	bicycle ergometer	50	-	50	2	73	122	49	80	142/90	160/90	-		.873	1.3	-
Slo	bicycke ergometer	50	25	75	6	68	109	41	64	120/80	120/90	-		1.068	2.2 aff. arm	1.0013
Ste	bicycle ergometer	50	-	50	3	91	115	24	62	130/60	170/80	-		.625	-	-
Totals n=9 unless otherwise stated				269.4 ±200.7	8.5 ±4.3	75.7 ±12.8	125.5 ±15.2	49.7 ±13.0	76	123/75	158/84	.796 ±.088 n=4	1.101 ±.074 n=3	1.114 ±.228 n=8	3.4 aff. arm ± 1.1 n=8	

Table 22

Experiment I - The test protocol and exercise response - subjects with back problems

Subject	Method of Testing	Initial Workload kpm/min	Increments kpm/min	Maximum Workload kpm/min	Duration of Work min	Pre-Ex H.R.	Voluntary H.R. Max. beats/min	H.R.R.	% Age-Predicted H.R. Maximum	Pre-Ex B.P. mmHg	B.P. at Maximum mmHg	$\dot{V}_{O_2}$ at 300 kpm l/min	Max. $\dot{V}_{O_2}$ l/min	Blood Lactate mmol/l
Dre	arm ergometer standing	300	200	900	11.5	82	159	77	86	130/90	160/80	1.280	2.697	15.2
Fri	bicycle ergometer	300	200	700	12	65	144	79	86	130/80	160/80	.853	1.795	3.9
Har	bicycle ergometer	300	200	1300	16.5	70	183	113	95	106/64	150/70	.854	2.990	9.2
Hil	bicycle ergometer	300	300	1200	11.5	77	170	93	91	120/84	180/70	.961	2.968	11.1
Lis	bicycle ergometer	300	200	700	6.5	83	181	98	92	108/68	130/80	-	-	
Lov	bicycle ergometer	300	200	1100	15	76	175	99	94	110/70	160/80	.961	2.888	8.6
Rou	bicycle ergometer	300	200	1100	15.5	82	166	84	88	100/60	160/80	-	-	6.8
Ven	bicycle ergometer	300	200	1100	13	83	183	100	92	124/82	160/90	.997	2.773	-
Wac	bicycle ergometer	300	200	1100	15	91	181	90	94	110/70	185/70	1.097	3.200	-
Wil	bicycle ergometer	100	150	700	15	61	147	86	98	130/70	220/70	(.849 at 250)	1.528	7.0
Totals n=10 unless otherwise stated				990 ± 213.3	13.2 ± 2.5	77 ± 8.0	168.9 ± 11.9	91.9 ± 9.7	92	117/74	166/77	1.000 ±.125 n=7	2.605 ±.308 n=8	8.8 ± 2.1 n=7

Table 23

Experiment II - The heart rate and percent of heart rate reserve for occupational therapy, physical therapy and other activities - non-traumatic amputee subjects

Subject	Pre-Ex HR	HRR	Occupational Therapy Activities: Lathe Work	Planing	Pulleys	Sanding	Sawing	Standing Light Work	Physical Therapy Activities: Exercise Class	Walking Class	Other: Wheelchair Propulsion
Ass	79	41			92 32%	81 5%	86 17%		74 0%		
Chom	83	40			93 25%			91 20%	92 22%	103 50%	
Chor	82	50		100 36%	100 36%		96 28%		94 24%	101 38%	110 56%
Der	64	80	77 16%			77 16%			65 1%		
Dyc	94*	69	103 13%		106 17%			106 17%	114 29%	130 52%	
Ewa	91	62		115 39%	110 31%		122 50%		104 21%	114 37%	
Hen	63	69			72 13%	72 13%			68 7%	90 39%	
Jac	49	65	77 43%			58 14%		66 26%		58 14%	
Koz	92*	62							95 5%	109 27%	
McC	82	79		101 24%	94 15%	101 24%	115 42%		106 30%	92 13%	
Mel	87	33		92 15%	89 6%	86 0%	90 9%			92 15%	78 0%
Ral	85	85	110 29%					109 28%	98 15%		
Rob	77	52	77 0%					78 2%			
San	80*	64		94 22%	114 53%	94 22%	104 39%		93 20%	94 22%	
Mean	79	61	20% n=5	27% n=5	25% n=9	13% n=7	31% n=6	19% n=5	16% n=11	31% n=10	28% n=2

* The pre-exercise HR was unusually high, possibly due to greater pre-test apprehension. An average of three mornning HR values was determined and used to calculate HRR and % HRR.

Table 24

Experiment II - The heart rate and percent of heart rate reserve for occupational therapy activities - traumatic amputee subjects

Subject	Pre-Ex HR	HRR	Occupational Therapy Activities							
			Climbing Ladder	Hammering	Pulleys	Sanding	Sawing	Shovelling Gravel	Transfer Practice	Walking with Crutches
Der	83	109	164 74%		154 65%		179 88%	170 80%		97 13%
Duc	71*	84				113 50%			102 37%	117 55%
Eag	87	94		117 32%			130 46%			
Rof	82	83								105 28%
Mean	81	92	74% n=1	32% n=1	65% n=1	50% n=1	67% n=2	80% n=1	37% n=1	32% n=3

* The morning HR was used to calculate HRR and % HRR for subject Duc.

Table 25

Experiment II - The heart rate and percent of heart rate reserve for occupational therapy activities - hemiplegic subjects

Subject	Pre-Ex HR	HRR	Lathe Work	Light Upper Limb Activity-Sitting	Light Upper Limb Activity-Standing	Oliver Bicycle	Pipe Assembly	Pulleys	Sanding	Transfer Practice	Walking	Wheelchair Propulsion
Ash	49	51										
Fen	76	50			80 8%				87 22%	80 8%		
Ham	95	53			112 32%	107 23%	112 32%	100 9%			104 17%	
Han	76	50			104 56%					103 54%		92 32%
Hoj	83	38	89 16%		94 29%	87 10%						
Hol	84	45			125 91%	98 31%					101 38%	
Ken	76	50		77 2%		81 10%					81 10%	
Kow	76	50		103 54%		98 44%					104 56%	
Lup	76	50								>58 0%		>58 0%
Mal	62	95		94 34%	83 22%	75 14%				84 23%		96 36%
Mar	77	52		78 2%		85 15%				78 2%		
Ros	76	50		58 0%						>58 0%	>58 0%	
Slo	68	41	96 68%			93 61%					93 61%	
Ste	91	24	94 12%	90 0%						94 12%		88 0%
Szc	76	50		93 34%						104 56%		
Wen	76	50		109 66%		96 40%					107 62%	
Wur	76	50		94 36%	107 62%	110 68%					106 60%	93 34%
Mean	76	50	11% n=3	28% n=8	43% n=7	34% n=9	32% n=1	9% n=1	22% n=1	22 % n=7	49 % n=6	20% n=5

Mean values do not include subjects Ken or Ros as these subjects were on the beta-blocker propranolol

Table 26

Experiment II - The heart rate and percent of heart rate reserve for occupational therapy activities - subjects with back problems

Subject	Pre-Ex HR	HRR	Building Brick Wall	Lathe Work	Oliver Bicycle	Planing	Pipe Assembly	Pulleys	Sanding	Stairs and Ramp
Dre	82	77					120 49%	114 42%	120 49%	
Fri	65	79		136 90%	130 82%					147 104%
Har	70	113				166 85%				
Hil	77	93	125 52%					122 48%		103 28%
Lis	83	98			127 45%			144 62%		134 52%
Lov	76	99	127 52%	132 57%	142 67%					
Rou	82	84	147 77%		147 77%			136 64%		
Ven	83	100		92 9%		125 42%			121 38%	
Wah	91	90				139 53%	126 39%		121 33%	
Mean	79	92	60% n=3	52% n=3	68% n=4	60% n=3	44% n=2	54% n=4	40% n=3	61% n=3

Table 27

Experiment II - Comparison of the percent of heart rate reserve during occupational therapy activities - all experimental groups

Activity	Non-traumatic amputees	Hemiplegics	Traumatic Amputees	Subjects with back problems
Lathe work	n=5 20 %	n=3 32%	-	n=3 52%
Oliver bicycle	-	n=9 34%	-	n=4 68%
Planing	n=5 27%		-	n=3 60%
Pulleys	n=9 25%	n=1 9%	n=1 65%	n=4 54%
Pipe assembly	-	n=1 32%	-	n=2 44%
Sanding	n=7 13%	n=1 22%	n=1 50%	n=3 40%
Sawing	n=6 31%		n=2 67%	
Walking	n=10 31%	n=6 49%	n=3 32%	
Wheelchair propulsion	-	n=5 20%	-	-
	24% n=6 activities	28% n=7 activities	54%. n=4 activities	53% n=6 activities

and the reasons for termination of subjects who were included in the data analysis have also been recorded in Table 28.

Inter-group Differences

The mean and standard deviation for each of the measured values was calculated at pre-test and post-test. An analysis of variance was made by the Box-Anderson test. The T test for unequal variance was done for HR at 300 kpm/min for HR max, five minute recovery HR and for $\dot{V}_{O_2}$ at 200 kpm as indicated by the chi square values. The T test for equal variance was done matching the control and experimental group values at pre-test, and the control and experimental group values at post-test. No significant difference was found between the control and experimental groups at the pre-test or post-test for values with equal or unequal variance. Refer to Tables 29 and 30.

Intra-group Differences

The mean difference between the pre-test and post-test for each measured value was calculated for both the control and experimental groups. Significance ($p < .05$) was determined by the paired T test. The decrease in HR at 300 kpm from 136.2 $\pm$ 21.8 beats/min at pre-test to 127.2 $\pm$ 19.1 beats/min at post-test was significant for the control group (see Table 31).

The increase in maximum workload from 320.5 $\pm$ 52.4 kpm/min at pre-test to 375 $\pm$ 61.2 kpm/min at post-test and the decreases in HR at 200 kpm and 300 kpm of -9 beats/min and -16.8 beats/min respectively were significant for the experimental group. A significant decrease in the pre-exercise systolic blood pressure of -11.7 mmHg was also observed for the experimental group. The observed and calculated values are presented in Table 32.

The pattern of change from pre-test to post-test opposite to conditioning was observed for subject McC (see Table 33). This subject was excluded from the experimental group because of frequent illness and inability to tolerate activity at the end of the day. Profuse sweating accompanied light activity such as varnishing small wooden objects.

The Electrocardiographic Findings

Four of eight non-traumatic amputee subjects with P.V.D. had an abnormal resting ECG (right bundle branch block [RBBB], old infarct, quadrigeminy and left axis deviation, and ST segment depression $\geq$ 2mm). Two of six non-traumatic amputees with diabetes had an abnormal resting ECG (RBBB and atrial fibrillation). A first degree atrioventricular block (A-V block 1^{o}) was observed for subject Chom, who had both P.V.D. and diabetes.

Two non-traumatic amputees with P.V.D. who had a normal resting ECG had frequent multiform premature ventricular contractions (PVCs) and/or a horizontal or downsloping ST segment depression of at least 2 mm. Subject Hen, whose resting ECG showed an old infarct, also had an ST segment depression during exercise.

In total, a horizontal or downsloping ST segment depression of at least 2 mm was observed for 4 of 17 non-traumatic amputees at rest or during exercise.

Various additonal rhythm disturbances were noted for the above non-traumatic amputee subjects during Holter monitoring. A diabetic subject, De R, experienced a run of atrial tachycardia during monitoring. No other subjects with normal resting and exercise ECGs experienced major rhythm disturbances during monitoring. Table 34 presents the ECG findings for the non-traumatic amputees at rest, during the exercise test, during recovery from the exercise test and when Holter monitoring.

Non-specific T wave changes were observed for two of nine hemiplegic subjects, and in one case, was associated with a left axis deviation. Left ventricular hypertrophy was observed for subject Ste who had recovered from endocarditis and replacement of the aortic and mitral valves. During exercise, an ST segment depression was noted for two additonal subjects, and frequent multiform PVCs were noted for another subject. Major arrhythmias (frequent multiform PVCs and run of ventricular tachycardia) were noted for two of the above subjects and for three of nine hemiplegic subjects who were investigated by Holter recordings only. Two of these latter subjects experienced a second degree A-V block, and the third had a retrograde P wave and multiform PVCs (approximately 26 per hour). See Tables 35 and 36.

Normal resting ECGs were found for all the subjects with back problems. During exercise, an ST segment depression of at least 2 mm was observed for 3 of the 10 subjects. No major arrhythmias were noted during Holter monitoring. See Table 37.

No abnormal ECG findings were observed for the traumatic amputee subjects, and they have been omitted from the Tables.

Summaries of the ECG findings at rest, during exercise and recovery, and during Holter monitoring have been presented in Tables 38 to 40 respectively.

The abbreviations and unfamiliar terms used in Tables 34 to 40 have been defined in the GLOSSARY OF TERMS AND ABBREVIATIONS.

Table 28

The time in the program and reason for termination or exclusion for subjects included and subjects excluded from Experiment III

Control Subjects	Time in Program (nearest week)	Reason for termination or exclusion
subjects included		
Dyc	6 weeks	
Hen	6 weeks	
Koz	4 weeks	terminated to control for Ral
Mel	3 weeks	terminated to control for Ass
Rob	6 weeks	
subjects excluded		
Jac	2 weeks	previous amputation. Subject was hospitalized briefly for ulcer on stump.
Str	1 day	subject elderly (78 year) and withdrew
Experimental Subjects		
subjects included		
Ass	3 weeks	discharged to the General Centre for cataract removal
Chor	6 weeks	
De R	6 weeks	
Ewa	6 weeks	
Ral	4 weeks	poor stump healing. Subject discharged himself without prosthetic fitting.
San	6 weeks	
subjects excluded		
Chom	1 week	deceased.
McC	6 weeks	Frequent absence. Tolerated light activity only due to possible congestive heart failure.

Table 29

Experiment III - Comparison of the control and experimental groups at pre-test

Pre-test	Maximum workload kpm/min	Duration of work min	Pre-ex HR	HR at 100 kpm	HR at 200 kpm beat/min	HR at 300 kpm	Voluntary HR max	HR 5 min recovery	$\dot{V}_{O_2}$ at 100 kpm l/min	$\dot{V}_{O_2}$ at 200 kpm l/min	$\dot{V}_{O_2}$ at 300 kpm l/min	$\dot{V}_{O_2}$ max l/min	Pre-ex BP mmHg	Maximum BP mmHg	Blood lactate mmol/l
Control mean n=5	340 ± 54.8	9.5 ±1.0	87.6 ±18.8	102.2 ± 18.2	114.6 ± 17.0	136.2 ± 21.8	139.6 ± 18.1	98.5 ±18.4	.584 ±.082 n=3	.822 ±.162 n=3	-	1.064 ± .154 n=4	134.8 ± 19.6 n=5	175 ± 23.8 n=4	11.4 ± 5.0 n=3
Experimental mean n=6	320.5 ± 52.4	9.1 ±1.0	83.1 ±11.6	101.5 ± 15.1 n=4	113.3 ± 11.6	135.8 ± 10.1 n=5	141 ± 12.9	98 ±11.6	.649 ±.117 n=4	.794 ±.104	-	1.027 ± .085	135 ± 9.6	178.3 ± 19.2	10.9 ± 2.4 n=4
T test for equal variance	.214 NS	.463 NS	.231 NS	.743 NS	.021 NS	-	-	-	.661 NS	-	-	.289 NS	.000 NS	.060 NS	.022 NS
T test for unequal variance						.037 NS	.145 NS	.084 NS		.316 NS					

NS = not significant

Table 30

Experiment III - Comparison of the control and experimental groups at post-test

Post-test	Maximum workload kpm/min	Duration of work min	Pre-ex HR	HR at 100 kpm	HR at 200 kpm beat/min	HR at 300 kpm	Voluntary HR max	HR 5 min recovery	$\dot{V}_{O_2}$ at 100 kpm l/min	$\dot{V}_{O_2}$ at 200 kpm l/min	$\dot{V}_{O_2}$ at 300 kpm l/min	$\dot{V}_{O_2}$ max l/min	Pre-ex BP mmHg	Maximum BP mmHg	Blood lactate mmol/l
Control mean n=5	360 ± 54.7	9.9 ±1.5	77.8 ±12.4	92.4 ±11.7	104.6 ± 15.2	127.2 ± 19.1	133.4 ± 13.3	89.2 ±11.6	.533 ±.131	.730 ±.109	-	1.052 ± .215	126.8 ± 8.4	169 ± 30.2	10.7 ± 1.3 n=3
Experimental mean n=6	375 ± 61.2	10.8 ± 1.8	82.3 ±10.6	93 ±18.8	104.3 ± 15.7	122.3 ± 13.8	138.3 ± 17.3	94.2 ±12.1	.564 ±.060 n=4	.774 ±.063	.936 ±.051 n=5	1.115 ± .208	123.3 ± 12.1	173.8 ± 17.4	9.0 ±1.8 n=4
T test for equal variance	.180 NS	.655 NS	.429 NS	.003 NS	.001 NS	-	-	-	.187 NS	(.681 NS)	-	.243 NS	.290 NS	.077 NS	-
T test for unequal variance						.479 NS	.531 NS	.698 NS		.161 NS					

NS = not significant

Table 31

<u>Experiment III - The exercise response of control subjects</u>

Pre-test

Subject	Maximum workload kpm/min	Duration of work min	Pre-ex HR	HR at 100 kpm	HR at 200 kpm beat/min	HR at 300 kpm	Voluntary HR max	HR 5 min recovery	$\dot{V}_{O_2}$ at 100 kpm 1/min	$\dot{V}_{O_2}$ at 200 kpm 1/min	$\dot{V}_{O_2}$ at 300 kpm 1/min	$\dot{V}_{O_2}$ max 1/min	Pre-ex BP mmHg	Maximum BP mmHg	Blood lactate mmol/1
Dyc	400	10	100	118	126	163	163	123	-	.837	-	1.172	164	200	16
Hen	300	9	63	92	105	132	132	77	.660	.800	-	.973	110	150	-
Koz	300	8.5	111	123	139	154	154	112	.591	.831	-	.923	130	-	-
Mel	300	9	87	96	101	120	120	92	.502	.822	-	1.187	140	190	6
Rob	400	11	77	82	102	112	129	90	-	-	-	-	130	160	12.1
Totals Test 1 n=5	340 ± 54.8	9.5 ±1.0	87.6 ±18.8	102.2 ± 18.2	114.6 ± 17.0	136.2 ± 21.8	139.6 ± 18.1	98.8 ±18.4	.584 ±.792 n=3	.822 ±.162 n=3		1.064 ± .154 n=4	134.8 ± 19.6 n=5	175 ± 23.8 n=4	11.4 ± 5.0 n=3
Dyc	300	8	80	100	121	150	150	93	.631	.842	-	1.087	130	155	11.3
Hen	300	9	59	83	94	119	119	72	.317	.581	-	.748	120	140	9.2
Koz	400	10.5	89	104	117	142	144	100	.501	.706	-	.981	120	170	-
Mel	400	10	87	98	106	123	123	98	.630	.833	-	1.104	140	220	-
Rob	400	12	75	77	85	102	131	83	.584	.687	.996	1.340	124	164	11.5
Totals Test 2 n=5	360 ± 54.7	9.9 ±1.5	77.8 ±12.4	92.4 ±11.7	104.6 ± 15.2	127.2 ± 19.1	133.4 ± 13.3	89.2 ±11.6	.533 ±.131	.730 ±.109		1.052 ± .215	126.8 ± 8.4	169.8 ± 30.2	10.7 ± 1.3 n=3
Mean difference	20	.4	-9.8	-9.8	-10.0	-9.0	-6.2	-9.6	-.051 n=3	-.082		-.012 n=4	-8.0	-5.2	-0.7
Paired T	.535	.590	- 2.107	- 2.470	- 2.122	-2.951	- 1.724	- 1.631	-.747	-1.480		-1.450	-1.093	- .336	-
Significance	NS	NS	NS	NS	NS	p < .05	NS	NS	NS	NS		NS	NS	NS	-
% of pre-test value	5.8	4.2	11.2	9.6	8.7	6.6	4.4	9.7	8.7	10.0		0.0	5.9	3.0	6.1

Table 32

Experiment III - The exercise response of experimental subjects

Pre-test

Subject	Maximum Workload kpm/min	Duration of work min	Pre-ex HR	HR at 100 kpm	HR at 200 kpm beat/min	HR at 300 kpm	Voluntary HR max	HR 5 min recovery	$\dot{V}_{O_2}$ at 100 kpm l/min	$\dot{V}_{O_2}$ at 200 kpm l/min	$\dot{V}_{O_2}$ at 300 kpm l/min	$\dot{V}_{O_2}$ max l/min	Pre-ex BP mmHg	Maximum BP mmHg	Blood lactate mmol/l
Ass	300	8	79	92	104	120	120	87	.616	.684	-	.958	130	176	-
Chor	350	8	82	-	104	132	132	93	-	.764	-	1.113	144	210	10.7
De R	300	10	64	90	104	144	144	84	.653	.859	-	1.134	130	174	-
Ewa	400	10.5	91	101	115	139	153	105	.522	.726	-	.939	130	160	12.3
Ral	250	9	85	123	132	-	153	107	.804	.971	-	.971	150	190	13.1
San	350	9	98	-	121	144	144	112	-	.758	-	1.047	126	160	7.7
Totals Test 1 n=6	320.5 ± 52.4	9.1 ±1.0	83.1 ±11.6	101.5 ± 15.1 n=4	113.3 ± 11.6	135.8 ± 10.1 n=5	141 ± 12.9	98 ±11.6	.649 ±.117 n=4	.794 ±.104		1.027 ± .085	135 ± 9.6	178.3 ± 19.2	10.9 ± 2.4 n=4
Ass	300	8	84	92	102	107	107	83	.474	.712	-	.813	120	170	7.7
Chor	450	12	82	-	96	104	130	85	-	.827	1.011	1.379	140	198	7.8
De R	400	13	62	67	80	127	150	83	.587	.747	1.013	1.299	130	180	-
Ewa	400	11.5	92	103	112	127	151	98	.568	.705	.910	1.023	110	160	-
Ral	300	11	85	110	126	139	142	109	.627	.871	.975	1.010	130	185	11.4
San	400	9	89	-	110	130	150	107	-	.780	.897	1.166	110	150	9.3
Totals Test 2 n=6	375 ± 61.2	10.8 ± 1.8	82.3 ±10.6	93 ±18.8 n=4	104.3 ± 15.7	122.3 ± 13.8	138.3 ± 17.3	94.2 ±12.1	.564 ±.060 n=4	.774 ±.063	.936 ±.051 n=5	1.115 ± .208	123.3 ± 12.1	173.8 ± 17.4	9.0 +1.8 n=4
Mean difference	50	1.7	-.8	-8.5	-9	-16.8	-2.7	-3.8	-.085	-.020		.088	-11.7	-4.5	-1.9 n=3
Paired T	2.739	2.500	-.442	-1.449	-2.739	-5.749	-.807	-2.495	-1.717	-.682		1.562	-3.390	-1.664	- .743
Significance	$p < .05$	NS	NS	NS	$p < .05$	$p < .05$	NS	NS	NS	NS		NS	$p < .05$	NS	NS
% of pre-test value	15.6	18.7	1.0	8.4	7.9	12.3	1.9	3.9	8.0	2.6		7.9	9.5	2.6	5.7

Table 33

Experiment III - The exercise response at pre-test and post-test - subject McC

	Pre-test	Post-test	Difference
Maximum workload (kpm/min)	400	400	0
Duration of work (minutes)	9	8	-1
Pre-ex. H.R. (beats/min)	82	92	10
H.R. at 100 (beats/min)	97	98	1
H.R. at 200 (beats/min)	-	-	-
H.R. at 300 (beats/min)	127	143	16
H.R. at 400 (beats/min)	159	159	0
Voluntary H.R. max. (beats/min)	159	159	0
H.R. 5 min. recovery (beats/min)	98	109	11
$\dot{V}_{O_2}$ at 100 kpm (1/min)	.668	.675	-.007
$\dot{V}_{O_2}$ at 200 kpm (1/min)	-	-	-
$\dot{V}_{O_2}$ at 300 kpm (1/min)	1.054	1.096	.042
$\dot{V}_{O_2}$ at 400 kpm (1/min)	1.265	1.280	.015
$\dot{V}_{O_2}$ max. (1/min)	1.265	1.280	.015
Pre-ex systolic B.P. (mmHg)	120	124	4
Maximum systolic B.P. (mmHg)	180	180	0
Blood lactate (mmol/1)	8.5	8.2	-.3

Table 34

The electrocardiographic findings - non-traumatic amputee subjects

Subject	Disturbances of Rhythm				ST Segment Depression $\geq$ 2 mm			QRS Changes	T Wave Changes
	Rest	Exercise	Recovery	Holter Recording	Rest	Exercise	Recovery	Rest	Rest
Ass	PVC			APCs rare PVCs multiform rare					
Chom	A-V Block 1^{o} PVC	A-V Block 1^{o} PVCs Multiform rare	A-V Block	A-V Block 1^{o} PVC multiform rare Couplets				Old anterior infarct	
Chor									
De R				APCs rare PVCs uniform rare Run of Atrial Tachycardia					
Dyc									Tall T wave(12 mm)
Ewa				PVCs multiform rare					
Hen			Bigeminy	APCs rare PVCs uniform rare Run of Atrial Tachycardia		-2.5 at 300 kpm	-1.5	Old anterior septal infarct	U wave Non-specific T wave changes
Jac	Sinus Bradycardia	PVC uniform rare	PVC uniform rare	APCs rare PVC uniform 1-2 hr.					
Koz	RBBB	RBBB	RBBB	RBBB PVCs uniform 1-2 hr.				Left axis deviation	Secondary T wave changes

Table 34(cont'd)

The electrocardiographic findings - non-traumatic amputee subjects

Subject	Disturbances of Rhythm				ST Segment Depression $\geq$ 2 mm			QRS Changes	T Wave Changes
	Rest	Exercise	Recovery	Holter Recording	Rest	Exercise	Recovery	Rest	Rest
McC		PVCs multi-form Couplets	PVCs multi-form	PVCs multiform frequent Couplets Run of Atrial Tachycardia		-2.8 at 400 kpm	-1.0		
McL		Atrial fibrillation Hemiblock Couplets							
Mel	RBBB	RBBB	RBBB	RBBB					
Ral		PVC uniform every 6th beat PVC multiform rare		PVC multiform rare Trigeminy episode		-2.7 at 300 kpm	-2.7		
Rob	Quadrige-miny(test 2) PVCs uniform rare	PVCs uniform ↓ as workload ↑	Reverted to quadrigeminy at at 5R	Episode of quadrigeminy				Lt. axis deviation	U wave
San									
Sei		PVC uniform rare							
Str	Sinus Arrythmia				-2.0				Non-specific T wave changes

Table 35

The electrocardiographic findings - hemiplegic subjects

Subject	Disturbances of Rhythm				ST Segment Depression $\geq$ 2 mm			QRS Changes	T Wave Changes
	Rest	Exercise	Recovery	Holter Recording	Rest	Exercise	Recovery	Rest	Rest
Ash	Sinus Bradycardia							Left axis deviation	U wave Non-specific T wave changes
Ham	PVC	PVC multiform		PVC multiform > 90/hr. bigeminy & trigeminy run of ventricular tachycardia					
Hoj				PVCs uniform rare					
Hol				PVCs uniform 6-8/hr.					
Mal			PVC uniform rare			-3.4 at 700 kpm	-1.9		
Mar	PVC uniform rare	PVC uniform frequent Trigeminy	PVC uniform frequent Triplet (1) Bigeminy Quadrigeminy			-4.6 at 300 kpm	-1.8		
Sha				PVCs uniform rare Run of Atrial Tachycardia		-1.4 at 50 kpm	-1.4		Non-specific T wave changes
Slo									
Ste								Left ventricular hypertrophy	

Table 36

The electrocardiographic findings - subjects investigated by 'Holter' recording only

Subject	Disturbances of Rhythm	ST Segment Change $\geq$ 2 mm	QRS Changes	T Wave Changes
Fen	APC rare A-V Block 2nd^{o} PVC multiform frequent with some quadrigeminy Run of atrial fibrillation			U Wave
Han				
Ken	Trigeminy episodes (2)			
Kow	APC rare PVC uniform rare 3/6 hr.	ST segment depression > 2		
Lup	APCs occasional PVCs uniform rare Sinus Bradycardia			
Ros	PVCs multiform 26/hr. Retrograde P Wave Sinus Bradycardia	ST segment depression > 2		
Szc				
Wen				
Wur	PVCs uniform rare A-V Block 2nd^{o}			

Table 37

The electrocardiographic findings - subjects with back problems

Subject	Disturbances of Rhythm				ST Segment Depression $\geq$ 2 mm			QRS Changes	T Wave Changes
	Rest	Exercise	Recovery	Holter Recording	Rest	Exercise	Recovery	at Rest	at Rest
Dre						-2.5 at 700 kpm	-1.6		
Fri	Sinus Arrythmia		PVC uniform rare	PVC uniform rare					
Har			Sinus Brady-cardia at 3R						
Hil				PVCs uniform frequent					
Lis						-2.5 at 500 kpm	-1.9		
Lov									
Rou									
Ven									
Wac									
Wil						-2.7 at 700 kpm	-2.0		

Table 38

Summary of electrocardiographic findings at rest

ECG findings	Back problems n=10		Amputees n=17		Hemiplegics n=9	
sinus bradycardia	1	10%	1	6%	1	11%
sinus arrhythmia	1	10%	1	6%	0	
atrial fibrillation	0		1	6%	0	
PVCs uniform rare	2	20%	3	18%	2	22%
quadrigeminy	0		1	6%	0	
A-V block 1^{o}	0		1	6%	0	
hemiblock	0		1	6%	0	
RBBB	0		2	12%	0	
QRS changes	0		4	24%	2	22%
T wave changes	0		5	29%	2	22%
ST segment depression $\geq$ 2 mm	0		1	6%	0	

Table 39

Summary of electrocardiographic findings during exercise and recovery

ECG findings	Back problems n=10		Amputees n=17		Hemiplegics n=9	
sinus bradycardia - recovery	1	10%	0		0	
atrial premature contractions(APCs)	0		0		0	
atrial tachycardia	0		0		0	
atrial fibrillation	0		1	6%	0	
PVCs uniform rare	1	10%	3	18%	1	11%
PVCs uniform frequent	0		1	6%	1	11%
PVCs multiform rare	0		2	12%	1	11%
PVCs multiform frequent	0		1	6%		
couplets	0		2	12%		
triplet	0		0		1	11%
bigeminy	0		1	6%	1	11%
trigeminy	0		0		1	11%
quadrigeminy	0		1	6%	1	11%
hemiblock	0		1	6%	0	
RBBB	0		2	12%	0	
A-V block 1^{o}	0		1	6%	0	
ST segment depression ≥ 2 mm	3	30%	3	18%	2	11%

Table 40

Summary of electrocardiographic findings during Holter monitoring

	Back problems		Amputees		Hemiplegics	
	n=9		n=14		n=18	
sinus bradycardia	-		-		2	11%
APCs	0		4	29%	3	17%
atrial fibrillation	0		0		1	6%
atrial tachycardia	0		3	21%	1	6%
retrograde P wave	0		0		1	6%
PVCs uniform rare	1	11%	4	29%	6	33%
PVCs uniform frequent	1	11%	0		0	
PVCs multiform rare	0		4	29%	0	
PVCs multiform frequent	0		1	7%	3	17%
couplets	0		2	14%	0	
bigeminy	0		0		1	6%
trigeminy	0		1	7%	2	11%
quadrigeminy	0		1	7%	1	6%
ventricular tachycardia	0		0		1	6%
RBBB	0		2	14%	0	
A-V block 1^{o}	0		1	7%	0	
A-V block 2^{o}	0		0		2	11%

DISCUSSION

Experiment I

The hypothesis that patients with multiple system disease involving the heart or peripheral circulation have a low exercise capacity is supported by the data. Lower fitness was also found for the traumatic amputees and subjects with back problems, although no cardiovascular disease was apparent.

The low exercise capacity of the non-traumatic amputees is apparent, although comparable arm crank studies with healthy, age-matched normals have not been reported. The mean maximum workload of the non-traumatic amputees is lower than or comparable to the initial warm-up workloads used in arm crank studies with young normals. For example, Bar-Or and Zwiren (1975) used initial loads of 450 - 750 kpm/min to test 59 healthy males, mean age 28.2 years who were involved in university physical education programs; Vokac et al. (1975) used initial loads of 300 kpm to test seven healthy males, described as having average fitness, mean age 23.5 years. (A mean maximum workload of 1125 kpm was observed by Vokac et al.).

Our mean maximum workload of 321 kpm/min appears to be slightly higher than that obtained by Kavanagh and Shephard (1973) for similar non-traumatic amputee subjects. These investigators report that peak loads of 420 kpm/min were obtained by only three of 27 subjects. Their mean maximum workload was not documented.

A low exercise capacity has also been found in arm crank studies with older, able-bodied subjects who have cardiovascular disease (Wahren and Bygeman, 1971; Shaw et al, 1974). Wahren and Bygeman's subjects, mean age 52.5 years (n=10) obtained a comparable mean maximum workload of 315 $\pm$ 35 kpm/min at a lower HR, 76% of their age-predicted HR max vs the 87%

figure we observed. The age-predicted HR max for both groups was calculated as 220 - age beats/min (Amsterdam, 1977). The mean $\dot{V}_{O_2}$ max value of 1.07 $\pm$ .08 l/min, observed by Wahren and Bygeman, was reasonably close to our $\dot{V}_{O_2}$ max value of 1.09 $\pm$ .20 l/min.

Shaw et al. (1974) did not record their mean maximum workload for 47 subjects, mean age 57 years. However, the peak workload of 700 kpm/min was higher than observed in our study (600 kpm/min for subject Jac).

The mean maximum workload of 540 $\pm$ 190 kpm/min observed for the traumatic amputees was lower than the mean maximum workloads of 1125 kpm/min and 705 kpm/min obtained by Vokac et al. (1975) and Stenberg et al. (1967) respectively. The latter studies were done with younger normals (23.5 years and 23.5 years vs 27.8 $\pm$ 7.3 years). Our mean HR max value of 164 $\pm$ 22 beats/min was less than that obtained by Vokac et al. of 180 beats/min and by Stenberg et al. of 178 beats/min, and the difference cannot be attributed to age alone. The submaximal $\dot{V}_{O_2}$ values at 300 kpm/min were approximately equal, 1.00 l/min recorded by Vokac et al. and 1.07 l/min recorded by Stenberg et al. (n=9) as compared to 1.05 l/min observed in this study. The $\dot{V}_{O_2}$ max 1.79 $\pm$ .51 l/min obtained by the traumatic amputees, however, was very much lower than the $\dot{V}_{O_2}$ max values of approximately 3.3 l/min observed by Vokac et al. during cranking of a single arm crank with crank axis at shoulder level. Our $\dot{V}_{O_2}$ max was also lower than the $\dot{V}_{O_2}$ value obtained by Stenberg et al. of 2.3 l/min (details of crank not documented). It appears that the inability of the traumatic amputees to obtain higher workloads, higher voluntary HR max values and higher $\dot{V}_{O_2}$ max values, despite a good effort as indicated by blood lactate values 12 $\pm$ 3.8 mmol/l, was due to lower fitness, arm weakness or fatigue.

Our mean maximum workload, mean HR max and mean $\dot{V}_{O_2}$ max values for the hemiplegic subjects (269 kpm/min, 126 beats/min and 1.11 l/min, respectively) were slightly higher than those obtained by Bjuro et al. (1975) of 224 kpm/min, 123 beats/min and 0.75 l/min for nine subjects with hemiplegia. Our post-exercise blood lactate value of 3.4 mmol/l obtained from the paretic arm was also slightly higher than the 2.6 mmol/l value observed by Iseri et al. (1968) after their hemiplegic subjects cycled at 240 kpm/min for 10 minutes.

The low exercise capacity of hemiplegic subjects can be determined in comparison to the data of Erikssen et al. (1980) for healthy subjects of the same age. The mean maximal workload of the hemiplegic subjects was 76% lower than Erikssen's value of 1112 kpm/min. The mean HR max of 126 beats/min for the hemiplegic subjects was 24% lower than Erikssen's value of 165 beats/min.

Our HR max was almost the same as that found by Wahren and Bygeman (1971) of 123 $\pm$ 5 beats/min for 10 able-bodied subjects with coronary artery disease, mean age 52.5 years. Their subjects were limited by age and by cardiovascular disease presenting in the form of angina. Their mean maximum workload of 470 $\pm$ 39 kpm/min was still higher than obtained by our hemiplegic subjects. Although no angina was reported, our subject may have also been limited by age and cardiovascular disease but the primary problem was their neuro-muscular disability. Spasticity and clonus in the paretic legs limited the exercise capacity of three subjects. The poor contribution of the paretic leg to the workload overtly limited a further three subjects. The four subjects who obtained better than 80% of their age-predicted HR max still only tolerated low workloads of 300 to 500 kpm/min.

A more accurate measure of cardiopulmonary reserve may have been possible if we had tested the non-paretic leg with one-legged cycling as suggested by Landin et al. (1977). Similarly, the design of a unilateral arm-leg ergometer may allow for more productive testing. Nevertheless, two-legged cycling would seem to be an appropriate functional assessment prior to rehabilitation, as therapy activities are bilateral by design.

The mechanical efficiency of the hemiplegic subjects was lower than that observed for the subjects with back problems (also tested by cycling) as indicated by the respective submaximal $\dot{V}_{O_2}$ values at 300 kpm/min of 1.10 l/min (n=3) and .95 l/min (n=6 and excludes subject Dre).

The mean $\dot{V}_{O_2}$ max value of 1.114 observed for the hemiplegic subjects was also lower than the value of 1.24 l/min observed by Wahren and Bygeman (1971) at the same approximate HR. Low $\dot{V}_{O_2}$ during exercise of paretic muscle has been noted in the literature (Landin et al., 1975). The exercise capacity of Landin's subjects was limited by the paretic leg and the low $\dot{V}_{O_2}$ reflected the low workloads obtained during one-legged cycling with the paretic leg as compared with the non-paretic leg. Further investigation is indicated with respect to the central and peripheral factors which may limit muscle metabolism in hemiplegic subjects.

The mean maximum workload of 990 $\pm$ 213 kpm/min tolerated by the subjects with back problems (mean age 37.2 $\pm$ 11.8 years) was higher than the non-traumatic amputee, traumatic amputee or hemiplegic subjects. Nevertheless, it was only 32% of the mean maximum workload of 1456 kpm/min obtained by Erikssen et al. (1980) with 40 - 44 year old subjects by cycling. The HR max of 169 beats/min obtained by the subjects with back problems was 92% of their age-predicted HR max. Shephard et al. (1968) obtained 96% of the age-predicted HR max for 40 male subjects, mean age

26 years, who were also exercised by cycling. The $\dot{V}_{O_2}$ max obtained by Shephard's subjects of 3.56 $\pm$ 0.71 l/min (range 2.57 $\pm$ 5.23 l/min) was much higher than our $\dot{V}_{O_2}$ max of 2.60 $\pm$ .31 l/min (range 1.53 - 3.20 l/min, n=8). It is possible that decreased participation in conditioning activities subsequent to the back injury resulted in the lower fitness of our subjects. Alternatively, lower fitness may have predisposed these subjects to back injuries.

Experiment II

The hypothesis that occupational therapy will increase the heart rates of patients with multiple system disease involving the heart or peripheral circulation sufficiently to have a cardiovascular training effect was not supported by the data.

There is general agreement that heart rate should exceed 50% HRR to produce a training effect (Shephard, 1968, 1969; Pollock, 1973). The mean % HRR of 22.5% obtained by non-traumatic amputees for six treatment activities and 27% HRR obtained by hemiplegic subjects for ten treatment activities are considerably lower than the 50% HRR 'threshold' figure. The mean % HRR value obtained by both the traumatic amputees and subjects with back problems for eight treatment activities was 55%. One might speculate that these activities would produce a mild training effect for subjects within these latter groups whose initial fitness was low, given an appropriate duration and frequency of training.

The data gathered in Experiment II supports the argument that occupational therapy activities should be selected and monitored on an individual basis. Wide ranges in % HRR were observed for each activity. It appears that these variations were more dramatic in the groups where low fitness and cardiovascular disease were present.

Experiment III

The hypothesis that occupational therapy activities have a conditioning value for the non-traumatic amputees is supported in part by the data. The significant increase in maximum workload and decrease in HR at the 200 kpm/min observed for the experimental group at post-test were consistent with the conditioning effects observed by other investigators (Magel et al., 1978; Clausen et al., 1973; Simmons and Shephard, 1971; Clausen et al., 1970). The magnitude of the HR changes was greater than that found by Simmons and Shephard (1971) who recorded a mean decrease in submaximum HR of 5.9%, but less than found by the other investigators. Our mean decrease for all submaximum workloads was 9.5% and 8% for the control and experimental groups respectively.

The increase in $\dot{V}_{O_2}$ max observed for our experimental group of 7.9% was not significant, but was reasonably close to the 8.1% increase in $\dot{V}_{O_2}$ max observed by Simmons and Shephard.

It appears that conditioning was cumulative between the two therapy programs for, with the exception of $\dot{V}_{O_2}$ max and systolic B.P. at recovery changes in both groups were all in the same direction. The greater changes observed for the experimental group do not appear to be due to greater effort, as their mean post-exercise lactate values were lower at both Test 1 and Test 2, and decreased more at Test 2 than were the mean values of the cotrol group.

There is some evidence suggesting that the combined occupational and physical therapy programs may have been too demanding for subjects Chom and McC. Both subjects presented with significant ECG abnormalities during the exercise tests and during Holter monitoring. Although therapy was not directly implicated, Chom died a week after entering the combined rehabilitation program. Subject McC could not tolerate the combined program and his exercise capacity deteriorated. The collaboration of the occupational and physical therapy disciplines in planning their respective treatments in indicated.

Limitations of the Study

The low initial fitness of the subjects in both the control and O.T. groups was indicated by the low mean values for maximal workload, work time and $\dot{V}_{O_2}$ max at Test 1. Gains in fitness were small, as indicated by these values at Test 2. Although disappointing, the results are reasonable in view of the limitations of the study as follows:

a) the subject's age

b) their medical status

c) the low training intensity

d) the short training period

e) the lack of specificity of the training activities for arm-cranking

f) the subject's difficulty obtaining maximal cardio-respiratory stress.

Aging is associated with changes which may have limited the subject's tolerance for high intensity training activities. Older subjects have a decreased basal metabolic rate and a lower anerobic threshold. They are slower to achieve equilibrium at any given workload, obtain their peak performance at lower workloads, and require a longer recovery period (Shephard, 1978).

Other changes may have limited their response to our training stimulus. Blood flow to the myocardium and to skeletal muscle is characteristically decreased in the older adult, as is the activity of the tissue enzyme systems and the O_2 carrying capacity of the blood. Maximal heart rate, stroke volume and cardiac output are decreased, possibly because of factors such as decreased myocardial contractility and/or decreased sympathetic drive (Shephard, 1978).

Our subject's training response may have been limited by medical factors such as poor stump healing and by risk factors such as excessive smoking. We could not control these factors entirely.

Our low training intensity may also have limited our subject's training response. The mean training intensities for the control group (23.5% HRR) and the O.T. group (22.5% HRR) were considerably lower than the 50% HRR figure used as a 'threshold' stimulus for training young, healthy subjects (Shephard et al., 1978; Pollock, 1973).

The fact that a tendency toward conditioning was observed supports the findings of De Vries (1970) that exercise of low intensity may provide a training stimulus in older subjects with heart disease.

The short training period is another limitation of the study. Adults reach their optimal fitness some time after 20 to 30 weeks of training (Amsterdam, 1977). However, our six week program required that the patient be hospitalized at least eight weeks for recruitment, exercise testing, training and re-testing. Although some amputees are hospitalized much longer, four of our subjects were re-tested before six weeks because of early discharge.

The above factors limited our training response. Two factors may have limited our ability to measure the training response. The first was the lack of specificity of the training method. The specificity of arm and leg training has been documented (Reybrouck et al., 1975; Stenberg et al., 1967; Bevegard et al., 1966) and a variable exercise response has been reported for two types of arm work (Glaser et al., 1980) and for arm work in different positions (Åstrand et al., 1968). Our patients were trained using a variety of arm activities. Ideally, O.T. activities are similar to the functional activities of the patient after discharge. They do not train the patient for arm cranking specifically. However, arm cranking was the most objective and reproducable (Bar-Or and Zwiren, 1975) and best standardized measure of arm work available for our pre- and post-training evaluation.

The second factor which may have limited our ability to measure the training response was the subject's difficulty achieving a maximal cardio-respiratory stress. The low HR max value of 138.3 ± 17.3 beats/min and the $\dot{V}_{O_2}$ max value of 1.115 ± .208 l/min observed at post-test following conditioning suggest that arm fatigue or weakness rather than the central circulation limited the exercise capacity of the non-traumatic amputees.

Recommendations for Occupational Therapists

Low cardio-respiratory fitness should be expected for sedentary patients referred to occupational therapy. Particular attention should be given to the elderly. Evidence of underlying cardiovascular disease should be viewed as a major factor in treatment planning. The elements of intensity, frequency and duration should be considered before prescribing activity for these patients. Ideally, intensity during treatment should be based on an objective evaluation of the patient's present fitness. This evaluation would provide a baseline, in terms of tolerated workload, tolerated work time, and heart rate and oxygen uptake at a given workload, in order to measure the patient's response to treatment. In cases where an objective evaluation is not possible, the upper limits of intensity should be based on the patient's clinical tolerance for a given activity or workload. Angina, excessive sweating, fatigue, shortness of breath, changes in colour, or lapses in attention are the usual signs of intolerance.

The patient's response to treatment should be monitored on an individual basis, and can usually be carried out by pulse checks and by observation. Monitoring of the patient by 'Holter' recorder or by radiotelemetry may be indicated for assessment purposes or when signs of intolerance persist and are limiting the patient's response to treatment. Excessive monitoring may limit the patient's ability to function in unsupervised settings.

Occupational therapists should note that the intensity of a given activity can be increased in the following ways:

a) by involving all four limbs. Wood-turning on a lathe adapted with a pylon-like stump support is an example of an activity exercising all limbs. It is apparent that a greater intensity effort can be achieved using a purposeful activity requiring upper limb work as opposed to working the stump and unaffected leg only.

b) by increasing the resistance of the tool or of the medium. The use of coarse sand paper and a weighted sanding block are methods for increasing the resistance of the tool during sanding activities. The use of laminated projects and hardwoods are methods for increasing the resistance of the medium.

c) by increasing the rate of work. Activities can be selected where the rate of work can be graded by the therapist. For example, the rpm of the lathe is increased or decreased by the belt adjustment. Other activities, such as sawing, become inefficient when the rate of work is decreased, and the patient must maintain a vigorous pace to make the activity functional. In this latter example, the resistance of the saw (teeth per inch) and wood (pine vs birch) can be controlled but the rate of work is not gradeable.

Duration is an important element in the activity prescription when the intensity of work, as measured by heart rate, is less than 50% of the patient's cardiac reserve. Duration should be viewed in the context of the whole rehabilitation program. Safety precautions should be taken prior to activity whether or not evidence of cardiovascular disease has been noted. Examples are braking the wheelchair behind the patient, learning resuscitation techniques and practicing access to the medical alert system.

SUMMARY

The working capacity of four groups of patients was evaluated during a voluntary maximal exercise test. Seventeen non-traumatic amputees and five traumatic amputees were tested by arm-cranking. Nine stroke patients and ten patients with back problems were tested on a bicycle ergometer. All subjects were found to have low fitness. This was particularly true for the older amputee and stroke patients, where evidence of cardiovascular disease was present.

The intensity of work during occupational therapy was measured by 'Holter' recordings of the patient's heart rate and the peak heart rate during activity was stated as a percentage of the patient's cardiac reserve. The mean intensity for the older amputees and stroke patients during their regular occupational therapy period was less than 30%. The mean intensity for the younger amputees and back patients was greater than 50%. A wide range in intensity for each activity was noted and provides evidence for the necessity of individual monitoring during treatment.

Improved fitness was observed for fifteen non-traumatic amputees following a rehabilitation program. The small magnitude of the changes may have been due to many factors. The subjects were elderly, aged 54 - 78 years, and all but one had underlying cardiovascular disease. The training intensity was lower than is recommended, and the training period was only three to six weeks long. The subjects were trained using a variety of arm activities which did not specifically prepare them for exercise testing on the arm ergometer. Training appeared to be cummulative between physical and occupational therapy as with two exceptions, the changes after training were in the same direction for both the control and O.T. groups.

Recommendations have been made for occupational therapists.

GLOSSARY OF TERMS AND ABBREVIATIONS

atrial premature contraction (APC) - premature contraction of the atria arising from the sino-atrial node or from an ectopic atrial focus.

atrioventricular block (A-V block) - heart block involving the atrial-ventricular node.

bradycardia - heart rate less than 60 beats/minute.

bigeminy - a premature ventricular contraction occurs in every second beat.

couplet - two consecutive premature ventricular contractions.

frequent - approximately ninety or more beats per hour.

hemiblock - heart block involving one branch of fibres which conduct impulses to the left ventricle.

multiform - more than one ectopic focus.

premature ventricular contraction (PVC) - premature contraction of the ventricles arising from an ectopic focus in the ventricle.

quadrigeminy - a premature ventricular contraction occurs in every fourth beat.

rare - less than six beats per hour.

right bundle branch block (RBBB) - heart block involving the fibres which conduct impulses to the right ventricle.

ST segment depression - depression of a horizontal or downsloping ST segment greater than or equal to 2 mm.

tachycardia - rapid heart rate.

uniform - one ectopic focus.

GLOSSARY OF TERMS AND ABBREVIATIONS

a-v O_2 diff. - arterio venous oxygen difference

Bl La - blood lactate

B.P. - blood pressure

C.O. - cardiac output

Δ - change in

HR - heart rate

HR max - maximal heart rate

kcal - kilocalories

kpm/min - kilopound meters per minute

l/min - litres per minute

$\dot{V}_{O_2}$ - oxygen uptake

$\dot{V}_{O_2}$ max - maximal oxygen uptake

n - number

R - respiratory exchange ratio

RQ - respiratory quotient

rpm - revolutions per minute

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