EXPLORATIONS IN THE USE OF HEART RATE AS A PREDICTOR OF ENERGY EXPENDITURE

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The relationship between heart rate and oxygen consumption in an individual, when measurements are made at various levels of exercise, has been described by Wyndham, et al (1959), Malhotra, et al (1963) and Ekblom (1969). This relationship has been used by Malhotra, et al (1963) and Bradfield, et al (1969) to predict the energy cost of specific activities from measurements of heart rate alone. Because the regression varies between individuals it is necessary to determine the exact relationship for each individual and thus reduce the error involved in predicting from heart rate.

An extension of the use of this relationship with important possible uses, is the prediction of 24-hour energy expenditure from mean 24-hour heart rate once the nature of the relationship between oxygen consumption and heart rate has been determined for each individual. With the development of telemetry and latterly the Socially Acceptable Monitoring Instrument (SAMI), which has the advantages of not encumbering the subject and that considerations of range are not involved, the determination of mean 24-hour heart rate has become possible.

It was with this in mind that the oxygen consumption and heart rate measurements which constitute this report were made. Preliminary use was also made of the mean 24-hour heart rate as a predictor of energy expenditure.

Method

The measurements involved in calibration of each individual are described below:

1. Measurement of heart rate. Each subject was connected via suction electrodes to the SAMI Electrode Test Set, thus giving an auditory signal. An oberrver counted heart rate for 30 seconds in each minute of the test period. The mean of these values was taken as the heart rate for the period.

2. Measurement of Oxygen Consumption.

a. A Kofranyi-Michaelis respirometer with a face mask was used to measure the volume of expired air and to take a sample of 0.6% of expired air.

b. A single 30cc. sample was taken from the sample bladder of the respirometer and analyzed for oxygen, carbon dioxide and nitrogen using the Peters and Van Slyke manometric apparatus.

c. Oxygen consumption was calculated from the following formula:

$$\text{Oxygen consumption (liters/min.)} = \frac{\overline{V}}{100} \quad (20.93 - O_{2e})$$

where $\overline{V}$ = volume of expired air in liters/min. STPD

O_{2e} = oxygen content of expired air as %.

The caloric equivalent of the oxygen consumed was obtained by multiplying the amount of oxygen consumed by 4.92 as in the formula developed by Weir (1949).

3. Exercise levels. Heart rate and oxygen consumption were measured in all subjects at at least three levels of exercise.

a. Rest - sitting in a chair

b. Approximately 6 steps/minute on and off a stool.

c. Approximately 10 steps/minute on and off a stool.

Any variations in the number of steps per minute are shown in the results sheet.

Each subject wore the respirometer for approximately five minutes at rest before the "at rest" measurements were made.

Each exercise level was performed for one minute before measurement started, and then measurements were made over the next four minutes. A rest period of 4 to 5 minutes was allowed between exercise levels.

Subjects

The four male subjects ranged in age from 26 to 39 years.

C.V. and J.M. were calibrated twice.

Age, height and weight of each subject are shown in Table 1.

Results

J.M. was calibrated twice and thus there were 7 points determined. Within the range of heart rate measured the relationship seems to be linear (Graph 1).

C.V. was also calibrated twice resulting in a total of 6 points. With the exception of one point, the relationship appears linear within the range of heart rates tested (Graph 3).

Both subjects were more at ease on the second calibration.

J.C. was calibrated with only 3 points. The highest level of exercise was continued for only 2 minutes as heart rate had increased quickly. The subject also appeared to react to the respirometer more than other subjects. Thus the results obtained may not be valid and it is not possible to tell from the results whether the relationship is linear or curvilinear (Graph 4). It should also be noted that the lowest heart rate for D.M. was 88.

A measurement was also made of J.M.'s heart rate during a 7-hour period of sleep. The mean heart rate was 58 per minute.

Discussion

1. Within the range of heart rates tested for each individual and with the exception of D.M. the relationship seems to be linear.

2. A feasible method of calibration has been evolved.

3. Although the relationship between heart rate and oxygen consumption has been used successfully by others to predict the energy cost of specific activities, an extension of this method to the prediction of 24-hour energy expenditure depends on knowledge of the relationship when the subject is sleeping. If the relationship at sleep is linear with the relationship during waking hours it would be possible to predict total oxygen consumption from mean 24-hour heart rate.

The sleeping heart rate of J.M. would indicate that the relationship at sleep is not linear with the relationship during the waking hours, as extrapolation to a heart rate of 58 would give a negative value for oxygen consumption. Thus 24-hour oxygen consumption could be estimated from

a. An estimate of oxygen consumption during sleep. Basal oxygen consumption measurements could be used for this purpose.

b. An estimate of oxygen consumption during the waking hours. The relationship obtained during calibration, together with mean heart rate could be used.

Suggestions for future research

a. Calibration procedure.

1. Use of equipment such as a bicycle ergometer which would allow greater constancy of work level to be maintained during calibration and smaller differences between each work level.

2. Determination of up to 6 points for each individual allowing greater certainty as to the linearity of the relationship.

3. The use of more rapid, but equally accurate methods of respira-

tory gas analysis would greatly reduce the time required for calibration.

4. The use of duplicate samples of expired air to increase accuracy.
5. Modification of the electrode test set to allow a permanent auditory and/or visual record of heart rate to be obtained during calibration.

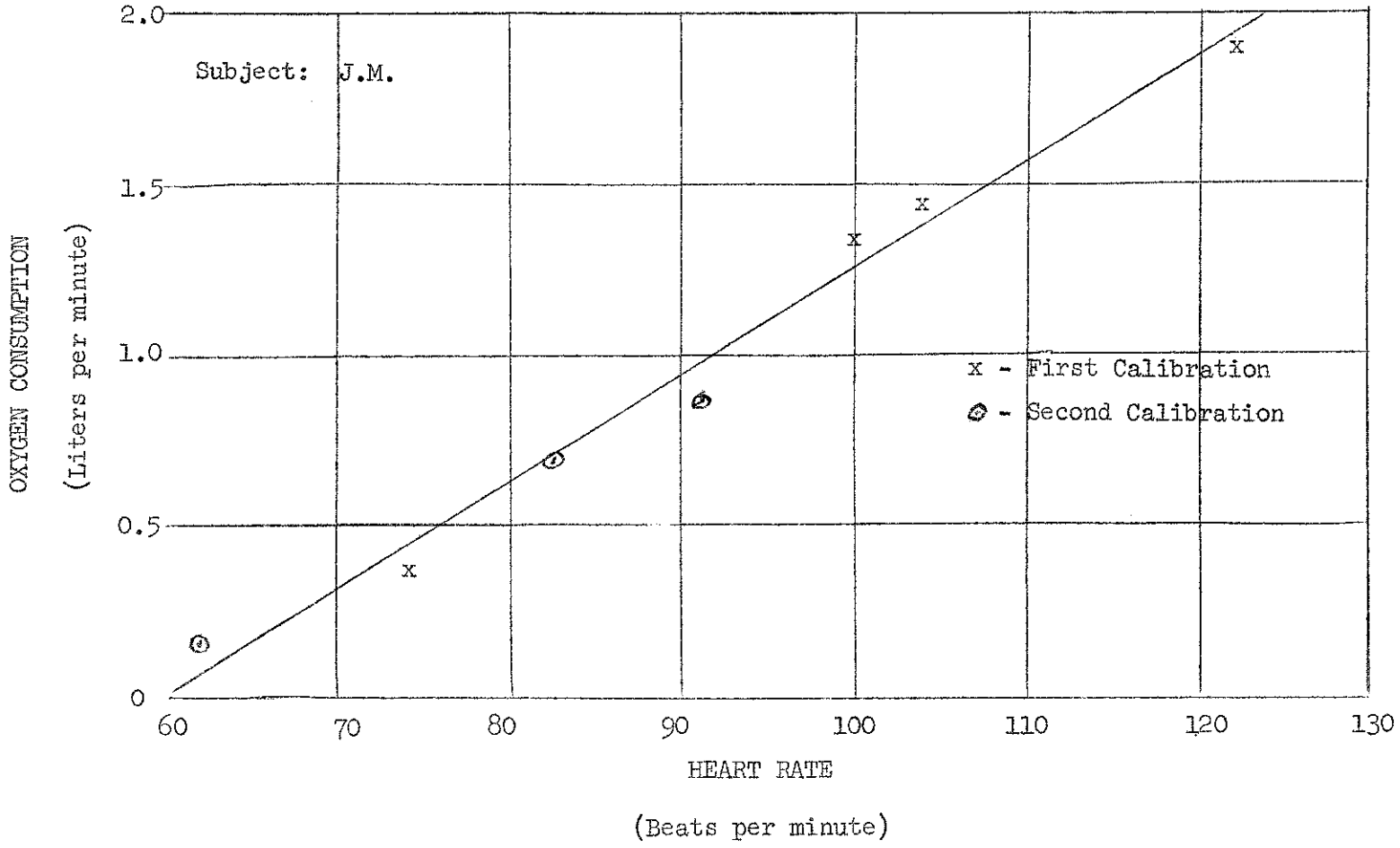
b. Pertaining to prediction of 24-hour energy expenditure.

1. Determination of the relationship between oxygen consumption and heart rate during sleep and its relation to other points determined during exercise.
2. Check results obtained by this method against results obtained by a diary method over a period of at least a week in a small group of subjects when knowledge of weight changes and fluid balance were also known.
3. Check the SAMI against an EKG over 24-hour periods both during sleep and exercise.

TABLE 1

Subject	Age (yrs)	Height (cms)	Weight (kg)	Activity Level	Rate STPD (l./min)	$\%CO_2$	$\%O_2$	O_2 Consumption (l./min)	Heart Rate	Av. Heart Rate Over 24 Hrs.	Predicted 24 Hr. Caloric Expenditure
J.M.	26	185.5	88.6	REST	9.2	3.4	16.55	.398	74	81	4750
				6/min	19.8	2.7	14.08	1.345	100		
				10/min	24.0	4.8	14.88	1.440	104		
				15/min	33.3	4.8	15.13	1.930	122		
J.M.	Second Calibration			REST	3.9		17.40	.136	62		
				4/min	12.1		15.05	.708	83		
				6/min	16.6		15.70	.864	91		
C.V.	39	178.0	68.2	REST	6.1	1.8	17.75	.189	70	82	2480
				10/min	21.2	5.1	14.63	1.335	103		
				15/min	25.7	4.7	15.30	1.440	121		
C.V.	Second Calibration			REST	6.6	3.4	17.1	.251	79		
				6/min	15.9	4.2	15.9	.795	98		
				10/min	22.8	4.6	15.7	1.170	115		
J.L.	27	178.0	70.0	REST	7.9	2.7	16.5	.348	79	82	2908
				REST	8.1	4.2	18.8	.170	69		
				6/min	13.1	3.7	16.0	.642	100		
				10/min	20.8	4.2	15.5	1.120	115		
D.M.	39	166.0	81.8	REST	7.3	2.9	17.3	.263	88		
				6/min	17.8	4.3	15.3	.998	110		
				10/min	25.9	4.5	15.7	1.348	138		

GRAPH 1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1.5
1.0
0.5
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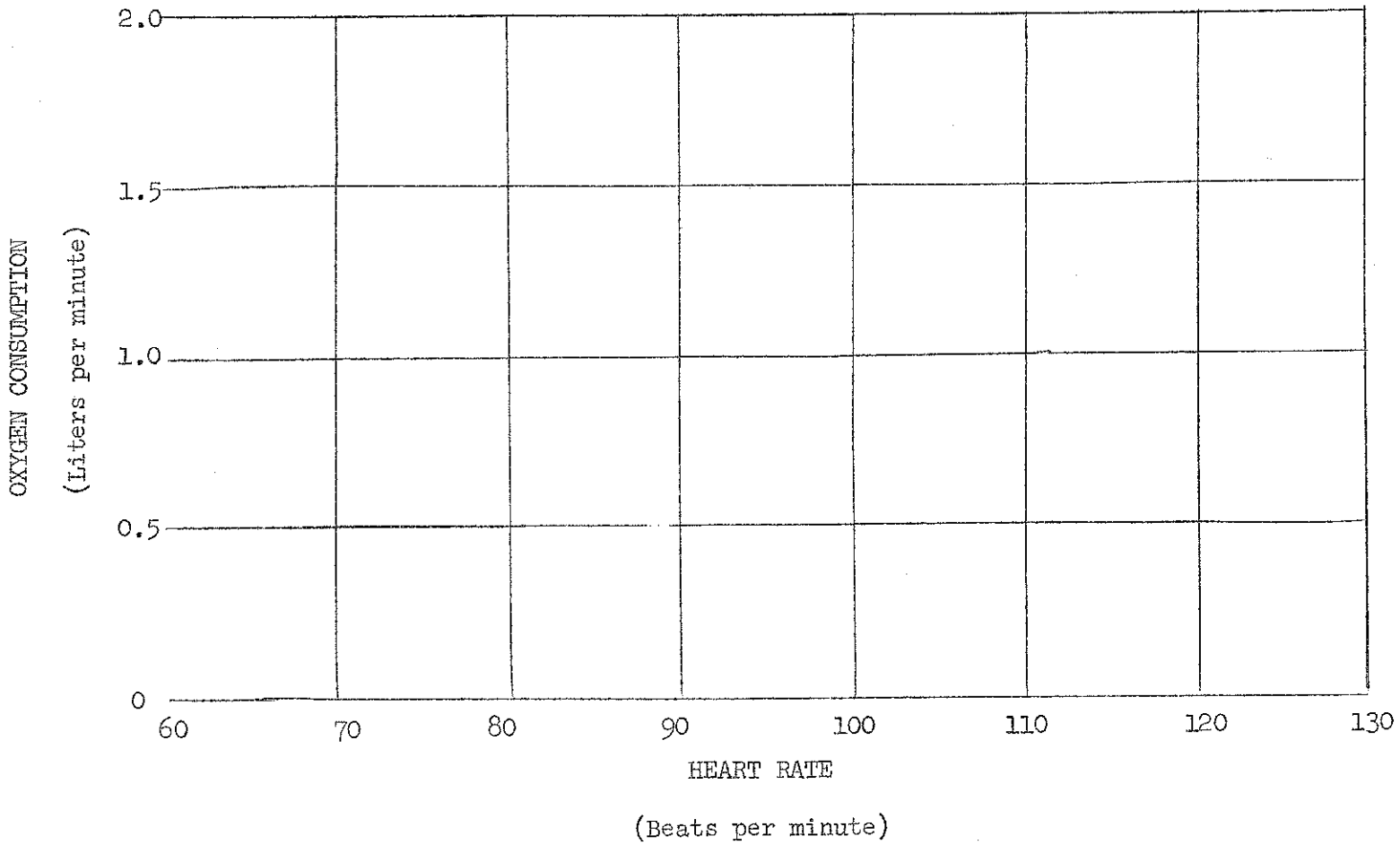
OXYGEN CONSUMPTION
(Liters per minute)
60
70
80
90
100
110
120
130
HEART RATE
(Beats per minute)
x - First Calibration
⊙ - Second Calibration

GRAPH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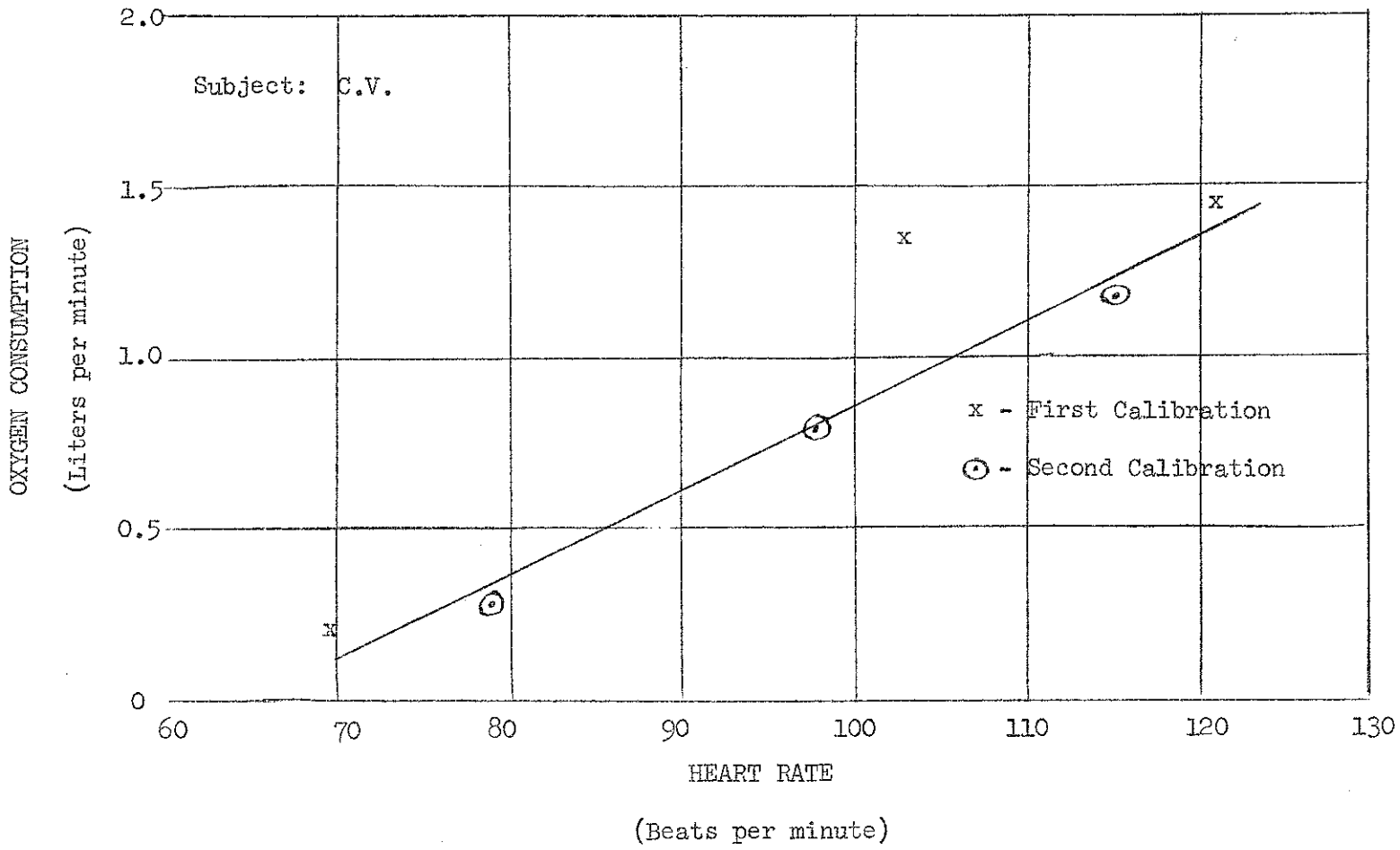
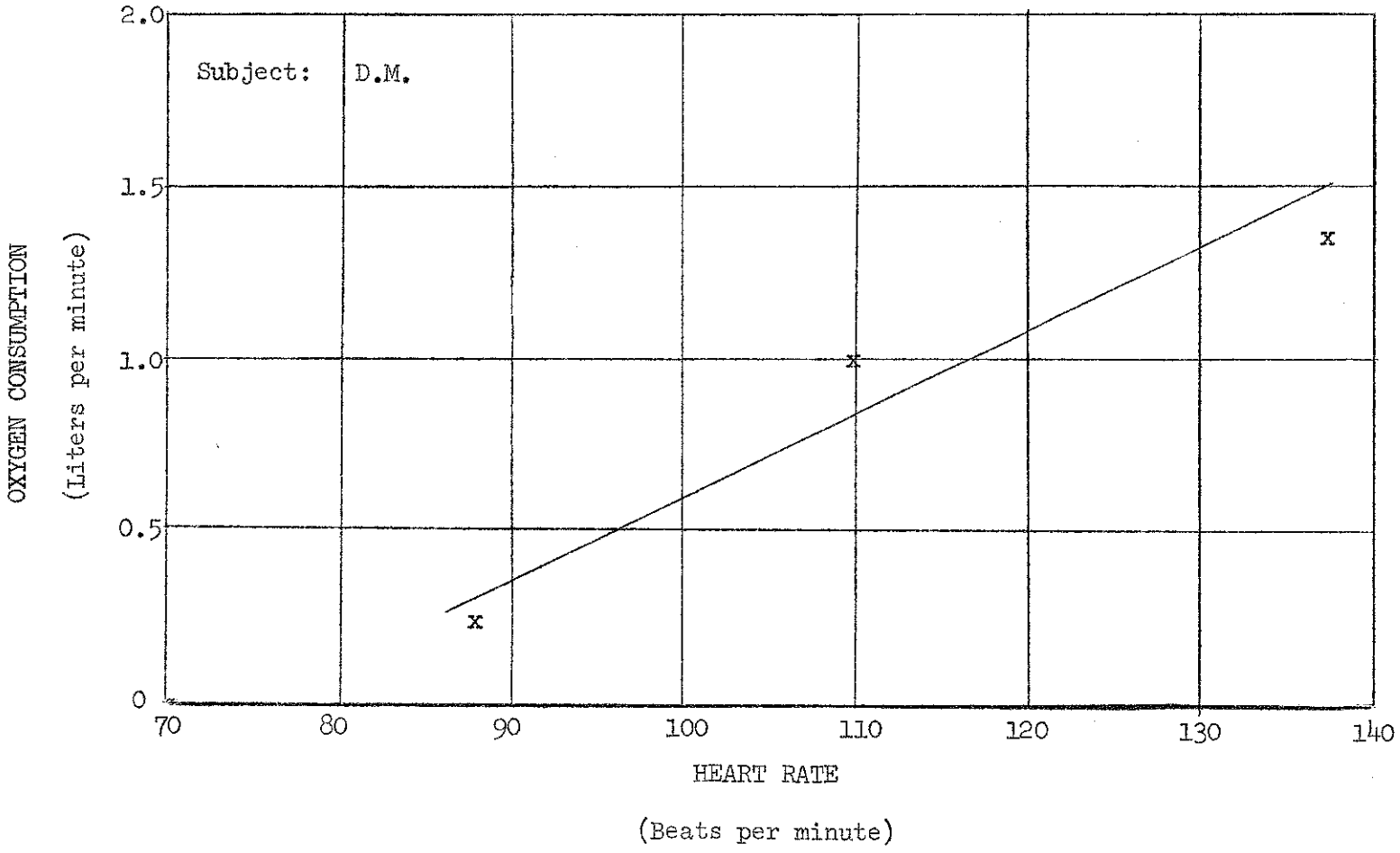
OXYGEN CONSUMPTION
(Liters per minute)
60
70
80
90
100
110
120
130
HEART RATE
(Beats per minute)

GRAPH 3


Subject: C.V.
OXYGEN CONSUMPTION
(Liters per minute)
2.0
1.5
1.0
0.5
0
60
70
80
90
100
110
120
130
HEART RATE
(Beats per minute)
x - First Calibration
⊙ - Second Calibration

GRAPH 4


Subject: D.M.
OXYGEN CONSUMPTION
(Liters per minute)
2.0
1.5
1.0
0.5
0
70
80
90
100
110
120
130
140
HEART RATE
(Beats per minute)

CITATIONS

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