UNPUBLISHED PRELIMINARY DATA

The Effects of Isometric Work on Heart Rate, Blood Pressure, and Net Oxygen Cost*

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ABSTRACT

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The purpose of this study was to investigate the effects of a ten second isometric exercise, which involved much of the large musculative, upon the heart rate, blood pressure and net oxygen cost. Six subjects, all athletes or former athletes in good physical condition exercised in a semi-reclining, fixed position against a Medart spring dynomometer. Each subject pulled to sixty per cent of his previously determined maximum effect.

The heart rate showed a slight increase during exercise followed by a sharp rise in the few seconds following exercise. This was followed by a drop almost to the resting level within twenty to thirty seconds following exercise.

Systolic pressure role following exercise and was highest in the period immediately following exercise. It then dropped slowly to resting levels but had done so in most cases within two and a half minutes.

Dystolic pressure fell slightly in the first thirty seconds following exercise, and returned to the resting level within a minute and a half.

Oxygen consumption varied widely both between subjects and between experiments in the same subject.

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The development of muscular strength and the physiological responses to a training program leading to such development have been extremely interesting to physiologists for many years. The studies of Müller and Hettinger (7) concerning isometric exercise have opened a new avenue of interest to researchers interested in the development of strength and have provoked much interest and discussion on the part of medical people because of the clinical implications of such a system of exercise and also of physical educators interested in the training of athletes. This remarkable piece of work which indicated that an isometric contraction of six seconds per day equal to 2/3 of the maximum strength of the muscle increased muscle strength as much as could be done if the muscle were contracted maximally and/or if the muscle were exercised longer (to exhaustion) or more frequently. The implications to athletes and to other interested people are staggering. Karpovich (9) in his remarks about isometric exercise indicates that he believes that there may be so many advantages to isometric exercise that the cumbersome, time-consuming isotonic programs may have been a waste of time.

Much of the research in this area offers credence to the findings of Müller and Hettinger. Baer, et al (1), Darcus and Salter (4), and Mathews and Kruse (10) found an increase in strength as a result of isometric training although they do not entirely agree as to the extent of the gains found or upon how their findings compare with the results of various isotonic programs. Rose, et al (15), and Rarich and Larsen (12) generally agreed with the findings of Müller and Hettinger although each disagreed on some points.

There have been some important dissenters to the Müller-Hettinger findings (2,5,6), but the increase in the number of people who use isometric training programs in the preparation of athletes for competition and in clinical practice helps to confirm their usefulness. It is remarkable that studies concerning the physiologic effects of isometric exercises have not kept pace with this interest. In an early study of the physiologic effects of isometric work, Cathcart et al (3), found that there was no marked increase in O_2 intake following the cessation of effort. They found a definite rise in respiratory and heart rates and in blood pressure during work. They also found that the rise in diastolic pressure was more marked than that of the systolic pressure.

J. H. McCurdy (11) studying the effects of effort (not isometric) on blood pressure commented that in order to have a true picture of blood pressure changes resulting from maximum effort it is necessary to take the blood pressure during the effort, as blood pressure falls too quickly for later readings to be reliable. He found that blood pressure rises to a great height during maximal effort, but that heart rate is only slightly changed and that at the end of the exercise period blood pressure and heart rate rapidly return to normal.

In a later study, Thompson (16), studying some of the physiologic effects of both isometric and isontonic work, found that isometric work caused a pronounced rise in both systolic and diastolic blood pressure but remarked that the diastolic pressure had returned to resting levels within about thirty seconds. The effect of isotonic work was different in that it caused no significant change in diastolic pressure. Rasch (13), on the other hand, found that having a subject hold a weight equal to about two-thirds of his maximum strength for a period of about 15 seconds caused an increase in systolic and a decrease in diastolic pressure. The principal difference he reported between the effects of isometric and isotonic exercises of roughly the same intensity was a considerably greater decrease in diastolic blood pressure in isotonic exercise.

Because of the seeming possibility of a shortcut into improved strength, isometric training programs have captured the interest of many people. It is apparent that the above studies offer only a limited amount of the total information needed before the real value of isometric exercise can be assessed. It was, therefore, the purpose of this study to investigate the effects of a brief period of an isometric activity which involved many of the larger muscles of the body upon the blood pressure and upon the heart rate; and, finally, to determine the magnitude and range of the energy cost of such exercise.

Methods and Procedures

The Subjects. The subjects in this study were six male athletes or ex-athletes all in good physical condition whose ages ranged from 23 to 34. All were experienced subjects being well use to all of the apparatus used in this study. Data concerning the subjects are contained in Table I.

The subject for each experimental run was placed on a training table and was told to lean back against a backrest which was placed at an angle of 45 degrees to the table. His position was adjusted so that his feet were placed upon the platform of a Medart spring back and leg dynamometer, his knees being bent to an angle of 135 degrees as measured by a goniometer. The dynamometer was positioned so that the platform was vertical and the indicator dial arranged so that the subject could see it. The dynamometer chain passed up between the subject's legs with the crossbar attached so that the subject could just grasp it, palms up, and still have head and shoulders against the backrest. After the subject was positioned, the backrest was removed.

Preceding the main part of the experimental runs the reliability of the apparatus was tested by having the subjects pull twice on different days against the apparatus while positioned as mentioned above. Each pull was to represent a maximal effort for a ten-second period. The result was satisfactory ($r = .94$), and the mean of the two attempts was taken to represent a maximal effort. For the actual experiment the subjects pulled only 60% of this established maximum.

Apparatus. The measurement of the force of the isometric pull was done with the back and leg dynamometer. This was equipped with two pointers; one whichmoved to indicate the amount of pull and another which could be moved to indicate any desired amount of pull. Heart rate was taken by means of telemetry. Disposable electrodes were placed on the subject's sternum and left side and were attached to a small Jaeger telemetering device. This transmitted the signal to an F.M. receiver placed nearby. The signal was recorded on a Sanborn Viso-Cardiette, Model 51 electrocardiogram. Arterial blood pressure was measured with a mercury sphymomanometer, and gas analyses were done on a Beckman Model E-2 oxygen analyzer and a Beckman Spinco Model LB-1 infra-red carbon dioxide analyzer.

Protocol. The subject was allowed to rest on the training table for fifteen minutes before the start of exercise, reclining against the backrest. Preliminary heart rates and blood pressures were taken every five minutes during this period to establish resting levels. At the end of the first ten minutes a nose clip was put on the subject and a mouthpiece was placed in his mouth. He now inhaled from a 120 liter Tissot means chain compensated type spirometer and exhaled through the collection hoses into the open room thus washing out the hoses with expired air. Thirteen minutes after the resting period began the subject was placed in the above described position and the movable needle on the dynamometer was placed at 60% of the subject's established maximum pull. Fourteen minutes and fifteen seconds after the start of the resting period, the subject was told to place his hands, palms up, on the crossbar; and twenty seconds before exercise began the backrest was removed, the subject being supported by a coinvestigator. Exercise began 15 minutes after the formal resting period began. The subject was instructed to pay strict attention to the dynamometer needles, pulling just hard enough so that they came exactly together and to be careful to maintain this amount of pull for the ten-second period as called off by a coinvestigator. He then was allowed to release the crossbar and to resume breathing, and the backrest was put into place. The first minute of expired air was now being collected in the first of a series of three 30-liter Douglas bags. The second and third minutes of expired air were collected in the second of the Douglas bags in the series, and the fourth and fifth minutes in the third bag. Expired volumes (BTPS) were calculated from a Kymograph record on the spirometer from which the subject inhaled.

Blood pressures were taken as soon as possible following exercise (the cuff was already in place) and then every thirty seconds counted from the beginning of exercise. Heart rates were figured on a three beat basis but are expressed as a per minute value. These were taken beginning five seconds before exercise, for thirty seconds beginning with the start of the exercise period, for the first fifteen seconds of every minute thereafter, and for the final fifteen seconds of the fifth minute.

Results

HEART RATE

As might be expected, there was a marked rise in the heart rate before exercise began. This was true in every experiment although the extent of the increase was greater in the first two experiments with each subject in all but one case. This decrease in the anticipatory rise in the heart rate was apparently due to familiarization with the apparatus. The heart rate generally went up slightly from the pre-exercise level, but the greatest increase in every experiment came in the few seconds immediately after the cessation of exercise. This was followed by a dramatic drop almost to the resting level, in some cases, within twenty seconds following exercise. The heart rate then fluctuated some, but in virtually every case had returned within two or three beats per minute of the resting level within the five minutes recovery period. In many cases, heart rate dropped below the resting level some time during this period. Means and standard deviations of heart rates of all experiments for each subject are shown in Table II and for all experiments in Table III.

BLOOD PRESSURE

Systolic pressure. The systolic pressure rose following exercise in every case and was highest in the period immediately following exercise. It then began to drop slowly to normal levels sometimes fluctuating as it did so but had reached the resting level in most cases within two and one half minutes following exercise. The fluctuation in the blood pressure was progressively less and less from this time until the end of the recovery period. Means and standard deviations of systolic pressures in all experiments for each subject may be seen in Table IV, and for all experiments in Table V.

Diastolic pressure. The diastolic pressure in nearly every case showed a decrease from the resting level in the firty thirty second period following exercise. In most cases it had returned to the resting level within the first minute and thirty seconds of the recovery period and remained at this level. Diastolic pressure changes were very small as compared with the systolic pressure and fluctuation was markedly less. Means and standard deviations of all experiments for each subject may be seen in Table VI and for all experiments in Table VII.

Oxygen consumption. The striking thing about oxygen consumption was the wide variability not only between subjects but in different experiments involving the same subjects. The net oxygen cost of exercise of one subject was as low as 3.16 ml. per kg. of body weight, and in one case, another subject absorbed 18.37 ml. per kg. of body weight. Total cost was highly variable in the xase of each subject, and one subject varied 9.97 ml. per kg. of body weight from one experiment to another. Results of these data are shown in Table VIII.

Discussion

Isometric contractions when put together into a sound system of total body exercise seem to have several advantages over isontonic (barbell) training. They are, first of all, less time consuming. They require no expensive equipment as exercises may be designed which involve only such things as chairs, doorways, or even other people in dual exercises. It is possible to do these exercises in a confined space such as a hospital bed or even in this age an astronaut's capsule. Clinical use of isometric exercise is bound to increase as it is the logical answer to problems which have existed for many years. There is no doubt now that bedridden people can, through a carefully administered program, maintain or even build muscular strength.

This is not an unreasonable expectation, for isometric contraction can involve real effort. This effort may involve, in the case of total body exercises such as were used in this study, a thirty-fold increase in the metabolic rate; a considerable amount of work.

These exercises may involve another factor heretofore largely unexplored. In view of the increase in heart rate and changes in arterial pressure noted in the above findings it may also be possible to make a substantial contribution to the general tonus and efficiency of the cardiovascular system and very likely also to the respiratory system. To the bedridden person or to the astronaut who is in cramped quarters for an extended period of time this factor may be as important as that of maintaining muscular strength. This aspect of isometric effort needs more investigation.

The seeming wide variability of the oxygen consumption data is given credence by the fact that the resting levels of O_2 consumption for each subject were quite close. The reason for the variability in O_2 consumption resulting from exercise is not clear and needs more investigation. This is particularly true since the designers of closed life support systems, such as space capsules, will need accurate data on the rate of utilization of oxygen and production of carbon dioxide during periods of isometric exercise.

TABLE I

AGES, HEIGHTS, AND WEIGHTS OF THE SUBJECTS

Subject	Age	Height	Weight in Kg.
EF	25	6'4"	78.09
RS	23	6'1"	96.25
RB	34	6'3"	97.16
FM	34	5'6"	74.91
DB	25	5'11"	71.73
FH	28	6'0"	74.00

TABLE II

MEANS AND STANDARD DEVIATIONS OF HEART RATES OF EXPERIMENTS FOR EACH SUBJECT

		TIME									
Subjects		Resting	Pre-Ex	Exercise	Post-Ex	30 Sec.	1 Min.	2 Min.	3 Min.	4 Min.	5 Min.
EF	M	72 25	90 25	101.00	108.25	79.75	68.25	69.50	72.00	73.50	67.25
	G	4.02	3.63	5.48	4.32	3.77	7.76	6.34	8.09	7.76	4.15
RS	M	74.50	126.25	123.25	140.00	64.00	69.75	74.75	77.00	76.25	81.50
	G	6.79	9.28	13.88	7.84	14.09	3.34	7.19	6.20	7.29	1.5
RB	M	61.75	88.75	98.75	121.25	59.00	61.75	62.75	66.25	63.50	65.00
	G	3.19	4.02	5.12	3.77	.71	7.12	5.40	4.82	1.50	1.85
FM	M	60.50	86.25	105.50	122.50	72.25	61.75	57.25	60.00	66.25	65.00
	G	3.77	6.94	3.20	1.12	3.63	3.63	1.09	3.54	4.71	3.54
DB	M	66.75	92.50	11.25	128.25	81.00	69.75	70.50	69.00	70.00	66.75
	G	5.72	3.64	3.83	5.45	10.65	5.17	8.62	3.94	6.04	2.77
FH	M	51.75	83.75	104.75	116.50	65.50	49.50	51.25	50.75	55.00	53.50
	G	2.28	17.81	12.56	12.01	12.87	2.60	1.48	2.17	1.58	1.50

TABLE III

MEANS AND STANDARD DEVIATIONS OF HEART RATES
FOR ALL EXPERIMENTS

	Resting	Pre-Ex	Exercise	Post-Ex	30 Sec.	1 Min.	2 Min.	3 Min.	4 Min.	5 Min.
M	65.00	94.63	107.25	122.79	73.58	63.46	64.33	66.25	67.42	66.50
G	6.74	17.03	11.67	11.90	11.76	8.86	9.97	8.28	8.85	8.61

TABLE IV

MEANS AND STANDARD DEVIATIONS OF SYSTOLIC PRESSURES
OF EXPERIMENTS FOR EACH SUBJECT

Subject		TIME										
Subject		Resting	30 Sec.	1/Min.	1/30	2/Min.	2/30	3/Min.	3/30	4/Min.	4/30	5/Min.
KF	M	112.00	134.50	127.33	116.00	105.33	102.50	106.00	107.50	110.00	108.50	108.67
	G	2.00	9.63	7.72	12.73	3.77	8.76	5.66	3.28	0	5.17	.94
RS	M	130.00	154.50	152.00	135.00	133.00	131.00	133.00	129.50	129.50	132.67	133.33
	G	00.00	12.60	7.48	10.05	9.00	1.73	5.20	.87	.87	5.25	3.40
RB	M	143.00	165.50	154.50	141.50	143.00	142.50	144.00	141.50	143.00	140.50	144.50
	G	4.58	8.41	11.17	3.84	7.14	2.60	3.75	1.66	3.00	.87	3.57
FM	M	125.50	141.00	127.50	128.00	126.00	126.00	128.00	127.50	126.00	127.50	128.50
	G	4.56	4.12	4.56	4.24	4.24	2.45	2.83	2.60	5.10	3.57	4.09
DB	M	123.50	160.00	152.00	143.50	136.00	135.33	132.50	133.00	130.00	128.50	126.00
	G	4.33	6.48	15.03	13.37	9.27	9.43	11.43	9.00	9.27	3.84	7.35
FH	M	118.00	139.50	132.00	122.00	128.50	122.50	122.50	120.50	121.00	121.00	119.00
	G	1.41	18.51	13.93	8.94	5.17	5.17	4.56	2.96	3.00	2.24	3.32

TABLE V

MEANS AND STANDARD DEVIATIONS OF SYSTOLIC PRESSURES
FOR ALL EXPERIMENTS

	Resting	30 Sec.	1/Min.	1/30	2/Min.	2/30	3/Min.	3/30	4/Min.	4/30	5/Min.
M	125.33	149.17	141.00	131.00	129.65	126.26	128.61	126.58	127.30	126.33	127.30
G	10.29	15.87	16.23	13.86	12.93	13.91	12.63	11.44	10.67	10.55	11.51

TABLE VI

MEANS AND STANDARD DEVIATIONS OF DIASTOLIC PRESSURES
OF EXPERIMENTS FOR EACH SUBJECT

Subject		TIME										
		Resting	30 Sec.	1/Min.	1/30	2/Min.	2/30	3/Min.	3/30	4/Min.	4/30	5/Min.
EF	M	76.00	71.50	75.33	76.00	77.33	77.50	80.00	77.00	77.33	77.50	78.66
	G	2.83	7.37	.81	1.41	2.47	2.60	4.90	2.24	1.82	1.48	1.88
RS	M	82.50	78.50	76.66	81.50	78.50	81.50	79.50	80.50	82.00	82.00	82.00
	G	2.96	5.72	4.99	2.96	2.96	3.04	2.12	2.12	2.45	1.41	2.45
RB	M	87.00	82.00	90.50	92.50	93.00	95.50	92.50	95.00	94.00	95.00	98.50
	G	4.12	4.90	6.02	4.33	4.12	4.56	4.33	4.12	4.00	4.12	5.17
FM	M	83.50	72.00	80.00	82.50	85.00	82.00	86.00	85.50	85.00	87.50	86.50
	G	4.50	2.45	6.16	6.27	3.00	2.00	2.45	2.59	5.00	4.33	3.55
DB	M	75.00	64.50	69.50	67.00	68.50	68.66	70.00	69.50	71.50	72.00	73.50
	G	6.40	5.35	3.28	4.12	2.58	1.94	4.24	3.56	1.65	4.69	4.33
FH	M	75.50	75.50	73.00	75.00	75.50	77.00	77.50	77.00	81.00	79.50	79.50
	G	.87	6.98	1.73	2.24	4.61	5.20	2.59	2.24	7.14	3.54	3.54

TABLE VII

MEANS AND STAND DEVIATIONS OF DIASTOLIC PRESSURES
FOR ALL EXPERIMENTS

	Resting	30 Sec.	1/Min.	1/30	2/Min.	2/30	3/Min.	3/30	4/Min.	4/30	5/Min.
M	79.67	74.00	77.64	79.08	79.74	80.87	80.70	80.75	82.00	82.25	83.30
G	6.02	7.90	8.28	8.79	8.59	8.58	7.90	8.48	8.06	8.17	8.84

TABLE VIII

NET OXYGEN COST OF EACH EXPERIMENT IN ML.PER KG.BODY WEIGHT

Subject	Experiment			
	No. 1	No. 2	No. 3	No. 4
KF	12.14	9.22	9.68	4.39
RS	18.37	12.10	8.40	15.47
RB	3.22	3.92	5.76	3.16
FM	13.44	7.43	7.64	5.31
DB	9.99	11.34	9.40	7.62
FH	6.97	8.03	9.02	5.81

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