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# Rescuer Exertion During Two-Man Cardiopulmonary Resuscitation (CPR)

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# RESCUER EXERTION DURING TWO-MAN CARDIOPULMONARY RESUSCITATION (CPR)

by

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## DEDICATION

To my parents, Antanas and Alina Lipskis, whose guidance, understanding, and encouragement have always been an inspiration to me.

To my darling wife, Lynn Anne, whose hard work, patience, and love have made all of this possible.

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# VITA

Edmund A. Lipskis, son of Dr. and Dr. A. Lipskis, was born November 5, 1953 in Chicago, Illinois.

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In September of 1971, he entered Loyola University of Chicago, Illinois, and in May 1975, received the degree of Bachelor of Science with a major in biology.

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## INTRODUCTION AND STATEMENT OF PURPOSE

Many researchers have reported that the performance of cardiopulmonary resuscitation (CPR), especially the compression role, requires a great deal of exertion. Effrom (1977) commented that after extended administration of CPR, rescuers may reach a point at which they are too fatigued to continue the CPR and must seek relief, or quit in order to not endanger their own health. Abbot and her co-workers (1978) recorded heart rates during CPR training of cardiac patients and found that in one third of the training sessions, patients' heart rates increased quite extensively. In our laboratory, Myczek (1979) noted substantial heart rate increases in young, healthy individuals after performance of CPR. In general, it can be said that performance of CPR, especially over an extended period of time, has been observed to be quite exhausting. In an average, healthy individual, this is probably not detrimental, but in those that are older, and especially in those who have led sedentary lives, just a one-minute performance of CPR on a mannequin seems seriously taxing. The potential for complications seems very real in those individuals should they be called upon to perform CPR for an extended period of time.

It is the purpose of this study to examine the level of physical exertion experienced by rescuers performing two-man CPR as evidenced by changes in heart rate. Experimentally, exertion from CPR performance will be compared to exertion from a standardized exercise test, a modified Harvard Step Test. Heart rate will be the parameter measured in this study as the indicator of the degree of exertion.

## LITERATURE REVIEW

In his discussion of coronary heart disease, Macleod (1977) states that atheromatous disease of the coronary arteries is the most important single cause of death in the western world. It is the most common cause of angina pectoris, and leads also to myocardial infarction, to cardiac failure, and to sudden death. Most of the victims of an acute myocardial infarction who die, do so within the first hour or so, often before being transferrred to a hospital. In cases of cardiac arrest, some method of restoring circulation immediately is critical. Six minutes after the heart stops, permanent brain damage will almost always occur. Because of this need for speed, investigators for over a hundred years have been studying methods of promoting some circulation in cases of cardiac arrest. Especially sought was a method that could be accomplished by any trained person without special instruments.

In one of the first experiments attempting to restore an arrested circulation artificially, Boehm (1878) used a closed chest cardiac massage technique on cats with a striking amount of success. Crile (1908) demonstrated on animals the successful use of an "adrenalin saline solution intravenously, combined with rhythmic pressure on the chest" as a means of resuscitation. Crile later (1910) used this technique to resuscitate a twelve-year old girl whose heart had arrested. Tournade and co-workers (1934) reported that when an abrupt compression of the thorax was performed on a dog in a state of cardiac arrest, peripheral blood pressures of 60 to 100 mm Hg could be produced.

Gurvich and Yuniev (1947) studied the effectiveness of sending a capacitor discharge through the chest of a dog after the onset of an induced ventricular fibrillation. They found that cardiac function resumed if the charge was applied within one and a half minutes of the beginning of fibrillation. Incidental to these findings they also reported that this strict time limit could be extended to eight minutes by rhythmical application of pressure on the thorax in the region of the heart. In tests that lasted ten to fifteen minutes, control animals not given artificial resuscitation died, whereas nineteen out of thirty animals given thoracic compressions did survive.

Kouwenhoven and his associates (1960) described a technique for external cardiac compression which was effective in cases of cardiac arrest in humans. Subsequent to this classic study, the inability of sternal compressions alone to produce ventilation, and the need to accompany external cardiac compression with some form of intermittent positive pressure ventilation was demonstrated by Safar, et al (1961) and others. Previously, both Safar, et al (1958) and Gordon, et al (1958) had independently demonstrated that mouth-to-mouth artificial ventilation resulted in far superior blood oxygenation and better $CO_2$ removal than manual techniques such as chest-pressure or arm-lift methods. Wilder and co-workers (1963) attempted to coordinate ventilation techniques and closed chest cardiac massage in dogs. Harris and his co-workers (1967) extensively studied ventilation and cardiac compression problems. They found that mouth-to-mouth lung inflations interposed between sternal compressions resulted in the most effective oxygenation of tissues. They also determined that adequate blood gas levels could be maintained at a compression-ventilation ratio of 15/2 for circumstances in which only one rescuer was present. When two rescuers were present, even better oxygenation could be obtained when one rescuer performed external cardiac compressions at one second intervals without interruption and the other rescuer interposed a ventilation after every fifth compression.

In 1966, the National Academy of Sciences—National Research Council sponsored a Conference on Cardiopulmonary Resuscitation that recommended the training of medical, allied health, and professional personnel in resuscitation techniques. In 1973, the American Heart Association and the National Academy of Sciences—National Research Council jointly sponsored a National Conference on Standards for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiac Care (ECC). The standards developed and recommended by this conference relate to life support techniques, and the training of medical and allied health personnel. Also the conference dealt with medico-legal aspects of CPR and ECC and in the role of national health agencies in training the lay public. These recommendations have led to the widespread acceptance of CPR and to a broadening of its role in emergency care.

In a statement released from the 1973 conference, emergency cardiac care was recognized to include the following elements:

1) Recognition of early warning signs of heart attacks, prevention

of complications, reassurance of the victim, and transport of the victim to a life-support unit without delay;

2) Provision of immediate basic life support at the scene, when needed;

3) Provision of advanced life support as quickly as possible; and

4) Transfer of the stabilized victim for continued cardiac care.

Cardiopulmonary resuscitation falls under the second category of the list above. Basic life support, as defined by the American Heart Association and the National Research Council, is an emergency first aid procedure that consists of the recognition of airway obstruction, respiratory arrest and cardiac arrest, and the proper application of cardiopulmonary resuscitation (CPR). CPR consists of opening and maintaining a patent airway, and providing artificial circulation by means of external cardiac compression.

The accepted standards developed in the 1973 conference provided a working guide for emergency cardiac care and especially for the performance of CPR. Since that time, there have been great increases in the number of studies involving CPR. Initially, the majority of the research concentrated on the effectiveness of resuscitation techniques. Heifetz, et al (1976) and others tested the adequacy of oxygentaion during performance of CPR. Coskey (1978) used long term survival studies in order to determine the success of CPR in relation to its frequency of use. Coskey, in his study, found an overall twenty-one percent long term survival in patients who would have died without resuscitation. Many studies have also been undertaken to examine training methods and their effectiveness. Banasik, et al (1976) demonstrated the usefulness of the Resusci-Anne mannequin in teaching modern methods of resuscitation. Gorry and Scott (1977) extensively examined current cardiopulmonary resuscitation training programs and made recommendations to improve their effectiveness.

Effrom (1977) stated that performance of external cardiac compressions requires "considerable exertion", and because of this, a rescuer may become fatigued to the point that he needs to be relieved. In a situation in which two rescuers were present, either the second rescuer could take over, or else the first rescuer could switch to performing ventilations only, and the second could take over the role of compressor. Two-man CPR has been demonstrated by Safar (1977) to be the most efficient technique for oxygenation of the tissues, however, it has often been observed that coordination of compressions and ventilations is difficult to achieve unless the rescuers are very experienced or have practiced together. In an unpublished study from our laboratory, Myczek (1979) compared the exertion of two rescuers performing two-man simultaneous CPR and two rescuers alternately performing on-man CPR on a mannequin. He found no evidence of significant differences in exertion. Although Myczek restricted his discussion to relative levels of exertion for the two CPR techniques, some of the quantitative values for heart rate changes in his results should be noted. All of the subjects were young, and in good health, yet cases of heart rates at 200% of their pre-experimental rate were reported. Abbot and her co-workers (1978) investigated physiologic changes during CPR training of cardiac patients, in order to determine if any ill effects would develop. Their observations were restricted to ten cardiac patients. In one third of the training sessions, patients' heart rates rose to between seventy and eighty-five percent of the estimated maximum determined by the experimenters. One patient had demonstrable ECG changes during one of the CPR training sessions. Abbot recommended that only patients who have been in an exercise program for a minimum of three months be given the opportunity for CPR training. Even then, she recommends that caution should be used during CPR training sessions, to insure that cardiovascular complications do not occur.

A review of the literature does not reveal any research which has correlated quantitatively cardiopulmonary resuscitation with a standardized form of physical exertion.

Heart rate and physical exertion have been related in many studies. Physiologists have long stated that ventilation, pulmonary gas transfer, cardiac output, and peripheral blood flow all increase in response to the metabolic demands of working muscles. Morehouse and Miller (1971) state that in a given subject, the maximal heart rate that is reached correlates fairly closely with the work load. Spiro and co-workers (1974) demonstrated that from base levels at the start of exercise, heart rate and cardiac output rise and reach a steady level as long as work continues at a given load. Jones (1975) noted that the increase in cardiac output during exercise is brought about mainly by an increase in cardiac frequency. Wilson and Welch (1975) support Jones and state that there is a direct correlation between increasing work load and heart rate in normal subject. Wilmore, et al (1976) showed that the use of heart rate as a parameter for measuring exercise intensity is valid and relates to the fact that the heart rate is a good indicator of the actual work done by the heart.

Brouha (1960) stated that when exercise ceases, the heart rate remains very close to the level attained at the end of exercise for a few seconds. Recovery then takes place and the behavior of the heart rate is determined by the preceding exercise and the environmental conditions. These statements have been supported by the experiments of Sheffield, et al (1965), Kobayshi (1979), Boning, et al (1979), and many others.

Astrand and Ryhming (1954) stated that when testing circulatory fitness and exertion levels, a type of work must be chosen which engages large groups of muscles and the work levels must be relatively high. The duration of work must be long enough to permit the adjustment of circulation and ventilation to the level of exercise. The above mentioned results, Astrand reports, can be achieved from a simple work test with the subject stepping up and down on a bench. The Harvard Step Test was described and developed by Johnson and his co-workers (1942). In a survey of accepted methods of exercise testing, Rochmis and Blackburn (1971) list the Harvard Step Test among five currently used standardized exercise tests. According to Wenger (1980), exercise tests can be divided into three main categories: symptom-limited, submaximal, and maximal exercise tests. The Harvard

Step Test is basically a standardized maximal exercise test. Wenger also states that there are five main uses of exercise tests. Most of them are concerned with diagnosis or monitering various cardiac disease states, but exercise tests are also used to compare the levels of effort from various activities in order to recommend appropriate and safe levels of exertion. She reports that "patients' tolerance to known energy levels for varied activities correlates reasonably well with tolerance to comparable work demands at exercise testing."

# MATERIALS AND METHODS

## Subjects:

Thirty (30) male volunteers from Loyola University School of Dentistry were used as subjects in this study. The subjects were all students between the ages of twenty-three and twenty-nine. Prior to participation in the experiment, each subject had received training and had been certified by an accredited instructor of cardiopulmonary resuscitation (CPR). In accordance with the recommendations of the Institutional Review Board for Protection of Human Subjects--Loyola University Medical Center, each subject received an electrocardiographic and physical examination from a licensed physician in order to insure that all volunteers would be able to perform the experiment without risking injury. Informed consent was obtained from each subject.

## Equipment and Materials:

The resuscitation technique was performed on Laerdal's Resusci-Anne mannequin. The indicator lights of the mannequin were turned into plain sight of each subject. Heart rate was the parameter in this experiment and was recorded through a Lead II electrocardiographic tracing. A Narco® Physiograph was used for these recordings at a paper printout speed of 0.5 cm. per second. Leads for the tracing were attached to the subjects' wrists and ankles and were long enough so as not to impede performance of CPR.

For the purposes of this experiment, a Harvard Step Test platform was constructed to the standard height of twenty inches and handrails were added as a safety precaution.

Carpeting was provided for those parts of the experiment in which the subject was required to kneel or assume a supine position.

Timing during the experiment was insured through the use of the Resusci-Anne metronome, the Physiograph timer, and through the use of a stopwatch.

Experimental Procedure:

Prior to beginning the experiment, procedures were reviewed with the subjects. They were informed that if at anytime they felt it necessary to stop, because of injury or exhaustion, they were to do so.

In addition to various control periods in which the subjects remained relatively motionless in a supine position, there were five procedures that each subject performed. Four involved cardiopulmonary resuscitation (CPR) and the fifth was performance of a modified Harvard Step Test. Each subject performed all of the CPR procedures on the same day within a seventy-minute period but the modified Harvard Step Test was done on a separate day. The two experimental periods were scheduled within one week, in order to eliminate as much variance as possible in the physical states of the subjects from one experimental period to the next. In order to control for any residual effect of exertion from one procedure to the next, a schedule was followed in which the order of experimental activities was varied. Each volunteer was randomly assigned a number (1-30) and placed in this schedule.* Half of the subjects performed the CPR portion of the experiment first and half performed the modified Harvard Step Test first.

1) CPR Session:

The subjects were randomly paired for this part of the experiment (according to the schedule mentioned above) in order to perform the two-man resuscitation. Ten-minute control heart rates were taken initially with the subjects lying motionless on the carpeted floor. After this period, one subject would assume the role of the ventiltor and the other performed cardiac compressions for either three or six minutes (depending on the subjects position in the schedule). At the end of the prescribed time the subjects immediately returned to their supine positions and their heart rates were recorded for another ten-minute period. Two-man continuous cardiopulmonary resuscitation (CPR) was performed according to American Heart Association recommendations (1980). The mannequin's metronome was audible to the subjects, and the experimenter was permitted the liberty of coaching in order to insure standardized performance. The subjects performed four cycles as described above so that each participant did ventilations for three and six minutes and did compressions for three and six minutes. The order for each subject was randomized through the predetermined schedule.

2) Harvard Step Test Session:

Once again, control heart rates were taken initially with the

* see Appendix

subject lying on the floor. There was no pairing for this part of the experiment. After the conntrol period, the subjects performed a modified Harvard Step Test for three minutes. This involves stepping up to and down from a twenty-inch platform at the rate of thirty times per minute. A standard Harvard Step Test follows the same procedure, but is not limited to a specific time period, it is performed until the subject is too exhausted to maintain the proper stepping rate. A metronome giving a one-second count was audible to the subjects, and coaching was permitted to maintain the proper rate.

For both sessions of the experiment, wrist and ankle leads remained attached at all times.

## RESULTS

The results were compiled from recorded heart rates after each section of the experiment. Control heart rates were determined for each section of the experiment, and heart rate changes during recovery from the experimental procedures were related to these control values. These results can be found in the Appendix. Data were determined from polygraph tracings for each subject.

Each subject's control heart rates was given the value of 100 and then the proportional difference in heart rate during the recovery period was calculated. In this way, a basis for comparison can be made between subjects having different control heart rates. Tables 1 through 5 present the experimental heart rates as percentages of the control values.

In order to check for differences in control heart rates for each subject on the two different days of the experiment (i.e. the day that CPR was performed and the day the modified Harvard Step Test was done) a modified t-test was used to compare the paired data. No significant differences were found and therefore comparisons made from the different parts of the experiment after conversion to percentage values are valid. A listing of the control heart rates for each subject on both days and the statistical analysis can be found in the Appendix.

Recovery heart rates after performance of any of the CPR sessions were very similar, especially those rates after thirty seconds

Table 1

Heart Rate after Performance of the

Modified Harvard Step Test

| Subject | Control Heart Rate | Percentage of Control Heart Rate | | | | |
|---|---|---|---|---|---|---|
| | | Elapsed Time | | | | |
| | | 30 sec | 1 min | 2 min | 4 min | 8 min |
| 1 | 60 | 218 | 195 | 163 | 145 | 138 |
| 2 | 71 | 214 | 177 | 150 | 155 | 139 |
| 3 | 53 | 289 | 243 | 190 | 168 | 170 |
| 4 | 55 | 262 | 218 | 184 | 156 | 156 |
| 5 | 56 | 214 | 202 | 155 | 170 | 150 |
| 6 | 67 | 219 | 191 | 170 | 152 | 148 |
| 7 | 77 | 201 | 187 | 166 | 148 | 144 |
| 8 | 53 | 264 | 236 | 202 | 179 | 175 |
| 9 | 67 | 200 | 175 | 148 | 124 | 124 |
| 10 | 72 | 179 | 162 | 150 | 140 | 142 |
| 11 | 59 | 214 | 186 | 161 | 156 | 151 |
| 12 | 63 | 228 | 195 | 167 | 151 | 148 |
| 13 | 47 | 255 | 217 | 170 | 166 | 179 |
| 14 | 70 | 221 | 204 | 180 | 158 | 150 |
| 15 | 59 | 247 | 224 | 188 | 168 | 176 |
| 16 | 56 | 236 | 212 | 186 | 171 | 164 |
| 17 | 64 | 234 | 206 | 173 | 155 | 136 |
| 18 | 63 | 219 | 194 | 162 | 136 | 136 |
| 19 | 60 | 210 | 175 | 133 | 125 | 118 |
| 20 | 59 | 264 | 239 | 198 | 178 | 168 |
| 21 | 68 | 215 | 179 | 146 | 128 | 122 |
| 22 | 62 | 189 | 172 | 135 | 116 | 124 |
| 23 | 49 | 282 | 251 | 214 | 184 | 184 |
| 24 | 75 | 192 | 176 | 159 | 140 | 131 |
| 25 | 88 | 162 | 146 | 119 | 101 | 99 |
| 26 | 71 | 235 | 193 | 160 | 152 | 146 |
| 27 | 73 | 171 | 151 | 136 | 127 | 126 |
| 28 | 47 | 242 | 208 | 189 | 160 | 160 |
| 29 | 45 | 271 | 231 | 207 | 187 | 158 |
| 30 | 49 | 224 | 190 | 147 | 145 | 135 |
| Mean | 62 | 226 | 198 | 167 | 151 | 147 |
| S.D. | ±10 | ±32 | ±26 | ±23 | ±21 | ±33 |

Table 2

Heart Rate after Performance of the Ventilation Role

for Three Minutes of Two-Man CPR

| Subject | Control Heart Rate | Percentage of Control Heart Rate — Elapsed Time 10 sec | 15 sec | 30 sec | 1 min | 2 min | 4 min | 8 min |
|---|---|---|---|---|---|---|---|---|
| 1 | 60 | 125 | 117 | 113 | 110 | 105 | 97 | 97 |
| 2 | 70 | 111 | 108 | 107 | 103 | 103 | 100 | 98 |
| 3 | 54 | 133 | 117 | 106 | 94 | 100 | 94 | 96 |
| 4 | 54 | 148 | 139 | 139 | 126 | 111 | 104 | 100 |
| 5 | 57 | 132 | 116 | 114 | 112 | 102 | 98 | 98 |
| 6 | 67 | 143 | 131 | 116 | 112 | 103 | 98 | 101 |
| 7 | 75 | 137 | 124 | 120 | 113 | 100 | 103 | 100 |
| 8 | 54 | 133 | 122 | 111 | 117 | 106 | 100 | 100 |
| 9 | 69 | 135 | 122 | 98 | 101 | 98 | 97 | 98 |
| 10 | 70 | 128 | 120 | 106 | 106 | 100 | 98 | 98 |
| 11 | 60 | 177 | 157 | 138 | 127 | 115 | 113 | 113 |
| 12 | 66 | 138 | 121 | 108 | 103 | 102 | 100 | 100 |
| 13 | 48 | 171 | 162 | 138 | 125 | 110 | 104 | 100 |
| 14 | 69 | 133 | 117 | 109 | 104 | 101 | 100 | 98 |
| 15 | 60 | 140 | 120 | 110 | 100 | 100 | 100 | 100 |
| 16 | 54 | 167 | 150 | 111 | 111 | 100 | 94 | 96 |
| 17 | 67 | 103 | 98 | 103 | 104 | 98 | 98 | 98 |
| 18 | 66 | 130 | 118 | 114 | 103 | 100 | 98 | 98 |
| 19 | 60 | 150 | 135 | 120 | 105 | 102 | 100 | 100 |
| 20 | 59 | 144 | 130 | 120 | 103 | 102 | 98 | 98 |
| 21 | 68 | 141 | 119 | 113 | 107 | 101 | 98 | 98 |
| 22 | 61 | 124 | 111 | 108 | 111 | 105 | 102 | 100 |
| 23 | 50 | 164 | 140 | 120 | 102 | 100 | 100 | 98 |
| 24 | 74 | 138 | 124 | 114 | 104 | 104 | 99 | 100 |
| 25 | 76 | 155 | 134 | 121 | 109 | 103 | 100 | 100 |
| 26 | 70 | 128 | 116 | 110 | 106 | 98 | 94 | 93 |
| 27 | 74 | 130 | 122 | 114 | 107 | 101 | 101 | 100 |
| 28 | 49 | 151 | 126 | 112 | 102 | 102 | 102 | 100 |
| 29 | 48 | 183 | 162 | 127 | 110 | 102 | 102 | 100 |
| 30 | 53 | 158 | 142 | 117 | 108 | 102 | 100 | 100 |
| Mean | 62 | 142 | 127 | 115 | 108 | 102 | 100 | 99 |
| S.D. | ±9 | ±18 | ±15 | ±10 | ±8 | ±4 | ±4 | ±3 |

Table 3

Heart Rate after Performance of the Compression Role

for Three Minutes of Two-Man CPR

| Subject | Control Heart Rate | Percentage of Control Heart Rate — Elapsed Time | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 10 sec | 15 sec | 30 sec | 1 min | 2 min | 4 min | 8 min |
| 1 | 60 | 130 | 123 | 120 | 117 | 100 | 100 | 98 |
| 2 | 70 | 120 | 114 | 111 | 108 | 103 | 98 | 98 |
| 3 | 54 | 135 | 126 | 115 | 107 | 111 | 104 | 100 |
| 4 | 54 | 148 | 130 | 111 | 106 | 100 | 96 | 98 |
| 5 | 57 | 153 | 137 | 116 | 112 | 105 | 102 | 96 |
| 6 | 67 | 143 | 133 | 122 | 119 | 107 | 101 | 100 |
| 7 | 75 | 128 | 120 | 112 | 109 | 99 | 100 | 100 |
| 8 | 54 | 167 | 152 | 134 | 107 | 100 | 102 | 100 |
| 9 | 69 | 130 | 116 | 109 | 104 | 97 | 98 | 98 |
| 10 | 70 | 123 | 111 | 103 | 103 | 97 | 97 | 98 |
| 11 | 60 | 180 | 160 | 143 | 133 | 125 | 115 | 108 |
| 12 | 66 | 138 | 121 | 112 | 106 | 104 | 103 | 100 |
| 13 | 48 | 171 | 146 | 131 | 112 | 104 | 102 | 100 |
| 14 | 69 | 133 | 119 | 112 | 104 | 101 | 101 | 100 |
| 15 | 60 | 140 | 125 | 115 | 100 | 100 | 98 | 100 |
| 16 | 54 | 167 | 152 | 144 | 100 | 100 | 98 | 98 |
| 17 | 67 | 125 | 121 | 109 | 107 | 98 | 98 | 98 |
| 18 | 66 | 132 | 129 | 127 | 118 | 106 | 102 | 98 |
| 19 | 60 | 150 | 135 | 127 | 115 | 103 | 98 | 100 |
| 20 | 59 | 142 | 134 | 122 | 114 | 102 | 98 | 98 |
| 21 | 68 | 137 | 117 | 115 | 106 | 98 | 101 | 100 |
| 22 | 61 | 144 | 130 | 110 | 105 | 107 | 102 | 98 |
| 23 | 50 | 168 | 138 | 114 | 102 | 100 | 100 | 98 |
| 24 | 74 | 140 | 124 | 115 | 107 | 100 | 100 | 99 |
| 25 | 76 | 158 | 142 | 122 | 110 | 104 | 100 | 99 |
| 26 | 70 | 131 | 116 | 111 | 106 | 98 | 94 | 94 |
| 27 | 74 | 128 | 120 | 112 | 107 | 101 | 101 | 99 |
| 28 | 49 | 161 | 128 | 114 | 102 | 102 | 98 | 102 |
| 29 | 48 | 185 | 158 | 129 | 112 | 102 | 104 | 102 |
| 30 | 53 | 160 | 140 | 126 | 109 | 102 | 98 | 100 |
| Mean | 62 | 146 | 130 | 119 | 109 | 102 | 100 | 99 |
| S.D. | ±9 | ±18 | ±13 | ±10 | ±7 | ±5 | ±4 | ±2 |

Table 4

Heart Rate after Performance of the Ventilation Role

for Six Minutes of Two-Man CPR

| Subject | Control Heart Rate | Percentage of Control Heart Rate | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Elapsed Time | | | | | | |
| | | 10 sec | 15 sec | 30 sec | 1 min | 2 min | 4 min | 8 min |
| 1 | 60 | 135 | 130 | 125 | 120 | 110 | 105 | 100 |
| 2 | 70 | 111 | 108 | 106 | 103 | 100 | 97 | 98 |
| 3 | 54 | 133 | 115 | 104 | 111 | 106 | 100 | 98 |
| 4 | 54 | 178 | 155 | 117 | 106 | 104 | 100 | 100 |
| 5 | 57 | 137 | 132 | 119 | 110 | 105 | 98 | 93 |
| 6 | 67 | 125 | 107 | 98 | 98 | 96 | 94 | 97 |
| 7 | 75 | 141 | 137 | 124 | 108 | 104 | 99 | 99 |
| 8 | 54 | 156 | 144 | 111 | 115 | 109 | 102 | 102 |
| 9 | 69 | 139 | 126 | 122 | 113 | 106 | 100 | 100 |
| 10 | 70 | 123 | 110 | 111 | 110 | 101 | 98 | 98 |
| 11 | 60 | 180 | 153 | 143 | 128 | 123 | 115 | 110 |
| 12 | 66 | 142 | 132 | 118 | 109 | 102 | 100 | 100 |
| 13 | 48 | 185 | 154 | 129 | 110 | 104 | 100 | 98 |
| 14 | 69 | 135 | 117 | 107 | 101 | 101 | 100 | 98 |
| 15 | 60 | 140 | 113 | 108 | 100 | 100 | 93 | 98 |
| 16 | 54 | 172 | 133 | 111 | 111 | 100 | 100 | 98 |
| 17 | 67 | 119 | 118 | 104 | 101 | 104 | 100 | 98 |
| 18 | 66 | 145 | 127 | 124 | 114 | 111 | 100 | 100 |
| 19 | 60 | 152 | 140 | 122 | 110 | 103 | 100 | 98 |
| 20 | 59 | 144 | 136 | 124 | 110 | 107 | 100 | 100 |
| 21 | 68 | 144 | 128 | 110 | 106 | 101 | 101 | 100 |
| 22 | 61 | 138 | 121 | 103 | 98 | 95 | 102 | 98 |
| 23 | 50 | 166 | 132 | 102 | 100 | 100 | 100 | 96 |
| 24 | 74 | 146 | 138 | 109 | 101 | 103 | 104 | 101 |
| 25 | 76 | 160 | 145 | 126 | 110 | 105 | 103 | 100 |
| 26 | 70 | 131 | 120 | 111 | 106 | 98 | 94 | 94 |
| 27 | 74 | 132 | 123 | 115 | 107 | 101 | 101 | 100 |
| 28 | 49 | 155 | 128 | 116 | 110 | 104 | 102 | 100 |
| 29 | 48 | 190 | 164 | 129 | 110 | 102 | 100 | 100 |
| 30 | 53 | 162 | 147 | 123 | 108 | 102 | 98 | 98 |
| Mean | 62 | 147 | 131 | 116 | 108 | 104 | 100 | 99 |
| S.D. | ±9 | ±20 | ±15 | ±10 | ±6 | ±5 | ±4 | ±3 |

Table 5

Heart Rate after Performance of the Compression Role

for Six Minutes of Two-Man CPR

| Subject | Control Heart Rate | Percentage of Control Heart Rate — Elapsed Time | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 10 sec | 15 sec | 30 sec | 1 min | 2 min | 4 min | 8 min |
| 1 | 60 | 130 | 125 | 117 | 110 | 105 | 96 | 98 |
| 2 | 70 | 117 | 111 | 107 | 107 | 103 | 98 | 98 |
| 3 | 54 | 150 | 126 | 122 | 117 | 111 | 102 | 100 |
| 4 | 54 | 167 | 156 | 118 | 106 | 104 | 98 | 100 |
| 5 | 57 | 147 | 137 | 132 | 105 | 105 | 102 | 96 |
| 6 | 67 | 143 | 130 | 116 | 116 | 112 | 101 | 100 |
| 7 | 75 | 137 | 128 | 120 | 108 | 99 | 99 | 97 |
| 8 | 54 | 156 | 148 | 126 | 111 | 106 | 104 | 102 |
| 9 | 69 | 139 | 125 | 109 | 100 | 101 | 101 | 100 |
| 10 | 70 | 120 | 113 | 113 | 106 | 104 | 100 | 100 |
| 11 | 60 | 182 | 160 | 140 | 130 | 122 | 115 | 113 |
| 12 | 66 | 138 | 130 | 121 | 108 | 103 | 102 | 100 |
| 13 | 48 | 183 | 156 | 133 | 114 | 106 | 104 | 100 |
| 14 | 69 | 132 | 120 | 109 | 104 | 101 | 100 | 100 |
| 15 | 60 | 140 | 125 | 115 | 110 | 93 | 100 | 98 |
| 16 | 54 | 144 | 130 | 117 | 102 | 100 | 100 | 100 |
| 17 | 67 | 134 | 125 | 112 | 103 | 101 | 100 | 98 |
| 18 | 66 | 132 | 118 | 121 | 118 | 104 | 104 | 102 |
| 19 | 60 | 153 | 143 | 127 | 115 | 103 | 98 | 100 |
| 20 | 59 | 147 | 136 | 125 | 112 | 103 | 100 | 98 |
| 21 | 68 | 137 | 131 | 113 | 101 | 103 | 100 | 100 |
| 22 | 61 | 143 | 133 | 113 | 111 | 102 | 98 | 98 |
| 23 | 50 | 170 | 136 | 104 | 100 | 100 | 98 | 98 |
| 24 | 74 | 147 | 140 | 114 | 103 | 101 | 100 | 100 |
| 25 | 76 | 163 | 150 | 126 | 112 | 106 | 103 | 100 |
| 26 | 70 | 134 | 118 | 110 | 107 | 98 | 94 | 93 |
| 27 | 74 | 131 | 122 | 114 | 108 | 100 | 101 | 99 |
| 28 | 49 | 155 | 131 | 116 | 108 | 102 | 100 | 98 |
| 29 | 48 | 188 | 162 | 131 | 110 | 104 | 102 | 100 |
| 30 | 53 | 164 | 145 | 121 | 109 | 104 | 100 | 100 |
| Mean | 62 | 147 | 134 | 119 | 109 | 103 | 101 | 99 |
| S.D. | ±9 | ±18 | ±14 | ±8 | ±6 | ±5 | ±3 | ±3 |

of recovery time had elapsed. In contrast, much higher heart rates are seen after the modified Harvard Step Test session. Figure 1 demonstrates the mean recovery heart rates after performance of the modified Harvard Step Test and three minutes of ventilation in two-man CPR. The curves derived from these recovery heart rates illustrate the degree of disparity in heart rates from the two parts of the experiment. It should also be noted that all of the other CPR sessions produced results comparable to three minutes of ventilations.

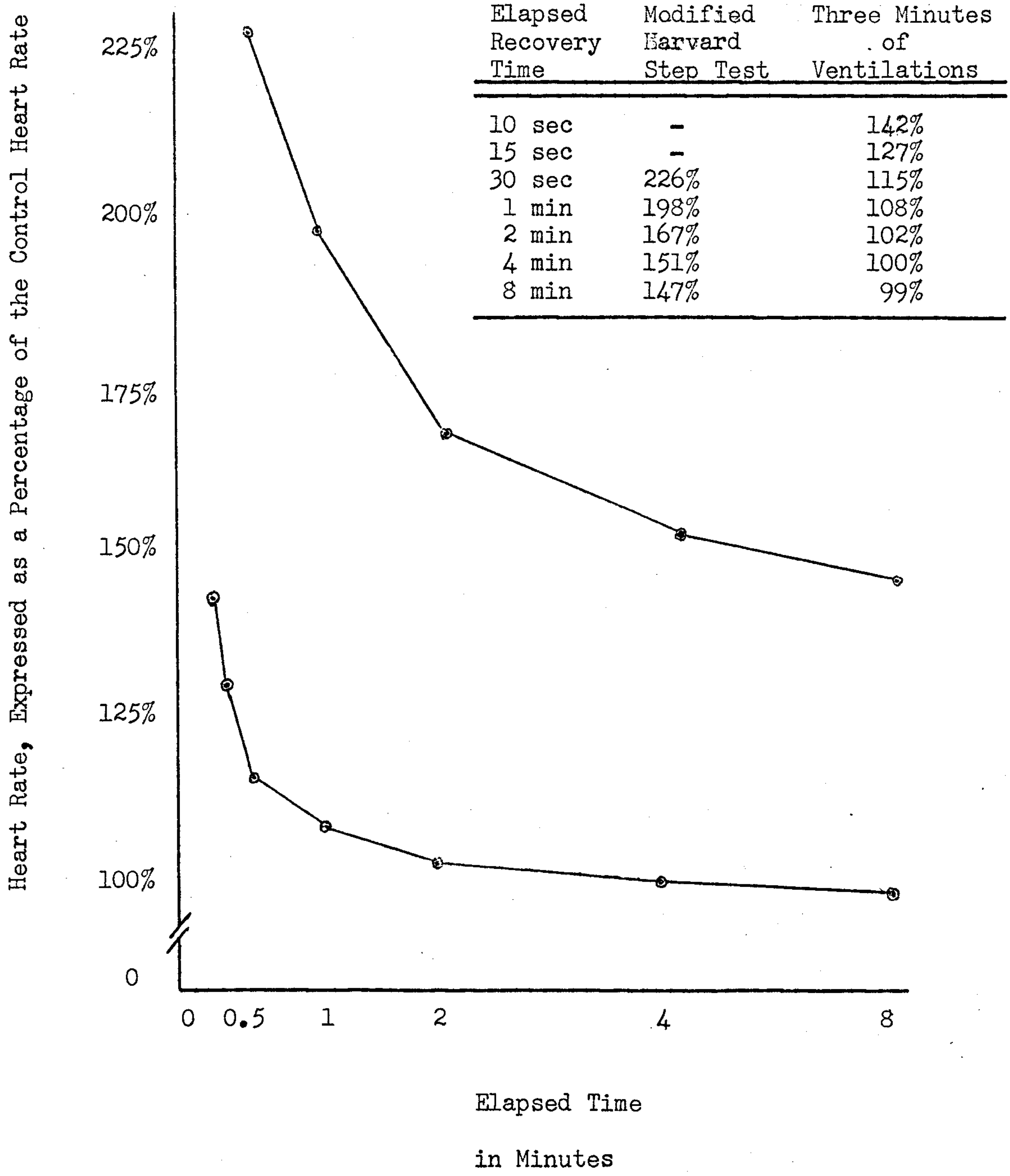
Table 6 represents the statistical analysis of the various blocks of data. Each procedure in the experiment was compared to all other procedures in order to see if any significant differences in heart rate changes could be obtained. For all these analyses, t-tests were used.

When the recovery rate from the modified Harvard Step Test was compared to the recovery rate from any of the other experimental procedures, a significant difference ($P<.001$) was always found. The heart rate after the maximal effort of the modified Harvard Step Test was consistantly much higher than the recovery rate after any of the CPR periods, even when the subjects performed the CPR procedure for twice as long as they did the Harvard Step Test.

The next comparisons made were to determine differences in recovery heart rates for subjects doing ventilations, as opposed to them performing compressions. For the three-minute CPR sessions a significant difference ($P<.05$) after ten seconds of recovery time was found in two cases, after fifteen seconds of elapsed recovery time and after thirty seconds. For both cases in the six-minute sessions and in the one

Figure 1

Mean Heart Rate during Recovery from the Modified Harvard Step Test and after Performance of the Ventilation Role for Three Minutes of Two-Man CPR




| Elapsed Recovery Time | Modified Harvard Step Test | Three Minutes of Ventilations |
|---|---|---|
| 10 sec | - | 142% |
| 15 sec | - | 127% |
| 30 sec | 226% | 115% |
| 1 min | 198% | 108% |
| 2 min | 167% | 102% |
| 4 min | 151% | 100% |
| 8 min | 147% | 99% |

Table 6: Comparison of Heart Rate Changes During Recovery from Experimental Procedures

| | | | Elapsed Recovery Time | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 10 sec | 15 sec | 30 sec | 1 min | 2 min | 4 min | 8 min |
| A | Harvard Step Test | mean percentage of base rate | - | - | 226 | 198 | 167 | 151 | 147 |
| | | ± standard deviation | - | - | ±32 | ±26 | ±23 | ±21 | ±33 |
| B | Ventilations 3 min | mean percentage of base rate | 142 | 127 | 115 | 108 | 102 | 100 | 99 |
| | | ± standard deviation | ±18 | ±15 | ±10 | ±8 | ±4 | ±4 | ±3 |
| C | Compressions 3 min | mean percentage of base rate | 146 | 130 | 119 | 109 | 102 | 100 | 99 |
| | | ± standard deviation | ±18 | ±13 | ±10 | ±7 | ±5 | ±4 | ±2 |
| D | Ventilations 6 min | mean percentage of base rate | 147 | 131 | 116 | 108 | 104 | 100 | 99 |
| | | ± standard deviation | ±20 | ±15 | ±10 | ±6 | ±5 | ±4 | ±3 |
| E | Compressions 6 min | mean percentage of base rate | 147 | 134 | 119 | 109 | 103 | 101 | 99 |
| | | ± standard deviation | ±18 | ±14 | ±8 | ±6 | ±5 | ±3 | ±3 |
| Probability Values | | A vs B, C, D, or E | - | - | P<.001* | P<.001* | P<.001* | P<.001* | P<.001* |
| | | B vs C | P<.05* | P≥.08 | P≥.06 | P≥.5 | P≥.9 | P≥.3 | P≥.8 |
| | | B vs D | P<.01* | P≥.06 | P≥.7 | P≥.9 | P≥.2 | P≥.5 | P≥.6 |
| | | C vs E | P≥.2 | P≥.06 | P≥.9 | P≥.9 | P≥.09 | P≥.5 | P≥.3 |
| | | D vs E | P≥.8 | P<.05* | P<.05* | P≥.4 | P≥.9 | P≥.4 | P≥.1 |

instance in the three-minute sessions, compressions had raised the heart rate to a higher level than the ventilations did. In fact, a trend can be seen in the data. Although differences were statistically significant in only three cases, in eight out of fourteen cases the mean heart rates during recovery from compression periods were higher than those during recovery from ventilation periods. In five other cases the mean values were identical. In only one case (after two minutes of recovery in the six-minute session) was the mean value during recovery from performance of ventilations greater than the mean heart rate after performance of compressions.

The last set of comparisons tested for differences in recovery heart rates for subjects performing the same task, but for different periods of time. When comparing the six and three-minute CPR sessions with regard to the effect of the compressions, no significant differences could be found. However, when checking for these same differences with regard to ventilations, a significant difference ($P<.01$) was found after ten seconds of elapsed time. Ventilations for six minutes resulted in a faster heart rate at the ten-second reading.

## DISCUSSION

All subjects performed two-man resuscitation in the four CPR procedures of the experiment, assuming the role of the ventilator for three and six-minute periods, and performing cardiac compressions for similar periods of time. Except for the length of the CPR sessions, performance of compressions was the same during the three-minute and six-minute periods, therefore, any differences in physical exertion during performance of identical CPR roles would have to be attributed to the variation in time. Any differences found in comparisons of dissimilar roles in CPR would have to be attributed to the different procedures performed, because the time periods and other variables were made consubstantial. In addition to the CPR procedures, the subjects performed a modified Harvard Step Test for three minutes. The Harvard Step Test is a standardized maximal exercise test, as defined by Wenger (1980) and is used to compare efforts from various activities with levels of exertion from the step test. Although, in this experiment, the Harvard Step Test was modified by placing a three minute time limit on its performance, no subjects were able to maintain the proper pace for the entire three minutes. It can therefore be said that, as performed in this experiment, the modified Harvard Step Test was a maximal stress test. Thus, physical exertion from the CPR procedures was compared to exertion from a standardized maximal exercise test.

Heart rate has been established as an indicator of the level of physical exertion by Spiro and his co-workers (1974), Jones, et al (1975) and many others. Heart rates after performance of each procedure were converted to percentages of the control (resting) heart rate, and these percentage values were compared utilizing t-tests.

In the comparison of the three-minute and the six-minute periods in which the subjects performed ventilations, a significant difference in exertion as measured by heart rate, was found only after ten seconds of recovery time had elapsed. As was expected, a faster heart rate at the ten-second recording was achieved after ventilations were performed for six minutes. When compressions were compared in this manner, no statistical differences were found. The absence of any differences in the two compression periods is probably best explained by a plateau effect. At the end of three minutes, a "steady-state" had been achieved in which physiologically, the body had established an equilibrium above the resting level, in which continued exertion at the same level would produce no significant increase in heart rate or other adaptive functions during the extended time period. This is in agreement with the observations of Spiro, et al (1974), regarding regulation of heart rate and cardiac ouput at a constant level of work.

When exertion from ventilations was compared to exertion from compressions, significant differences were found in three cases: after ten seconds in the three-minute periods, and after fifteen seconds and thirty seconds in the six-minute periods. In all cases, the performance of compressions produced a faster heart rate, as was expected. The performance of compressions "felt" more difficult to the subjects and to the observer it does appear that the compressor does more work than the ventilator. It is interesting to note however, that at the initial reading, after ten seconds for the six-minute periods, heart rate from compressions and ventilations were virtually identical, even though there were significant differences after fifteen and thirty seconds. This can be explained if the type of work being done is considered. Compressions are basically a normal exercise in which many different factors operate to increase the rescuer's cardiac output. These factors include: 1) sympathetic stimulation which increases myocardial function and also increases the mean systemic pressure; 2) contraction of the muscles around the blood vessels which further increases the mean systemic pressure; and 3) dilation of the resistance vessels in the muscles which decreases the resistance to venous return. In performance of compressions all these factors work together to increase cardiac output. Performance of ventilations introduces a negative factor in this efficient system. Breathing against a positive pressure, such as in performance of ventilations, causes a more positive right atrial pressure. In a functioning circulatory system, the greater the difference between the mean systemic pressure and the right atrial pressure, the greater the venous return becomes. The difference between these two pressures is the pressure gradient for venous return. It is obvious that venous return from the systemic circulation must equal the cardiac output from the heart. In the performance of ventilations, resistance from increased intrathoracic pressure causes a decreased venous return, and in doing that, a decreased cardiac output due to increased right atrial pressure. The other factors noted above that operate during exercise to increase the cardiac output must exert an even greater effect in order to balance the effect of the increased intrapleural pressure during ventilations. It is most likely that it is this compensation that is being demonstrated at the ten-second heart rate reading, after performance of six minutes of ventilations.

When the heart rate during recovery from the modified Harvard Step Test was compared to the heart rate during recovery from any of the CPR procedures, the modified Harvard Step Test was always found to be significantly greater. Constant (1980) states that a good estimate of predicted maximal heart rate is obtained by subtracting the subject's age from two hundred and twenty. In studying performance of the double Master's test, Constant has found that most subjects will reach a heart rate approximately eighty-five percent of their predicted maximal heart rate. The double Master's is a submaximal exercise test, whereas the modified Harvard Step Test, as performed in this experiment, is a maximal exercise test, designed to raise the heart rate even closer to the predicted maximal rate. Therefore, at the end of the performance of the modified Harvard Step Test, it can be said that the heart rates of the subjects were between eighty-five and one hundred percent of the predicted maximal heart rate. If the curves from Figure 1 of the previous section are extrapolated to the y-axis (i.e. no time elapsed after completion of the experimental procedure) heart rate at completion of ventilations would reach approximately two-hundred percent of the control rate, and heart rate at the end of performance of the modified Harvard Step Test would be approximately three hundred and twenty percent of the control rate. The mean control heart rate for both procedures in Figure 1 was sixty-two, therefore the approximate mean heart rates at the end of performance of the modified Harvard Step Test and three minutes of ventilations would be one hundred and ninety-eight and one hundred and twenty-four respectively. In following Constant's formula, as noted above, with a mean age of just under twenty-five, the experimental value from the modified Harvard Step Test can be seen to be very close to the predicted maximal value of one hundred and ninety-five. Although the experimental value is actually higher than the predicted maximal heart rate, this is not abnormal. Ellestad (1980) states that in patients who are physically fit, the maximal predicted heart rate is often slightly exceeded. In addition to the results from the modified Harvard Step Test, it can also be seen that the heart rate at the end of three minutes of ventilations can be seen to be approximately sixty percent of the predicted maximal heart rate.

Performance of CPR, as evidenced in this experiment, cannot be classified as an extremely strenuous exercise, but has been shown to be moderately strenuous. Heart rates often doubled during performance of CPR and reached approximately sixty percent of their predicted maximal rates. In normal healthy individuals this presents no danger, but in persons with compromised cardiovascular systems caution should be used before any performance of CPR. Ellestad (1980) reported several cases in which patients died during or immediately after stress testing. Heart rates achieved during testing in these cases ranged from ninety-eight to sixty-three percent of their predicted maximal rates as determined by Ellestad. The exertion from the mere physical work during CPR performance, as determined by this experiment, approaches this range very closely. Additional stress from an actual life-and-death situation in which individuals may be called upon to perform CPR would most likely place a much greater load on the heart through emotional influences mediated by the autonomic nervous system. Bruhn, et al (1970) reported that cardiac patients who witness an arrest have definite increases in systolic blood pressure, heart rate, and anxiety levels. It is likely that this amount of stress could prove hazardous to some individuals. Scherer and Kaltenbach (1979) further demonstrate this need for caution through a study of the frequency of life-threatening complications associated with stress testing. In examining 353,638 cases of submaximal stress testing in normal or athletic individuals, no deaths or life-threatening complications were found. However, in studying 712,285 cases involving coronary patients, approximately four deaths per thousand patients and seventy-four life-threatening complications per ten thousand patients were reported.

Ellestad (1980) has set up guidelines for contraindications for stress testing and these guidelines seem very appropriate for use as contraindications for CPR training. These guidelines are divided into absolute contraindications and relative contraindications. Absolute contraindications include: 1) patients with an acute myocardial infarction; 2) patients suffering from an acute myocarditis or pericarditis; 3) patients exhibiting signs of unstable progressive angina (this includes the patient who has long periods of angina of fairly recent onset while at rest); 4) patients with rapid ventricular or atrial arrhythmias; 5) patients with second or third degree heart block; 6) patients with congestive heart failure; and 7) acutely ill patients, such as those with infections, hyperthyroidism, or severe anemia. The relative contraindications include: 1) aortic stenosis; 2) left main coronary disease or left main equivalent (very high grade proximal obstruction in branches of the left coronary artery); 3) severe hypertension; 4) idiopathic subaortic stenosis and asymmetric septal hypertrophy; 5) severe S-T segment depression at rest; and 6) compensated congestive heart failure. All individuals falling into the second major category (i.e. relative contraindications for CPR performance) should consult with a physician prior to beginning any CPR training. Also it would be advisable to have a physician and an emergency kit adjacent to the training area if compromised individuals are performing CPR procedures.

Research in this field has been extremely limited. Further studies should include heart rates recorded during performance of CPR and electrocardiographic analysis of coronary patients performing CPR as compared with healthy individuals. Until such time as more definitive informations is available regarding stress during performance of CPR, the guidelines above probably will help determine those individuals at greatest risk in performance of CPR.

Finally, some suggestions may be helpful to persons planning to teach CPR to cardiac patients. Abbot (1978) recommended that only patients who have been in an exercise pregram for a minimum of three months be given the opportunity for CPR training. This may give the patient some valuable experience in pacing himself within a safe heart rate range. Also, caution should be used during CPR practice sessions in which patients learn ventilation techniques. Participants should be specifically warned and often reminded not to attempt forceful blowing against resistance which may occur if the mannequin's head is not fully extended. Also, rhythmic patterns should be encouraged and patients should be required to count time (i.e. 1-1,000, 2-2,000, etc.) out loud in order to avoid possible hypertensive responses that could occur if chest compressions were performed while holding one's breath.

## SUMMARY

Levels of physical exertion experienced by rescuers performing two-man CPR were studied. Subjects performed ventilations for periods of three minutes and six minutes, and compressions for similar periods of time. In addition to the CPR procedures, the subjects performed a modified Harvard Step Test for three minutes. Heart rate was the parameter measured in this study as the indicator of physical exertion and was recorded during recovery periods after the subjects had performed each part of the experiment. The recovery heart rates were related to the control (resting) heart rate of each subject for purposes of analysis. Statistical comparisons were made between the various CPR procedures and between the CPR procedures and the modified Harvard Step Test. In only one case out of fourteen was a significant difference found in recovery heart rates after performance of CPR for three minutes and for six minutes. In this isolated case, the six-minute period caused a greater increase in heart rate than did the three-minute period. Exertion from compressions was also compared to exertion from ventilations. In those cases that proved to have significant differences, compressions increased the heart rate to a greater extent than did ventilations. In all of the CPR comparisons, all differences were found within the first minute of recovery time. Finally, exertion from the various aspects of two-man CPR was compared to the modified Harvard Step Test, a standardized maximal exercise test. There were significant

differences in every comparison made between the CPR procedures and the modified Harvard Step Test. In examining these differences, it can be demonstrated that although CPR is not maximally exerting, it appears to be moderately stressful and should be considered potentially hazardous for those with compromised cardiovascular systems. Ellestad (1980) has presented some guidelines to help identify those individuals who might face some risk if they were to participate in cardiac stress testing. These guidelines seem appropriate to identify those at risk in performance of CPR, as the physical exertion in performance of CPR is similar to or less than the stress from some types of stress testing.

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# APPENDIX

Table 7: Experimental Schedule

Subjects were randomly assigned numbers from one to thirty. Numbers one through fifteen performed the Harvard Step Test prior to the CPR procedures, and sixteen through thirty had the CPR session first.

Pairing for Two-Man CPR

| | | |
|---|---|---|
| 1-2 | 11-12 | 21-22 |
| 3-4 | 13-14 | 23-24 |
| 5-6 | 15-16 | 25-26 |
| 7-8 | 17-18 | 27-28 |
| 9-10 | 19-20 | 29-30 |

Sequence of Performance of the Four CPR Sessions

| | CPR Procedure Performed by the Subject | | | |
|---|---|---|---|---|
| | Ventilations 3 minutes | Compressions 3 minutes | Ventilations 6 minutes | Compressions 6 minutes |
| First CPR Session | 1,5,9,13, 17,21,25,29 | 2,6,10,14, 18,22,26,30 | 3,7,11,15, 19,23,27 | 4,8,12,16, 20,24,28 |
| Second CPR Session | 2,8,12,16, 18,24,28 | 1,7,11,15, 17,23,27 | 4,6,10,14, 20,22,26,30 | 3,5,9,13, 19,21,25,29 |
| Third CPR Session | 3,5,11,13, 19,21,27,29 | 4,6,12,14, 20,22,28,30 | 1,7,8,15, 17,23,25 | 2,8,10,16, 18,24,26 |
| Fourth CPR Session | 4,8,10,16, 20,24,26 | 3,7,9,15, 19,23,25 | 2,6,12,14, 18,22,28,30 | 1,5,11,13, 17,21,27,29 |

Table 8: Heart Rate after Performance of the Harvard Step Test

| Subject | Control Heart Rate | Heart Rate During Recovery — Elapsed Time: 30 sec | 1 min | 2 min | 4 min | 8 min |
|---|---|---|---|---|---|---|
| 1 | 60 | 131 | 117 | 98 | 87 | 83 |
| 2 | 71 | 152 | 126 | 113 | 110 | 99 |
| 3 | 53 | 153 | 129 | 101 | 89 | 90 |
| 4 | 55 | 144 | 120 | 101 | 86 | 86 |
| 5 | 56 | 120 | 113 | 87 | 95 | 84 |
| 6 | 67 | 147 | 128 | 114 | 102 | 99 |
| 7 | 77 | 155 | 144 | 128 | 114 | 111 |
| 8 | 53 | 140 | 125 | 107 | 95 | 93 |
| 9 | 67 | 134 | 117 | 99 | 83 | 83 |
| 10 | 72 | 129 | 117 | 108 | 101 | 102 |
| 11 | 59 | 126 | 110 | 95 | 92 | 89 |
| 12 | 63 | 144 | 123 | 105 | 95 | 93 |
| 13 | 47 | 120 | 102 | 80 | 78 | 84 |
| 14 | 70 | 155 | 143 | 126 | 111 | 105 |
| 15 | 59 | 146 | 132 | 111 | 99 | 104 |
| 16 | 56 | 132 | 119 | 104 | 96 | 92 |
| 17 | 64 | 150 | 132 | 111 | 99 | 87 |
| 18 | 63 | 138 | 122 | 102 | 86 | 86 |
| 19 | 60 | 126 | 105 | 80 | 75 | 71 |
| 20 | 59 | 156 | 141 | 117 | 105 | 99 |
| 21 | 68 | 146 | 122 | 99 | 87 | 83 |
| 22 | 62 | 117 | 107 | 84 | 72 | 77 |
| 23 | 49 | 138 | 123 | 105 | 90 | 90 |
| 24 | 75 | 144 | 132 | 119 | 105 | 98 |
| 25 | 88 | 143 | 129 | 105 | 89 | 87 |
| 26 | 71 | 167 | 137 | 114 | 108 | 104 |
| 27 | 73 | 125 | 110 | 99 | 93 | 92 |
| 28 | 47 | 114 | 98 | 89 | 75 | 75 |
| 29 | 45 | 122 | 104 | 93 | 84 | 71 |
| 30 | 49 | 110 | 93 | 72 | 71 | 66 |

The recovery heart rates are converted to percentages of the control rate in Table 1.

Table 9: Heart Rate after Performance of the Ventilation Role for Three Minutes of Two-Man CPR

| Subject | Control Heart Rate | Heart Rate During Recovery — Elapsed Time | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 10 sec | 15 sec | 30 sec | 1 min | 2 min | 4 min | 8 min |
| 1 | 60 | 75 | 70 | 68 | 66 | 63 | 58 | 58 |
| 2 | 70 | 78 | 76 | 75 | 72 | 72 | 70 | 69 |
| 3 | 54 | 72 | 63 | 57 | 51 | 54 | 51 | 52 |
| 4 | 54 | 80 | 75 | 75 | 68 | 60 | 56 | 54 |
| 5 | 57 | 75 | 66 | 65 | 64 | 58 | 56 | 56 |
| 6 | 67 | 96 | 88 | 78 | 75 | 69 | 66 | 68 |
| 7 | 75 | 103 | 93 | 90 | 85 | 75 | 77 | 75 |
| 8 | 54 | 72 | 66 | 60 | 63 | 57 | 54 | 54 |
| 9 | 69 | 93 | 84 | 68 | 70 | 68 | 67 | 68 |
| 10 | 70 | 90 | 84 | 74 | 74 | 70 | 69 | 69 |
| 11 | 60 | 106 | 94 | 83 | 76 | 69 | 68 | 68 |
| 12 | 66 | 91 | 80 | 71 | 68 | 67 | 66 | 66 |
| 13 | 48 | 82 | 78 | 66 | 60 | 53 | 50 | 48 |
| 14 | 69 | 92 | 81 | 75 | 72 | 70 | 69 | 68 |
| 15 | 60 | 84 | 72 | 66 | 60 | 60 | 60 | 60 |
| 16 | 54 | 90 | 81 | 60 | 60 | 54 | 51 | 52 |
| 17 | 67 | 69 | 66 | 69 | 70 | 66 | 66 | 66 |
| 18 | 66 | 86 | 78 | 75 | 68 | 66 | 65 | 65 |
| 19 | 60 | 90 | 81 | 72 | 63 | 61 | 60 | 60 |
| 20 | 59 | 85 | 77 | 71 | 61 | 60 | 58 | 58 |
| 21 | 68 | 96 | 81 | 77 | 73 | 69 | 67 | 67 |
| 22 | 61 | 76 | 68 | 66 | 68 | 64 | 62 | 61 |
| 23 | 50 | 82 | 70 | 60 | 51 | 50 | 50 | 49 |
| 24 | 74 | 102 | 92 | 84 | 77 | 77 | 73 | 74 |
| 25 | 76 | 118 | 102 | 92 | 83 | 78 | 76 | 76 |
| 26 | 70 | 90 | 81 | 77 | 74 | 69 | 66 | 65 |
| 27 | 74 | 96 | 90 | 84 | 79 | 75 | 75 | 74 |
| 28 | 49 | 74 | 62 | 55 | 50 | 50 | 50 | 49 |
| 29 | 48 | 88 | 78 | 61 | 53 | 49 | 49 | 48 |
| 30 | 53 | 84 | 75 | 62 | 57 | 54 | 53 | 53 |

The recovery heart rates are converted to percentages of the control rates in Table 2.

Table 10: Heart Rate after Performance of the Compression Role for Three Minutes of Two-Man CPR

| Subject | Control Heart Rate | Heart Rate During Recovery — Elapsed Time | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 10 sec | 15 sec | 30 sec | 1 min | 2 min | 4 min | 8 min |
| 1 | 60 | 78 | 74 | 72 | 70 | 60 | 60 | 59 |
| 2 | 70 | 84 | 80 | 78 | 76 | 72 | 69 | 69 |
| 3 | 54 | 73 | 68 | 62 | 58 | 60 | 56 | 54 |
| 4 | 54 | 80 | 70 | 60 | 57 | 54 | 52 | 53 |
| 5 | 57 | 87 | 78 | 66 | 64 | 60 | 58 | 55 |
| 6 | 67 | 96 | 89 | 82 | 80 | 72 | 68 | 67 |
| 7 | 75 | 96 | 90 | 84 | 82 | 74 | 75 | 75 |
| 8 | 54 | 90 | 82 | 72 | 58 | 54 | 55 | 54 |
| 9 | 69 | 90 | 80 | 75 | 72 | 67 | 68 | 68 |
| 10 | 70 | 86 | 78 | 72 | 72 | 68 | 68 | 69 |
| 11 | 60 | 108 | 96 | 86 | 80 | 75 | 69 | 65 |
| 12 | 66 | 91 | 80 | 74 | 70 | 69 | 68 | 66 |
| 13 | 48 | 82 | 70 | 63 | 54 | 50 | 49 | 48 |
| 14 | 69 | 92 | 82 | 77 | 72 | 70 | 70 | 69 |
| 15 | 60 | 84 | 75 | 69 | 60 | 60 | 59 | 60 |
| 16 | 54 | 90 | 82 | 78 | 54 | 54 | 53 | 53 |
| 17 | 67 | 84 | 81 | 73 | 72 | 66 | 66 | 66 |
| 18 | 66 | 87 | 85 | 84 | 78 | 70 | 67 | 65 |
| 19 | 60 | 90 | 81 | 76 | 69 | 62 | 59 | 60 |
| 20 | 59 | 84 | 79 | 72 | 67 | 60 | 58 | 58 |
| 21 | 68 | 93 | 81 | 78 | 72 | 67 | 69 | 69 |
| 22 | 61 | 88 | 79 | 67 | 64 | 65 | 62 | 60 |
| 23 | 50 | 84 | 69 | 57 | 51 | 51 | 50 | 49 |
| 24 | 74 | 104 | 92 | 85 | 79 | 74 | 74 | 73 |
| 25 | 76 | 120 | 108 | 93 | 84 | 79 | 76 | 75 |
| 26 | 70 | 92 | 81 | 78 | 74 | 69 | 66 | 66 |
| 27 | 74 | 95 | 89 | 83 | 79 | 75 | 75 | 73 |
| 28 | 49 | 79 | 63 | 56 | 50 | 50 | 48 | 49 |
| 29 | 48 | 89 | 76 | 62 | 54 | 49 | 50 | 49 |
| 30 | 53 | 85 | 74 | 67 | 58 | 54 | 52 | 53 |

The recovery heart rates are converted to percentages of the control rates in Table 3.

Table 11: Heart Rate after Performance of the Ventilation Role for Six Minutes of Two-Man CPR

| Subject | Control Heart Rate | Heart Rate During Recovery — Elapsed Time | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 10 sec | 15 sec | 30 sec | 1 min | 2 min | 4 min | 8 min |
| 1 | 60 | 81 | 78 | 75 | 72 | 66 | 63 | 60 |
| 2 | 70 | 78 | 76 | 74 | 72 | 70 | 68 | 69 |
| 3 | 54 | 72 | 62 | 56 | 60 | 57 | 54 | 53 |
| 4 | 54 | 96 | 84 | 63 | 57 | 56 | 54 | 54 |
| 5 | 57 | 78 | 75 | 68 | 63 | 60 | 56 | 53 |
| 6 | 67 | 84 | 72 | 66 | 66 | 64 | 63 | 65 |
| 7 | 75 | 106 | 103 | 93 | 81 | 78 | 74 | 74 |
| 8 | 54 | 84 | 78 | 60 | 62 | 59 | 55 | 55 |
| 9 | 69 | 96 | 87 | 84 | 78 | 73 | 69 | 69 |
| 10 | 70 | 86 | 77 | 78 | 77 | 71 | 69 | 69 |
| 11 | 60 | 104 | 92 | 86 | 77 | 74 | 69 | 66 |
| 12 | 66 | 94 | 87 | 78 | 72 | 67 | 66 | 66 |
| 13 | 48 | 88 | 74 | 62 | 53 | 50 | 48 | 47 |
| 14 | 69 | 93 | 81 | 74 | 70 | 70 | 69 | 68 |
| 15 | 60 | 84 | 68 | 65 | 60 | 60 | 56 | 59 |
| 16 | 54 | 93 | 72 | 60 | 60 | 54 | 54 | 53 |
| 17 | 67 | 80 | 79 | 70 | 63 | 70 | 67 | 66 |
| 18 | 66 | 96 | 84 | 82 | 75 | 73 | 66 | 66 |
| 19 | 60 | 91 | 84 | 73 | 66 | 62 | 60 | 59 |
| 20 | 59 | 85 | 80 | 73 | 65 | 63 | 59 | 59 |
| 21 | 68 | 98 | 87 | 75 | 72 | 69 | 69 | 68 |
| 22 | 61 | 84 | 74 | 63 | 60 | 58 | 62 | 60 |
| 23 | 50 | 83 | 66 | 51 | 50 | 50 | 50 | 48 |
| 24 | 74 | 108 | 102 | 81 | 75 | 76 | 77 | 75 |
| 25 | 76 | 122 | 110 | 96 | 84 | 80 | 78 | 76 |
| 26 | 70 | 92 | 84 | 78 | 74 | 69 | 66 | 66 |
| 27 | 74 | 98 | 91 | 85 | 79 | 75 | 75 | 74 |
| 28 | 49 | 76 | 63 | 57 | 54 | 51 | 50 | 49 |
| 29 | 48 | 91 | 79 | 62 | 53 | 49 | 48 | 48 |
| 30 | 53 | 86 | 78 | 65 | 57 | 54 | 52 | 52 |

The recovery heart rates are converted to percentages of the control rates in Table 4.

Table 12: Heart Rate after Performance of the Compression Role for Six Minutes of Two-Man CPR

| Subject | Control Heart Rate | Heart Rate During Recovery — Elapsed Time: 10 sec | 15 sec | 30 sec | 1 min | 2 min | 4 min | 8 min |
|---|---|---|---|---|---|---|---|---|
| 1 | 60 | 78 | 75 | 70 | 66 | 63 | 58 | 59 |
| 2 | 70 | 82 | 78 | 75 | 75 | 72 | 69 | 69 |
| 3 | 54 | 81 | 68 | 66 | 63 | 60 | 55 | 54 |
| 4 | 54 | 90 | 84 | 64 | 57 | 56 | 53 | 54 |
| 5 | 57 | 84 | 78 | 75 | 60 | 60 | 58 | 55 |
| 6 | 67 | 96 | 87 | 78 | 78 | 75 | 68 | 67 |
| 7 | 75 | 103 | 96 | 90 | 81 | 73 | 74 | 73 |
| 8 | 54 | 84 | 80 | 68 | 60 | 57 | 56 | 55 |
| 9 | 69 | 96 | 86 | 75 | 69 | 70 | 70 | 69 |
| 10 | 70 | 84 | 79 | 79 | 74 | 73 | 70 | 70 |
| 11 | 60 | 109 | 96 | 84 | 78 | 73 | 69 | 68 |
| 12 | 66 | 91 | 86 | 80 | 71 | 68 | 67 | 66 |
| 13 | 48 | 88 | 75 | 64 | 55 | 51 | 50 | 48 |
| 14 | 69 | 91 | 83 | 75 | 72 | 70 | 69 | 69 |
| 15 | 60 | 84 | 75 | 69 | 66 | 56 | 60 | 59 |
| 16 | 54 | 78 | 70 | 63 | 55 | 54 | 54 | 54 |
| 17 | 67 | 90 | 84 | 75 | 69 | 68 | 67 | 66 |
| 18 | 66 | 87 | 78 | 80 | 78 | 69 | 67 | 66 |
| 19 | 60 | 92 | 86 | 76 | 69 | 62 | 59 | 60 |
| 20 | 59 | 87 | 80 | 74 | 66 | 61 | 59 | 58 |
| 21 | 68 | 93 | 89 | 77 | 69 | 70 | 68 | 68 |
| 22 | 61 | 87 | 81 | 69 | 68 | 62 | 60 | 60 |
| 23 | 50 | 85 | 68 | 52 | 50 | 50 | 49 | 49 |
| 24 | 74 | 109 | 104 | 84 | 76 | 75 | 74 | 74 |
| 25 | 76 | 124 | 114 | 96 | 85 | 81 | 78 | 76 |
| 26 | 70 | 94 | 83 | 77 | 75 | 69 | 66 | 65 |
| 27 | 74 | 97 | 90 | 84 | 80 | 74 | 75 | 73 |
| 28 | 49 | 76 | 64 | 57 | 53 | 50 | 49 | 48 |
| 29 | 48 | 90 | 78 | 63 | 53 | 50 | 49 | 48 |
| 30 | 53 | 87 | 77 | 64 | 58 | 55 | 53 | 53 |

The recovery heart rates are converted to percentages of the control rates in Table 5.

Table 13: Comparison of Control Heart Rates from the Two Experimental Sessions

| Subject | Modified Harvard Step Test Control Heart Rate | CPR Control Heart Rate |
|---|---|---|
| 1 | 60 | 60 |
| 2 | 71 | 70 |
| 3 | 53 | 54 |
| 4 | 55 | 54 |
| 5 | 56 | 57 |
| 6 | 67 | 67 |
| 7 | 77 | 75 |
| 8 | 53 | 54 |
| 9 | 67 | 69 |
| 10 | 72 | 70 |
| 11 | 59 | 60 |
| 12 | 63 | 66 |
| 13 | 47 | 48 |
| 14 | 70 | 69 |
| 15 | 59 | 60 |
| 16 | 56 | 54 |
| 17 | 64 | 67 |
| 18 | 63 | 66 |
| 19 | 60 | 60 |
| 20 | 59 | 59 |
| 21 | 68 | 68 |
| 22 | 62 | 61 |
| 23 | 49 | 50 |
| 24 | 75 | 74 |
| 25 | 88 | 76 |
| 26 | 71 | 70 |
| 27 | 73 | 74 |
| 28 | 47 | 49 |
| 29 | 45 | 48 |
| 30 | 49 | 53 |
| Mean | 62 | 62 |
| Standard Deviation | ±10 | ±9 |
| Probability Value | $P>.9$ | |

Null Hypothesis = Control Heart Rates have significant differences.

As P is not $<0.05$, there are no significant differences in the Control Heart Rates.

APPROVAL SHEET

The thesis submitted by Edmund A. Lipskis has been read and approved by the following committee:

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The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the Committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Masters of Science in Oral Biology.

January 29, 1981
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