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A DETERMINATION OF THE ENERGY COST OF GOLF DURING PLAY

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

Shirley Frances McGill, B.A., M.S.

* * * * *

The Ohio State University
1963

Approved by

[Signature]

Adviser

Department of Physical Education
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CHAPTER I

INTRODUCTION

Energy is required by the human body for every aspect of living. The amount of energy expended varies with the activity performed. For some people this expenditure covers a wide range, from sleeping to hard manual labor. The daily activities of others may cost very little energy. Man was made for movement, made to spend rather than hoard the currency of energy. Wise investment of such funds in activity contributes to the structure and function of the organism. Miserly saving impairs both.

Physical education is concerned with many of the activities in which energy is expended and with the cost to the person performing them. The physiological cost of sports activities has been of interest to physical educators for a number of years. The usual methods of assessing energy cost of activity may be found in texts of exercise physiology\(^1\) or medical physiology.\(^2\) By the use of one of these methods the

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energy expended while walking, running, or bicycling can be measured in the laboratory. Study of the energy cost of active sports, however, has been limited by the measuring apparatus used.³

Statement of the problem

This study was undertaken to utilize a method of measuring energy cost that can be applied to active sports participation. The immediate purpose of the study was to determine the energy expended in golf during play.

Limitations of the study

This study was made of two women students who were members of the Women's Golf Club at The Ohio State University during the year 1962-1963. A third subject included in preliminary runs had to withdraw from the study. Both subjects completing the study participated in the Midwest Collegiate Golf Tournament for Women in May, 1963, and one (DR) participated in the National Women's Collegiate Golf Tournament in June, 1963. Assessment of energy expenditure was made on the basis of nine holes of play for one subject (DR) and on the basis of four holes of play for the other subject (JW).⁴ The


⁴Recording was terminated in the middle of the round because of battery failure.
previous average score of subject J.W. was 110, and the
average score of subject D.R. was 86. Both subjects played
on the Scarlet Course of The Ohio State University Golf
Course, May 29, 1963, and both carried their own golf bags.

Significance

Studies of energy expenditure in exercise provide
information that is useful in determining a proper diet as
well as prescribing for activity needs. Mayer has shown
that a balance of food intake and energy output is extremely
important if not essential to the prevention of overweight.
Karpovich notes an increasing concern about our sedentary
life and expresses the hope that some day the science of
physical education will prescribe physical activities for
all in measured amounts and according to individual needs.
The physical therapist is interested in exact prescriptions
of activity as pointed out by Murphy in a report to the
Therapeutic Section of the American Association of Health,
Physical Education, and Recreation. Activity for patients
with certain types of heart disorders is coming to be an
accepted phase of treatment.

5Jean Mayer, Science and Medicine of Exercise and Sports,
pp. 301-309.

6Karpovich, op. cit., p. 93.

6KarpovichMurphy, "An Examination of the Need for Research
in Corrective Therapy and Adapted Physical Education," A
Report to the Therapeutic Section, American Association for
Physical education and sports programs deal with group activity. Determination of the dosage of activity in kind and amount to be recommended for any particular group at a given time should be based on an analysis of the health status of each individual and an estimation of the energy requirements of the activity. Information on health status is provided by a medical examination. Energy requirements for many types of activities can be calculated from the material of Dill, Passmore and Durnin, and Karpovich. The energy expended in walking, running, bicycling, and working at various kinds of industrial tasks has been studied and determined. Data regarding the energy expended during participation in active sports is not extensive because the bulk of the measuring equipment hampers performance.

Rapidly expanding opportunities for interscholastic and intercollegiate competition in girls and women's sports have focussed the attention of women physical educators on standards of participation and guidelines for the conduct of meets and tournaments. Determination of the optimum

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10 Karpovich, op. cit., pp. 75-123.

11 National Joint Committee on Extramural Sports for College Women, *Guidelines for the Conduct of Extramural Events*. (In preparation.)
length of practice periods and play periods should be based to a great extent on scientific evidence of the cost of the activity, but such evidence has been unavailable for most of the activities included in the program. In addition, there has not been a large number of studies dealing with the energy expenditure of girls and women during sports activity.

Energy cost is determined directly by measuring the amount of heat produced or indirectly by calculation from the amount of oxygen consumed. Neither method is readily applicable to most active sports situations. For this reason an alternate method of assessing energy cost has been suggested by Berggren and Christensen which involves the use of pulse rate as an index to oxygen consumption. The development of the technic of telemetering, utilizing the radio electrocardiograph, makes possible the determination of heart rate during performance in active sports.

By using the method of assessing energy cost suggested by Berggren and Christensen, it should be possible to determine energy expenditure not only during active sports participation in sports but also during actual competition. Data


secured from women subjects should prove valuable in the further development of standards and guidelines for the women's extramural program of athletics.

Definition of terms

Two methods of measuring the amount of energy used for activity are generally recognized.14 In direct calorimetry the subject is placed in a specially built chamber surrounded by water of known volume and temperature. Heat liberated by the subject is absorbed by the water and calculated. Indirect calorimetry requires less elaborate equipment and is more widely used. In the open circuit method of indirect calorimetry the subject inhales atmospheric air and exhales into a collecting receptacle. When the volume and the percentage of oxygen of the exhaled air is determined, the oxygen intake can be calculated since the composition of atmospheric air is constant. The closed circuit method of indirect calorimetry measures oxygen consumption directly. The subject inhales oxygen from a spirometer. His exhaled air passes through a carbon dioxide absorber and back into the spirometer. Oxygen consumption is recorded on a kymograph.

The steady state is defined as the period during moderate and uniform exercise when the oxygen intake, heart rate, and respiration maintain a steady level. According to

14Karpovich, op. cit., p. 77.
Karpovich\textsuperscript{15} and Asmussen\textsuperscript{16} this level is usually reached in one or two minutes.

\textsuperscript{15}Karpovich, \textit{op. cit.}, p. 66.

CHAPTER II

REVIEW OF RELATED LITERATURE

The energy that is required for every aspect of living is derived ultimately from the oxidation of food. Since essentially all the energy expended by the body is converted into heat, metabolic rate is usually expressed in terms of the heat liberated. Direct calorimetry therefore measures the subjects' heat production directly in a human calorimeter. Indirect calorimetry measures the subjects' oxygen consumption to use as a basis for calculating energy metabolism. The latter method has been used most frequently in studies of human energy expenditure because it is simpler and less time-consuming. The equipment required for indirect calorimetry, however, is rather bulky, consisting of face mask or mouth-piece, hose, and collecting spirometer or Douglas bag.

Physiologists have classified the degree of work involved in an activity by its energy requirements. These requirements may be expressed in terms of oxygen consumption or in calories. The classification proposed by Dill\textsuperscript{1} is based on

the ratio of work metabolic rate to basal metabolic rate. Karpovich\textsuperscript{2} used the ratio of work metabolic rate to resting metabolic rate. Christensen\textsuperscript{3} has classified work by the energy cost in liters of oxygen. Light work involves energy expenditure of 0.5 to 1.0 liter of oxygen. Moderate work requires 1.0 to 1.5 liters and heavy work 1.5 to 2.0 liters.

A great many studies of human energy expenditure have been made. Passmore and Durnin\textsuperscript{4} compiled data from papers written in five different countries to prepare tables which list the energy expended in the performance of various human activities. Their results are expressed as kilocalories per minute of gross energy expenditure (metabolism for activity plus basal metabolism). When some authors reported energy cost only in liters of oxygen consumed, these figures were converted to kilocalories using from 4.8 to 5.0 as the caloric equivalent of one liter of oxygen. The table covering recreation activities ranges from an energy cost of 1.4 kilocalories per minute in lying at ease to 18.6 kilocalories per minute in skiing. A value for golf of 5.0 kilocalories per minute was obtained by measuring the oxygen consumption of a nine handicap player continuously over two holes.

\textsuperscript{2}Karpovich, op. cit., p. 85.


\textsuperscript{4}Passmore and Durnin, loc. cit.
Karpovich and Taylor discuss the determination of the energy cost of sports activity in some detail. Both of these physiologists refer to the difficulty of measuring by indirect calorimetry the energy expended during participation in active sports because of the bulkiness of equipment required. For this reason Karpovich suggests the use of pulse rate as an alternate method of estimating energy metabolism.

The method of utilizing pulse rate to assess energy expenditure was proposed by Berggren and Christensen and documented by Lundgren and Muller. This method is made possible by the linear relationship between heart rate and oxygen consumption during activity.

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5Karpovich, op. cit., pp. 93-123.
7Berggren and Christensen, loc. cit.
12Asmussen, loc. cit.
correlation (0.95-0.97) exists between the two, and the method is recognized by a number of physiologists. As work intensity is increased the intake of oxygen goes up and heart rate rises. Because of this consistent rise in both oxygen intake and heart rise during activity, oxygen consumption alone can be used to estimate the increased work of the heart, or pulse rate alone can be used to estimate oxygen intake. Pulse rate can also be used to calculate metabolic rate.

However, both heart rate and oxygen intake vary

16 P. O. Astrand, "Human Physical Fitness with Special Reference to Sex and Age," Physiological Reviews, 36:310, 1956.
18 Weiss and Karpovich, loc. cit.
19 Lundgren, loc. cit.
20 Berggren and Christensen, loc. cit.
a great deal with individuals performing the same activity, so the relationship between the two also shows individual variation. For this reason the relationship between oxygen consumption and heart rate must be determined for all subjects to be used in a study. Such a determination can be made by requiring every subject to exercise at several different intensities on a treadmill or a bicycle ergometer. During each intensity of exercise oxygen consumption and heart rate are measured. A calibration curve, plotting oxygen consumption against heart rate, is prepared for each subject. Individual curves can be used for measurement during the performance of other activities.

Karpovich suggests that the pulse rate determined during the first ten seconds after exercise ends will quite accurately reflect the exercise pulse. This observation has been substantiated by Cotton and Dill. In his study of the energy expenditure of lumber workers, Lundgren timed the pulse during the first ten beats after exercise. He concluded that these measurements taken from time to time

23 Berggren and Christensen, op. cit., p. 255.
24 Karpovich, op. cit., p. 84.
25 Karpovich, loc. cit.
26 Karpovich, loc. cit.
28 Lundgren, loc. cit.
during work were quite suitable for the purpose of calculating metabolic rate.

The development of the technic of telemetry, utilizing the radio electrocardiograph, has made possible the study of heart rate during activity. Telemetering\textsuperscript{29} does not require connecting wires between the subject and the recording apparatus. Instead, the electric potential of the heart is broadcast by a lightweight radio transmitter which is worn by the subject. Disposable electrodes are connected to the transmitter and signals are picked up by a receiver and recorded on a conventional electrocardiograph.

Telemetry, originally developed for use in the space program, has been found a valuable technic by medicine,\textsuperscript{30} industry,\textsuperscript{31} and physical education.\textsuperscript{32} Kozar\textsuperscript{33} telemetered the heart-rate of young men during performance of the rope climb and several sports activities. He studied the rapid initial acceleration of heart rate during activity and found it to occur in patterns similar to those observed by

\begin{footnotesize}
\begin{enumerate}
\item Bellett, \textit{loc. cit.}
\item Special report in the \textit{Columbus Dispatch}, May 15, 1963.
\item Andrew J. Kozar, "A Study of Telemetered Heart Rate During Sports Participation of Young Adult Men," PhD. dissertation, University of Michigan, 1961.
\item Ibid.
\end{enumerate}
\end{footnotesize}
Rushmer in the dog. The second purpose of Kozar's study was to determine the relative strenuosity of six selected sports using heart rate as the criterion for determining their severity. He assumed, however, that the activity producing the highest heart rate was the most strenuous. For reasons pointed out above this assumption should be true for one individual participating in different activities, but might not be valid in a comparison between individuals.

Recently, Skubic and Hodgkins used telemetry to establish the reliability of pulse counting as a method to be used in a cardiovascular efficiency test for girls and women.

Summary of related literature

The energy cost of exercise has been studied extensively in the laboratory. Some studies have been made of the energy expended in performing various industrial tasks, but the energy cost of sports during participation has not been investigated to a great extent because of the bulk of equipment required to measure this expenditure. Berggren and Christensen have proposed a method of assessing energy cost by utilizing pulse rate as an index of oxygen consumption. This method was used by Lundgren, who timed the pulse during

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the first ten beats after exercise in order to estimate the energy expended by lumber workers. The development of telemetry makes it possible to obtain a record of heart rate during activity with very little encumbrance to the subject being studied.
CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to ascertain the energy cost of golf, utilizing a measurement that could be made during actual play. The method selected was that suggested by Berggren and Christensen\(^1\) and described by Karpovich.\(^2\) Because of the linear relationship which exists between oxygen consumption and heart rate during activity, heart rate alone is used to determine oxygen consumption. Energy expended during activity may then be expressed in liters of oxygen consumed. Since the relationship between oxygen uptake and heart rate varies from individual to individual each subject must be calibrated to determine the relationship applicable to her exercise.

Preliminary calibration

Three women subjects, ages 18-20, were required to walk for 5 minutes on the treadmill at four different intensities of work. The intensity of each bout was increased by

\(^1\)Berggren and Christensen, op. cit., pp. 255-260

\(^2\)Karpovich, loc. cit.
raising the grade of the treadmill. Grades selected for this study were (1) zero per cent or level, (2) 6 per cent, (3) 10 per cent and (4) 14 per cent. Speed was maintained at a constant rate of three miles per hour.

In a preliminary run each subject was oriented to walking on the treadmill at each grade, to breathing through a mouthpiece, and to wearing electrocardiograph leads during the exercise. The subject breathed room air through the mouthpiece and exhaled into a 120 liter spirometer. Four electrodes were secured on the chest, two in front and two in back, and attached through leads to a Sanborn Viso Cardiette Electrocardiograph with paper speed of twenty-five millimeters per second. During the final runs the spirometer was washed out three times with the subject's exhaled air and then air was collected throughout the fifth minute of exercise. In light and moderate exercise the steady state level should be reached in one or two minutes. Four minutes were given to allow ample time for the steady state level to be reached. Heart rate was monitored by the electrocardiogram during the fifth minute. The subjects rested fifteen minutes between each grade of exercise.

Volume of the expired air was measured and recorded on a spirogram. Samples of the air were taken from the spirometer and analyzed for percentage of oxygen by a Beckman

\(^3\) Asmussen, loc. cit.
oxygen analyzer, and volume of oxygen uptake was calculated. All gas volumes were converted to STPD (Standard Temperature and Pressure, Dry). Heart rate per minute was determined from the electrocardiograph record. The results are shown in Appendix A.

A graph of the relationship between heart rate and oxygen consumption was constructed for each subject (Figures 1, 2, and 3). The heart rate of each subject could now be used as an index of her oxygen consumption. Heart rates of the two subjects were telemetered during play on The Ohio State University Golf Course.

Measurement by telemetry

Disposable electrodes were placed on each side of the heart. Small wires connected the electrodes to the battery powered transmitter. The transmitter was contained in a case measuring 7.5 cm. by 11.5 cm. and worn suspended from the belt of the subject. Signals were received by a portable desk model receiver and transmitted to the Sanborn Viso Cardiette electrocardiograph. The electrocardiograph was powered by a twelve volt automobile battery through a converter to step down the voltage. The electrocardiograph record was recorded on tape. Receiving and recording equipment were transported around the golf course by means of an electric cart.

Recordings of heart rate were made before the start of play and at intervals throughout the round. Heart rate
immediately before and after all shots was recorded with the exception of a few putts which were too distant to pick up. In most approach shots and putting it was possible to pick up heart rate during the execution of the shot as well as immediately before and after the shot. During the execution of drives and most fairway shots, however, the heart rate was obscured by the action potentials of skeletal muscles. The average duration of the shot itself was only from one to two seconds, however, so the recordings before and after should reflect heart rate with a good degree of accuracy. Records were also made of the walk between shots in several instances.

The duration of the telemetered record of heart rate varied from twenty seconds to one minute as the types of golf shots made varied in execution time. Average time of recording was about thirty seconds. The time between telemetered records also varied with the type and length of the golf shot. Total playing time was one hour and forty-five minutes per nine holes.

Computations

Heart rates during each interval of recording were determined by measuring from peak to peak of the ventricular complex and calculating rate per minute from the paper speed of the electrocardiograph. A sample of the electrocardiograph record obtained by telemeter and an example of the method of computation are included in Appendix B. A check was made of
the determined rate by counting the number of spikes in each time interval. Mean heart rates for each interval of recording were calculated, and the mean heart rate of each subject for each hole as well as the entire round of play was determined. The above mean heart rates were then translated into oxygen consumption per minute by using the individual graphs shown in Figures 2 and 3 as indices.
CHAPTER IV

ANALYSIS OF DATA

The heart rates of two subjects were telemetered at intervals during nine holes of play and four holes of play respectively. Oxygen consumption was determined by referring to individual calibration curves of heart rates and oxygen consumption. Table 1 gives hole-by-hole range and mean heart rate and oxygen uptake for each subject.

**TABLE 1. Energy Expenditure Hole-by-Hole Shown by Oxygen Consumption Derived from Heart Rate**

<table>
<thead>
<tr>
<th>Holes</th>
<th>Subject</th>
<th>Heart Rate (Beats/min.)</th>
<th>Oxygen Uptake (Liters/min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>10</td>
<td>DR</td>
<td>136 - 158</td>
<td>143</td>
</tr>
<tr>
<td></td>
<td>JW</td>
<td>108 - 131</td>
<td>123</td>
</tr>
<tr>
<td>11</td>
<td>DR</td>
<td>131 - 159</td>
<td>146</td>
</tr>
<tr>
<td></td>
<td>JW</td>
<td>104 - 120</td>
<td>112</td>
</tr>
<tr>
<td>12</td>
<td>DR</td>
<td>131 - 150</td>
<td>137</td>
</tr>
<tr>
<td></td>
<td>JW</td>
<td>125 - 136</td>
<td>129</td>
</tr>
<tr>
<td>13</td>
<td>DR</td>
<td>136 - 150</td>
<td>145</td>
</tr>
<tr>
<td></td>
<td>JW</td>
<td>125 - 131</td>
<td>128</td>
</tr>
<tr>
<td>14</td>
<td>DR</td>
<td>131 - 158</td>
<td>143</td>
</tr>
<tr>
<td>15</td>
<td>DR</td>
<td>150 - 166</td>
<td>158</td>
</tr>
<tr>
<td>16</td>
<td>DR</td>
<td>125 - 150</td>
<td>134</td>
</tr>
<tr>
<td>17</td>
<td>DR</td>
<td>125 - 150</td>
<td>142</td>
</tr>
<tr>
<td>18</td>
<td>DR</td>
<td>136 - 166</td>
<td>151</td>
</tr>
</tbody>
</table>

It is interesting to note that although the heart rates of
D.R. covered a wider range than those of J.W., the range of oxygen usage of J.W. was the wider of the two. This observation holds true for the range on each hole as well as the range for the total round of play. The apparent discrepancy can be explained by a comparison of the slopes of the individual calibration curves in Figures 2 and 3. J.W. shows a slight increase in heart rate for a wide range of oxygen uptake. An increase in heart rate of ten beats per minute denotes an increase in oxygen consumption of about one-half liter for J.W. A ten beat increase for D.R. means only a one-fifth liter increase in oxygen uptake.

Breakdown by holes

The range of heart rate and reflected oxygen consumption varied somewhat from hole-to-hole as shown in Table 1. This range did not seem to depend on the length of the hole, the difficulty of the hole, or the number of strokes played. Table 2 gives the yardage, handicap, women's par, and score made on each hole to compare with heart rate and oxygen consumption. Energy expenditure of subject D.R. appears to be rather constant throughout the round.

Some fluctuations in heart rate occurred during play on each hole. Figure 4 shows the variation between ten intervals of telemetering on a typical hole for each subject. Although there is a great difference in heart rate between the two subjects, their energy output, shown by the oxygen equivalents on the right ordinate, is quite similar.
### TABLE 2. Hole difficulty, Score, and Energy Expenditure

<table>
<thead>
<tr>
<th>Hole</th>
<th>Yds.</th>
<th>Hand</th>
<th>Par</th>
<th>D.R.</th>
<th>Heart Rate</th>
<th>O₂ Uptake</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>385</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>136 - 158</td>
<td>1.3 - 1.6</td>
</tr>
<tr>
<td>11</td>
<td>400</td>
<td>18</td>
<td>4</td>
<td>7</td>
<td>131 - 159</td>
<td>1.2 - 1.6</td>
</tr>
<tr>
<td>12</td>
<td>540</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>131 - 150</td>
<td>1.2 - 1.5</td>
</tr>
<tr>
<td>13</td>
<td>175</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>136 - 150</td>
<td>1.3 - 1.5</td>
</tr>
<tr>
<td>14</td>
<td>485</td>
<td>14</td>
<td>5</td>
<td>7</td>
<td>131 - 158</td>
<td>1.2 - 1.6</td>
</tr>
<tr>
<td>15</td>
<td>405</td>
<td>16</td>
<td>5</td>
<td>5</td>
<td>150 - 166</td>
<td>1.5 - 1.8</td>
</tr>
<tr>
<td>16</td>
<td>365</td>
<td>10</td>
<td>4</td>
<td>5</td>
<td>125 - 150</td>
<td>1.1 - 1.5</td>
</tr>
<tr>
<td>17</td>
<td>180</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>125 - 150</td>
<td>1.1 - 1.5</td>
</tr>
<tr>
<td>18</td>
<td>395</td>
<td>12</td>
<td>4</td>
<td>5</td>
<td>136 - 166</td>
<td>1.3 - 1.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hole</th>
<th>Yds.</th>
<th>Hand</th>
<th>Par</th>
<th>J.W.</th>
<th>Heart Rate</th>
<th>O₂ Uptake</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>385</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>108 - 131</td>
<td>1.0 - 1.8</td>
</tr>
<tr>
<td>11</td>
<td>400</td>
<td>18</td>
<td>4</td>
<td>4</td>
<td>104 - 120</td>
<td>0.8 - 1.4</td>
</tr>
<tr>
<td>12</td>
<td>540</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>125 - 136</td>
<td>1.6 - 2.0</td>
</tr>
<tr>
<td>13</td>
<td>175</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>125 - 131</td>
<td>1.6 - 1.9</td>
</tr>
</tbody>
</table>

The energy expenditure of two subjects during play on two different holes is compared in Figure 5. The lower graph shows play on number ten hole and the upper graph play on number twelve.

**Breakdown by types of shot**

There was not a great deal of difference in the energy cost of different types of golf shots. For subject D.R. t
Figure 5 — Energy expenditure during play on two holes
mean oxygen consumption for drives and fairway shots was 1.4 liters per minute and for approach shots and putts, 1.3 liters per minute. Two sandtrap shots showed an oxygen consumption of 1.5 liters per minute. Subject J.W. showed slightly more variation. Drives, fairway shots, and approaches produced an oxygen consumption of 1.5, 1.6, and 1.7 liters per minute respectively, but putts showed a consumption of only one liter per minute.

Other factors

It is recognized that many factors may contribute to the stress of playing golf, affecting heart rate and derived oxygen consumption. The influence of emotions, external temperature, and terrain may be very significant in some situations. In the present study neither temperature nor terrain should have affected heart rate to a great extent. The temperature ranged from 64 to 67 during the hours of play, and there was no precipitation. The Scarlet Course of The Ohio State University is considered a "flat" course by the professional with no grades of any significance.

Emotional stress caused by bad shots, poor scoring, etc., may have had a significant influence on the heart rates of the two subjects. Because of the difficulty in measuring this stress, emotional factors were not evaluated in this study.

Comparison of subjects

Mean heart rates for each hole played are shown in
Figure 6. Heart rates of subject D.R. are substantially higher than those of subject J.W. This difference in heart rate between the two subjects was evident in every comparison of data. In fact all ranges of heart rate during play were higher for D.R. than for J.W. with the exception of the ranges on one hole. On hole twelve the upper limit of heart rate range for J.W. was five beats faster than the lower limit of D.R.'s range of heart rate (Table 1).

The most impressive characteristic of the heart rate record of both subjects was its rapid fluctuation. Rate may change as rapidly as every other beat. This occurred when the heart rate of subject D.R. increased from 136 to 150 in eighteen seconds. The increase was noted during the walk between shots on hole 10. Pulse rate almost invariably increases before a shot. This observation is in agreement with the findings of Kozar in his study of telemetered heart rate during sports participation.¹ The greatest increases in heart rate noted in the present study, however, occurred after a shot. The mean heart rate of subject D.R. was eight beats slower before tee shots than after tee shots and the mean heart rate of subject J.W. was eighteen beats slower. This increase in heart rate after the shot was made continued for two to three seconds. In two instances the pulse slowed before a shot and remained slow.

¹Kozar, loc. cit.
Statistical analysis

The difference in heart rate of the two subjects is given in Table 3. As might be expected from previous analysis of data, this difference is considerable. The obtained \( t \) ratio of 4.59 is significant beyond the .001 level which is 4.587.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Range</th>
<th>Mean</th>
<th>( m )</th>
<th>( t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.R.</td>
<td>125 - 166</td>
<td>143</td>
<td>4.9</td>
<td>1.99</td>
</tr>
<tr>
<td>J.W.</td>
<td>108 - 136</td>
<td>123</td>
<td>6.7</td>
<td>3.96</td>
</tr>
</tbody>
</table>

\(^a\text{Significant beyond the .001 level which is 4.587.}\)

Oxygen consumption derived from heart rate did not show a significant difference, however, as shown in Table 4. The range of subject D.R.'s oxygen uptake was 0.7 liters with a mean of 1.37 liters per minute. The range of oxygen uptake for subject J.W. was 1.2 liters with a mean of 1.55 liters per minute. The \( t \) ratio of 1.05 is significant at the .35 level.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Range</th>
<th>Mean</th>
<th>( m )</th>
<th>( t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.R.</td>
<td>1.1 - 1.3 L.</td>
<td>1.37 L.</td>
<td>0.083</td>
<td>0.32</td>
</tr>
</tbody>
</table>
| J.W.    | 0.8 - 2.0 L.| 1.55 L.| 0.287  | 0.170| 1.05
Energy expended in golf

The energy expended while playing golf falls mainly into the range of moderate work proposed by Christensen,² 1.0 to 1.5 liters of oxygen consumption per minute. There were occasional excursions into the range of heavy work, 1.5 to 2.0 liters per minute. These excursions were particularly noticeable with subject J.W. The mean oxygen consumption of subject D.R., 1.37 liters, was within the classification of moderate work. The mean oxygen uptake of subject J.W., 1.55 liters, slightly exceeded the upper limit of moderate work.

Energy expenditure varies during play on one hole as shown in Figures 4 and 5. There is also a variation in energy expenditure from hole-to-hole as depicted in Figure 7. The more relatively constant and lower values obtained for subject D.R. may have been partially due to her higher degree of skill. Taylor³ states that improved performance reduces the oxygen cost of work. The variation in energy expenditure reflected by heart rate while playing golf indicates that no steady state level is reached.

By using the caloric equivalent of 4.062 for a liter of oxygen which is true for an ordinary mixed diet when respiratory quotient is assumed to be 0.85, the energy cost values of oxygen consumption can be converted into kilocalories.

²Christensen, loc. cit.
³Taylor, op. cit., p. 133.
Such conversion produces the following quantities. The mean energy expenditure of subject D.R. expressed in kilocalories would be 6.6 kilocalories per minute. The mean expenditure for subject J.W. would be 7.5 kilocalories per minute. Both caloric rates are slightly higher than the 5.0 kilocalories per minute reported by Passmore and Durnin. The discrepancy does not seem too large, however, since their figure was based on the oxygen consumption of one male subject playing two holes of golf, and the mean energy expenditure of subject J.W. on hole eleven was 5.0 kilocalories per minute. The mean rates of energy expenditure found in the present study would involve a caloric cost of between 693 and 787 kilocalories for nine holes of golf or between 1386 and 1575 kilocalories for eighteen holes of golf. Since the amounts above are figured on the basis of three and one-half hours for eighteen holes of play, the energy expenditure per hour would amount to from 400 to 450 kilocalories. Falling midway in Mayer's table of the energy cost of sport, this amount could make a significant contribution to weight control.

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4 Passmore and Durnin, loc. cit.
5 Mayer, op. cit., p. 309.
CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The energy cost of playing a round of golf was determined by assessing the energy expended by two subjects during play of nine and four holes respectively. The method used to determine energy cost was that suggested by Berggren and Christensen\(^1\) and utilized by Lundgren\(^2\) and Muller.\(^3\) Because heart rate and oxygen consumption during exercise are linearly related, heart rate alone may be used as an index of oxygen consumption. Individual calibration curves must be constructed, however, since there is a large variation in the heart rate/oxygen uptake relationship from person to person. Graphs showing this relationship were made for the two subjects from data collected during exercise of four different intensities. These graphs were then used to determine oxygen consumption from heart rate.

Heart rate was telemetered at intervals during the play of the two subjects. Mean heart rates were calculated

\[^1\] Berggren and Christensen, \textit{loc. cit.}\n
\[^2\] Lundgren, \textit{loc. cit.}\n
\[^3\] Muller, \textit{loc. cit.}\n
36
for each interval of recording, for each hole of play, and for the round of play. Oxygen consumption was determined from mean heart rate by referring to individual calibration curves.

During play, the heart rate of one subject, D.R., was found to be consistently higher than that of the other subject, J.W. The difference between the mean heart rates of the two subjects was significant beyond the .001 level; however, there was no significant difference in the oxygen consumption of the two subjects. The range of oxygen consumption for subject D.R. was 1.1 to 1.8 liters of oxygen per minute. The range for subject J.W. was 0.8 to 2.0 liters per minute. Mean oxygen consumption during play was 1.37 liters and 1.55 liters respectively. Oxygen consumption of 1.37 liters per minute falls within the range of moderate work established by Christensen. Oxygen consumption of 1.55 liters per minute is slightly above the upper limit of this classification.

The conversion of liters of oxygen into kilocalories by use of the caloric equivalent of an ordinary mixed diet shows an energy cost of 6.6 kilocalories per minute for one subject and 7.5 kilocalories per minute for the other subject. These figures are roughly comparable to the figure reported by Passmore and Durnin. At these rates of energy expenditure the energy cost of eighteen holes of golf would be between 1300 and 1600 kilocalories.
Conclusions
The following conclusions were derived from analysis of the data in the study:

1. Playing golf involved a moderate expenditure of energy for the subjects.
2. The energy cost of playing golf may be lower for the skilled player.
3. Within the same range of energy expenditure heart rates may vary a great deal from individual to individual.
# APPENDIX A

## RESULTS OF CALIBRATING RUNS

<table>
<thead>
<tr>
<th>Subject: J.W.</th>
<th>Grade</th>
<th>Heart Rate I</th>
<th>Heart Rate II</th>
<th>$O_2$ Uptake I</th>
<th>$O_2$ Uptake II</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>110</td>
<td>108</td>
<td></td>
<td>940 ml.</td>
<td>905 ml.</td>
</tr>
<tr>
<td>6%</td>
<td>120</td>
<td>119</td>
<td></td>
<td>1469 ml.</td>
<td>1445 ml.</td>
</tr>
<tr>
<td>10%</td>
<td>130</td>
<td>133</td>
<td></td>
<td>1885 ml.</td>
<td>2033 ml.</td>
</tr>
<tr>
<td>14%</td>
<td>150</td>
<td>149</td>
<td></td>
<td>2507 ml.</td>
<td>2371 ml.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject: D.R.</th>
<th>Grade</th>
<th>Heart Rate I</th>
<th>Heart Rate II</th>
<th>$O_2$ Uptake I</th>
<th>$O_2$ Uptake II</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>103</td>
<td>102</td>
<td></td>
<td>622 ml.</td>
<td>781 ml.</td>
</tr>
<tr>
<td>6%</td>
<td>125</td>
<td>123</td>
<td></td>
<td>978 ml.</td>
<td>1191 ml.</td>
</tr>
<tr>
<td>10%</td>
<td>142</td>
<td>145</td>
<td></td>
<td>1269 ml.</td>
<td>1551 ml.</td>
</tr>
<tr>
<td>14%</td>
<td>170</td>
<td>169</td>
<td></td>
<td>1603 ml.</td>
<td>2007 ml.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject: B.F.</th>
<th>Grade</th>
<th>Heart Rate I</th>
<th>Heart Rate II</th>
<th>$O_2$ Uptake I</th>
<th>$O_2$ Uptake II</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>103</td>
<td>95</td>
<td></td>
<td>749 ml.</td>
<td>679 ml.</td>
</tr>
<tr>
<td>6%</td>
<td>122</td>
<td>108</td>
<td></td>
<td>1070 ml.</td>
<td>1008 ml.</td>
</tr>
<tr>
<td>10%</td>
<td>135</td>
<td>132</td>
<td></td>
<td>1438 ml.</td>
<td>1395 ml.</td>
</tr>
<tr>
<td>14%</td>
<td>170</td>
<td>160</td>
<td></td>
<td>1827 ml.</td>
<td>1831 ml.</td>
</tr>
</tbody>
</table>
APPENDIX B

METHOD OF COMPUTING TELEMETERED HEART RATES

Electrocardiograph paper speed = 25 mm/sec.

Heart rate = \(60 \div \frac{x}{25}\) \((x = \text{peak-to-peak distance})\)

Distance Peak-to-Peak and Computed Rate

<table>
<thead>
<tr>
<th>Distance</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 mm</td>
<td>187</td>
</tr>
<tr>
<td>9 mm</td>
<td>166</td>
</tr>
<tr>
<td>10 mm</td>
<td>150</td>
</tr>
<tr>
<td>11 mm</td>
<td>136</td>
</tr>
<tr>
<td>12 mm</td>
<td>125</td>
</tr>
<tr>
<td>13 mm</td>
<td>115</td>
</tr>
<tr>
<td>14 mm</td>
<td>107</td>
</tr>
<tr>
<td>15 mm</td>
<td>100</td>
</tr>
<tr>
<td>16 mm</td>
<td>94</td>
</tr>
<tr>
<td>17 mm</td>
<td>88</td>
</tr>
<tr>
<td>18 mm</td>
<td>83</td>
</tr>
</tbody>
</table>

Telemetered Record of Heart Rate

![Telemetered Record of Heart Rate](image-url)
APPENDIX C

COMPUTATION OF t RATIO FOR DIFFERENCE IN HEART RATES

Subject J.W.

\[ M = 123 \]

\[ \sigma = 6.74 \]

\[ \sigma_M = \frac{\sigma}{\sqrt{N-1}} = \frac{6.74}{1.7} = 3.96 \]

Subject D.R.

\[ M = 143 \]

\[ \sigma = 4.9 \]

\[ \sigma_M = \frac{\sigma}{\sqrt{N-1}} = \frac{4.9}{2.6} = 1.88 \]

\[ \sigma_{\text{diff}} = \sqrt{\sigma_{M_1}^2 + \sigma_{M_2}^2} = \sqrt{15.68 + 3.42} = 4.35 \]

\[ t = \frac{M_1 - M_2}{\sigma_{\text{diff}}} = \frac{143 - 123}{4.35} = 4.59 \]
APPENDIX D

COMPUTATION OF $t$ RATIO FOR DIFFERENCE IN OXYGEN CONSUMPTION

Subject J.W.

\[ M = 1.55 \]
\[ \sigma = 0.287 \]
\[ \sigma_M = \frac{\sigma}{\sqrt{N-1}} = \frac{0.287}{1.7} = 0.17 \]

Subject D.R.

\[ M = 1.37 \]
\[ \sigma = 0.0831 \]
\[ \sigma_M = \frac{\sigma}{\sqrt{N-1}} = \frac{0.0831}{2.6} = 0.032 \]
\[ \sigma_{\text{diff}} = \sqrt{\sigma_{M_1}^2 + \sigma_{M_2}^2} = 0.0289 + 0.001 = 0.17 \]
\[ t = \frac{M_1 - M_2}{\sigma_{\text{diff}}} = \frac{0.18}{0.17} = 1.05 \]
BIBLIOGRAPHY

BOOKS


PERIODICALS


I, Shirley Frances McGill, was born in Fordyce, Arkansas, December 24, 1919. I received my secondary-school education in the public schools of Santa Fe, New Mexico, and my undergraduate training at Mills College, California, which granted me the Bachelor of Arts degree in 1941. From the University of Washington in Seattle, I received the Master of Science degree in 1943. After serving with the American Red Cross overseas for three years, I accepted an appointment as Instructor in the Department of Physical Education at the University of New Mexico. I remained at the University of New Mexico until 1962, when I was granted a year's leave of absence to complete the requirements for the Doctor of Philosophy degree.