SOME OBSERVATIONS ON BODY TEMPERATURE.

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These observations were made by the officers specializing in physical training during their course at the Royal Army Medical College. All the temperature records, except those before rising, were taken in the rectum, with half-minute clinical thermometers retained for a full minute. All temperatures are Centigrade readings, and for convenience the corresponding Fahrenheit values are also given.

Many observers have drawn attention to the fact that a rise of body temperature occurs during muscular work and all are agreed that it is physiological, but that the rise of temperature may be of assistance to the body is not wholly understood. That the respiratory centre is rendered more sensitive by, and that the extensibility of muscle increases with a rise of body temperature are two points quoted in the textbooks. Lately Barcroft and King (Journal of Physiology, vol. xxxix) have shown that the dissociation of oxyhaemoglobin is facilitated by a rise of temperature, as "it appears that the oxygen dissociates from the haemoglobin about twice as rapidly at 41°C. as at 36°C."; they argue that this helps the mechanism for meeting the increase of metabolism in muscle which occurs during muscular work, because "each corpuscle spends a much shorter time in the capillary than when the muscle is at rest, and therefore it must divest itself of oxygen at a greater rate than is normally necessary." In "Further Advances in Physiology," Pembrey states: "It appears that a rise in temperature within certain narrow limits is beneficial. The chemical changes associated with muscular work are probably facilitated by a temperature a degree or two above the temperature during complete rest."

The point at which this rise may become pathological is of importance. In the "Second report on the physiological effects of food, training and clothing on the soldier" the committee state that "no abnormal results were observed when the rectal temperature of some men reached 38.8°C. (102°F.), but above that point inefficiency and a rapid irregular pulse were observed." The range of temperature in a normal man is less than 2°C. (3.5°F.) (Pembrey, "Animal heat, 'Schäfer's Physiology'"), and only once in our records
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was this exceeded. It is probable that in the relationship of surface and deep temperature will be found an indication of impending pathological conditions, and it is in this direction that more work is required.

The results of eight marches carried out by five subjects are here charted and all particulars will be found in the tabulated diary.

![Chart 1](image1)

**Chart 1.**—The average rise for the five subjects for eight marches.

![Chart 2](image2)

**Chart 2.**—The average rise of the five subjects during each of the eight marches.
Chart 3.—The average individual hourly temperature during the eight marches.

(1) Temperature on rising.
(2) " at end of 1st hour's marching (10 minutes' halt).
(3) " 2nd (lunch halt, 30 minutes).
(4) " 3rd (10 minutes' halt).
(5) " on return home.

Mean weight of each subject (stripped) . . . 68·2 kilos. (10 st. 10 lb.).
" (loaded) . . . 78·1 , (12 st. 5 lb.).
The average distance marched . . . . . . . 24·4 kilometres (15½ miles).
" rate of march . . . . . . . 98 metres per minute.
" daily temperature . . . . . . . 77 per cent.
" relative humidity . . . . . . . 77 per cent.

Individual age, height and weight (stripped):

D. . . 36½ years. Height, 5 ft. 8½ in. Weight, 65·6 kilos.
W. . . 35 " 5 " 9¾ " 72·7 "
B. . . 32 " 5 " 10½ " 67·2 "
F. . . 32 " 5 " 10½ " 64·9 "
S.-B. . . 32 " 5 " 11 " 71·2 "
# Tabulated Diary of All the Marches

<table>
<thead>
<tr>
<th>Date</th>
<th>Time of start; hrs. and min. a.m.</th>
<th>Condition of roads</th>
<th>Weather</th>
<th>Thermometer (W.B.D.B.)</th>
<th>Total time in hours and minutes</th>
<th>Distance travelled (miles and metres)</th>
<th>Rate of march, metres per min.</th>
<th>Calories per kilo.</th>
<th>Body weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb. 6</td>
<td>10.33</td>
<td>Greasy and heavy</td>
<td>Dull and misty; breeze E.N.E.</td>
<td>35 38 36 39</td>
<td>4.41 3.51</td>
<td>273.9</td>
<td>97.5</td>
<td>13.5</td>
<td>2.1</td>
</tr>
<tr>
<td>7</td>
<td>11.30</td>
<td>Dry and good going</td>
<td>Dull and misty; breeze S.W.</td>
<td>35 38 35 38</td>
<td>4.15 3.35</td>
<td>273.9</td>
<td>101.0</td>
<td>13.2</td>
<td>2.1</td>
</tr>
<tr>
<td>9</td>
<td>10.26</td>
<td>Dry, good going, except 3 miles very hilly</td>
<td>Dull and cloudy; no breeze</td>
<td>35 38 36 38</td>
<td>5.45 4.40</td>
<td>478.3</td>
<td>97.7</td>
<td>16.4</td>
<td>3.6</td>
</tr>
<tr>
<td>11</td>
<td>10.43</td>
<td>Heavy and slippery</td>
<td>Clear and sunny</td>
<td>38 40 35 39</td>
<td>5.14 4.2</td>
<td>434.4</td>
<td>90.0</td>
<td>12.4</td>
<td>2.2</td>
</tr>
<tr>
<td>13</td>
<td>10.39</td>
<td>Good, slippery in places</td>
<td>Clear and sunny</td>
<td>37 42 38 39</td>
<td>5.55 4.40</td>
<td>419.5</td>
<td>101.7</td>
<td>17.4</td>
<td>3.1</td>
</tr>
<tr>
<td>14</td>
<td>10.30</td>
<td>Slippery at start, later dry</td>
<td>Misty, then sun; breeze S.W.</td>
<td>36 37 37 39</td>
<td>5.37 4.18</td>
<td>419.5</td>
<td>101.7</td>
<td>16.1</td>
<td>2.0</td>
</tr>
<tr>
<td>15</td>
<td>10.45</td>
<td>Slippery and muddy</td>
<td>Bright and clear; slight N. breeze</td>
<td>45 47 40 47</td>
<td>5.10 4.17</td>
<td>208.9</td>
<td>90.0</td>
<td>14.2</td>
<td>1.5</td>
</tr>
<tr>
<td>17</td>
<td>10.42</td>
<td>Very muddy and greasy in places</td>
<td>Bright and sunny; breeze N.W.</td>
<td>46 51 48 51</td>
<td>5.0 3.54</td>
<td>455.9</td>
<td>103.2</td>
<td>15.1</td>
<td>3.4</td>
</tr>
</tbody>
</table>
Particulars of walk: Distance 32.18 kilometres (20 miles) at 97.5 metres per minute; no wind, cloudy and rain last 2 miles. Body weight 50 kilos, calories expended 1,704.

This chart is inserted to give some idea of the changes in body temperature before, during, and after a long walk. The unbroken-line curve, together with the hours above, represent height of and times of taking the temperature during the walk; the dotted-line curve and hours below are the average hourly variations per day of a medical student, representing some 343 observations. (Pembrey and Nicol, Journal of Physiology, vol. xxiii, 1898.)

Consideration of these records, in relation to the following:—

(1) Work done.—This has had no influence, as the amount performed did not vary greatly, although the rate of marching, an important factor in heat production, showed considerable variation. The average weight carried was 10 kilos. (22 lb.).

(2) Clothing.—All the subjects wore ordinary dress with ruck-sacs every day except on the 17th, when three (D., W., and F.),
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wore "shorts," which appeared to make no difference, a result to be expected considering the season of the year.

(3) External Temperature.—This, which is generally acknowledged to be the most important factor of all in heat production during muscular work, has here had no influence, as the daily temperature varied so little. Later we shall discuss this point, comparing our figures with some obtained in India which have been placed at our disposal.

(4) Food.—"The effect is to slightly raise the temperature of the rectum." (Pembrey and Nicol, Journal of Physiology, vol. xxiii, 1898.)

In Chart 1, the rise after lunch is seen even when the temperature is already above 37·7° C. (100° F.). Chart 2 demonstrates this on all days except the 6th, when there is no change, and the 11th, which shows a slight drop. In Chart 3 of individual averages all show rises except subject W., who at lunch ate far less than the others.

(5) Training.—It is well established that this may considerably lessen the rise. Quoting again from the "Second report of the committee on physiological effects of food, training and clothing on the soldier," the experiments "show that after three weeks practice a trained soldier in full marching order can march the same distance over the same road with less fatigue than that produced when he performed the first march of the series in ordinary dress," as shown by a diminished rise of the rectal temperature. Also A. Mosso ("Life of Man in the High Alps," p. 132), summing up the results of some experiments with students climbing to a height of 400 metres, says "We see thus that training gradually lessens the increase of temperature after exertion." It is of course a well-known fact that with practice muscular work can be performed more economically and hence with less combustion, or as Mosso puts it, "Training is an unconscious instruction, which we give to the nervous system, which is thus taught to effect the contraction of the muscles without unnecessary expenditure of chemical work." All the subjects on this occasion had been living a somewhat sedentary life for the previous three months but had as a rule been accustomed to regular exercise. Here we find no reduction in the level attained in the later marches (see Chart 2); perhaps the number of marches was not enough to show this.

(6) Fatigue (see Chart 5).—On February 9, the third march of the series, subject S. B., the only one of the party really fatigued, shows a high temperature at the finish which continued for some hours. This may have been due to delayed combustion of metabolites.
(7) Individual Idiosyncrasies.—As is well seen in Chart 3, some of the individuals attained their maximum temperature at the end of the first hour, while in others the temperature rose more slowly; the level maintained throughout the march varied in different individuals.

General Conclusions.—It would appear, provided the heat regulating mechanism of the body is not interfered with by causes such as unsuitable clothing or a high wet-bulb temperature, that there is a "normal rectal temperature" for marching, in exactly the same way as there is a normal rectal temperature in bed after a night's rest. One might say that there is an optimum temperature for different amounts of body work, and in marching this appears to be somewhere between 37·8° C. (100° F.), and 38·3° C. (101° F.). Referring to Chart 1, we might go further and say that it was somewhere between 37·9° C. (100·2° F.) and 38·1° C. (100·6° F.). Similar observations to these made at the same time of the year in
1910 show that the average marching (33 observations) of three subjects was between 37.9° C. (100.3° F.) and 38.1° C. (100.5° F.).

One of us (N. D. W.) has made some further observations after bicycling and playing squash-racquets. They were obtained in the same way, using a one-minute Kew-certificated clinical thermometer retained for two full minutes. All these observations were made during the months of March and April, 1910. Walks taken during the same period are also tabulated and all records are for one hour’s exercise.

<table>
<thead>
<tr>
<th>Form of exercise</th>
<th>Clothing worn</th>
<th>Number of observations</th>
<th>Average temperature on starting</th>
<th>Average temperature after one hour</th>
<th>Difference</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>Ordinary dress</td>
<td>8</td>
<td>Degrees 37.1 (98.8)</td>
<td>Degrees 38.1 (100.5)</td>
<td>0.96 (1.7)</td>
<td>4 miles per hour</td>
</tr>
<tr>
<td>Bicycling</td>
<td>Ordinary dress</td>
<td>6</td>
<td>Degrees 37.3 (99.1)</td>
<td>Degrees 38.1 (100.6)</td>
<td>0.81 (1.5)</td>
<td>11 miles per hour</td>
</tr>
<tr>
<td>Squash-racquets</td>
<td>Flannels</td>
<td>8</td>
<td>Degrees 37.7 (99.9)</td>
<td>Degrees 38.5 (101.4)</td>
<td>0.81 (1.5)</td>
<td>Closed court</td>
</tr>
</tbody>
</table>

From the above table it will be seen that the highest temperatures occurred during squash-racquets, the maximum rise was 1.4° C. (2.4° F.). It should be noted that the starting temperature was high; this is because all the observations except one were made between 4 p.m. and 6 p.m., the time of the highest daily variation (Fembrey and Nicol, Journal of Physiology, vol. xxxi, 1898). It seems immaterial at what temperature one starts playing; on one occasion, starting at 10 a.m., it was found that the temperature rose in half an hour from 37.2° C. (99° F.) to 38.3° C. (101° F.). All the observations were made on separate days. The bicycling was over undulating country, and where more than one observation was made on the same day one hour’s rest always intervened. In walking, each observation is that of a separate walk. The light clothing worn when playing squash-racquets and the rapid passage through the air when bicycling no doubt increased convection and evaporation, and hence the "difference" is not so great as in walking, but we do not think the figures are comparable by estimating "difference." It would appear that what has been suggested about optimum temperature may also apply here and that for a more rapid and violent exercise such as squash-racquets a higher level is attained than in walking, to facilitate the more rapid chemical changes that are in progress.

1 "Difference" is the rise of temperature between the beginning and the end of the exercise.
To medical officers, this subject is of interest when considering the load carried and the clothing of the soldier when marching, and also the atmospheric conditions during marches. Zuntz and Schumburg ("Physiologie des Marches," p. 309), say: "Heat production is four or five times greater when marching than at rest," and again, p. 128, "It is interesting to note that a load of 31 kilos. (68 lb.) in favourable weather causes approximately the same rise of temperature (38°-39.7°) as a light one (22 kilos. or 48 lb.) in tropical heat." It should be noted these observers took the temperature in the urine stream. It is to prevent such physiological rises of temperature as we have recorded from becoming pathological that recommendations of medical officers should be directed and further research engaged in. The regimental officer now realizes the importance of the clothing, load, and march as discipline factors. The danger of the physiological temperature becoming pathological lies in the fact that once the balance of the mechanism of heat regulation in the human body has been definitely upset by high external temperature, combined with almost total abolition of heat loss in evaporation, a vicious circle is established. The internal temperature rises, and as a result the oxidation processes and therefore the production of heat also increase, so that the body temperature rises still further, and so on." (Sutton, Journal of Pathology and Bacteriology, 1908, vol. xiii, p. 62). It is the difference between the dry and wet-bulb temperatures to which we wish to direct attention. Haldane (Journal of Hygiene, vol. v) in his broad conclusions says, "During muscular work in still air, the limit of wet-bulb temperature which could be borne without abnormal rise was much lower" (than when at rest). "At a wet-bulb temperature of about 87° F. (30.5° C.) the rectal temperature rose about 3.5° F. in an hour. In an air current of 155 linear feet per minute, a wet-bulb temperature of about 84° F. (29.5° C.) could be borne without abnormal rise of body temperature, but 87° F. (30.5° C.) was beyond the limit."

By permission of the Professor of Hygiene we have been allowed to examine Captain L. E. L. Parker's observations made in Poona, 1909. These have been compared with the results in the "Second Report on the Physiological Effects of Food, Training and Clothing on the Soldier," and are here charted and diagrammatically represented.

The diagram shows the rise of rectal temperature after marching two hours (about 7 miles) with a ten minutes halt at the end of the first hour. At Aldershot one of the marches (ordinary dress, with
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jacket) was without a halt and another march (marching order, with jacket) was only of one hour's duration.

A comparison of the effect of different amounts of clothing and equipment on men marching at Poona and Aldershot. (Average of five men at Poona and four men at Aldershot.)

Captain Parker on both occasions superintended these marches and they differ only in the following points:

<table>
<thead>
<tr>
<th>Points of difference</th>
<th>Aldershot</th>
<th>Poona</th>
</tr>
</thead>
</table>
| (1) Dress            | Serge, with trousers | Drill with "shorts."
| (2) Hour of starting | 11 a.m. | 8.30 a.m. |
| (3) Average starting body temperature | 37.5° C. (99.5° F.) | 37.2° C. (99.9° F.) |
| (4) Average wet bulb temperature | 60° F. | 85° F. |
| (5) Relative humidity | 73 per cent. (average) | 58 per cent. |

Humidity (mean) at 8 hours for May, 1910, Bombay Gazette Supplement, Part II.
The rectal temperature (average of four men at Aldershot and five at Poona) after marching two hours at Aldershot and Poona charted for comparison. The marches are recorded in sequence, irrespective of clothing worn and equipment carried. (See table below.)

There was a ten minutes' halt at the end of the first hour, except on August 21, when the march was only for one hour and on August 22 and 23, when there was no halt.

<table>
<thead>
<tr>
<th>Date—1906</th>
<th>Aldershot</th>
<th>Date—1909</th>
<th>Poona</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug. 21...</td>
<td>Marching order.</td>
<td>May 10...</td>
<td>Ordinary dress with jacket; no equipment.</td>
</tr>
<tr>
<td>&quot; 22...</td>
<td>In shirt sleeves, overcoat carried on the back.</td>
<td>&quot; 11...</td>
<td>Ordinary dress, no jacket or equipment.</td>
</tr>
<tr>
<td>&quot; 23...</td>
<td>Ordinary dress.</td>
<td>&quot; 12...</td>
<td>Drill order, no rifle or jacket.</td>
</tr>
<tr>
<td>&quot; 27...</td>
<td>&quot; no jacket.</td>
<td>&quot; 13...</td>
<td>&quot; &quot; no rifle.</td>
</tr>
<tr>
<td>&quot; 28...</td>
<td>&quot; Drill order, no jacket.</td>
<td>&quot; 14...</td>
<td>&quot; Marching order, no jacket or greatcoat.</td>
</tr>
<tr>
<td>&quot; 29...</td>
<td>&quot;</td>
<td>&quot; 15...</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td>&quot; 30...</td>
<td>&quot; &quot;</td>
<td>&quot; 16...</td>
<td>&quot; Marching order, no greatcoat.</td>
</tr>
<tr>
<td>Sept. 3...</td>
<td>Marching order, no jacket or overcoat.</td>
<td>&quot; 18...</td>
<td>Full marching order.</td>
</tr>
<tr>
<td>&quot; 6...</td>
<td>&quot; and 100 rounds ball ammunition.</td>
<td>&quot; 19...</td>
<td>&quot;</td>
</tr>
<tr>
<td>&quot; 7...</td>
<td>Marching order, no jacket.</td>
<td>&quot; 20...</td>
<td>&quot; with 100 rounds ball ammunition.</td>
</tr>
<tr>
<td>&quot; 10...</td>
<td>&quot;</td>
<td>&quot; 21...</td>
<td>Marching order.</td>
</tr>
</tbody>
</table>
| Note.—The five men at Poona had all been in India from two to five years.

It is significant that the point to which the body temperature rose in Poona, with an average wet-bulb temperature approaching Haldane's limit (on the three last marches passing it) should not be greater than that at home in Aldershot, though the "difference" appears greater in the diagram on account of the starting temperature in India being lower, the earlier hour of starting possibly accounting for this. But in Chart 6, where the average march temperatures are recorded in sequence without comparing load or clothing, the lower level of body temperature maintained at Poona is very evident. With the lowered metabolism of Europeans in tropical climates, it might a priori be expected that the body temperature would be maintained at a lower level than in temperate climates; on this point the evidence is conflicting. Rattray (mouth), Davy (mouth), and Crombie (mouth and axilla) say it is raised. Boileau (axilla) confirmed by Thornley and Furnell, Pinkerton (axilla), and Wick (mouth), all maintain there is no change. Johnston (axilla) records an actual reduction. We can
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find only one authority (Crombie) who has made any observations on rectal temperature in the tropics regarding this point, and he only states "that in healthy Europeans in India the rectal temperature is higher than that in the axilla." A series of rectal observations on new arrivals and those long resident in the tropics to clear up this matter would be most valuable. It should be noted that in the Poona experiments the difference between the wet and dry bulbs is very considerable, and that on no occasion did the atmospheric conditions approach saturation. At Aldershot the relative humidity was considerably higher than at Poona, and this with the difference in clothing at each station may partly explain the lower level maintained at Poona. It is of interest to note that with a thermometer below zero Linhard ["Danmark Expeditionem Til Grönlands Nordoskyst," 1906-8, vol. iv, No. 1 (see British Medical Journal, April 8, 1911)], says, "that on going for a walk with the thermometer 36° C. below zero the rectal temperature rose." These experiments in India tend to bear out our contention that there is an optimum marching temperature somewhere between 37°-8° C. (100° F.) and 38°-3° C. (101° F.) provided every facility is afforded to the natural means of heat regulation.

Our thanks are due to Captains G. A. K. Reed, W. W. Browne, R. H. Bridges, H. H. J. Fawcett, and C. R. Sylvester-Bradley for placing their results at our disposal and to Lieutenant-Colonel C. H. Melville for kind assistance with suggestions.

References consulted not mentioned in the text: