Modulation of red cell metabolism by states of decreased activation: Comparison between states

Permalink
https://escholarship.org/uc/item/7vn8k3vf

Journal
Physiology and Behavior, 35(5)

ISSN
0031-9384

Authors
Jevning, R
Wilson, AF
Pirkle, H
et al.

Publication Date
1985

DOI
10.1016/0031-9384(85)90396-8

License
CC BY 4.0

Peer reviewed
Modulation of Red Cell Metabolism by States of Decreased Activation: Comparison Between States

R. JEVNING, A. F. WILSON, H. PIRKLE, S. GUICH AND R. N. WALSH

Departments of Medicine and Physiology, University of California, Irvine, CA 92717

Received 9 July 1984

JEVNING, R., A. F. WILSON, H. PIRKLE, S. GUICH AND R. N. WALSH. Modulation of red cell metabolism by states of decreased activation: Comparison between states. PHYSIOL BEHAV 35(5) 679-682, 1985.—Marked decline of red cell metabolism has been described during the acute state of decreased activation associated with the stylized mental technique of transcendental meditation (TM) in long-term meditators (5–10 years regular elicitation, TM instructors). It is not known whether unstylized rest is accompanied by a similar effect and it is not known what effector(s) may contribute to red cell metabolic changes in these states. In the present study ordinary, unstylized rest was found to be accompanied by small increase of red cell glycolytic rate. Apparently, either repeated elicitation of TM behavior or some special feature of this practice become associated with new mechanisms of metabolic control than those previously in operation. Although the data of this study do not permit isolation of the precise psychological determinants of this effect, the range of possible physiological effectors can be delimited. Blood pH, PCO₂, PO₂, and phosphate can be eliminated as significant for red cell metabolic changes in these states. In the present study of these questions we measured whole blood lactate, red cell oxygen consumption [5], and prevalence of high amplitude theta bursts in the electroencephalogram (EEG) [8]. These two groups are referred to as “rest” and TM groups in this report.

Subjects and Experimental Protocol

We studied two separate groups of subjects: (1) 22 normal, lean, college educated adults (6 women, 16 men, ages 25–36) who had no experience of a stylized rest/relaxation procedure and were studied prior to learning TM; (2) 30 individuals of similar background (7 women, 23 men, ages 21–34) who were long-term TM practitioners (that is, 6–10 years of regular elicitation for 30 to 40 minute periods twice daily). The long-term TM practitioner subjects were also TM instructors. We studied this precise group of TM subjects because several particularly marked physiologic changes have been recently identified during these individuals' elicitation of this state, including approximately a fivefold increment of arginine vasopressin (AVP) [18], 40–60% declines of oxygen consumption [5], and prevalence of high amplitude theta bursts in the electroencephalogram (EEG) [8]. These two groups are referred to as “rest” and TM groups in this report.

Subjects of each of the 2 groups were studied on 2 occasions, approximately 2 weeks apart, each subject serving as his or her own control. Subjects fasted since midnight and were observed between 10:30 and 12:00 a.m. On one (practice) occasion TM subjects were asked to close their eyes and practice TM for 45 minutes followed by an eyes-open recovery period of 30 minutes; analogously, subjects of the rest group were asked to close their eyes and simply rest on the practice occasion for 45 minutes followed by an eyes-open 30 minute recovery period. On the other (control) oc-
FIG. 1. Change of aerobic lactate generation rate by whole blood during and after unstylized eyes closed rest (practice) or control periods. Rest incubations at 37 ° (■); 25 ° (□). Control incubations at 37 ° (●); 25 ° (○). Values displayed for each 15 minute interval are means (±S.E.) of percentages of initial value.

FIG. 2. Change of aerobic lactate generation rate by whole blood during and after TM practice or reading control periods. TM aerobic incubations were at 37 ° (▲), and 25 ° (●); control aerobic, at 37 ° (●) and 25 ° (○). Means (±S.E.) of percentages of initial value.

Preparation of Blood and Metabolic Measurements

Eighteen milliliter arterial blood samples were drawn every 15 minutes into heparinized syringes throughout practice (i.e., rest or else TM) and post-practice periods at 0, 15, 30, 45, 60, and 75 minutes. Two milliliters of blood were used for blood gas determination (Radiometer ABL Blood Gas Laboratory, Radiometer, Copenhagen), glucose and hematocrit.

The remaining 16 ml of blood were immediately used for determining blood lactate generation rate, and concentrations of whole blood lactate. Generation rate was determined during 90 minutes of aerobic incubation of blood (that is, open to air) at 25 ° and 37 ° from slopes of best fit lines through lactate concentrations measured after 0, 30, 60 and 90 minutes of incubation.

Measurements of lactate concentration were performed in duplicate utilizing a Technicon autoanalyzer (Technicon Instrument Corp., Tarrytown, NY) by use of an enzymatic method [19], except that the supernate for analysis was prepared by delivery of 0.45 ml of sample into 0.90 ml of 5 N ice-cold perchloric acid followed by neutralization with 5.63 N K2 CO3 according to the method of Beutler [2] with modifications of McManus (personal communication). Mean difference (±SE) between known and determined standard lactate concentrations in the assays was 4.1 ± 1.8% with correlations 0.97<r<0.99.

Metabolic data consisted of rates of aerobic lactate generation rate every 15 minutes at 37 ° and 25 ° by whole blood. Data were analyzed by analysis of variance with group and time as classification variables [26].

RESULTS

Figure 1 indicates that small increases of aerobic blood glycolytic rate at 25 ° and 37 ° occurred during eyes closed rest without change on the control occasion for these subjects. For comparison, we show in Fig. 2 previously reported [12] aerobic blood glycolytic rate variation during TM and the corresponding control occasion for this group. Trends of increased glycolytic rate at 25 ° and 37 ° during rest differed significantly from the sharp declines of glycolytic rate at 25 ° and 37 ° found during TM. Initial (time 0) glycolytic rates at 25 ° and 37 ° in rest subjects did not differ significantly from initial blood glycolytic rates in the TM subjects (Table 1).

Gourley and Matschiner [7] reported marked increase of blood pH upon exposure to air, due probably to loss of CO2. In this study, whole blood pH during the 90 minute aerobic incubations increased to approximately 8.0 at 37 ° and to approximately 7.8 at 25 °. Initial blood pH values of rest and control incubation series at times 0, 15, 30, 45, 60, and 75 were very similar (Table 2); they were also constant during the experiment and similar to those of the TM group [12].

Concentration of arterial lactate did not change during rest or control occasions, and there was no significant variation of arterial O2 and CO2 tensions (PO2 and PCO2, respectively), base excess, hematocrit, or glucose (Table 2). The data in the TM group were similar except for lactate [12].

On the average, 84% of the unstylized rest period was spent in wakefulness and 16% in stage 1 sleep, almost identical with findings for the TM group (90% and 10%, respectively) [12]. Galvanic skin resistance (GSR) increased during both TM and rest with significantly greater increase during TM (Fig. 3).

DISCUSSION

Since 90-95% of whole blood glycolysis is accounted for by red cells [1], these data indicate probable small increase

TABLE 1

<table>
<thead>
<tr>
<th>WHOLE BLOOD INITIAL LACTATE GENERATION RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
</tr>
<tr>
<td>37 °</td>
</tr>
<tr>
<td>2.8 ± 0.6</td>
</tr>
</tbody>
</table>

Values are means ± S.E. in μmoles/ml cells per hour.

*From [12].
of red cell glycolysis during unstylized rest, as compared
with marked TM-induced decline. This result is consistent
with relative constancy of arterial lactate during rest (Table
2) as compared with decline during TM [12], since the red
cell is a primary contributor to the lactate content of blood
[16]. Since total sleep and sleep stage percent were almost
identical in the 2 groups, sleep cannot account for the re-
sults.

Whereas the data of this study do not allow specification
of mechanism of this effect, the agency of several effector(s)
can be reduced in likelihood. For example, the data lend
added support to the hypothesis [12] of lack of significant
role of the powerful effector, pH (in plasma) in these
metabolic effects of rest states, since, despite large differ-
ence of blood metabolic changes, pH differed little between
the behaviors (Table 2 and [12]). This does not completely
rule out the possibility of altered cell pH in the metabolism,
but such alteration is unlikely because hydrogen ions are
believed to be passively distributed across the red cell mem-
brane in most circumstances according to Gibbs-Donnan
equilibrium. The agency of weaker effectors, such as PO2
and PCO2 and variation of red cell numbers, can also be
eliminated, since blood gases and hematocrit did not change.
Finally, since facilitated glucose transport in the mammalian
red cell is 2- to 250-times greater than rate of glucose phos-
phorylation [20,25], and glucose levels were unaltered, a role
for blood glucose is unlikely.

These results support the specificity of TM in its
metabolic control of the erythrocyte. However, the reasons
for the difference between TM and unstylized rest remain
unknown. The TM subjects of these investigations are long-
term practitioners. Whereas the results of early research
studying only whole body respiratory change were consis-
tent with physiologic similarity of TM and rest, more recent
measurements—specifically on TM subjects who have now

![FIG. 3. Galvanic skin resistance (GSR) during and after TM (●) and
during and after eyes closed rest (○) (practice occasions only).](image-url)
been eliciting this behavior for 5-10 years—indicate development of other fundamentally different hormonal, circulatory, and electrophysiologic changes [7, 11-14, 18] in this group.

Since participation of a humoral agent(s) in the TM-induced decline of red cell glycolysis is likely [12], it is possible that repeated elicitation or some special feature of this behavior is necessary for elaboration of the responsible effector. While some known hormones have been reported to affect red cell 2,3-diphosphoglycerate levels, deformability, osmotic fragility, membrane structure, and size [21], their significance for physiological control of human red cell metabolism is not established, except possibly for T₃ and T₄ (27). However, in a recent study [11], we found that T₃ and T₄ concentrations did not vary during either TM or rest.

Although insulin receptors have recently been identified in the red cell [22], their significance for red cell carbohydrate metabolism is unlikely [5], and we also found little variation of insulin concentration during these behaviors [11]. Finally, the temporal patterns of plasma arginine vasopressin (AVP), oxytocin, growth hormone, and prolactin [11, 14, 18] during TM diminish the likelihood of their participation in this response.

ACKNOWLEDGEMENTS

This research was supported by National Heart, Lung, and Blood Institute Grant HL-27894 and the John D. and Catherine T. MacArthur Foundation.

REFERENCES
