Acute Hypoglycemia Impairs Nonverbal Intelligence

Importance of avoiding ceiling effects in cognitive function testing

Roderick E. Warren, MRCP1
Kate V. Allen, MRCP1
Andrew J. Sommerfield, MRCP1

ANDREW J. SOMMERFIELD, MRCP1
KATE V. ALLEN, MRCP1
RODERICK E. WARREN, MRCP1

A
cut hypoglycemia causes a pro-
gressive, reversible deterioration in
cognitive function that becomes de-
tectable at blood glucose concentrations
below ~3.0–3.4 mmol/l (1). In an earlier
study in nondiabetic subjects, we re-
ported that several facets of attention de-
teriorated significantly at an arterialized
blood glucose level of 2.6 mmol/l (2).
However, performance on Raven’s Pro-
gressive Matrices (RPM) was not sig-
nificantly impaired at either 20 min or
completion of the test (with no time
limit). This was unexpected, because,
previously, various domains of cognitive
function had consistently been impaired at
this level of hypoglycemia (1). Additionally,
the RPM is acknowledged as being among
the best indicators of general fluid intelli-
gence (3) and has a substantial correlation
with working memory (4), which is exquis-
tely sensitive to hypoglycemia (5).

Hypoglycemia disrupts performance
on different cognitive function tests to a
variable degree, leading to speculation
that different mental functions vary in
their sensitivity to hypoglycemia. This is
complicated by a lack of a universally ac-
cepted battery of cognitive measures and
variable experimental methodology (6,7).
We speculated that the higher-level cog-
nitive skills required for abstract problem
solving (as in the RPM) are resistant to the
effects of hypoglycemia. However, this
contradicted a widely held opinion that
higher-level skills are more sensitive to
hypoglycemia than simple, repetitive cog-
nitive or motor tasks (1). An alternative
explanation was the possibility of a ceiling
effect, as the RPM includes a large propor-
tion of easy problems that involve straight-forward pattern completion, and
mean scores during euglycemia and hy-
pglycemia were 49.5 and 48.7, respec-
tively, out of a maximum of 60. The
present study was designed to test the
celiling effect hypothesis by substituting
two more difficult tests of general fluid
intelligence that are known to be discrimi-
natory in highly able adults. Raven’s Ad-
vanced Progressive Matrices (RAPM) (8)
uses harder problems than RPM, which
consist of geometric designs from which
the subject must induce logical rules,
hold the rules in working memory, and
apply them simultaneously to complete a
pattern (9). The Alice Heim 5 test (AH5)
similarly requires identification and ap-
plication of simultaneous patterns to
complete verbal, numerical, and geometric
sequences (10).

RESULTS — The scores are given in Ta-
ble 1 as means (±SD), except TMB, which
is given as completion time in seconds. Per-
formance on TMB, DSST, and RAPM deta-
riorated significantly during hypoglycemia,
with a trend toward deterioration on AH5.
The effect size of hypoglycemia on RAPM
was substantial, amounting to approxi-
mately three-quarters of an SD.

CONCLUSIONS — These results
suggest that our earlier findings were in-
deed due to a ceiling effect (2) and indi-
cate that hypoglycemia does impair
general fluid intelligence, but it is neces-
sary to use a test appropriate to the ability
level of the participants. Research volun-
tees tend to be more able than the pop-
ulation they are intended to represent,
and the ceiling effect may be common in
studies of hypoglycemia. Care should be
taken to avoid the ceiling effect, and,
while general consensus on cognitive test-
ing is desirable, a single battery of cogni-
tive tests for all subjects may be
inappropriate (7).

The different results for RAPM and
AH5 may reflect differences in the stan-
dard administration of these tests; paper
working is permitted for the AH5 but not
for the RAPM. Holding and applying rules
tirely in working memory is demand-
ing (8), and as we have previously shown
that working memory is obliterated by

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From the 1Department of Diabetes, Royal Infirmary of Edinburgh, Edinburgh, U.K.; and the 2Department of Psychology, University of Edinburgh, Edinburgh, U.K.
Address correspondence and reprint requests to Professor Brian M. Frier, Department of Diabetes, Royal Infirmary of Edinburgh, 51 Little France Crescent, Edinburgh EH16 4SA, U.K. E-mail: brian.frier@luht.scot.nhs.uk.
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Abbreviations: AH5, Alice Heim 5 test; DSST, Digit Symbol Substitution; RAPM, Raven’s Advanced Progressive Matrices; RPM, Raven’s Progressive Matrices; TMB, Trail Making B.
moderate hypoglycemia (5), it is likely that this had a greater impact on RAPM than AH5.

Table 1 — Cognitive function scores during euglycemia and hypoglycemia, plus significance level and effect size for comparison

<table>
<thead>
<tr>
<th>Test</th>
<th>Euglycemia</th>
<th>Hypoglycemia</th>
<th>P</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAPM</td>
<td>18.9 ± 3.1</td>
<td>16.5 ± 3.5</td>
<td>0.007</td>
<td>0.465</td>
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<tr>
<td>AH5</td>
<td>15.6 ± 5.6</td>
<td>13.9 ± 5.0</td>
<td>0.057</td>
<td>0.269</td>
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<tr>
<td>TMB</td>
<td>38.8 ± 8.2</td>
<td>46.3 ± 16.1</td>
<td>0.037</td>
<td>0.339</td>
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<tr>
<td>DSST</td>
<td>87.7 ± 12.5</td>
<td>79.4 ± 9.3</td>
<td>0.019</td>
<td>0.409</td>
</tr>
</tbody>
</table>

Data are means ± SD.

References