Intermittent High-Intensity Exercise Does Not Increase the Risk of Early Postexercise Hypoglycemia in Individuals With Type 1 Diabetes

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Exercise is generally recommended for individuals with type 1 diabetes because it is associated with numerous physiological (1,2) and psychological (3,4) benefits. However, participation in exercise can also increase the risk of experiencing severe hypoglycemia, during both exercise (5) and recovery (6). Unfortunately, there are no evidence-based guidelines for safe participation in intermittent high-intensity exercise (IHE), which characterizes most team and field sports, manual labor occupations, and spontaneous play in children. This is because the response of blood glucose levels to this type of exercise is not known, as previous research on intermittent exercise has employed exercise protocols that do not accurately reflect the high-intensity work–to–recovery ratios observed in intermittent sports (7,8). Therefore, the aim of this study was to investigate the effect of IHE that simulates the high-intensity work–to–recovery ratios observed in intermittent sports on blood glucose levels and glucoregulatory hormones in individuals with type 1 diabetes in order to assess the risk of hypoglycemia.

RESEARCH DESIGN AND METHODS

— Eight volunteers with type 1 diabetes (aged [±SD] 18.6 ± 2.1 years, BMI 22.1 ± 1.5 kg/m^2, $V_{O_{2peak}}$ 42.4 ± 7.3 ml · kg^{-1} · min^{-1}, type 1 diabetes duration 7.0 ± 4.6 years, and HbA_{1c} 7.0 ± 0.4%), who were free of complications and not taking any prescribed medication other than insulin, gave informed consent to participate in the study in accordance with both the University of Western Australia and Princess Margaret Hospital Human Ethics Committees.

The participants visited the laboratory on three separate occasions, first for a familiarization session followed by either a control rest (CON) or IHE trial administered in a random counterbalanced order. At 8:00 AM on CON and IHE trials, the participants injected their usual morning insulin into the abdomen (mean dose 9.4 ± 4.8 units), or in the case of one participant on subcutaneous insulin infusion pump, their usual insulin bolus was infused. Following this, all participants consumed their normal breakfast, which was standardized to be identical on both visits. An antecubital vein was subsequently cannulated for blood sampling, while capillary blood was sampled from a hyperemic earlobe every 15 min for determination of blood glucose levels, which peaked postprandially and then began to decline. As blood glucose levels approached 11 mmol/l, either the CON or IHE protocol was commenced (112 ± 27 min after insulin injection). This procedure was designed to simulate a "real life" situation in which insulin is injected and food is consumed before morning exercise. The IHE protocol was based on time-motion analyses of various intermittent sports (9–11) and spontaneous play in children (12) and consisted of 11 4-s maximal sprints repeated every 2 min on a cycle ergometer for a total duration of 20 min. In contrast, the CON protocol required the participants to be seated on the cycle ergometer for 20 min without exercise. Capillary blood from the hyperemic earlobe and venous blood from the cannulated antecubital vein were sampled during both protocols and for the first hour of recovery. Data were analyzed using two-way repeated-measures ANOVA and paired samples *t* tests using the SPSS 11.0 for Windows software package. Statistical significance was accepted at $P < 0.05$. Data are expressed as means ± SD.

RESULTS

— All trials were commenced when plasma insulin levels were high following subcutaneous injection (178.6 ± 60.7 vs. 198.1 ± 148.0 pmol/l, CON vs. IHE), and there was no difference in insulin levels between trials. Mean blood glucose levels before the commencement of exercise was 10.9 ± 1.9 mmol/l in CON and 11.0 ± 1.8 mmol/l in IHE, and blood glucose level results were normalized relative to these starting levels (Fig. 1*A*). During the first 15 min of IHE, blood glucose levels declined more rapidly compared with CON ($P < 0.05$), indicating that the risk of hypoglycemia was increased at this time. However, during the subsequent hour of recovery from IHE, blood glucose levels remained sta-

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Abbreviations: CON, control rest; IHE, intermittent high-intensity exercise.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

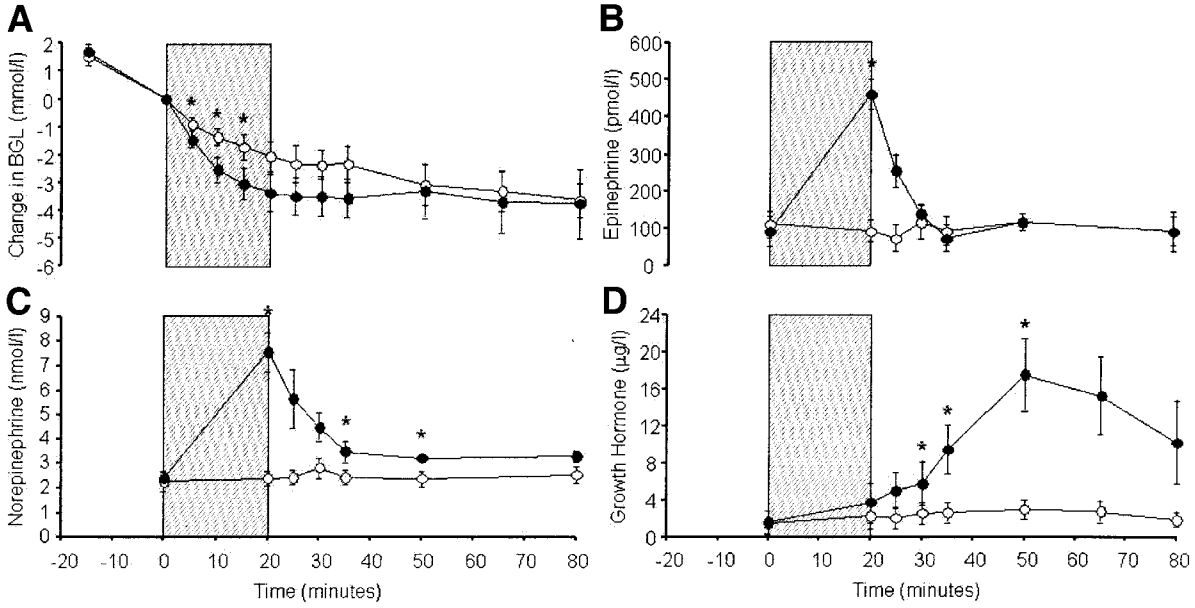

Figure 1—*Effect of 20 min (represented by box) of IHE (●) or CON (○) on normalized blood glucose levels* (A)*, epinephrine* (B)*, norepinephrine* (C)*, and growth hormone* (D)*. Results are expressed as means ± SE. *Indicates statistically significant difference* ($P < 0.05$) *between IHE and CON.*

ble, while continuing to decline in CON ($P < 0.05$), suggesting that the risk of hypoglycemia was not increased during early recovery from IHE.

In response to IHE, blood lactate increased progressively to peak at 6.0 ± 2.1 mmol/l at the cessation of exercise ($P < 0.05$). During that time, there was also a fivefold increase in epinephrine ($P < 0.05$, Fig. 1*B*) and a threefold increase in norepinephrine levels ($P < 0.05$, Fig. 1*C*). Growth hormone levels also increased in response to IHE to peak at 30 min of recovery ($P < 0.05$, Fig. 1*D*). No change in plasma free fatty acids, cortisol, glucagon, or the ratio of glucagon to insulin was observed in either CON or IHE, and there was no difference between trials.

CONCLUSIONS — This study shows for the first time that IHE does not increase the risk of early postexercise hypoglycemia in individuals with type 1 diabetes. This is surprising since the exercise was commenced when plasma insulin levels were high, a time when exercise is generally not recommended (5). Some of the metabolic and hormonal responses to IHE, specifically elevated catecholamine and growth hormone levels, might contribute to preventing the decline in blood glucose levels during early recovery, since these hormones stimulate increased hepatic glucose production (13,14) and inhibit insulin-mediated glucose uptake (15,16).

Caution should be taken against the generalization of these findings to all types of IHE. First, the recovery between high-intensity bouts was passive, while in the field, intense bursts are often interspersed by periods of lower intensity activity (9–11). In addition, the duration of exercise examined here was only representative of a portion of a game, with many intermittent sports lasting for up to 90 min. Thus, more research of this kind is required to further characterize the risk of hypoglycemia associated with IHE and to assist in the development of improved guidelines to allow individuals with type 1 diabetes to safely enjoy the benefits of regular physical activity.

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