Leptin and insulin response to varying energy availability in women

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Introduction

Nutrition and physical activity have a profound impact on reproductive function and other metabolic processes. Most women benefit from regular exercise and experience significant improvements in cardiovascular and muscular fitness. However, some women, in particular those involved in low body weight or aesthetically-demanding sports, deprive themselves of an adequate energy intake and increase their risk for developing menstrual disturbances (Loucks, 2004), reduced metabolic efficiency (Redman & Loucks, 2005) and reduced recovery from athletic performance (Harber et al, 1998).

Inadequate energy availability (defined as dietary energy intake minus energy expended) results in reduced levels of numerous hormones including thyroid hormones, leptin, insulin and luteinizing hormone (Loucks & Thuma, 2003). These hormonal profiles are associated with reproductive irregularities, lower resting metabolic rate (RMR), reduced bone mineral density and impaired recovery following exhaustive exercise (Redman & Loucks, 2005; Myerson et al, 1991; Harber et al, 1998). Sedentary women have been shown to have a threshold of energy availability between 19 and 30 kcal/kg lean body mass (LBM)/day, below which the concentrations of these hormones drop significantly (Loucks & Thuma, 2003). Data from our lab show trained women experience reductions in thyroid hormones at higher energy availabilities (Foster et al, 2000) which may suggest an increased susceptibility to the other metabolic conditions described above.

Objective

The purpose of this project is to characterize the functional relationship between energy availability and leptin and insulin metabolism in trained women to gain insight into the extent of the dietary and physical activity reform that might be necessary for maintaining a healthy metabolic status. We hypothesized that trained women would have a lower threshold of energy availability compared to sedentary women described in the literature (Loucks & Thuma, 2003).

Design

Quasi-experimental design.

Setting

University of Alberta, Edmonton.

Subjects

Twenty-nine healthy, trained women (age=24.1±0.9 yr; VO_{2max}=48.0±0.5 ml/kg/min) volunteered to participate in this study. Subjects participated in a wide variety of sports (eg cross-country running, cycling, field hockey, rowing, soccer) and were free from use of oral contraceptives and other medications known to alter hormonal status. This study was approved by a University Research Ethics Board.

Intervention/Main Outcome Measures

Leptin and insulin concentrations were measured during the follicular phase of the menstrual cycle in all participants before and after 4 days of controlled exercise and energy intake. A brief description of the completed protocol follows: total energy expended during cycle ergometry for all subjects

approximated 30 kcal/kg FFM/day at an intensity equivalent to just-below ventilation threshold. Supervised exercise sessions were performed in 30-minute bouts on a cycle ergometer with 10-minute rest periods until the required energy expenditure was reached. Energy availability was manipulated across 5 groups (5, 11, 19, 25, 40 kcal/kg LBM/day) by controlling energy intake with a liquid nutritional supplement (Ensure, Ross Labs, Quebec)(Loucks & Heath, 1994). For 7 days, beginning 2 days before the exercise protocol, a fasting blood sample was obtained once daily between 7:30-8:30 a.m. and analyzed for numerous thyroid hormones. Baseline leptin and insulin concentrations were determined by pooling the samples from days 1-3 and subtracted from the hormone concentration on the morning of day 7.

Main Results

Statistical analysis of insulin revealed a main effect of time. Post-treatment levels of insulin were significantly lower compared to baseline concentrations in all energy availability groups ($p<0.05$). There were no differences between the energy availability groups. In contrast, analysis of leptin revealed an interaction between group and time; post-treatment levels of leptin decreased significantly in the 2 lowest energy availability groups (11 and 5 kcal/kgFFM/day) compared to baseline ($p<0.05$) and remained unchanged in the 3 higher energy availability groups.

Conclusions

Insulin levels declined significantly in all 5 energy availability groups whereas leptin only declined in the 2 lowest energy availability groups. These results suggest that insulin concentrations may be more sensitive to large acute increases in exercise and less so to energy availability alone. Leptin, on the other hand, appears to be more sensitive to energy availability as supported by the observed decrease.

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Commentary

The response of insulin and leptin to decreasing energy availability in trained women differs. Insulin appears to be most sensitive to the total amount of exercise performed whereas the leptin response may be more sensitive to change in substrate utilization in the face of lower total energy intake. Leptin concentrations dropped significantly in the energy availability groups below 19 kcal/kgFFM/day; this is the same threshold we identified for in reverse T_3, a marker of energy insufficiency. Our findings suggest that energy availability for active women should remain above 20 kcal/kgFFM/day to avoid changes to leptin and potential metabolic adaptations associated with menstrual irregularities, altered metabolic status and decreased recovery in athletic females.