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MUSCLE GLYCOGEN UTILIZATION DURING SHIVERING THERMOGENESIS IN HUMANS.

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Increased thermogenesis in humans during cold exposure is caused by shivering. Although there is much evidence that circulating substrates are used to fuel this enhanced skeletal muscle activity, there are no studies describing intramuscular substrate utilization during shivering in humans. It has been demonstrated, however, that intramuscular glycogen is an important substrate for shivering hypothermic birds and small mammals. The purpose of the present study was to clarify the importance of skeletal muscle glycogen as a fuel for shivering thermogenesis in humans during cold water immersion.

Fourteen lean male subjects (mean±SEM) (11±1 % body fat), wearing only bathing suits, were immersed to the shoulders in 18°C water until 90 min had elapsed or rectal temperature (T_{re}) decreased to 35.5°C. T_{re}, metabolic rate, heart rate, and electromyographic activity from the *vastus lateralis* and *deltoid* muscles were monitored continuously during the immersion. Biopsies from the *vastus lateralis* muscle and venous blood samples were obtained prior to and immediately after the immersion.

Metabolic rate increased to 3.5±1.1 times resting values ($p<0.01$) and T_{re} decreased by 0.9±0.3°C during the immersion ($p<0.001$). Muscle glycogen concentration in the *vastus lateralis* decreased from 410±57 to 332±68 *mmol glucose kg^{-1} dry muscle* ($p<0.001$), each subject showing a decrease. Plasma volume decreased ($p<0.001$) markedly during the immersion (-24±5%). Correcting for this decrease, blood lactate and plasma glycerol levels increased by 60 % ($p<0.05$) and 38 %, respectively ($p<0.01$), while plasma glucose levels decreased by 20 % ($p<0.001$). No changes in plasma FFA or β-hydroxybutyrate levels were observed after the immersion. The respiratory exchange ratio increased during the immersion from 0.80±0.06 to 0.85±0.05 ($p<0.01$). The rate of carbohydrate oxidation increased from 0.09±0.01 to 0.49±0.08 g min^{-1} during the immersion.

The results demonstrate clearly that in addition to ciculating substrates, intramuscular glycogen reserves are also used as an energy source in response to intense thermogenic shivering activity within human skeletal muscle.