Glycogen degradation during isometric exercise at low contraction force

E. Hultman and K. Söderlund

Department of Clinical Chemistry II, Huddinge University Hospital, S-14186 Huddinge, Sweden

Summary. The glycogen content was measured in biopsy samples of human vastus lateralis muscle during prolonged isometric contraction with low force generation. In the first experiment 15% of the maximum voluntary contraction force (MVC) was held for 10 min. Glycogen utilization was 68.1 mmol glucosyl units \cdot kg^{-1} \cdot d.m. The study was continued by intermittent contractions of 50 s duration and 10 s rest repeated for 50 min. This resulted in a total glycogen utilization of 167.5 mmol glucosyl units \cdot kg^{-1} \cdot d.m. The study was repeated with a force set to 7.5% MVC starting with 20 min continuous contraction followed by the same intermittent contractions for a further 100 min. The glycogen decrease was 15 mmol after the continuous contraction and totally 50 mmol after 2 h with the lower force. Thus the glycogen degradation rate even at low contraction force was related to the force level, being 6 times higher when the force was increased from 7.5 to 15% MVC. With prolonged isometric work periods at work loads corresponding to 15% MVC or higher depletion of the glycogen store can limit work performance capacity.

Key words: Glycogen degradation — Low contraction force

Introduction

Isometric muscle contractions of varying force are a normal component in everyday life. In many types of occupational work, the work is confined to distinct muscle groups and repeated monotonously during the working days. The contraction force utilized has to be kept low if the contraction is repeated regularly for longer periods. It is well known today that this type of work often causes muscle damages after shorter or longer periods of daily work, but very little is known about the energy metabolism in muscle during isometric work with low contraction force. In this study we have investigated glycogen utilization during isometric contractions with forces corresponding to 7.5% and 15% of maximum voluntary contraction force (MVC) in quadriceps femoris.

Material and methods

6 normal healthy volunteers participated in the study, 4 men and 2 women aged between 21 and 51 years. 4 participants took part regularly in some form of organized physical activity, and 2 were inactive. Voluntary consent was obtained from the subjects following an explanation of the experimental procedures and the possible risks involved. The study was approved by the Ethical Committee of the Karolinska Institute. The subjects reported to the laboratory in the morning after an overnight fast. They were placed on a bed with the lower part of the legs flexed over the end of the bed to 90°. A strain gauge (AB Bofors, Karlsga, Sweden) was attached by an ankle strap for measuring force production, and the signal was amplified (d.c. amp. Medelec AD6, Surrey, England) and displayed on an oscilloscope placed in front of the subjects. MVC was measured repeatedly for each leg of the subjects. The force was set to 7.5 and 15% MVC and the subjects controlled the force production by observing the oscilloscope signal.

The experiment started with a 10 min isometric contraction at a force corresponding to 15% MVC. Thereafter the volunteers contracted isometrically for 50 s and rested for 10 s repeatedly for a total of 50 min. The total work time was 60 min. Muscle biopsies (Bergström 1975) were taken from vastus lateralis before the experiment and after 10 and 60 min contractions. After the first experimental session the participants were allowed to rest for 2 hours and ingested a light lunch of 300 ml sour milk, 1 egg, and coffee. In the second session the experiment started with a 20 min isometric contrac-
tion at 7.5% MVC. Thereafter the volunteers continued to contract repeatedly for 50 s periods with 10 s rests for 100 min. The total work time was 120 min. Biopsy samples were obtained at rest, and after 20 and 120 min.

The muscle samples were immediately frozen in liquid nitrogen, freeze-dried and dissected free of blood and connective tissue. Glycogen was determined according to the method described by Harris et al. 1974.

### Results

All the subjects could sustain the contractions during the predetermined time periods with the preset loads. All experienced subjective feelings of fatigue especially at the end of the 60 min of intermittent contractions at the higher work load (15% MVC).

The glycogen content in quadriceps femoris before contraction was 409±50 mmol·kg⁻¹·d.m. and decreased during the 10 min contraction at 15% MVC to 340.9±69.5. The mean decrease was thus 68.1 mmol glucosyl units·kg⁻¹·d.m. or 6.8 mmol·kg⁻¹·min⁻¹. During the following 50 min of intermittent contraction the decrease totalled 99.4 mmol·kg⁻¹ or 1.98 mmol·kg⁻¹·min⁻¹ (Tables 1 and 2). The corresponding lactate values in the muscle were at rest 3.9±1.2 mmol·kg⁻¹·d.m. and after 10 and 60 min 18.6±18.0 and 10.3±7.9 mmol·kg⁻¹·d.m. respectively. During the second period of contractions at 7.5% MVC the degradation of glycogen was 15 mmol·kg⁻¹·d.m. (or 0.75 mmol·kg⁻¹·min⁻¹) in the first 20 min of continuous contraction. This was followed by an intermittent contraction for 100 min in which a total of 35 mmol glucosyl units·kg⁻¹·d.m. was degraded. The corresponding glycogenolytic rate was 0.35 mmol·min⁻¹·kg⁻¹·d.m. The muscle lactate content before the contraction was 4.9±2.1 mmol·kg⁻¹, after 20 min continuous contraction

### Discussion

The results show the difference in substrate utilization during the two isometric contractions with different contraction forces. During the continued 10 min contraction with the higher force (15% MVC) a rapid degradation of glycogen took place, probably due to increased utilization of muscle glycogen as energy substrate for both anaerobic and aerobic metabolism. The blood flow in the leg muscle during static contraction at 15% MVC was reported by Kilbom and Persson (1982) to increase from approximately 0.4 l·min⁻¹ to 0.97 l·min⁻¹ and simultaneously the oxygen uptake increased four fold. During intermittent exercise with the same load, the lactate content was 10.3 compared to 18.6 mmol·kg⁻¹·d.m. at the end of the continuous 10 min contraction. This relatively low lactate concentration can be explained by the increased blood flow and increased availability of oxygen with predominantly oxidative degradation of glycogen.

The rate of glycogen utilization during the intermittent contraction was 1.98 mmol glucosyl units·min⁻¹·kg⁻¹·d.m., which would correspond to a production of 77 mmol ATP·min⁻¹·kg⁻¹·d.m. if completely utilized for oxidative ATP formation. In earlier studies we have determined the maximum ATP utilization rate during electrical stimulation of quadriceps femoris to be of the order of 480–660 mmol ATP·kg⁻¹·d.m.·min⁻¹ (Hultman and Sjöholm