26.5

WOMEN HAVE LONGER ENDURANCE TIMES FOR CONSTANT-POSITION AND CONSTANT-FORCE FATIGUING CONTRACTIONS

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The purpose of this study was to compare the endurance time of men and women during constant-position and constant-force fatiguing contractions. Six men (mean ± SE, 29 ± 2 yr) and five women (24 ± 1 yr) performed 2 fatiguing contractions on different days with the left elbow flexor muscles at 15% of maximal voluntary contraction (MVC) force: (1) a constant-force contraction, and (2) a constant-position contraction, with a load equivalent to 15% MVC. Men were 57% stronger than the women (409 ± 47 N vs 175 ± 7 N; $p<0.001$). There was no difference in the MVCs performed on the separate days before the fatigue tasks ($p>0.05$). The endurance time of the constant-force task (1561 ± 235 s) was longer than that for the constant-position task (797 ± 203 s, $p<0.01$). For the constant-force task, the endurance time of the women (1933 ± 284 s) was 54% longer than that of the men (1252 ± 284 s; $p<0.05$). For the constant-position task, the endurance time of the women (1251 ± 345 s) was 200% longer than that of the men (418 ± 95 s; $p<0.05$). The longer endurance time often performed by women during a submaximal contraction, is further enhanced when the task involves matching position rather than force.

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26.6

GENDER DIFFERENCES IN FORCE DEFICITS AFTER STRETCHES OF ACTIVE RAT SKELETAL MUSCLES

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Twenty stretches of plantar flexor muscles, imposed on isometric contractions (80 Hz, stimulation time 1.1 s, rest periods 3 min), were produced by dorsiflexion ($a = 3000°\cdot s^{-2}$, ankle position 90° to 40°) in weight-matched anaesthetized female (F, $n = 6$, bw 273 ± 18 g, age 141 ± 23 days, mean ± SD) and male (M, $n = 6$, bw 285 ± 25 g, age 62 ± 10 days) Sprague Dawley rats. Forces were measured at the plantar surface of the foot. Relative declines in isometric force at 90° and stretch force at 40° during the stretch protocol, and the isometric forces at 90° at 5, 10, 20, 40, 60, and 80 Hz before and after 1 hr of rest following the active stretches were measured. No gender differences were observed for isometric forces at each stimulation frequency before the stretch protocol. During the stretch protocol, the course of relative declines in isometric force and stretch force were similar for F and M rats. At the end of the stretch protocol, deficits in isometric force were 49.9 ± 5.1% (F) and 45.9 ± 5.3% (M) ($P = 0.2$) and deficits in stretch force were 32.2 ± 5.5% (F) and 35.0 ± 4.4% (M) ($P = 0.4$). One hour after the stretches, the remaining isometric force deficits at 5, 10, and 20 Hz were not different. However, isometric force deficits at 40, 60, and 80 Hz were 18.6% ($P < 0.05$) (F: 50.4 ± 4.9%; M: 42.5 ± 5.8%), 13.7% ($P < 0.05$) (F: 51.0 ± 4.3%; M: 44.9 ± 4.4%), and 16.3% ($P < 0.05$) (F: 47.8 ± 4.1%; M: 41.1 ± 4.2%) larger for F than for M rats. In conclusion, the susceptibility of skeletal muscles to force deficits one hour following repeated active stretches is larger for 4 months old female rats than for male rats of comparable body weight. Supported by NIOSH R01-OHAR-02918.

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26.7

LACTATE PROTECTS CONTRACTILITY IN MUSCLE EXPOSED TO HIGH EXTRACELLULAR K^+. K. Overgaard, T. Clausen and O. B. Nielsen. Dept. of Physiology, University of Aarhus, DK-8000 Aarhus C, Denmark.

It is well known that exercise can produce hyperkalemia and intensive exercise may increase extracellular K^+ concentration ($[K^+]_o$) more than 2-fold. Because high $[K^+]_o$ is associated with reduced excitability of skeletal muscle, this may contribute to fatigue. In addition, strenuous exercise leads to accumulation of lactic acid and acidification. Using isolated rat soleus muscles mounted on isometric force transducers the combined effect of hyperkalemia and lactic acid on muscle contractility was examined. An increase in $[K^+]_o$ to12.5 mM reduced twitch and tetanic force to 16±4 and 14±3 %, respectively, of the control force determined at a $[K^+]_o$ of 4 mM (mean±SEM, n=4 and 9). Subsequent addition of 20 mM lactate, which reduced pH of the incubation medium from 7.4 to 6.8, led to a recovery of twitch and tetanic force to 91±14 and 74±6 %, respectively, of the control force. In muscles at 4 mM K^+, 20 mM lactate was almost without effect on force. Other experiments showed that 20 mM lactate increased the $[K^+]_o$ that was necessary to reduce tetanic force by 50 % from 11.1±0.2 to 13.0±0.1 mM (n=6). Effects similar to those of lactate could be elicited by increasing the fraction of CO_2 in the gas used for equilibration of the buffers from 5 to 50%, which reduced pH to 6.7. These results show that acidification caused by lactate or CO_2 provides some protection of muscles against the depressing effects of high $[K^+]_o$. During exercise, where $[K^+]_o$ is elevated, this will make muscles less prone to fatigue caused by loss of excitability and the production of lactate may, therefore, protect against muscle fatigue.

26.8

EFFECTS OF STIMULATION FREQUENCY AND DURATION ON METABOLISM AND FATIGUE IN HUMAN SKELETAL MUSCLE. Russ, D.W., Binder-Macleod, S.A., Walter, G.A., & Vandenborne, K. University of Delaware, Dept. of Physical Therapy, Newark, DE 19716 and University of Pennsylvania, Department of Physiology, Philadelphia, PA 19104.

OBJECTIVE: This study determined the relative metabolic cost of stimulation trains of different frequencies (20, 40, and 80 Hz) and durations (300, 600, 1200, and 1800 ms), and to examine the fatigue produced by these trains. **METHODS:** All experiments isometrically tested the medial gastrocnemius muscle. Metabolic changes in response to different stimulation trains were recorded using ^{31}P-NMR spectroscopy, under ischemic conditions. These same trains were also to fatigue the muscle under free-flow condtions. **RESULTS:** For a given duration, higher- frequency trains produced greater metabolic changes than lower-frequency trains. For a given frequency however, increasing the duration of stimulation produced a progressively lesser degree of metabolic changes. This progressive reduction in metabolic cost of stimulation roughly coincided with the plateau of force during stimulation, suggesting that maintenance of force is less metabolically demanding than generating force. In the fatiguing experiments, protocols employing the more metabolically-demanding trains produced the greatest fatigue. Other factors such as the number of stimulation pulses, duty cycle, and isometric "work" (force-time integral) did not appear to be related to the fatigue produced. **CONCLUSIONS:** It appears that the force-generation phase of an isometric contraction is more metabolically demanding than the force-maintenance phase. Fatigue as a result of repetitive, intermittent, electrical stimulation appears to be related to the forces generated by the trains, rather than any specific stimulation characteristics. These results have important implications for the clinical application of Functional Electrical Stimulation.

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26.9

DIFFERENTIAL FATIGUE RATES OF MUSCLE FIBER TYPES IN RESPONSE TO HYPOXIA. RA Howlett & MC Hogan, Dept. of Medicine, Univ. of California - San Diego, La Jolla, CA 92093-0623.

This study compared the fatigability of rat hindlimb muscles composed of different fiber types when simultaneously stimulated for a fixed period and intensity with and without hypoxia. Hindlimb muscles of 11 rats were exposed and the soleus (SOL) and gastrocnemius/plantaris (GP) were each isolated and attached to individual force transducers. Rats were then equilibrated with either normoxic (N; arterial PO_2 = 87.7 ± 1.5 Torr) or hypoxic (H; arterial PO_2 = 30.0 ± 2.4 Torr) conditions. Following stimulation, muscle fatigue (final tension/initial tension) was similar for both N and H in SOL (54.3 ± 4.2 vs. 54.2 ± 3.5 %) but in GP was significantly greater in H than N (10.8 ± 0.9 vs. 43.0 ± 8.9 %). SOL PCr content fell to similar levels (21.1 ± 4.9 vs. 24.1 ± 1.6 mmol/kg dw) during N and H, but in WG, PCr following H was significantly lower than N (14.3 ± 1.5 vs. 34.0 ± 6.0 mmol/kg dw). Similarly, muscle lactate increased in both fiber types at fatigue, but only in WG was the increase significantly greater with H (SOL 5.3 ± 1.1 vs. 7.1 ± 2.0; WG 5.3 ± 2.2 vs. 13.7 ± 4.5 mmol/kg dw). Increases in calculated muscle $[H^+]$, free ADP, and free AMP were similar between N and H in SOL but were significantly greater during H in WG. These data suggest that less oxidative rat hindlimb muscles are more sensitive to hypoxia. This sensitivity is likely due to a greater relative mismatch between oxidative capacity or mitochondrial content and maximal rates of myosin ATPase activity in these fibers.

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