APS Conference

Integrative Biology of Exercise

Red Lion Hotel and
Sheraton Colorado Springs Hotel
Colorado Springs, Colorado
September 23–26, 1992

The American Physiological Society
The American College of Sports Medicine

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# Integrative Biology of Exercise

**September 23–26, 1993**  
**Colorado Springs, Colorado**

<table>
<thead>
<tr>
<th>Wednesday, September 23</th>
<th>Thursday, September 24</th>
<th>Friday, September 25</th>
<th>Saturday, September 26</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symposium 3:00–6:00 pm</strong></td>
<td><strong>Tutorial 8:00–9:00 am</strong></td>
<td><strong>Tutorial 8:00–9:00 am</strong></td>
<td><strong>Tutorial 8:00–9:00 am</strong></td>
</tr>
</tbody>
</table>
| Limiting factors for maximum aerobic performance: how do we define and test them? | Exercise in the diabetic  
Speaker: Edward Horton | Protein polymorphism and muscle function  
Speaker: Richard Moss | Metabolic integration during exercise  
Speaker: Bengt Saltin |
| Chair: Stan Lindstedt | **Tutorial 8:00–9:00 am** | **Minisymposium 8:00–9:00** | **Tutorial 8:00–9:00 am** |
| Control of glycolysis in contracting muscle  
Speaker: Richard Connell | Theories for the decreased maximal blood lactate level in chronic hypoxia  
Chair: Paolo Cerretelli | Evolution of olympic performance  
Speaker: Per-Olof Astrand | **Symposium 9:00–Noon** |
| **Symposium 3:00–6:00 pm** | **Symposium 9:00–Noon** | **Symposium 9:00–Noon** | **Symposium 9:00–Noon** |
| Body fluid homeostasis during exercise  
Chairs: Ethan Nadel and Carl Gisolfi | The lung at the limit of its function during exercise  
Chair: Brian Whipp | The PO2 gradient from hemoglobin to cytochromes  
Chair: Peter Wagner | Human versus nonhuman models of exercise: what can we learn from animals?  
Chair: Jim Jones |
| **Symposium 3:00–6:00 pm** | **Symposium 9:00–Noon** | **Symposium 9:00–Noon** | **Symposium 3:00–6:00 pm** |
| Anaerobic threshold: evidence for and against  
Referees: Brian Whipp and John Reeves  
For: Karlman Wasserman  
Against: George Brooks | Control of lipid oxidation in contracting muscle  
Chair: Jeanie McMillin | Cellular bases of muscle adaptation  
Chair: Kenneth Baldwin | Regulation of respiration in striated muscle  
Chair: Martin Kushmerick |
| **Flying W Ranch** | Microvascular function in contracting skeletal muscle  
Chair: Brian Duling | **Symposium 3:00–6:00 pm** | **Symposium 3:00–6:00 pm** |
| 6:30–10:00 pm | Muscle mechanics: from molecular crossbridges to intact animals  
Chair: Richard Taylor | Cellular bases of skeletal muscle fatigue  
Chair: Robert Godt | **Symposium 3:00–6:00 pm** |
| Dinner and entertainment | **Symposium 3:00–6:00 pm** | Effects of exercise training on the coronary circulation  
Chair: Harold Laughlin | Exercise during physiological and pathophysiological states  
Chair: Gunnar Blomqvist |
| | | Banquet Lecture and Award Presentations  
7:30 pm  
Featuring Sir Roger Bannister | |
Sessions with Contributed Abstracts

Thursday

Gastrointestinal Physiology 171
Acid-Base Balance 171
Kidneys and Fluid Balance 173
Thermoregulation 174
Endocrine Physiology 176
Adaptation 178
Disease States 181
Exercise Testing 184
Locomotion and Biomechanics 185
Protein Metabolism 187
Fat Metabolism 188
Carbohydrate Metabolism 190

Friday

Muscle Structure and Function 194
Muscle Fatigue 198
Skeletal Muscle Damage 201

Contractile Properties 204
Energetics 206
Lactate Metabolism 209
Cellular Regulatory Mechanisms 212
Molecular Regulatory Mechanisms 216

Saturday

Integrated Systems 217
Microcirculatory Physiology 218
Microcirculatory Structure and Function 220
Heart 221
Comparative Physiology 223
The Lungs 227
Oxygen Transport and Kinetics 233
Autonomic Responses 235

Index 241

The kind support of the Gatorade Sports Science Institute for the APS Conference: Integrative Biology of Exercise is gratefully acknowledged.
10.1 HEPATIC GLUCONEOGENESIS IS LIMITED BY PRECURSOR DELIVERY, NOT OXYGEN AVAILABILITY, DURING SEVERE REDUCTIONS IN FLOW. K. S. Deming, J. H. Uriel, and C. M. Rosenwasser
Univ. of Calif., Dept. Exer. Sci., Los Angeles, CA 90095

Reduced hepatic blood flow has been observed during exercise and prolonged as a limitation for hepatic gluconeogenesis. In the in vivo reduced flow are decrements in precursor delivery and oxygen availability, both potential limitations for hepatic glucose output (HGO). To determine the role of reduced hepatic precursor delivery or oxygen availability, for gluconeogenesis, we utilized in situ perfused livers from 24 hr fasted rats. Following a 30 min 'washout' period with Krebs-Henseleit buffer, fresh bovine erythrocytes (Hct = 20%) and no substrate, steady-state perfusions were initiated using 2nd reservoir containing lactate (2.5 mM) and glucagon (0.25 us/ml). Hct was adjusted with erythrocytes (30% or 40%) and was unaltered (Hct = 2.02 ± 0.02 ml/min) was observed for elevated Hct 2.97 ± 0.17 compared to unaltered Hct, 1.91 ± 0.10. Relative HGO (umol/min/g) was not significantly different between elevated Hct (40%) and unaltered Hct at 0.66 ml/min/g, 0.49 ± 0.03 nor between elevated Hct (30%) and unaltered Hct at 0.83 ml/min/g, 0.66 ± 0.03, respectively. Raising the 2nd reservoir [L]A to 4 mM significantly increased HGO to 0.66 ml/min/g, 0.41 ± 0.04. VO2 was significantly higher for elevated Hct, 3.32 ± 0.24, compared to unaltered Hct, 2.70 ± 0.30. HGO was unaffected by Hct level. Results indicate that during severe reductions in flow, in situ HGO is limited by precursor delivery, not oxygen availability.

10.3 RAPID OROCOLONIC TRANSIT OF A SOLID MEAL IN CHRONICALLY ACTIVE PERSONS WITH HIGH ENERGY INTAKE, Alon Harris, John B. Watkins, Carmen A. Tiamovannis, Joseph A. Near* and Bruce J. Martin

Increases in energy requirements and energy intake alter digestive strategy in several animal species. Whether similar intestinal adaptations to hypophagia (eat less) or increased energy intake (eat more) in humans was associated with accelerated oro-colonic transit of a liquid meal. This study investigated the influence of chronic exercise on dietary intake in the transit rate of a solid meal from the mouth to the colon. Orocolonic transit was determined by using a HPLC assay for sulphapyridine. This technique employs the conversion of sulphasalazine to sulphapyridine and 5-aminosalicylic acid by microsomal arylaminopropionate present in the human colon. The sulphapyridine formed is absorbed into the circulation and detected in peripheral venous blood when transit occurs. Dietary records completed for the subjects for 3 days were analyzed for total calories, and proportions of fat, protein, carbohydrate and dietary fiber. Subjects were given a solid meal consisting of commercially available breakfast bars (250 Kcal) supplemented with 500 mg sulfasalazine, with venous blood samples taken, thereafter, every 30 minutes. In 9 young healthy men with a wide range of energy intake (1760-5100 kcal/day), resting mouth-to-cecum transit was faster in high calorie consumers (r = -0.69, p<0.05). Dietary fiber intake was also statistically correlated with energy intake (r = -0.74; p<0.05). We conclude that the hypophagia of chronic exercise in humans may be linked with significant gastrointestinal adaptations.

11.1 CARBONIC ANHYDRASE III IN CO2 TRANSPORT IN CELL-FREE MEDIUM. P. Virtanen*, H.K. Vääränen and T.E.S. Takala* (SPON: V. Kovanen). Univ. of Oulu, SF-90220 Oulu, Finland.

The role of carbonic anhydrase III (CA III) in the facilitation of CO2 transport was examined in the extracts of soleus, tibialis anterior, vastus lateralis and cardiac muscle of rat. The facilitation of the CO2 transport depended on the CA III concentration in the extracts. The CA III effect was most pronounced on the tibialis anterior extract, in the vastus lateralis and cardiac extracts the CA III effect was not as pronounced. Purified CA III and CA II accelerated CO2 transport almost as much as in equimolar concentrations but the specific hydratase activity of CA II is more than 100 times greater than that of CA III. The data suggests that the concentration but not the hydratase activity is the rate limiting factor in the CA III facilitated CO2 transport in soleus extracts with acetazolamide gave a K+s value of 1.5×10-7 M, which further confirmed the involvement of CA III in the CO2 transport. The CA III facilitated CO2 diffusion was considerably suppressed in polymyxin B gel. The results suggest that part of CO2 could be transported bound to the active site of diffusing CA III.

Dept. of Medicine, McMaster University, Hamilton, Ontario, Canada, L8S 4J9

This study examined changes in femoral venous plasma ion and acid-base status during exercise in rats after glycogen depleting (GD) conditions. In 2 trials separated by 1-2 weeks 6 healthy males in NC or GD state cycled at 75% of peak VO2 for 20 minutes. Blood was sampled at both 0 and 20 minutes from the femoral vein. Plasma [H+] rose by 20.2 ± 2.9 mM (NC) or 13.3 ± 3.6 mM (GD) at 5 minutes of exercise from 42.1 ± 2.6 mM (NC) or 45.2 ± 2.6 mM (GD) at rest. In NC [H+] remained high until 30 minutes but in GD it decreased by 1/2 before exhaustion. Increases in [H+] were due to increases in plasma [proteins] and Pco2 (NC and GD) and decreases in the strong ion difference (SID) (NC only). PCO2 and [H+] rose from 49.9 ± 5.4 mM (NC) and 42.1 ± 4.1 mM (GD) at rest to 72.4 ± 4.4 mM (NC) or 71.4 ± 7.2 mM (GD) at 5 min and 64.2 ± 2.5 mM (NC) or 57.4 ± 7.2 mM (GD) at 50 min. Both [H+] and [PCO2] did not change from rest. In NC, after 5 min exercise (SID) decreased 4.3 mM (P<0.05) from 35.85 (±0.45) to 31.52 (±1.2) mM. The discrepancy between these 2 changes was made up by a 1.3 mM rise in [Na+] and a 1.0 mM decrease in [Cl-]. But in GD/SID did not change despite a rise in [lactate] from 1.9 ± 2.0 mM to 3.1 ± 2.8 mM and 3.1±0.5 mM at 5 and 30 min. The rise in [lactate] was balanced by a 5.6 mM rise in [Na+] (NC) and a 3.1 mM rise in [K+] at both 5 and 30 min; [Cl-] did not change. Supported by the Medical Research Council and the Natural Sciences and Engineering Research Council of Canada.
11.4 K' REDISTRIBUTION DURING EXERCISE IN MAN. Jostein Hallein*, Lars Gullestad* and Ole W. Nielsen. General Hospital, Oslo, Norway.

The rise in plasma [K'] during exercise with a large muscle mass might be pronounced since little resting muscles is accessible for redistribution. K' was measured in the femoral vein by K'-selective electrodes and in arterial blood samples. Leg blood flow was measured by bolus injection of indocyanine green. Initial rates of rise and peak venous [K'] were not different and after 4 min K'-release was 0.13 and 0.11 in the BC and KE groups (ns). Even so, arterial [K'] rose by 0.20 mmol/l in the BC group compared with 0.39 mmol/l in the KE group (p<0.05). By 40 min, 0.42 mmol more K' was redistributed in the KE group. Thus contrary to the hypothesis, redistribution of K' significantly attenuates the rise in arterial plasma [K'] during BC but not during KE.

Figure: Change in [K'] in femoral vein (unbroken line) and artery (broken line)

11.6 GLYCOCEN DEPLETION RESULTS IN ALTERED ION AND ACID-BASE STATE DURING EXERCISE. J.C.J. Heigenschau, M.L. Linden, R.S. McKeilv, L. Lands, E. Holtme, L. Spriet, T. Humber, W. Muller, R. Podbe, and M.J. Lindinger. Dept. of Physiology, Memorial University, St John's, Newfoundland, St John's, Newfoundland, Canada.

This study compares the origins of the arterial plasma acidosis seen during prolonged exercise in normal (NC) vs glycogen depleted (GD) conditions. In 2 trials separated by 1-2 weeks, 4 healthy males, either NC or GD, cycled at 75% of peak VO2 until exhaustion (50-70 min for NC and 60-110 min for GD). Blood was sampled from a catheter placed in the brachial artery. Arterial plasma [H+] rose from 39.1±0.5 mM (NC) and 42.9±0.3 mM (GD) at rest to 49±3 mM (NC & GD) at 8 min and then decreased 15-20% in NC and decreased 15-25% in GD. NC and GD, cycled at 75% of peak VO2 until exhaustion (50-70 min for NC and 60-110 min for GD).

In NC the acidosis persisted throughout exercise, but in GD [H+] returned to 41±1 mM by 30 min and 39±4 mM at 50 min. The rise in plasma [protein] was similar in both trials and contributed 5% to the acidosis. A 5 mmol/kg decrease in PCO2, partially offsets the acidifying effects of increased [protein] and decreased strong ion difference (SID).

In NC the drop in [SID] from 38.2±0.3 to 17.5±0.1 mEq/L after 5 min of exercise was partially accounted for by a 11±2.1 mM rise in [lactate]. About 2-3 mEq/l of the rise in [lactate] was offset by increases in [Na+] (1-2 mEq/l) and [K'] (1.15 mEq/l) ([Cl] remained unchanged. In contrast, in GD increases in [lactate] consistently accounted for the changes in [SID] as 3 mEq increases in [Na+] and [Cl] balanced each other. Associated changes in [HCO3] in both trials were 30-40% less than the equivalent changes in [SID] and [lactate].

Supported by MRC and NSERC of Canada.

11.7 EFFECTS OF PRIOR EXERCISE OR CHEMICALLY INDUCED ACIDOSES ON SUBSEQUENT MUSCULAR STRENGTH AND ENDURANCE. Douglas G. Belt, Tom M. McLenan and Ira Jacobs. UKIM, Toronto, Ont., M3M 3B9

Muscular fatigue is linked with a decrease in blood pH. To further clarify this association, this study compared the effects of two models of inducing acidosis on a subsequent criterion task (CT) of muscular strength and endurance. Acidosis was induced in 8 subjects prior to the CT by injecting 0.3 g/kg ammonium chloride (AC) for one trial, by upper body exercise for another trial, or for another trial occurred after placebo (PL) treatment. Strength (S) was evaluated as force generated during a maximum voluntary contraction (MVC) of the quadriceps. Muscular endurance (E) was the integration of force generated during a 45-s MVC. Electrical stimulation used during the trials to measure the strength of voluntary motor unit recruitment. The acid-base status of arterialized whole blood was assessed before, during, and after the test. The results showed that pH was significantly decreased to a similar extent by both AC (7.26) and UBE (7.24) compared with PL (7.41). S was not affected by the experimental treatments but E was significantly and simuliately reduced (6.5%) by both AC and UBE. In addition the electrical stimulation indicated that neither UBE nor AC resulted in an impairment.

Supported by NSERC of Canada and MRC.

11.8 PRESERVATION OF THE ICF PROTEIN BUFFER SYSTEM DURING ACUTE METABOLIC ACIDOSIS. M.L. Halperin, J. Cogges, B. Buhan-Chen and Sheera Dhudi. Renal Division, St. Michael's Hospital, Toronto, Canada.

Buffering is carried out by both the bicanurate (bic) buffer system (BBS) and the non-BBS (largely intracellular proteins). We have recently shown that most of the acid-base effects of two models of inducing acidosis on a subsequent criterion task (CT) of muscular strength and endurance. Acidosis was induced in 8 subjects prior to the CT by injecting 0.3 g/kg ammonium chloride (AC) for one trial, by upper body exercise for another trial, or for another trial occurred after placebo (PL) treatment. Strength (S) was evaluated as force generated during a maximum voluntary contraction (MVC) of the quadriceps. Muscular endurance (E) was the integration of force generated during a 45-s MVC. Electrical stimulation used during the trials to measure the strength of voluntary motor unit recruitment. The acid-base status of arterialized whole blood was assessed before, during, and after the test. The results showed that pH was significantly decreased to a similar extent by both AC (7.26) and UBE (7.24) compared with PL (7.41). S was not affected by the experimental treatments but E was significantly and simuliately reduced (6.5%) by both AC and UBE. In addition the electrical stimulation indicated that neither UBE nor AC resulted in an impairment.

Supported by NSERC of Canada and MRC.


The interaction between systems regulating acid-base balance (i.e., CO2, strong acids, weak acids) was studied in 6 subjects for 10 min following 30s maximal isokinetic cycling during control (CON) and after 3 days acetazolamide (ACZ) administration (500 mg/kg p.o.) to inhibit tubular acidification. Gas exchange and acid-base status were measured during a 45-s MVC. Electrical stimulation (interpolated twitch technique) was used during a maximum voluntary contraction (MVC) of the quadriceps. Acid-base status was assessed before, during, and after the test. The results showed that the tissues minimized the extent of the hyperkalemia by 0.20 mmol/l in the BC group compared with 0.39 mmol/l in the KE group (p<0.05). By 40 min, 0.42 mmol more K' was redistributed in the KE group. Thus contrary to the hypothesis, redistribution of K' significantly attenuates the rise in arterial plasma [K'] during BC but not during KE.

Hydration status has not been emphasized or extensively examined in swimming. Thirteen male (69, 7c) collegiate swimmers swam two 200 yd time-trials (3 d apart) in euhydrated (E) and hyperhydrated (H) states. Preexercise plasma osmolality (E: 288.4 ± 284.9 mmol kg⁻¹; Pc:0.01) and aldosterone level (E: 1.02 ± 1.01; P<0.01) values distinguished the hydration status of the swimmers. There were no differences (P>0.05) in postexercise plasma volume (E: ±16.4 ± 11.9 %; Pc:0.001) plasma lactate (E: 21.8 ± 17.8 mmol l⁻¹), plasma glucose (E: 5.76 ± 5.12 mmol l⁻¹), heart rate (E: 167.1 ± 165.2 beats min⁻¹), or perceived exertion responses. Performance time improved for 8 swimmers during H, but the data was not statistically significant (P>0.05), perhaps due to the wide ability range of this group (E: 108.7 to 133.6 s). These data demonstrate that hyperhydration had no performance advantage over euhydration, for this group, during a 200 yd time-trial swim.


To test the hypothesis that older men (65+ ) have a diminished drive to rehydrate after a thermal/insensible-induced dehydration, we studied twelve 65+ (60-79 yr) and six 20-30 yr (subj. Y) exercise subjects (Y: 20-30 yr) in 3-h recovery from 105 min of heat ([36°C, <30% RH] and exercise (70% age-predicted maximal heart rate) protocol which elicited a 2.3% and 3.9% decrease in body weight in 65+ and Y, respectively. Cardiovascular, subjective thirst, and urine volume were measured pre and post exercise and during rehydration (sodium appetite [blue]) in 65+ (Y). Plasma volume (PV), plasma osmolality (POM), and arginine-vasopressin (AVP) were measured pre and post exercise and during rehydration. Baseline PV was not different between groups whereas PV was higher in 65+ than Y (347 ± 19 vs 381 ± 22 ml/kg) (P<0.05). Throughout the dehydration period, PV did not change significantly in 65+ but decreased significantly in Y (E: 5.6 ± 4.9 ml/kg; P<0.05) and Y (E: 5.8 ± 4.9 ml/kg; P<0.01) post exercise. Plasma osmolality (POM) was elevated in 65+ and Y but was not statistically different between the groups. Urine volume and thirst were measured pre and post exercise in both groups. Urine volume (U) increased in response to the decrease in [Na⁺] in plasma in both groups, and plasma osmolality (POM) and thirst increased with dehydration. Urine volume increased by 126 ± 72 ml/kg in 65+ and 126 ± 72 ml/kg in Y post exercise. Before and after dehydration subjects rested at 28°C without fluids for 30 min to allow body fluid compartments to stabilize. Dehydration induced by 105 min of heat and exercise (70% age-predicted heart rate) caused plasma volume to decrease by 5-6% and plasma osmolality (POM) to decrease by 11-12%. Free water clearance (CH₂O) increased by 109 ± 48 ml/kg-min in 65+ and Y, respectively. Elevated POM after exercise was reduced with fluids, indicating a reduced ability to concentrate urine following dehydration in 65+ subjects. During dehydration (fluid intake = 18.0 ± 3.4 ml/kg in Y and 8.0 ± 3.5 ml/kg in 65+) plasma aldosterone (ALDO) decreased by 3.3 ± 3.6 pg/ml and returned to 140 ± 90 pg/ml in Y and 65+ subjects. The relationship between the urine Na⁺/creatinine ratio and fractional Na⁺ reabsorption and ALDO was similar for Y and 65+ during dehydration and rehydration.


Methods. To determine combined influences of exercise and chronic hypoxia on plasma erythropoietin (EPO), atrial natriuretic peptide (ANP), and aldosterone (ALDO) levels, blood samples from 27 men at 3700 m (BN) and ten lowlanders (GM, 50 m; LL) were investigated during exercise and during a 24 h rest at 3000-3500 m. Antagonists were given before experiments and before the acute effect of exercising at high altitude. Data shown were significantly different if P<0.05. Results. At rest, BN's PV was higher and ALDO was lower than LL. Exercise at 3700 m increased PV and ALDO in both groups (BN ±36.5 ± 17.1, LL ±36.5 ± 17.1 ml/kg), and returned to initial values thereafter (24 h) in both groups (BN ±16.5 ± 17.1, LL ±16.5 ± 17.1 ml/kg). PV and ALDO similarly increased during exercise in both groups (BN ±16.5 ± 17.1, LL ±16.5 ± 17.1 ml/kg), and returned to initial values thereafter (24 h). PV and ALDO were also increased during exercise in BN (BN ±16.5 ± 17.1, LL ±16.5 ± 17.1 ml/kg), and returned to initial values thereafter (24 h). In BN, PV and ALDO were also increased during exercise in BN (BN ±16.5 ± 17.1, LL ±16.5 ± 17.1 ml/kg), and returned to initial values thereafter (24 h). Data shown were significantly different if P<0.05. Conclusions: 1. Exercise does not directly stimulate EPO, but may increase erythropoietin. 2. ALDO levels possibly affect changes in PV during and after exercise, which may be one cause for the lower arterial blood pressure in BN (BN at rest: ± 140 ± 11, LL ±119 ± 9 mm Hg; exercise: BN 127 ± 10, LL ±80 ± 9 mm Hg).
at 12.9


The effects of exercise on urinary excretion of red blood cells, pigments, and protein were studied in mares performing treadmill exercise at speeds eliciting 40, 60, and 95% of the maximal oxygen consumption (V\text{O}_{\text{max}}). Gross hematuria and pigmenturia were observed in all horses during exercise at the two highest intensities, whereas those findings were detected in only 1 of 5 mares during exercise at 40% of the V\text{O}_{\text{max}}. Reagent strip analysis revealed microscopic hematuria/pigmenturia in the remaining 7 mares exercised at 40% of the V\text{O}_{\text{max}}. An increase in urine flow (U) during exercise at 40% of the V\text{O}_{\text{max}} likely contributed to the infrequent observation of gross hematuria and pigmenturia. In contrast, V decreased during moderate and high intensity exercise but increased dramatically for a short period following exercise. This resulted in rapid resolution of gross hematuria and pigmenturia following exercise at 60 and 95% of the V\text{O}_{\text{max}}, although microscopic hematuria/pigmenturia persisted for up to 60 min. Urinary protein excretion (U\text{Protein}) increased from a resting value of 4.8 ± 0.4 mg/kg/m\text{mi} to 32.0 ± 10.3 mg/kg/m\text{mi} after exercise at 60 and 95% of the V\text{O}_{\text{max}} respectively. U\text{Protein} was no different from the resting value following exercise at 40% of the V\text{O}_{\text{max}}. Exercise-induced hematuria, pigmenturia, and post-exercise proteinuria appear to be common in horses. Their occurrence is related to exercise intensity but appears to be transient and without lasting changes in renal function.

Supported by the Washington State Equine Research Program.

12.10

RELAGEO RESPONSE TO HALF-MARATHON RACE WITH SPECIAL REFERENCE TO HEMATURIA AND PROTEINURIA. Hakan Gür Selçuk Kılıçakçı* and Isma Süremler Dept. of Medical Faculty University of Uludag, Bursa, Turkey

Hematuria and proteinuria have been noted in athletes after heavy exercise. To observe the effects of different NSAID treatments on renal response, fresh urine specimens were obtained from 45 marathon runners 2 hours before and immediately after the half marathon race. All samples were analyzed for glucose, bilirubin, ketones, specific gravity, protein, white cells, red cells, and leucocytes using Multiple Reagent strips ( Ames, Miles Lab, Ltd, England) and urine sediment analysis. All prerace samples were normal but 24 (53.3 %) of 45 postrace urine analysis showed hematuria of which 11 (24.4 %) were trace, 8 (17.8 %) were trace and 5 (11.1 %) were ++. Proteinuria was present in 6 (13.3 %) of the 45 samples; 3 (6.7 %) were trace, 2 (4.4 %) were 1 , and 1 (2.2 %) was large. In addition, 33 (73.3 %) of postrace urine analysis showed proteinuria, 13 (28.9 %) of these were 30 g/l, 14 (31.1 %) of them were 100 g/l and 6 (13.3 %) were >200 g/l. There were also leucocytes in 6 (13.3 %) : bilirubin in 4 (6.7 %) and ketones in 3 (6.7 %) postrace urine samples.

It can be concluded that intensive running conditions as a half-marathon race or training for it may result in athletic anaemia and protein depletion. Finally, we recommend to distance runners to supply their athletic anaemia and protein depletion for a better performance.

13.1


The neurotoxin capsaicin desensitises the skin by impairing the function of a specific group of C-fibres i.e. a sub-population of the polymodal nociceptors. The suggestion that sympathetic post-ganglionic C-fibres may be responsible for this effect has been substantiated in vitro

and in vivo by studies showing that capsaicin application reduces the activity of sympathetic vasodilator fibres.

The purpose of this study was to assess the combined effect of NSAID treatment and sub-maximal exercise on urine 
p values. Twelve healthy non-smoking adult male subjects were treated orally by NSAID (Diclofenac 100mg) and placebo (C group) 1hr before exercise. Treatment was performed in a random (counter-balanced) single-blind design. Subjects ran for 30 min on a treadmill at 70% V\text{O}_{\text{max}} and by placebo (C group) 1hr before exercise. Treatment was performed in a random (counter-balanced) single-blind design. Subject ran for 30 min on a treadmill at 70% V\text{O}_{\text{max}} and by placebo (C group) 1hr before exercise. The subjects were exercised on a treadmill at 30% V\text{O}_{\text{max}}.

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The sheep uses panting as its primary mode of evaporative heat loss. The purposes of this study were 1) to partition respiratory evaporative heat loss (REHL) of exercise into that which is a consequence of the increase in ventilation (V\text{E}) and that due to thermoregulation and 2) to assess the effects of stride frequency (SF) on respiration during exercise. Sheep were exercised on a constant speed treadmill at 3.01 m.s\text{-1} with stride frequency (SF) of 1.0 SF and 1.5 SF. The effect of an increased V\text{E} associated with exercise represented 14 f 2% of the increment in V\text{E} during exercise. REHL continued to increase in proportion to the increase in T\text{a}. Respiratory frequency also continued to increase in proportion to the increase in T\text{a}.

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13.3

This study examined how accurately a commercial (Human Technologies, Inc.) temperature pill (Tₚ) measured core temperature (Tₚ) compared to esophageal temperature (Tₑ) and rectal temperature (Tₑᵣ) during exercise/rest cycles. Two hours after swallowing the pill, subjects (n=8) exercised on a cycle ergometer (25°C, Tₑᵣ = 34°C) for 40 min at 40% peak VO₂. Tₑ was measured in 3 cycles of 5 min of exercise at 40% peak VO₂ and 5 min of rest. Tₑ and Tₑᵣ were recorded every 30 seconds. When comparing mean temperature responses (time in min for Tₑ or Tₑᵣ to detect Tₑ or 0.1°C) during exercise/rest cycles, differences (p<0.01; n=6) were found between Tₑᵣ (6.4±1.2), Tₑ (3.7±0.6) and Tₑᵣ (6.7±3.3). Tₑᵣ responded faster than Tₑᵣ and Tₑᵣ. During all exercise/rest cycles, Tₑᵣ exceeded Tₑₚ (36.86±0.35°C) by 0.6°C. From 50 minutes, exercise in TN and CO caused Tₑᵣ to rise 0.15°C, continued exercise in CO caused Tₑᵣ to rise a further 0.15°C and 0.2°C respectively, while after rest, Tₑᵣ (37.8±0.1°C) and Tₑᵣ (37.4±0.3°C) were within 0.1°C in all cases, and Tₑᵣ (36.8±0.3°C) by 0.6°C. During the first 50 min of exercise in TN, Tₑᵣ and Tₑᵣ rose in parallel by 0.1°C. From 45 minutes, exercise was interrupted, while Tₑᵣ further 0.15°C. Continued exercise in TN caused Tₑᵣ and Tₑᵣ to rise a further 0.15°C and 0.2°C respectively, while after rest, Tₑᵣ (37.8±0.1°C) and Tₑᵣ (37.4±0.3°C) were within 0.1°C in all cases. After 50 minutes, exercise in TN and CO, Tₑᵣ and Tₑᵣ may not accurately reflect, central temperature changes measured elsewhere, becoming disproportionately elevated perhaps due to local blood flow from active muscle. Tₑᵣ experiences changes in Tₑᵣ. Fluctuations in Tₑᵣ, attributed to increased ventilation and salvia, may not be fully insulated aural thermometer a more practical measure of core temperature during lower-body exercise.

13.4
OSSEOPHAGEAL AND RECTAL TEMPERATURE DURING UPPER BODY EXERCISE AT SIMILAR RELATIVE AND ABSOLUTE EXERCISE INTENSITIES. Elisabeth M. Guse* and Greg C. Fosco, Faculty of Health Sciences, The University of Sydney, Sydney, Australia.

This study used a model of interrupted (paraplegic) and uninterrupted (able bodied) neural supply to investigate the relationship between osseophaegual (Tₑ) and rectal (Tₑᵣ) temperatures, during upper body exercise. 5 paraplegics (Tₑᵣ = 11°C) and 5 able bodied (AC) after 15 minutes adapteo to standard anthropometry and an incremental test to exhaustion. Heart rate (HR), oxygen uptake (VO₂) and related variables were measured throughout exercise (Ex). 3-5 days after each test after eating a meal (Spray, 1996) and 3-5 min of Ex at 60% VO₂. Throughout and Ex Tₑᵣ and Tₑᵣ were recorded. Data were analysed by t-tests (p < 0.05). There were no significant differences in the Ex for both groups, however the AC group was significantly higher than the P group. The AC group was significantly lower than the P group (38.16 ± 0.24°C) for (P) group. These results indicate the relationship between Tₑᵣ and Tₑᵣ in those with uninterrupted neural supply and in light of the results from the subjects with interrupted neural supply continue to question the contribution of muscle mass and (TS) exercise intensity upon effector response.

13.5
DISOCIATION OF RECTAL AND AURAL TEMPERATURES DURING LOWER-BODY EXERCISE. Kameren J. Ham* & Nigel H.G. Taylor* (SPOR: S.H. Boucher). Univ. of Wollongong, NSW 2500, Australia.

This study compared osseophaegual (Tₑ) and rectal (Tₑᵣ) and aural (Tₑᵣ) temperatures in 6 healthy males at rest and during cycle ergometry (150 W) in thermoneutral (TN: 24°C, RH 50%), cold (5°C, RH 60%) and hot (34°C, RH 40%) environments. Subjects were monitored at rest in TN for 30 mins, and later during 30 mins cycling in TN, followed by 10 mins cycling in either 5°C or 34°C. In TN, Tₑᵣ (37.8±0.1°C) and Tₑᵣ (37.4±0.3°C) were within 0.1°C in all cases, and Tₑᵣ (36.8±0.3°C) by 0.6°C. During the first 10 mins of exercise in TN, Tₑᵣ and Tₑᵣ rose in parallel by 0.1°C. From 45 minutes, exercise was interrupted, while Tₑᵣ further 0.15°C. Continued exercise in TN caused Tₑᵣ and Tₑᵣ to rise a further 0.15°C and 0.2°C respectively, while after rest, Tₑᵣ (37.8±0.1°C) and Tₑᵣ (37.4±0.3°C) were within 0.1°C in all cases. After 50 minutes, exercise in TN and CO, Tₑᵣ and Tₑᵣ may not accurately reflect, central temperature changes measured elsewhere, becoming disproportionately elevated perhaps due to local blood flow from active muscle. Tₑᵣ experiences changes in Tₑᵣ. Fluctuations in Tₑᵣ, attributed to increased ventilation and salvia, may not be fully insulated aural thermometer a more practical measure of core temperature during lower-body exercise.

13.6
EXERTIONAL HEAT EXHAUSTION IN CYCLISTS NOT CAUSED BY ENDOTOXEMIA. Geoffrey E. Moore, M. E. Blair & Isobelle*, James Granner*, James P. Knochel

Presbyterian Hospital, Dallas, Texas, 75231.

Endotoxin (blood-borne bacterial lipopolysaccharide) occurs after intestinal ischemia, triggers cytokines, and causes shock. At rest, normal endotoxin titers range from <10 to 100 pg/ml, but has been shown to average >300 pg/ml in athletes during exercise. We used the LD₅₀ (40°C) for survival on coronary blood flow (CBF) in rats exposed to an ambient temperature of 40°C. Radioactive microspheres 15 microns in diameter (Sn = 0.0001). Regression analysis for data falling within 95% confidence limits revealed strong positive correlations between CBF and Tₑ (r = 0.385, p = 0.001). Caudal artery blood flow increased with heating, while renal blood flow fell throughout the heating period. Mesenteric and ileal artery blood flow decreased before increasing slightly at the peak and then fell again. We conclude that unlike other instances of severe hyperthermia, CBF is maintained. This suggests that the precipitous fall in MAP during the prodromal period of heat stroke is not attributable to myocardial ischemia and cardiac failure. Supported by NIH Grants HL 38939, HL 14338 and HL 57295.

13.7

The purpose was to determine if maternal exercise (65% of peak VO₂) resulted in a fetal stress response as represented by the accumulation of inducible isofrom shock protein 72P (SP721, in trained rats). The accumulation of SP721 (R.M. Tarnawski) was assessed in fetal brain, heart, kidney, hind limb and placenta of trained animals on day 20 of pregnancy (term = 21 days). The exercise protocol consisted of treadmill running at 8 km/h on a 10° incline, 60 min/day, 5 days/week for 4 weeks prior to pregnancy and then continued throughout gestation up to and including day 210. After inducing the above fetal stress response, day 20 of gestation with SP721 antibody, no significant differences were found for fetal heart, hind limb or placenta between trained animals and sedentary controls. SP721 was not detected in fetal kidney or brain in the trained or sedentary groups. Although a heat shock response was not detected in the fetuses of the trained animals, fetal body weight and placental weights were significantly lower (p<0.05) sedentary controls, suggesting factors other than temperature may affect fetal growth. Support: NSERC Canada #0035666 & UWO.

13.8
CORONARY BLOOD FLOW IS NOT COMPROMISED BY SEVERE HYPERTERMIA IN RATS. K.E. Anderson, R.J. Tognacci and C.Y. Ugoz. Univ. of Iowa, Iowa City, IA 52242.

This study examined the selective loss of myocardium in the rat left ventricle of anesthetized Sprague-Dawley male rats (300-350 g) at Tₑᵣ approximating 37.0, 39.5, 41.0, and 42.5°C. Heart rate increased to 600 bpm and was highly correlated with Tₑᵣ (r = 0.92, P = 0.001). Regression analysis for data falling within 95% confidence limits reveals strong positive correlations between CBF and Tₑ (r = 0.385, 0.66, P = 0.001). Caudal artery blood flow increased with heating, while renal blood flow fell throughout the heating period. Mesenteric and ileal artery blood flow decreased before increasing slightly at the peak and then fell again. We conclude that unlike other instances of severe hyperthermia, CBF is maintained. This suggests that the precipitous fall in MAP during the prodromal period of heat stroke is not attributable to myocardial ischemia and cardiac failure. Supported by NIH Grants HL 38939, HL 14338 and HL 57295.
13.10 STRENuous EXERCISE IN MILD AND HOT ENVIRONMENTS: METABOLIC, CARDIORESPIRATORY, AND THERMAL COMPARETIONS. C. Gabaree! J. Hoffman! M. Whittlesey! M. Bergeron!
A. Pauschinger! Human Performance Laboratory, University of Connecticut, Storrs, CT 06269-1110.

The purpose of this study was to describe the relationship between bone mineral density (BMD) and estimated caloric expenditure (KCAL-E) in BMD measurement sites included: lumbar spine, young (12-22yrs), healthy eumenorxheic females. 

The mechanisms underlying the effect of brief or prolonged central and peripheral cooling on reaction time and central nervous system conduction velocity are not well understood. In the present study, reaction time (RT), median amplitude evoked potentials (SEP), visual evoked potentials (VEP), auditory evoked potentials (AEP), rectal and skin temperature (T, Ta), and perceived thermal discomfort were measured in 10 men (21f3 yr, 57.3+5 mlemin-'*kg' VO2 max) before (PRE) and after (IP) exercise-heat sessions (90 min, 5.4+0.2°C; 333% grade; 33°C air temperature). These 4 sessions involved combinations of PRE hydration status (dehydrated (EU) or hypohydrated (HY, -3.8% body weight)) and estimated caloric expenditure (KCAL-E) in.

In the present study, simple reaction time (RT), somatosensory evoked potentials (SEP), visual evoked potentials (VEP), auditory evoked potentials (AEP), rectal and skin temperatures (T, Ta), and perceived thermal discomfort were measured in 10 men (21f3 yr, 57.3+5 mlemin-'*kg' VO2 max) before (PRE) and after (IP) exercise-heat sessions (90 min, 5.4+0.2°C; 333% grade; 33°C air temperature). These 4 sessions involved combinations of PRE hydration status (dehydrated (EU) or hypohydrated (HY, -3.8% body weight)) and estimated caloric expenditure (KCAL-E) in.

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Plasma hormone concentrations were measured in 17 male residents before and after a marathon race at approx. 2700 m altitude. Blood samples were obtained at 0, 24, 48 and 72 h before and 0, 24, 48, and 72 h after the race. Subjects were divided into two groups: group A (n=8) followed the race without sleep. Sleep was then provided at 1 h intervals thereafter. Blood samples were taken at 0 h, 24 h, 48 h, 72 h, and at 24 h and 48 h of recovery (R). Hormonal analysis consisted of total (t) T4, free (f) T4, fT3 and FT3, and TSH. Main effects for time (i.e., days) were observed for all hormones (p<0.001). TSH decreased significantly (p<0.001) from t0 to t2, and fT3 increased in the first 24 h, then declined daily through R-24 h. By R-48 h fT4, fT3 and TSH showed trends towards returning to 0 h levels; however, TSH was still significantly lower than 0 h (p<0.05). No differences (p>0.05) were observed in group A compared to group B. These data indicate that an increased blood hydrogen ion concentration is partly responsible for the serum growth hormone response to acute, high-intensity anaerobic exercise.

14.4 INDUCED ALKALOSIS SUPPRESSES THE GROWTH HORMONE RESPONSE TO ACUTE, HIGH-INTENSITY CYCLE EXERCISE. S.R. Gordon, W.L. Krane, G.L. Fedak and N.H. Voss. Center for Sports Medicine, Penn State University, University Park, PA 16802.

To investigate the effects of acid base balance on serum growth hormone (GH) concentration after an acute, high intensity, anaerobic exercise bout, ten normally active men (age, 24.6±4.9 yr) participated in a randomised, double-blinded, counterbalanced experiment with crossover design. Each subject reported in a fasted state at the same time of day for two experimental sessions separated by 7 days. Each session consisted of a 20 min exercise (38 kpm) at 74% Vo2max followed by 5 min of 120 mmHg constant pressure hyperventilation. Serum samples were obtained before (baseline, BL) and 75 min after (PER-EX) the exercise period, as well as at 0, 5, 10, 15, 20, and 30 min post-exercise. The exercise task immediately followed the PER-EX blood draw, and consisted of standing against opposing force of 0.49 N (0.05kg) per kg of body weight. There were no differences between the two groups in mean or peak power output or total work. Mean (±SE) blood pH and serum [GH] results were t=0.05 vs. corresponding BL within condition; t=0.05 vs. corresponding P timepoint: 14.5 REPRODUCTIVE FUNCTION IN MALE RUNNERS. M.J. De Souza, J.C. Ayres, L.S. Pesce & A.A. Louzada*. Div. Reproductive Endocrinology and Infertility, Dept. of OB/GYN, University of Connecticut Health Center, Farmington, CT 06030. The purpose of this study was to evaluate the effects of volume of endurance training on reproductive function in male runners. Analyses of reproductive hormones and semen quality were performed in 11 high mileage runners (HR) (67±2.8 mi/wk), 9 moderately mileage runners (MR) (44±2.6 mi/wk) and 11 control subjects (C). No differences (p>0.05) in LH, FSH, testosterone, estradiol, prolactin or PRL were observed in HR compared to MR and C. An indicator of fertility, sperm motility and morphology and sperm penetration of standard cervical mucus (PENETR) were measured during a 1 hr period of serial blood sampling (20 min). Urinary excretion of 24 hr LH (ULH) was determined on two separate occasions. Sperm count, density, motility and morphology and sperm penetration of standard cervical mucus (PENETR) were performed. Levels of TT and FT were significantly lower in HR (15.2±1.8 nmol/l and 86±2.5 µmol/l) compared to MR (23.1±1.6 nmol/l and 88±2.9 µmol/l) and C (25.6±1.9 nmol/l and 79±2.6 µmol/l). No differences (p>0.05) were found in LH, LH, FSH, and PRL among the three groups. Total motile sperm count and density were lower in HR compared to MR and C. A decreased (p<0.001) sperm motility and a higher (p<0.004) volume of immature sperm and round cells were observed in HR compared to MR and C. This finding suggests that a high volume of endurance running results in decreased gonadal steroids and alterations in semen quality that may negatively affect fertility capacity.

14.6 FEMALE SEX HORMONES AND ATHLETIC PERFORMANCE. Constance M. Lebrun, Donald C. McKenzie, Jettlyn C. Prie*; Jack E. Taunton, University of British Columbia, Vancouver, Canada, V6Z 1Z3.\n
Fourteen cyclic ovulatory, elite athletes had Vo2max tested during the follicular (F) and luteal (L) phases of a normal menstrual cycle, and were then randomized to one of two equal treatment (RX) groups: pill (PILL: 27.1±1.6 yr, mean ± SE); Ht=168.5±1.9 cm; Wt=60.2±1.7 kg) or placebo (PLA: 28.3±1.6 yr, Ht=168.6±2.0 cm; Wt=60.0±3.5 kg). The third test was done between days 14-17 on PILL (Symptonic, a low-dose contraceptive oral contraceptive) or PLA. In the placebo group on RX. To confirm the cycle phase, exercise estradiol and progesterone levels were obtained. All 14 women showed hormonal evidence of normal ovulation. Relative Vo2max decreased slightly in both groups during the luteal phase, and there was a significant differential response to RX (p=0.018) between the subjects on PILL (t=54.7±1.7; t=53.7±1.8; RX: 52.0±1.0 ml/kg/min) as compared to the women on PLA (F: 53.0±1.1; L: 51.8±3.1; RX: 53.78±1.7 ml/kg/min). Since at the time of the third test, women in the PLA group had various endogenous hormone levels, concomitant hormonal analysis was essential to accurately interpret any subtle exercise adaptation changes. The data suggest that the female sex hormones, both endogenous and exogenous, may have an adverse effect on aerobic performance at the elite level.

Supported by Sport Canada and Synutra, Inc.

14.7 EFFECTS OF SLEEP DEPRIVATION AND PHYSICAL ACTIVITY ON THYROID HORMONES DURING MILITARY MANEUVERS IN THE ARCTIC. A.C. Hacknev, \(\text{t}^{\text{t}}\) A. Rojas, W. Schmidt, H. Bernall, S. Garcia and V. Rojas (SPON: G Gros). Search Center, San Diego, CA 92152.

Military field maneuvers involving sleep deprivation (SLP) and high physical activity (PA) levels in thermoenviromental conditions cause transient increases, followed by decreases in thyroid hormones. However, brief cold exposure is associated with elevated levels of thyroid hormones. We examined the effects of SLP and PA level during military field maneuvers in the arctic on thyroid hormone levels. Norwegian soldiers (n=35) were divided into 4 groups having low (2 h) or high (6 h) levels of SLP, and low or high PA requirements during maneuvers. Maneuvers were 3 days of simulated combat scenarios during winter. Day 1 consisted of 24 h without sleep. Sleep was then provided at 12 h intervals thereafter. Blood samples were taken at 0 h, 24 h, 48 h, 72 h, and at 24 h and 48 h of recovery (R). Hormonal analysis consisted of total (t) T4, free (f) T4, fT3 and FT3, and TSH. Main effects for time (i.e., days) were observed for all hormones (p<0.001). TSH decreased significantly (p<0.001) from t0 to t2, and fT3 increased in the first 24 h, then declined daily through R-24 h. By R-48 h fT4, fT3 and TSH showed trends towards returning to 0 h levels; however, TSH was still significantly lower than 0 h (p<0.05). No differences (p>0.05) were observed in group A compared to group B. These data indicate that an increased blood hydrogen ion concentration is partly responsible for the serum growth hormone response to acute, high-intensity anaerobic exercise.


Sleep deprivation (SLP) and high physical activity (PA) levels in thermoenviromental conditions are associated with reductions in blood testosterone (T) and elevations in cortisol (C) levels. It is unclear whether or not the effect of these stressors vary in different individuals, as some may be more resistant to the effects of SLP and PA level on the T and C response to arctic military maneuvers.
14.0
EXPOSURE TO β C AIR SUPPRESSES ACTH, B-ENDORPHIN AND CORTISOL DURING HIGH INTENSITY CYCLE ERGOMETRY. David W. Armstrong III, Lawrence Nestorovic, and Mark U. Thoren, NASA Johnson Space Research Institute, Houston, TX 77055.

Exercise of sufficient intensity and duration is a potent stimulus of the hypothalamic-pituitary-adrenal (HPA) axis under euthemic conditions. The purpose of this study was to measure plasma ACTH, beta-endorphin (B-endo) and cortisol (Cort) concentrations during 60 min of cycle ergometry at two exercise intensities (60% and 80%) while exposed to (30°C) hot (H) or (2°C) cold (C) air. Active (n=15), but not endurance trained, men of average fitness (45 ± 5 kg*m²/min) participated in this randomized, repeated measures design study. Plasma samples were obtained via intravenous (IV) catheter at euthermic rest, every 15 min during exercise in an environmental chamber and 15 min post exercise at euthermic rest. At a 28% dose of plasma (N) or equivalent dose of saline (S) was administered IV push, 15 min prior to exercise. This was followed by a N or S IV drip. The total dose of N administered was 0.1 mg/kg. ACTH and B-endo concentrations were unchanged from rest during 60% exercise and cold/saline (CS), cold/saline (CN) or hot/saline (HS) conditions. The hot/saline (HS) condition at 60% resulted in ACTH and BE nearly doubling compared to rest. Cort increased 50% at 60% intensity during HS and CN compared to CS and CN, which were decreased slightly from rest. Exercise at 80% intensity, did not change C between rest for CS, CN, HS and HS. During HS, ACTH and BE increased 300% above rest and HS conditions resulted in a 200% increase above rest. ACTH and BE were unchanged from baseline during CS and CN conditions. We conclude that exposure to cold air which does not result in lowered core temperature, suppresses the HPA axis response to exercise at high intensity.

14.11
EXERCISE TRAINING AND CLENBUTEROL REDUCE THE INSULIN RESISTANCE OF OBESE ZUCKER RATS C. L. Torgan, J. J. Brotznick*, R. E. Banks*, M. T. Cooper*, and J. L. H. Exercise and Nutritional Metabolism Laboratory, Dept. of Kinesiology, The University of Texas, Austin, TX 78712

This study compared the effects of exercise training and chronic administration of the beta-2 adrenergic agonist, clenbuterol, on whole body and skeletal muscle insulin resistance in obese (fa/fa) Zucker rats. Obese rats were randomly assigned to training, clenbuterol or sedentary control groups. Lean littermates served as a second control group. After 4-5 wk later by hindlimb perfusion during which time the rates of glucose uptake and 3-O-methyl-D-glucose (3-OMG) transport were assessed in the presence of a submaximal (500 nM) insulin concentration. Training resulted in significant increase in citrate synthase and cytochrome oxidase activity in the recruited muscles (28-78%). Clenbuterol induced a large increase in muscle mass, but provoked a significant decrease in oxidative enzyme activity (34-55%) and beta-2 adrenergic receptor density (61%). Both treatments increased whole body glucose tolerance and reduced the post-glucose insulin response. However, only exercise training improved hindlimb muscle glucose uptake (11.37±0.65, 8.73±0.77, and 8.27±0.41 μmol/g/h for trained, clenbuterol and sedentary control groups, respectively), and 3-OMG transport when expressed per gram of tissue. Clenbuterol treatment increased total hindlimb glucose uptake by increasing the quantity of muscle. These results indicate that the two interventions attenuated the insulin resistant condition in obese Zucker rats through different mechanisms.

ADAPTATION

15.1

Trained runners performed supervised training 3 times a wk for 6 wks. group CT (n=12) with continuous running for 30 min at 92% of HRmax per training bout, and group IT (n=12) with six 4 min intervals at 95% HRmax (from 36.4±7.6 to 60.8±9.4 min; p<0.001), increased 27% more in CT (from 35.5±9.3 to 69.8±15.1 min; p<0.001) than interval training which, however, also has a significant effect. The intensive continuous training is a more potent stimulus for endurance capacity, i.e. time to exhaustion at 85% of pretraining VC,max, in-creasing 7% in both groups (54.7±1.2 to 58.6±1.9 ml W/min/kg; mean±SD; p<0.001). Mean endu-

14.10

Endocrine responses to chronic resistance exercise have been documented, but it is unclear whether the hormone changes are related to the amount or type of exercise performed. With this in mind, the present study used standardized testing procedures to induce acute changes in hormone levels. The primary goal of the present study was to measure changes in plasma hormone levels in response to a single session of strength training performed under the same conditions as the testing was performed during the acute response period.

Supported by a Research Grant from East Carolina University.

15.2
PLASMA B-ENDORPHIN IMMUNOREACTIVITY FOLLOWING RESISTANCE EXERCISE. A. Plane*, N. Kestman, H. Traylor*, K. Olenko, & W. Hare. University of Richmond and Medical College of Virginia, Richmond, VA 23273

Previous research investigating the response of plasma b-endorphin (b-EP) to resistance exercise has resulted in equivocal findings. To examine the response of an acute bout of resistance exercise on b-EP immunoreactivity, six resistance trained athletes (age (yr) = 20.8±1.4; height (cm) = 180.4±6.9; weight (kg) = 37.6±4.5) participated in a 3 set series of 8 repetitions at 60% of 1 repetition maximum (1-RM) for each of the following three free weight exercises: 1) bench press 2) incline press 3) standing curls 4) flat bench dumbbell raises, and 5) leg curl. The results showed the maximum + b-EP values were not significantly different between exercises and completion of the exercises required approximately 45 minutes. Blood was sampled from the group by venipuncture, both prior to and following the acute bout and b-EP was determined by radioimmunoassay. A student's t-test for paired observations indicated that plasma levels of b-EP following resistance exercise (10.0±3.4 (55) pg b-EP ml⁻¹) were not significantly changed from pre-exercise (control) levels (19.6±4.0 pg b-EP ml⁻¹), although there was considerable inter-individual variability. Our results suggest that the acute response to resistance exercise which has reported no significant change...

The effects of physical activity on spatial learning performance and associated hippocampal function were examined in C57BL/6 and DBA/2 (2M) mice. Performance in a Morris water maze was measured across 8 training days. Genetically defined mice were similarly enhanced to perform similarly to C57 mice. These alterations in performance were accompanied by alterations in hippocampal protein kinase C activity in C57 and DBA mice, which characteristically perform poorly in comparison to C57 mice, were enhanced to perform similarly to C57 mice. These effects were monitored by alterations in membrane-bound protein kinase C activity (p<0.05). The data from this study, therefore, indicate that the protein kinase C second messenger system, as well as cholinergic function, in the hippocampus may be involved in the physical activity induced enhancement of spatial learning performance.

Supported by NSF RNR-R000076 and NIH HD-07996 postdoctoral grants.

15.5

ALERNATIONS IN HUMAN SKELETAL MUSCLE ENERGY METABOLISM INDUCED BY 8 HOURS PER DAY OF LOW-FREQUENCY ELECTRICAL STIMULATION. R. Thériault*, V. Gélinas*, G. Thériault, and A. Simard. Physical Activity Sciences Laboratory, Laval University, Ste-Foy, Quebec, Canada, G1K 7P4.

The purpose of the study was to verify the influence of chronic low-frequency electrical stimulation (LFES) on the energy metabolism of human skeletal muscle. LFES was delivered to the knee extensor muscles of 5 subjects at 8 Hz, 8 hours per day, 6 days/week, with the use of a portable stimulator and adhesive electrodes (Hespond ii and Pals Plus, Medtronic). Vastus lateralis muscle samples were taken before, after 4 weeks, and after 8 weeks of LFES, and analyzed for enzyme activities of phosphofructokinase (PFK), citrate synthase (CS), cytochrome c oxidase (COX), and 3-hydroxyacyl-CoA dehydrogenase (HAUD). ANOVA revealed no significant change in PFK (p<0.05) after 4 or 8 weeks of LFES. On the other hand, CS, COX, and HAUD activities increased significantly by 36% (p<0.05), 29% (p<0.05), and 21% (p<0.05) after 4 weeks, and by 23% (p<0.05), 36% (p<0.05), and 13% (p<0.05) after 8 weeks of LFES, respectively. Although chronic LFES has significantly altered the human skeletal muscle aerobic-oxidative metabolism, results of the present study suggest that human skeletal muscle has a limited capacity of adaptation in response to a chronic increase in contractile activity.

Supported by GONQ, FCAP, Medtronic of Canada, & NSERC of Canada.

15.6

PHYSICAL CONDITIONING CAN MODULATE ENDOTHELium-DEPENDENT VASORELAXATION IN RABBITS. Ning-Jing Chen and Hsing-Tam LC. Department of Physiology, Medical College, National Cheng-Kung University, Tainan, Taiwan 70101, Republic of China.

To investigate whether exercise training can modulate the endothelium-dependent vasoconstriction or vasodilation of young normotensive rabbits, 23 male New Zealand rabbits were randomly assigned to one of two training groups. Each rabbit was subjected to an eight week physical activity protocol consisting of moderate exercise. Group 1 was trained by treadmill running with running speed of 0.88 km/hr, 0.5 mile/day for 4 weeks. The running speed was increased to 4.5 km/hr, 0.5 mile/day for subsequent 4 weeks. The running time was increased from 30 min/day on the first week to 120 min/day on the last week. Group 2 was the sedentary control group. At the end of these experiments, thoracic aorta was removed from each rabbit and was divided into 15 mm Tri-HCl buffer (pH 7.4). Following 30 min of incubation, the incubating buffer was discarded and replaced with fresh buffer for another 10 min. PGI2 release from these vessels was then determined by radioimmunoassay of its stable metabolite, 6-keto-PGF1α. In addition, vessel segments, i.e., thoracic aorta, pulmonary artery and common carotid artery (0.5 mm in length for each) were isolated and pre-contracted with 10−5 M KCl. The vessel tension was measured by a force transducer. Basal release of endothelium-derived relaxing factor (EDRF) was measured by stimulation of hemoglobin. Endothelial release was also simulated by endothelin-dependent vasodilator, acetylcholine (ACh) released from thoracic aorta in 15 mM Tri-HCl buffer (pH 7.4). Following 30 min of incubation, the incubating buffer was discarded and replaced with fresh buffer for another 10 min. PGF2α released from these vessels was then determined by radioimmunoassay of its stable metabolite, 6-keto-PGF1α. The results indicated that after exercise training, 1) PGI2 release from thoracic aorta was increased; 2) PGF2α released from thoracic aorta was significantly higher than that from inferior vena cava; 3) ACh release from thoracic aorta was released; 4) ACh release from thoracic aorta and pulmonary arteries was lowered; 5) (NF) of the thoracic aorta was elevated; 6) there was no significant difference in basal release of EDRF and ACh-induced maximal relaxation of precontracted vessel segments between control and trained rabbits. Our data suggest that exercise training may modulate endothelium-dependent vasodilatation.

15.7

SUPERIOR WORK PERFORMANCE IN LIFELONG TIBETAN RESIDENTS OF 4400m COMPARED WITH 3658m. L. Curran-Everett*, J.G. Zhang*, G.S. Duma*, and L.G. Moore. Tibet Institute of Lawrence Berkeley Laboratory, Colorado, Denver CO 80217, and Cardiovascular Pulmonary Research Laboratory, U. of Colorado Health Sciences Center, Denver CO 80262.

Exercise performance is a measure of the integrated functioning of the human species and work at some of the highest altitudes in the world. Their ability to exercise under these conditions may define the limits of human adaptation. We studied 30 male residents born and raised at 4400m and 16 male lifelong residents of Lhasa (3658m), matched for age, height, and weight. All studies were performed in Lhasa. Standard test protocol and criteria were used for obtaining VO2max on a Monark bicycle ergometer. Nomads compared with Lhasa residents had, at maximal effort, similar VO2 (48±5.2 vs. 52±3.5 ml/kg/min, p=ns), higher workloads attained (21±1 vs. 17±1 watts, p=0.01), lower heart rate (178±2 vs. 191±3 bpm, p=0.01), lower ventilation (127±5 vs. 146±15 l/min, p<0.01), and similar SATs (81±9 vs. 81±9%, p>0.05). Furthermore, over the course of submaximal workloads, nomads compared with Lhasa residents had lower VO2 (p=0.01), lower heart rate (p=0.01), and lower ventilation (p=0.01) and SaO2 (p<0.05). We conclude that Tibetans living at 4400m compared with those at 3658m achieve greater work performance for a given VO2 at submaximal and maximal workloads, with less cardiorespiratory effort. This research was supported by NSF grant #BNS0913645 and a University of Colorado-Denver faculty research grant.

15.8

The interaction of creatine depletion and endurance exercise upon aerobic capacity of muscle. B. D Morgan*, H. Park*, R.P. Farrar. Dept. of Kinesiology, Univ. of Texas, Austin, TX.

Depletion of creatine phosphokinase (CPK) activity in the diet has been utilized to determine whether changes in the spatial and temporal buffering of the phosphorylation potential can induce changes in aerobic capacity of the muscle. F344 male rats were divided into two dietary groups, a pair-fed group on laboratory rat chow and a CPK diet group. Exercise was implemented to exacerbate changes in the phosphorylation potential induced by creatine depletion. Two forms of endurance training were used, steady-state training (Wehner et al., 1087, Brain Res 520:161-167) and interval training (Wehner et al., 1989). The results of these two protocols the soleus (SOL) and plantaris (PLN) muscles were examined for changes in citrate synthase (CS) activity. CPK increased the CS activity by 24% and 40% in the PLN and SOL, respectively, of the sedentary rats. The steady-state training in the SOL increased CS activity by 50% in the PLN and 80% in the SOL, while the interaction with CPK induced 160% and 100% in the PLN and SOL muscles. In the interval trained rats the CS activity was same as the steady-state trained in the PLN, but lower in the SOL, demonstrating only a 40% increase compared to control values vs 100% in the steady-state SOL. The interaction of CPK and interval training induce the same increase in the PLN and SOL muscles as the steady-state trained CPK group. Contractile activity in the creatine depleted SOL is sufficient to induce large increases in CS activity, even though the load on the muscle at the high velocity runs is reduced, as evidenced by the CS activity of SOL of interval trained rats on control diet.

Supported by NSF BNS-8820076 and NIH HO-07289 postdoctoral grants.

15.9

Exercise training may modulate endothelium-dependent vasodilatation. B. D Morgan*, H. Park*, R.P. Farrar. Dept. of Kinesiology, Univ. of Texas, Austin, TX.

Endothelium-dependent vasodilatation, acetylcholine (ACh), in the preconstricted vessel segments between control and trained rabbits. Our data suggest that exercise training may modulate endothelium-dependent vasodilatation.

Supported by NIH HO-07289 postdoctoral grants.
15.9 CAN ALTIMITUDE VO2MAX AND ENDURANCE PERFORMANCE BE MEASURED FROM SEA LEVEL MEASUREMENTS? Anthony Suco, Brad Kopp, James Moxham, \*Physical Education, San Diego State and Naval Health Research Center, San Diego, CA 92189

It has been shown in the literature that moderate hypoxia (AH) alters a variable influence on fit athlete's VO2max when compared to sea level (SL) values. This fact has led some experts to conclude that the VO2max at AL may not be a valid measure at AL. Thus our purpose was to investigate the relationship between endurance performance, as compared by cycle-based spiroergometry, one-mile (1MI) and two-mile (2MI) times at SL and AL. VO2max (2-4 L) in 19 young distance runners (12 males & 7 females) with a mean age of 22.8 & 2.5 yr, mean weight of 70.4 & 13.7 kg. Their mean 1MI and 2MI times at SL were 5.20 & 11.6 min, respectively. At 8,000 ft (IAP = 7 Torr) the SS were measured for VO2max and the 1MI and 2MI on separate days. The effects of the acute, AL was the reduction of VO2max to 54.1 ml/kg/min and the 1MI and 2MI times to 11.1 and 19.6 min, respectively. 

15.11 \*EFFICACY OF STAIRCLIMBING EXERCISE: A LOOK AT POSTOPERATIVE LEG RESPONSE. Michael C. Myers, S. David Czopp, Robert R. Marley, T. Keith Duhon and James C. Sterling, Texas Sports Science Institute, Sugar Land, TX 77478

The increased use of stairclimbing devices to improve fitness has recently been promoted as an alternative to stationary cycling for bone rehabilitation in the inured athlete. However, the efficacy/response in an actual postoperative sports rehab population has not yet established. The purpose of this on going study was to quantify and compare leg response in 37 patients (25 males, 12 females; age 25.4 ± 2.5 yr, weight 70.4 ± 13.7 kg) following postoperative anterior cruciate ligament (ACL) rehabilitation using a stationary cycle (C) or a stairclimbing (S) regimen following withdrawal of informed consent. Athletes were randomly assigned to either C or S programs previously matched by METS and heart rate.

15.12 IMPROVEMENTS IN TREADMILL, CYCLE, AND ARM EROCTOMY FOLLOWING CYCLE AND RUN TRAINING IN SEDENTARY FEMALES. B. C. Rahn, S. A. Robbins, C. W. Schulte, C. M. Marmur, T. W. Clark, Unics of New Mexico, Albuquerque, NM 87131

To determine the training effects associated with central and peripheral adaptations, previously sedentary females (N=16) were assigned to one of three (n=6) training groups (run, cycle, cycle-run) and compared their peak test reliability coefficients. It is concluded that VO2max, 1MI and 2MI at SL will predict the same measures made at moderate AL.

15.13 OPTIMIZING EXERCISE INTENSITY, G.L. Greenwood, Life Clinic, Brandon, FL 33311

Optimizing exercise intensity, 011, and cardiovascular responses is of extreme importance when determining the best intensity to use. The current thought is that the O2 metabolic capacity of the weakest tissue involved in the exercise is the primary limiting factor. This is thought to be the case because of the inverse relationship between O2 delivery and increased O2 extraction. The present study was designed to investigate the relationship between VO2max and endurance performance and to evaluate the effects of exercise intensity on VO2max and other cardiovascular responses. In the present study, 10 unranked skaters (Grp 1: 80.9±3.3, Grp 2: 76.7±2.1% of VO2p) or SUPMX (Grp 1: 1.15±0.13, Grp 2: 1.07±0.13 min): Grp 1 also had average fitness compared with the other 8

15.14 NATIONALY RANKED PAIRS SKATERS POSSESS AVERAGE LEVELS OF FITNESS. E. Mannix, A. Healey* and M. Farber*, Indiana Univ Sch of Med, Methodist Hospital and VAMC, Indpls IN 46202.

We reported that a group of unranked figure skaters (n=15, XGE age=13.9±2.0 yr) possessed average fitness compared with age/gender matched, non-athlete controls (FAO2EJ 6(4):1235, 1991). Thus, when cycle training was added to on-ice training of the skaters, others every 2 to 3 yrs. This procedure has demonstrated in over 500 people that the rate of increasing functional capacity is usually 20% to 50% in 3 weeks.
16.1 SKELETAL MUSCLE FUNCTION AND ION FLUX IN CYSTIC FIBROSIS

L.C. Landis, G.S. Heigenhauser, and N.L. Jones

Department of Exercise Science, Michigan State University, East Lansing, MI 48824

Skeletal muscle performance is affected by alterations in the plasma electrolytes (Lindquier and Heigenhauser, Am J Physiol 1988;254:R117). During exercise, plasma ion concentrations are modulated by the erythrocyte (McKelvie et al, Can J Physiol Pharmacol 1991;69:564). It is unclear whether defects in electrolyte transport exist in blood cells from Cystic Fibrosis (CF) patients (Bouchet et al, Ped Res 1994;10:139; Chen et al, Science 1989;243:93). We hypothesized that these defects might affect skeletal muscle performance during intense exercise. Seven well nourished CF patients were compared to 7 healthy age-matched control subjects. Skeletal muscle performance was assessed during a 30 s sprint on an isokinetic cycle ergometer. Iont flux was evaluated by sampling from arterialized venous blood at rest, at peak exercise, and after 5 min of recovery. Sprint performance did not differ between the CF (total work: 93.7±30.0% predicted; endurance: 30.8±9.9% decline) and control (100±7.19±30; 25.8±14.7%) groups. The changes in plasma and erythrocyte ions and blood gases did not differ between the groups. However, the contribution of decreases in the strong ion difference to increases in pH was less in the CF group, primarily due to a smaller increase in lactate concentrations. This may be due to alterations in ionic flux in CF but the influence of inadequate arterialization of the blood supply could not be ruled out. The CF patients’ responses to prolonged exercise do not suggest a difficulty with lactate release from exercising muscle.

Supported by the Canadian CF Foundation

16.2 SLOWER PHOSPHOCREATINE RESYNTHESIS RATES IN MULTIPLE SCLEROSIS


Previous studies have suggested that the muscle fatigue common in multiple sclerosis (MS) may be due in part to a metabolic deficit within the muscle. The purpose of this study was to measure the rate of recovery of phosphocreatine (PCr) after exercise to determine whether oxidative metabolism is impaired in MS. Thirteen MS patients underwent 9 min of intermittent tetanic contractions of the tibialis anterior muscle elicited by stimulation of the peroneal nerve (240 ms every 3 sec, 50 Hz). Eight healthy control subjects (C) performed the same exercise to assess metabolic changes similar to those in the MS group. Intracellular PCr and pH were measured continuously using a 1.9T magnetic resonance spectroscopy unit. PCr resynthesis rate was determined during the first 5 min of recovery using a mono-exponential corrected for extent of depletion. The patients were divided into two subgroups demonstrating 1) fast (MS-F) and 2) slow (MS-S) PCr recovery. At the end of exercise, there were no differences between groups in either [PCr]/C: 16.5±4.6 mM, MS-F: 18.2±5.0 mM, MS-S: 20.2±9.0 mM (urea/3D) or pH: C: 6.77±0.30, MS-F: 6.79±0.15, MS-S: 6.72±0.36. The t½ of PCr recovery was C: 46.2±7 sec, MS-F: 40.7±15 sec, MS-S: 126.4±60 sec. The MS-S group was significantly slower to recover than both the C and MS-F groups (p<0.05). The data indicate that some MS patients have impaired oxidative capacity which may explain their excessive muscle fatigue.

16.3 AEROBIC TRAINING EFFECTS IN HEMIPARETIC STROKE PATIENTS

K. Potenza, M. Lopes, L. Kuban, P. Slagter, A. Fuku, T. Inanami, R. Lee

University of Illinois, Chicago, IL 60612

The purpose of this study was to document the aerobic trainability and related physiologic effects in hemiparetic stroke patients. Twenty-six Stroke patients (mean age 59 (SD-11), with similar levels of physical disability and initial levels of fitness (peak VO₂) were randomly assigned to 12-weeks of twice-weekly aerobic training on an adapted bicycle ergometer (AT) or ten-weeks of passive range of motion (PROM) exercises, 3 times per week for a total of 30 min. In the AT group showed a significant increase (11.6%) in peak VO₂ (ml/kg/min), whereas the PROM group showed no changes. AT Ss also showed increases in pre-training exercise times (p=0.03) and peak workload (p=0.03). There were no reductions in submaximal HR or diastolic BP in either group, but a significant reduction in systolic BP (p=0.02) was observed only in AT Ss. These results demonstrate that modest improvements in aerobic capacity and exercise systolic BP can occur in hemiparetic stroke patients with adequate training, which may have important influences on functional ability and cardiovascular risk management.

16.4 ISOMETRIC QUADRICEPS FUNCTION IMPROVES AFTER SPINAL CORD STIMULATION INDUCED FOR INTRACTABLE LEG PAIN

S.M. Griffith, C.M. Bogdanoff, D.D. Ohmohles, R.P. Rashbaum, Texas Tech Institute Research Foundation, Plano, TX 75075

Chronic intractable pain often results in the inability to lead a normal, active life. Physical function is limited in patients exhibiting intractable leg pain. Spinal cord stimulation (SCS) is a surgical procedure in which electrodes are placed over the spinal cord in the thoracic area, stimulating electromagnetic signals to transmit from the legs to brain. The reduction in pain and disability by this procedure has created a major favorable quality of life. The purpose of this study was to evaluate quadriceps function following SCS. Sixteen patients (mean age 47, 5 yrs) were treated for intractable leg pain by SCS. Leg function was evaluated isometrically (10sec) on a Lido Active Dynamometer at 5° of knee extension. Impulse values (ft/lbs/sec) were adjusted for body weight (BW). An age and sex matched, asymptomatic group (n=16) was used as the control. One year after SCS, the mean painless leg strength increased from 59% of control values to 53% of control values (p<0.05). The less painful leg showed an increase in function from 49% to 71% (p<0.05). Control values were 7.20 and 7.60 (Impulses/BM) in the normal and subnormal groups, respectively. The data demonstrate that isometric quadriceps testing can be used to evaluate objective changes in a clinically compromised population and that SCS can reduce pain such that leg function is improved, but not totally restored.
10.5 Cardiorespiratory responses of the spinal cord injured to three modes of exercise. D. Luim, R. H. Hough, R. A. Krause, R. F. O. and J. D. Gilbert. Human Performance Laboratory, Univ. of New Mexico, Albuquerque, NM 87131

The cardiopulmonary response to exercise was studied in 10 spinal cord injured subjects evaluated during computerized functional electrical stimulation (CFES LE), arm ergometry (AE), and a combination of the two (CFES LE + AE). Data were collected over six weeks of CFES LE training and six weeks of AE training. The heart rate (HR), oxygen consumption (VO2), respiratory exchange ratio (RER), minute ventilation (VE) and carbon dioxide production (VCO2) data are presented in the table below.

<table>
<thead>
<tr>
<th>Group</th>
<th>HR (bpm)</th>
<th>VO2 (ml/min)</th>
<th>VCO2 (ml/min)</th>
<th>RER</th>
<th>VE (L/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFES LE</td>
<td>115.2±7.3</td>
<td>142.1±20.5</td>
<td>128.1±18.9</td>
<td>1.08</td>
<td>54.2±7.4</td>
</tr>
<tr>
<td>AE</td>
<td>113.5±8.9</td>
<td>140.3±22.6</td>
<td>125.9±19.3</td>
<td>1.07</td>
<td>53.8±8.2</td>
</tr>
<tr>
<td>CFES LE + AE</td>
<td>114.8±9.1</td>
<td>141.5±21.0</td>
<td>127.6±18.7</td>
<td>1.09</td>
<td>54.1±7.8</td>
</tr>
</tbody>
</table>

The greater HR response for AE exercise versus both CFES LE and CFES LE + AE is consistent with the observed trend for VO2 and VCO2. The RER and VE data reflect the increased workloads associated with each exercise mode.

10.6 Exercise training attenuates diabetes-induced circulatory dysfunction in rats. W. J. Seustegui. Department of Physiology, Kirkville College Osteopathic Medicine, Kirkville, MO 65561.

To determine whether exercise training can attenuate the diabetes-induced alterations in circulatory control, male Sprague-Dawley rats were randomly divided into sedentary (SG) and exercise (EX) groups. The EX group received 30 min of treadmill exercise (65 kg/mg STZ iv) three times per week, while the SG group was sedentary. Blood glucose (BG) levels were measured at rest (R) and after 8 min of exercise (E). The BG levels were significantly lower in the EX group compared to the SG group. These results suggest that exercise training can attenuate the diabetes-induced circulatory dysfunction.

16.7 Vanadyl Sulfate Effects on Glucose Oxidation in Isolated Cardiac Myocytes from STZ-Diabetic Rats. S.J. Kopp, J. L. Diaz. Chicago College of Osteopathic Medicine, Department of Cardiology, Downers Grove, IL 60515.

The hypothesis that vanadyl sulfate (0.6-4.0 mg VO=O/mg) administered orally (Vsupp) would suppress the chronic metabolic complications of insulin deficient diabetes mellitus was tested in male Sprague-Dawley rats made diabetic with streptozotocin (60 mg/kg). Control and diabetic rats were randomly assigned to one of two groups: non-supplemented or Vsupp. Following excision of hearts for myocardial isolation, blood samples were taken for plasma glucose, triglycerides, total cholesterol, HDL cholesterol and glycosylated hemoglobin. All blood metabolites were improved significantly with Vsupp. Analysis of glucose oxidation by isolated cardiac myocytes revealed significantly less basal and insulin-stimulated (100M) glucose oxidation in hearts from diabetic rats (9.1±4.11 0.1 ±11 nmol/mg/min) relative to control (9.0±3.1 0.1±11 nmol/mg/min). Vsupp to diabetic rats did not affect basal glucose oxidation (5.0±6.0 0.1±0.03 nmol/mg/min), however it significantly enhanced insulin stimulated glucose oxidation (t Control non-supplemented: 8.9±3.1); Control + Vsupp: 6.9±2.0 0.1±0.03 nmol/min). Endogenous glycogen and lactate levels detected in the cardiomycocytes from the various groups showed no significant differences. These results indicate that oral Vsupp preserved the ability of cardiac myocytes to utilize glucose and respond to insulin stimulation.


Pulmonary emphysema augments lung compliance and mechanically disadvantages the diaphragm. Respiratory muscle work is increased and the diaphragm undergoes enhanced oxidative enzymatic capacity. The purpose of this study was to investigate the effects of spontaneous running exercise on diaphragm (DIA) and soleus (SOL) muscle performance in vitro. Dystrophic (mdx) and control (C57BL/6J) mice were studied at rest and after 8 weeks of exercise. The results suggest that exercise training attenuates the diabetes-induced circulatory dysfunction.
10.11 MUSCLE EDEMA AFTER ECCENTRIC EXERCISE. Kazunori Nosaka and Priscilla M. Clarkson, Yokohama City University, Yokohama, Japan 220 and University of Massachusetts, Amherst, MA 01003.

Muscle damage, decreased muscle function, and increased muscle proteins in the blood are well documented indicators of muscle damage. Relative little data exist on muscle swelling after such exercise. This study examined muscle edema using measures of circumference (CIR), ultrasonography (USG), and magnetic resonance imaging (MRI) after 14 college age males performed 24 muscle eccentric actions of the lower leg, sampled muscles 5 days post-exercise. Muscle edema was measured at 4 sites on the upper arm, and USG using 7.5MHz linear probe were taken from the upper arm. Measures were taken pre and for 5 days post-exercise. On a subsample (n=6), MRI was performed on the upper arm using a 0.5-T superconducting unit with a circularly polarized receive-transmit coil, and measures were taken pre and 1, 3, 6, and 10 days post-exercise. Established indicators of muscle damage (range of motion, muscle soreness level, plasma creatinine kinase, glattamic oxaloacetic transaminase, and C-reactive protein <CRP>) were also measured pre and for 5 days post-exercise. Muscle damage indicators, except CRP, changed significantly (p<.01). A large increase in CIR (26.0±14.0mm, peak) was found 4-5 days post-exercise and this coincided with USG showing an increase in the distance from the skin to the humerus and an increase in echogenicity. MRI showed enlargement of the biceps and brachialis cross-sectional areas, peaking at 6 days post-exercise, and an increase in signal intensity on T2-weighted and proton density images that were more conspicuous at 6 or 10 days post-exercise. Subjects who showed greater changes in muscle damage indicators also showed greater incidence of edema, although the time course of the changes differed among the measures. The most profound edematous changes occurred after muscle function had began to recover.

10.12 EFFECTS OF TRAINING ON MUSCLE BLOOD FLOW RESPONSE TO EXERCISE IN HYPOTHYROID RATS. Richard M. McAllister, Michael D. Davis, and M. Harold Landis. College of Veterinary Medicine, University of Missouri, Columbia, MO 65211.

We have previously reported that hypothryoidism is associated with reduced blood flow to high oxidative muscle fibers during exercise (Med Sci Sports Exer 24:5117, 1992). We hypothesized that exercising muscle blood flow in rats with this hypothesis, rats were made hypothryoid with propylthiouracil and then trained on a treadmill at 30 m/min (15% grade) for 60 min, 5 days per 10-12 wk. Efficency of training was indicated by a 60% increase (p<0.001) in citrate synthase activity in plants in trained hypothryoid rats (T-HYPO, 26.16±1.51 mmol/min/g) over sedentary hypothyroid animals (HYPO, 16.20±1.64). Efficency of training was indicated by a 60% increase (p<0.001) in citrate synthase activity in plants in trained hypothryoid rats (T-HYPO, 26.16±1.51 mmol/min/g) over sedentary hypothyroid animals (HYPO, 16.20±1.64). Regional blood flow was determined by the microsphere method in HYPO (n=5) and T-HYPO (n=5) rats of similar size during post-exercise standing and at 1-2 min of treadmill running at 15 m/min (8% grade). Pre-exercise blood flows were unaffected by training. Muscle blood flows during exercise were also similar between groups for red venous lumenaria (HYPO, 15.6±2.3; T-HYPO, 14.3±4.9), but significantly lower (p<0.001) for white venous lumenaria (HYPO, 23.4±5.5; T-HYPO, 23.0±7.5), and soleus m. (HYPO, 166.4±17.0; T-HYPO, 183.5±42.2). Mean arterial pressures during exercise were unaffected by training (HYPO, 106±8 mmHg; T-HYPO, 112±4). These findings do not support our hypothesis and indicate that exercise training does not normalize reduced high oxidative muscle blood flow during exercise in hypothyroid rats. Further, these data suggest that left ventricular function is not improved with training and may account for these findings.

Supported by NIH grant HL-43680, a grant from U. OF COR, and a fellowship from AHA, MO affiliate.


In previous studies, we have shown that fatigue resistance in soleus muscles from 6 month old SHR was significantly lower than in normotensive WKY rats. In the current study, we used radioactive microspheres to determine whether differences in muscle blood flow might underlie the differential response to a fatigue stimulus. At rest, one of two labelled microspheres (99Sr, 141Ce) was injected into the left ventricle of N-phenobarbital anesthetized animals via a right carotid cannula, an arterial blood sample was taken from the left renal artery. During 4 mins stimulation of the cut tibia1 nerve (20-25 Hz for 330 ms, 1 train/s) to induce fatigue, the 2nd microsphere was given and an arterial sample was taken during the last 1.5 mins of contraction, muscles and other tissues were sampled and counted. Fatigue indices (CFI and PFD) were significantly different in the 2 strains. Mean right MBP (mmHg/min/100g) was slightly higher in SHR at rest (WKY=207±4, SHR=213±7), but slightly lower during fatigue (WKY=220±4, SHR=216±7) and during fatiguing exercise (WKY=61.34±7.81; SHR=49.10±8.56). Although blood flows were not significant, they were consistent. Vascular resistances (mmHg/min/100g) for the 2 strains however, were significantly different during all 3 flow states: at rest (WKY=14.64±1.70; SHR=20.74±1.87), after denervation (WKY=4.01±0.51; SHR=7.00±1.87) and during fatiguing exercise (WKY=1.77±0.25; SHR=3.96±1.12). The data suggest that the hemodynamic state of the muscle is different in the 2 strains and SHR soleus muscle is not able to reduce the high vascular resistance to the same degree as WKY during a hypoxic stimulus, thus IBF may be related to the increased fatigueability in SHR. (NIH grant HL-42463).


The existence of post-exercise hypotension after acute exercise is well documented in hypertensive populations. Previously, we reported (J Physioligist 36:124, 1991) reductions, regardless of the training state of the animal, in mean arterial pressure at either 30 mins (-1655 mmHg) or 60 mins (-1745 mmHg) recovery from 75 mins of treadmill exercise at 70% VO2max. As expected, naloxone hydrochloride (N-HCl; 1 ml/kg) prevented the decline in pressure both in the nontrained and trained animals. However, since N-HCl influences both central and peripheral opioid receptors, the site of action in the prevention of post-exercise hypotension by N-MI remains unknown. Therefore, we infused either naloxone methiodide (N-MI; 5 mg/kg) or saline into the jugular vein of hypertensive rats (SHR) after the completion of an exercise test. N-MI was used because published reports indicate that it cannot cross the blood-brain barrier. The MBP results, recorded from the carotid artery, were as follows (values are means±SE; significantly different from pre-exercise, p<0.05):

<table>
<thead>
<tr>
<th>Condition</th>
<th>Pre-exercise</th>
<th>Post-exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saline</td>
<td>20±1</td>
<td>15±1</td>
</tr>
<tr>
<td>SHR</td>
<td>16±1</td>
<td>10±1</td>
</tr>
<tr>
<td>Naloxone M.I.</td>
<td>16±1</td>
<td>15±1</td>
</tr>
<tr>
<td>Naloxone M.I.</td>
<td>16±1</td>
<td>15±1</td>
</tr>
</tbody>
</table>

These findings suggest that the prevention of post exercise hypotension by N-HCl occurs because of its central action on the opioid receptors. Future studies that incorporate central infusions and hemodynamic measurements will provide insights into the responsible mechanisms. (Supported in part by NIH grant HL-33782-04).


To examine the impact of exercise mode on cardiovascular disease (CVD) risk, we administered a comprehensive CVD risk profile, including total cholesterol (TCHOL) and high density lipoprotein (HDL), cholesterol, mean arterial pressure (MAP), and CVD inventories (CVI) to 28 young adult males: endurance-trained (E) and strength-trained athletes (S), wrestlers (W), and controls (C). A unique continuum was calculated for all CVI, TS, and TCHOL to the lowest risk for W and E and the highest for S and C. Despite lowest CVD risk for W and E and the highest for S and C. Despite consistent energy expenditures exceeding thresholds established for inawing CVD risk, the training regimens and/or dietary habits of strength-trained athletes place them at a CVD risk greater than or equal to that of inactive subjects. These data demonstrate the need for longitudinal studies which closely examine the interrelationships of exercise mode and diet vs CVR risk.

10.16 EFFECTS OF AEROBIC EXERCISE AND DIET HIGH IN MonoCENs ON PLATELET AGGREGATION AND THROMBOGENESIS. Piotr Przeworski, Tycoon M. Backstrom, Ben Valkenier, Dan Mygly, and Ulika Perelmut. Kuopio Research Institute of Exercise Medicine, 70110 Kuopio, Finland.

The aim of the study was to analyze the effects of exercise and diet intervention on thrombogenesis. 120 men aged 51 to 53 years were randomly assigned to either reference group, or to three exercise groups (2, 4 or 6 weekly exercise sessions) or diet groups (3 or 6 weekly exercise sessions) or diet groups (3 or 6 weekly intervention on thrombogenesis. 120 men aged 51 to 53 years were randomly assigned to either reference group, or to three exercise groups (2, 4 or 6 weekly exercise sessions) or diet groups (3 or 6 weekly exercise sessions) or diet groups (3 or 6 weekly exercise sessions) or diet groups (3 or 6 weekly exercise sessions). The duration of the intervention was six months. Blood sampling took place once every two weeks after stopping the exercise program, whereas monounsaturated diet continued until blood donation. No statistically significant between group differences were evident in any measures of platelet aggregation, in plasma fibrinogen, Factor VII, antithrombin III or in tissue plasminogen activator activity. The present data suggest the need for additional studies on the role of coagulation factors and fibrinolysis to aerobic exercise, if any, are a temporary phenomenon in terms of normal body weight. High monounsaturated diet do not seem to modify thrombogenic properties.
EXERCISE TESTING

17.1
VALIDATION OF A LIGHT WEIGHT PORTABLE DEVICE FOR MEASURING OXYGEN UPTAKE DURING SPACE FLIGHT. Phillip Bishop, Stuart Lee, Michael Greenisen*, NASA Exercise Countermeasures Project, Johnson space center, Houston, TX 77058

Assessment of oxygen uptakes (VO₂) of humans and animals who are mobile is difficult. We evaluated the accuracy and utility of a small, portable, lightweight (800g) battery-powered telemetry system for measuring VO₂ during space flight. Ventilation measurements agreed closely with a mechanical calibrator and a reference system (R² = 0.98-1.0). Measures of VO₂ (n=78) were compared in humans between the PMS and a mass-spectrometer based VO₂ system over a broad range of VO₂'s and for 30 min at a constant work rate. Agreement between systems was maximized by:

\[ \text{VO}_{2} = 0.942 \times \text{VO}_{2\text{PMS}} - 0.055 \quad (R^2 = 0.973; S.e. = 0.148) \]

Drifts in VO₂ measurement were acceptable in relation to time and across the range of VO₂'s. The PMS was comfortable for the subject even for prolonged use. With the above equation, the PMS VO₂'s were sufficiently accurate for most applications including space flight and may also be adaptable to animals of appropriate size. The PMS appeared to be highly portable, comfortable, rugged, mechanically reliable, and useful for many research applications.

17.2
RESPONSES DURING SIMULATED COMPETITION. Carl Foster, Megan Green, Ann C. Snyder and Nancy N. Thompson, Sinal Samarian Medical Center, Milwaukee, WI 53233

Laboratory studies with competitive athletes often use graded exercise protocols (GXT) to elicit physiologic responses. This pattern of power output is different than ordinarily employed by athletes during competition. In order to understand physiologic responses during competition, we studied 12 athletes (speed skaters, cyclists, triathletes) during simulated competition, a 5 km time trial (TT) on a racing bicycle attached to a windload simulator, and during cycle ergometer GXT (n=6). During TT the velocity pattern was similar to 'real world' competitions and the subjects indicated that the TT was perceptually similar to competition. Physiologic responses were of significantly greater magnitude vs GXT (VO₂ max: 3.46 ± 0.73 vs 3.27 ± 0.79 l/min; VE max: 138 ± 27 vs 119 ± 22 l/min; HR max: 184 ± 11 vs 175 ± 11 b/min; HLa: 14.8 ± 3.7 vs 11.9 ± 1.9 mm). All physiologic measures increased steadily throughout the TT (p < 0.05). VO₂ = 1.03, 2.95, 3.42, 3.69, 3.92 & 3.92 l/min; HR = 93, 175, 181, 186, 190 & 194 b/min; VE = 31, 90, 120, 193, 145 & 156 l/min; HLa = 2.9, 5.6, 7.2, 8.2, 10.6 & 13.0 mm). In 9 subjects (speed skaters), the peak values observed during TT for HR (106 ± 5 vs 191 ± 5 b/min) and HLa (16.4 ± 3 vs 17.0 ± 4.2 mm) were not significantly different than observed during "real world" competition. The results demonstrate that the physiologic responses demonstrated by athletes under competitive conditions may be significantly greater than suggested by conventional laboratory testing and that ergonomic protocol may be an important element in laboratory studies with athletes.
NEW AIR FORCE CARDIOVASCULAR FITNESS TEST: ITS DEVELOPMENT, IMPLEMENTATION, AND FIELD-EVALUATION FOR OPERATIONAL TASK RELEVANCE. L.L. Ploutz and G.K. Duday, Armstrong Laboratory, Brooks AFB, TX 78235

INTRODUCTION. On 1 Oct 92 the US Air Force will replace the annual 1.5 mile run with an adaptation of the Astrand-Ryhming test for assessing cardiovascular fitness (VO2 max) using cycle ergometry. The implementation of this technology, culminating more than ten years of research and development, will unequivocally reduce the risk while enhancing the validity of fit-for-duty testing of Air Force personnel. This paper summarizes a series of studies (1-3) evaluating the validity and reliability of the testing protocol for administering submaximal cycle ergometry to a large and physically diverse population, and (2) study the relationship between these test scores and true physical performance capability in simulated strenuous operational scenarios. A random sample of 1,124 male and 184 female Air Force personnel were tested to develop valid population norms for this specific test. Additional samples of 192 Air Force Firefighters and 64 groundcrew assigned to training for rapid-deployment were used as a basis for relating ergometer test scores to the level of performance observed for specific operational tasks. Determinations of VO2 max during exhaustive exercise by standard indirect calorimetry were performed on a smaller random sample of men (n = 32) to provide a criterion measure against which predictions obtained from cycle ergometry, RESULTS. The distribution of test scores by submaximal cycle ergometry was not significantly different from that expected for a large, normal population. Thus, test scores were developed with a high level of confidence (P = 0.01). Reliability of test-retest scores for n = 642 was excellent; values obtained on different days agreed within an average of 1.2 ml/kg/min in predicting VO2 max. Scores predicted by submaximal cycle ergometry were highly correlated (r = 0.99) with those determined by indirect calorimetry for exhaustive exercise. CONCLUSION. Aerobic capacity can be validly and reliably predicted using a precisely standardized protocol for submaximal ergometry. Norms developed from this relatively large sample of military personnel may be of considerable value to civilian populations as well.

USE OF THIGH MUSCULATURE IN THE SQUAT EXERCISE. L.L. Ploutz and G.K. Duday, NASA Kennedy Space Center, FL 32899

It is difficult to determine involvement of individual muscles in a given activity because of their limited and overlapping function and EMG activity. Accordingly, we examined contrast shifts in MR images to assess involvement of thigh muscles in squat exercise. We tested the hypothesis that the number of joints a muscle crosses and its apparent parallel visualization of individual muscles and show exercise-and hamstring (HAM) muscle groups, and the rectus femoris (RF) the knee joint and head of the femur before and immediately after a squat-with a resistance that induced failure within each set. Multiple echo transaxial T1 weighted MR images (T1, TR/TE:2000/30,1 nex, slice at 0.5 cm intervals) were collected between

compared to HAM and multi-joint counterpart (RF). Supported by a NASA grant administered under contract NAS1 011624

LOCOMOTION AND BIOMECHANICS

18.1

USE OF THIGH MUSCULATURE IN THE SQUAT EXERCISE. L.L. Ploutz and G.K. Dudley, NASA Kennedy Space Center, FL 32899

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compared to HAM and multi-joint counterpart (RF). Supported by a NASA grant administered under contract NAS1 011624

18.3

GENERALITY OF A SPRING-MASS MODEL IN PREDICTING THE DYNAMICS OF MANY-LEGGED, TERRESTRIAL LOCOMOTION. R.J. Full and R. Blackiston*, Univ. of Calif., Berkeley, CA 94720 and Universitat des Saarlandes, Saarbrucken, FRG

Despite impressive variation in leg number, length, position and type of skeleton, similarities of legged, pedestrian locomotion exist in gait, stride frequency and ground-reaction force. A bounding, spring-mass model approximate the dynamics of trotting, running, and hopping in 2-, 4-, 6-, and 8-legged animals. From the mechanical-energy fluctuation of an animal's center of mass and ground-reaction force, we calculated the compression of a monopod's virtual leg and its stiffness. Dimensionless parameters revealed that locomotor dynamics depend on gait and leg number, but not body mass. Surprisingly, relative stiffness per leg was similar for all animals and appears to be a very constant quantity across the range of terrestrial locomotion. The dynamic gait is based largely on the number of legs acting simultaneously to determine the total stiffness of the system. Trotters (quadrupeds and hexapods) had a greater whole body stiffness than runners (bipods). Since trotters and runners operated their systems at about the same relative speed, the greater whole body stiffness in trotters resulted in a smaller compression of the virtual leg and a higher stride frequency. Concomitantly, a spring-mass model supports the hypothesis that musculo-skeletal systems operate as springs during terrestrial locomotion. Supported by NSF Grant PVI DBC 80-58138 to RJF.

18.4

A METHOD FOR CONTINUOUSLY MONITORING GROUND REACTION FORCES DURING DAILY ACTIVITY. J.L. Enoka* and R.W. Swanson, University of California, Irvine, CA 92717

Theoretical models and experimental studies of bone remodeling suggest that bone density and geometry are determined by high frequency cycles, skeletal loading history. To test our theoretical model and further investigate the influence of mechanical forces on bone density, we have focused on the calcaneus as a model site loaded by calcaneal talar surfaces which are predominantly determined by the magnitude of the external ground reaction force (GRF). We have now developed instrumentation to monitor and record GRFs during normal daily activity in order to obtain daily calcaneal loading histories. METHODS: The vertical component of the GRF is sensed and logged using a capacitive inseline transducer and a microprocessor. Results: Data from simulations of daily walking recorded using an on-line, non-exercising day of a working male adult revealed that, based on duration, the calcaneus is rarely loaded above -1.0 BW (0 min or 1% of the non-exercising day). However, -41% of the load cycles had a range of -1.0 BW or greater, whereas -45% were equal to or below a range of -0.5 BW. Importantly, the sensor was able to detect the few higher force (1.5 - 1.9BW) events as well as those of lower magnitude significantly to the daily bone maintenance stimulus. Sensor data used to estimate daily walking cycles and digital accelerometer readings, recorded simultaneously, were within 0.5% of each other. Conclusion. Measurement of daily GRFs promises to be a valuable method for quantifying physical activity in terms of external loading history with applications to research and bone maintenance and adaptation with age and exercise.

1.8.5

ESTIMATION OF MAXIMAL OXYGEN UPTAKE FROM SUBMAXIMAL EXERCISE TESTING IN WOMEN. G. Harley Hartung, David A. Lally, Roberts J. Blankenship and Larry P. Brock, Univ. of Hawaii at Manoa, Honolulu, HI 96822

Simple, valid and reliable methods of estimating maximal oxygen uptake (VO2max) are needed in epidemiologic studies of physical activity and to assist in prescription of exercise. Such methods exist in some cases however, due research attention. Heart rate (HR) responses to submaximal cycle ergometry and VO2max during treadmill testing were measured in 37 healthy women aged 19-47 yr (wt = 61.4 ± 8). The submaximal test was used with a regression fit (r = -0.82), but overestimated measured VO2max by 2.46 vs 2.24 L/min; r = -0.77, standard error of estimate (SEE) = 2.253. Multiple regression analysis yielded an equation which included submaximal estimate of VO2max and body weight with an R2 of .74 and SEE = 2.24. For VO2max normalized for body weight, the equation included estimated VO2max, rating of physical activity, % body fat, and rating of perceived exertion on the submaximal exercise test, yielding an R2 of .70 and SEE of 3.6 ml.kg-1.min-1. Simple submaximal exercise protocol provides reliable test-retest estimates of VO2max when used for women. It also provides a reasonably good estimate or measured VO2max, especially if other easily measured variables are included in a prediction equation. Supported by the Air Force Office of Scientific Research.
A MATHEMATICAL MODEL FOR THE ESTIMATION OF HIDDEN MASS DISPLACEMENT IN PERIODIC MOVEMENTS. A. G. Minevitch* and G. Belli, Dep. Science and Biomedical Technology, Section of Physiology, School of Medicine, University of Udine, 33100 Udine, Italy.

The derived equation for the vertical displacement, assuming a periodic movement with or without an axial slide, and in knowing the value for the hidden mass (m), is:

\[ \Delta \theta = \frac{M + m}{M + m + \frac{\Phi(\theta)}{\Phi(\theta)}} \left[ \frac{1}{(M + m)^2} \Delta \theta - \frac{1}{(M + m)^2} \Delta \theta - \frac{\Phi(\theta)}{(M + m)^2} - \Phi(\theta) \right] - \frac{x_i - x_f}{x_i - x_f} \]

where M is the mass of the system, \( \Phi(\theta) \) is ground reaction force (vertical component), \( x_i \) is the initial vertical position, \( x_f \) is the final vertical position, and \( \Delta \theta \) is the angular displacement. This equation has been tested with a subject rhythmically raising and lowering a load while standing on a force platform. When applied to periodic vertical jump, assuming m of about 9 kg, this method reveals an excursion of the vertical mass in range of 2.5 m, with an out-of-phase oscillation with respect to the body movement.

18.7 TOQUE AND THE ENERGETICS OF SWIMMING THE FRONT CRAWL.
R. G. Soulé*, A. Giglio, C. Capelli, P. Zanuso, M. Ongirola, Dep. of Science and Biomedical Technology, Section of Physiology, School of Medicine, University of Udine, 33100 Udine, Italy.

Pendegast et al. (1977) reported that underwater torque (\( T_{\text{Nmv}} \)), i.e. a measure of the capacity of the body mass for controlled horizontal motion, gives a good estimation of the effort, assuming vertical position in a group of technologically homogeneous swimmers of both sexes was linearly related to the energy cost of crawl swimming per unit distance (\( C_{\text{swm}} \) m\(^{-1} \) per m\(^{2} \)). Similar relations for horizontal displacement have been obtained. The method has been tested with a subject rhythmically raising and lowering a load while standing on a force platform. When applied to periodic vertical jump, assuming m of about 9 kg, this method reveals an excursion of the vertical mass in range of 2.5 m, with an out-of-phase oscillation with respect to the body movement.


Small animals are less efficient at running up hills than large ones. Mice and rats are able to reach maximal efficiencies of only about 5% in converting their metabolic energy input to work, compared to 20-30% in humans, dogs and horses. The muscles that perform this work reach efficiencies of 20-30% in vitro. We asked, Why don't small animals reach these high values in vivo, where it matters? Maximal efficiency occurs when muscles shorten at about 0.2-0.3 of their maximal shortening velocity, \( V_{\text{max}} \). Small animals use faster muscles and their maximal efficiencies occur at higher work rates, in direct proportion to the \( V_{\text{max}} \) of active muscles. Students hypothesizing that small animals are not able to reach their maximal efficiencies when they run uphill. To test this idea we compared two birds that differed in weight by 30-fold, 0.12 kg quails and 3.5 kg turkeys. We measured efficiency and the time of force application by each foot, \( \tau \), over a range of speeds and inclines. We assumed that a V\(_{\text{max}}\) was proportional to \( V_{\text{max}} \), at their equivalent speeds (where ground force per body weight is similar for both animals), the quails used fibers 1.79 times faster than the turkeys and ran at slower speeds (5.6 m/s vs 1.0 m/s). The quails would have to work at 3.0 times harder to reach the same efficiency. As predicted, we found that the efficiency was the same when the ratio of work rate to \( V_{\text{max}} \) was the same, regardless of speed or incline. Supported by NIH Grant RO1 AR 18140.
18.11
EXERCISING INTERMITTENTLY ALTERS DISTANCE CAPACITY IN THE LIZARD TERRATOCRINUS PRZEVALSKI. R.B. Weinsteint and R.J. Full. Univ. of California, Berkeley, CA 94720

Most laboratories have previously focused on physiological responses to continuous treadmill exercise, yet many animals move intermittently. We have examined the importance of rest pauses on locomotor performance limits by exercising lizards intermittently on a treadmill. Lizards exercised continuously at 0.3, 0.6, and 0.9 km/hr (90%, 180%, and 270% of the maximum aerobic speed, respectively). At an exercise speed of 0.9 km/hr, lizards exercising intermittently with a 15 sec exercise duration (E) and 30 sec pause duration (P) exhibited an 11-fold increase in distance capacity (total distance traveled before fatigue) compared to lizards exercised continuously at 0.9 km/hr and a 2-fold increase in distance capacity compared to lizards exercising continuously at 0.3 km/hr (the same average speed). At an exercise speed of 0.6 km/hr, lizards exercising intermittently with both E and P = 30 sec or 120 sec did not exhibit an increase in distance capacity compared to lizards exercising continuously at the same average speed (0.3 km/hr). The aerobic cost of intermittent exercise was not significantly different from the maximal rate of oxygen consumption. These results support our observations in insects and crustaceans. Since moving intermittently can alter performance limits identified for continuous locomotion, physiological systems need to be re-evaluated with a focus on transitions.

18.13
EFFECTS OF EXERCISE ON POSTURAL CONTROL. FOLLOWING EXPOSURE TO SIMULATED WEIGHTLESSNESS. J.E. Davis, R.J. Fauss, S.L. Hooper, L. Bassey, Exercise and Health Science, Alma College, Alma, MI 48801

The effects of exercise on postural control (during walking) in four lower extremity muscles was evaluated following exposure to simulated weightlessness (6° head down tilt - HDT). Two groups of male subjects (mean age = 21.4 years ± 1.4) were exposed to 5 days of HDT. One group remained HDT for 5 days with no intervention (C-6 subjects), while the second group exercised 90 minutes per day (N-12 subjects). EMG activity in the tibialis anterior (TA), gastrocnemius (GA), vastus lateralis (VL), and biceps femoris (BF) was collected during walking before (PRE) and after (POST) 5 days of HDT. Mean integrated EMG (mi-sec ± SE) were as follows:

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<tr>
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<th>C</th>
<th>E</th>
<th>C</th>
<th>E</th>
</tr>
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<tbody>
<tr>
<td>TA</td>
<td>754.6 ±10.7</td>
<td>783.1 ±15.7</td>
<td>775.6 ±13.7</td>
<td>777.1 ±12.5</td>
</tr>
<tr>
<td>GA</td>
<td>742.5 ±14.6</td>
<td>744.0 ±14.9</td>
<td>760.3 ±21.7</td>
<td>758.2 ±23.9</td>
</tr>
<tr>
<td>VL</td>
<td>714.6 ±19.2</td>
<td>716.0 ±21.2</td>
<td>735.7 ±21.0</td>
<td>736.1 ±21.0</td>
</tr>
<tr>
<td>BF</td>
<td>748.1 ±21.6</td>
<td>746.6 ±21.7</td>
<td>746.7 ±21.9</td>
<td>746.8 ±21.7</td>
</tr>
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A two-way ANOVA was used to determine statistical significance. Postural control was significantly increased in both groups for all muscles (p<0.05). However, there were no significant differences in ZRC activity between the C and E groups following HDT. These data indicate that the ability of the neuro-vestibular system to adapt to the gravitational environment was not compromised as a result of HDT. In addition, these data suggest that the exercise protocol used was not an effective countermeasure to the neuro-vestibular system disturbances. Supported by NASA grant 7NAG9-400.

PROTEIN METABOLISM

19.1
COLLAGEN SYNTHESIS IN DIABETIC AND TRAINED RATS. Jarmo Karpakka*, Timo Takala*, Xiaoyan Han*, Kalervo VMmnen*, and Rauli Hakkarainen*. Deaconess Institute of Oulu and University of Oulu, SF-90 100 Oulu, Finland

The activities of prolyl 4-hydroxylase (PH and galactosyl-hydroxylase (GH) were measured in vastus lateralis, rectus femoris and gastrocnemius muscles after 12-16 weeks of running in normal and streptozotocin-induced diabetic rats. Diabetic decreased collagen marker enzyme activities whereas training slightly increased their activities above the control level. GP was partially able to prevent the decrease of PH activity and in rectus femoris and gastrocnemius the specific activity of GH was even increased above the control level. GH activity decreased in vastus lateralis in the trained rats and increased in gastrocnemius in the diabetic trained rats.

The results suggest that in diabetic muscle atrophy collagen synthesis and balance follows the overall negative muscular protein balance. Training could prevent only partially the negative effects of diabetes. Therefore the lack of insulin in a more important regulator of muscular collagen synthesis than physical activity as such.

This study was supported by a grant from the Ministry of Education, Finland.

19.2
DEVELOPMENT OF TWO-CELL MOUSE EMBRYOS IN MEDIA CONTAINING GLUCOSE AND AMINO ACIDS. Barbara Ehring. Univ. of Tulsa, Tulsa, OK 74104

Mouse embryos were cultured from the two-cell stage in media that contained glucose and in media that contained L-phenylalanine, L-valine, L-leucine, L-proline, L-tryptophan, and L-arginine to determine whether these compounds inhibit early development of mouse embryos as they do hamster embryos. Embryos were cultured from the two-cell stage to 24, 48, and 72 hours of culture. When glucose was the only potential energy source provided, development was arrested at the two-cell stage, as expected, but when pyruvate was provided as well, development was not inhibited by the presence of glucose. Moreover, when media that contained pyruvate also contained either glucose or lactate, embryo development was enhanced after 48 hrs of culture. The amino acids tested, like glucose, had no effect on rate of embryo development in the first 48 hrs of culture but enhanced development after 48 hrs. It was concluded that mouse embryos, unlike hamster embryos, are not adversely affected by glucose and the six amino acids tested, that these compounds need not be excluded from media in which two-cell mouse embryos are cultured, and that these compounds can enhance later preimplantation development.
19.3 MAINTENANCE OF CARDIAC COLLAGEN RATIO IN EXERCISE TRAINED RATS. Maria Lonnert-Brun, France L. Abel, Robert Price, Greg Lenton, James Buggy and Thomas L. Barron. Univ. of South Carolina School of Medicine.

Chronic exercise training (X) and hyperoxia (H) are known to alter physiological and biochemical properties of the heart. Cardiac collagen content and composition can be changed in response to the physical and pathological stimuli associated with X or H, respectively. These changes may be associated with cellular modifications such as increased collagen turnover. Electron microscopy of ventricles in both X and H showed an increased thickening of collagen fibers in the ECM. However, the ratio of collagen types I/III was maintained in X (0.5), whereas it decreased in H (0.2). This decrease indicates accumulation of predominantly type I fibrous (Type I fibrous) collagen in the cardiac ECM. In addition, collagen fibers in the X were more closely packed and had increased crosslinking, probably enhanced in X vs. H, respectively. Significant correlation between the collagen (collagen) and physiological (rCB/F) variables were observed (rCB = 0.0). These results support the concept of an important role for adaptations in ECM components in the changes in cardiac function observed in both chronic exercise and hyperoxia.

19.4 PLASMA AND MUSCLE AMMONIA METABOLISM IN THE IN SITU CANINE GASTROCNEMIUS MUSCLE DURING 3 DIFFERENT TYPES OF STIMULATION. K.A. MacKenzie, J.K. Barclay and T.G. Graham. School of Human Sciences, University of Guelph, Guelph, Ont. Canada N1G-2W1

Mongrel dogs (n = 15) were anesthetized and the vasculature of the left gastrocnemius plantaris muscle group was surgically isolated. The sciatic nerve was stimulated at 3, 4, and 5 Hz while blood flow (q) and arterial-venous differences were taken at rest. Muscle biopsies were obtained at rest, 5, 30, and 60 min. The muscle ammonia (NH3) levels were determined (w/w) using a standard testing technique supported using myo-inositol and choline as supplements to reduce adipose tissue mass. It is unknown whether a reduction in liver fat is advantageous or detrimental to a person's health and well being.


We studied the responses of ammonia (NH3) and amino acids (AA) to exercise (3h) in trained (Tr) and untrained (UTr) men. Each subject exercised the same extensor muscles of one leg at 60% of their maximum capacity. Thigh blood flow and femoral arterial-venous differences were taken for NH3 and AA measurements. In both groups there were no significant differences in the amount of chow consumed (3.0 ± 0.0) and T-chol levels in these subjects, 3. Support for the muscle that other factors within the muscle such as the constant impact on T-chol levels in these subjects, 3. There appears to be a rebound of T-chol levels following exercise (3h) in trained (Tr) (n=6) and untrained (UTr) (n=6) men. Each subject exercised the same extensor muscles of one leg at 60% of their maximum capacity. Thigh blood flow and femoral arterial-venous differences were taken for NH3 and AA measurements. 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20.3

Effect of Dietary Manipulation on Physiological and Metabolite Adjustment to Maximal VO2 and Endurance in Trained Runners

Heather W. A. Lepak, James M. Malmberg, Abraham Gettes,* Lawrence L. Rudel*, and John S. Parks*, The Bowman Gray School of Medicine of Wake Forest University, Winston-Salem, N.C. 27157

Endurance athletes often consume a diet which is high in carbohydrates and low in fat. Many of the adaptations which occur in response to endurance training result in an increased capacity to utilize fat, up to 90% VO2max. The present study examined the effects of diet composition in six runners. The energy content of the diets ranged from carbohydrate-rich (C, 56% of energy) to fat-rich (F, 61% of energy) to 61/24/1, 50/38/12 and 73/15/12 for the normal (N), fat (F) and carbohydrate (C) diets, respectively. Respiratory and blood responses to a maximum (VO2max) and prolonged (75-85% VO2max) treadmill run were determined following seven days on each diet. Free fatty acids (FFA), triglycerides, glucose, and lactate were measured. Statistical evaluation was performed using ANOVA (p<.05); values are mean±SEM. Running time to exhaustion was greatest after F (91.2±9.5 min) compared to C (75.8±7.6 min) and N (69.3±7.2 min). VO2max was also higher on F (64.6±7.7 ml/kg/min) vs. C (59.6±8.2 ml/kg/min) and N (63.7±7.2 ml/kg/min). FFA were higher and glycerol was lower during F than C and N. Other biochemical measures did not differ significantly between diets. Elevated FFA on the F diet provided enhanced oxidative potential, as evidenced by an increased VO2max and running time. Severe restriction of dietary fat may be detrimental to endurance performance.

Supported by the Office of Naval Research.

20.5

Polyunsaturated Dietary Fat Reduces the Cholesterolyser (CE) Transition Temperature (TM) of Low-Density Lipoprotein (LDL)

J. R. Jacobson, R. W. Winkler, and J. W. Seelig, Oklahoma State University, Stillwater, OK 74078.

The purpose of this study was to identify the exercise intensity (EI) which maximizes fat oxidation (FO) in young women and compare and contrast the effect of the following EI’s on the following parameters: (1) VO2max, (2) relative EI, (3) RQ, and (4) FC. Sixteen trained female subjects volunteered as subjects. Identifying characteristics included: Age 21.3±2.4 years; height 62.3±3.4 in; weight 155.5±9.2 lb; body fat 22.5±3.7% and FC 18.7±3.4F and FC 11.8±1.3 METS. Each subject completed a maximal, modified Bruce treadmill test with the epidemic arm at hip level. Expired gases were collected every 15 seconds and analysed using a metabolic cart. HR and RQ were continuously monitored. The FO EI was determined by an energy balance calculation of the VO2max and RQ to kcal fat/min using a husk RQ table. FO EI for our sample was 50.4±4.5 METS. Pair t-tests depicted both HR (134.8±8.9 vs 151.3±10.2) and RQ (0.78±0.04 vs 0.89±0.06) to be significantly (P<.01) lower at FO EI. Relative FO (kcal/min) was slightly (4.4±1.0 vs 3.2±1.9) but insignificantly (P>.05) higher at FO EI. If each EI was continued to 300 kcal of total energy expenditure, FO EI would result in a projected doubling of total FO (195.5±44.4 vs 97.9±59.1 kcal). We conclude exercise at 50% FO will oxidize at least as much fat as higher intensity exercise and will project a greater total kcal expended will project a substantial increase in total FO.

20.6

Long Term Resistive (Weight) Training Effects on Plasma Lipoprotein and Lipid Metabolism in Premenopausal Women


The ability of resistive training to alter plasma lipoprotein and lipid metabolism in the premenopausal female remains unclear. The goal of this investigation was to evaluate the effects of long term weight training on plasma lipoprotein in this population. 104 previously untrained, normocholesterolemic females (78.4±10.4 year) were randomly assigned to an Experimental (n=56) and a control group (n=48). The six group lifted weights (under supervision) 3 days/wk for 18 months. Both E and C were liquid-crystalline. These data suggest that n-3 and n-6 polyunsaturated dietary fat may have decreased atherosclerosis in the premenopausal female with little effect on plasma triglycerides.

20.7

Decrease in Muscle Malonyl-CoA Unaffected by Adrenal Medullation

W. W. Winder and J. E. Jones*, Brigham Young University, Provo, UT 84602

Malonyl-CoA is an inhibitor of carnitine palmitoyl transferase, a rate limiting enzyme of fatty acid oxidation. Previous studies have indicated that muscle malonyl-CoA declines in rats during treadmill running. This study was designed to determine if epinephrine is essential for inducing the decline in muscle malonyl-CoA during exercise. Male Sprague-Dawley rats were adrenomedullated (ADM) or sham operated (SO). After allowing 3 wks for recovery, rats (fed ad libitum) were killed at rest or after running at 21 m/min up a 15% grade for 60 min. Rats were anesthetized by intravenous injection of sodium pentobarbital. Red and white regions of the quadriceps muscle were quick frozen in liquid nitrogen and later analyzed for malonyl-CoA. Red quadriceps malonyl-CoA decreased from 2.6±0.3 to 0.8±0.07 nmol/g in ADM (n=10-12). While quadriceps malonyl-CoA decreased to similar levels (0.11±0.03 nmol/g) during exercise in both ADM and SO rats. The hormones of the adrenal medulla are therefore unessential for inducing the exercise-induced decline in muscle malonyl-CoA. (NIH DE40448 and AR41430)
21.1 EFFECT ON ENDURANCE PERFORMANCE OF ADDING POLYACTATE TO A GLUCOSE POLYMER SOLUTION. Thomas Swinnen1, G. Craytor2, and E.T. Howley. University of Tennessee, Knoxville, TN. 37996

Four highly trained male cyclists (mean VO2max = 71 mmol·min⁻¹·kg⁻¹) volunteered to perform two endurance trials each until exhaustion at 70% of their VO2max on a modified Monark ergometer. In a double-blind, and randomised design, the athletes consumed either an artificially sweetened and flavored glucose polymer solution (GP) or a similarly sweetened and flavored glucose polymer/polyactate (GP/PL) mixture. The dosage was adjusted according to body weight every 20 min in a 7% solution. As determined from pilot work, the maximum tolerable GP/PL mixture was approximately 9 parts GP and 1 part polyactate (v/v). There was no difference in time to exhaustion between the trials, as the athletes rode for 196±35 min when they drank the GP solution versus 199±43 min when they drank the GP/PL solution. Moreover, there was also no difference in the respiratory exchange ratio, rates of perceived exertion, blood lactate, blood pH, and serum glucose between the trials. Based on those findings, adding PL to a GP solution had no effect on endurance performance.

This work received support from the Cycling Science Association, Champion Nutrition, Ross Australia, and the University of Tennessee's Department of Zoology and Life Sciences Program.

21.2 EFFECTS OF HEPATIC PORTAL PYRUVATE INFUSION ON HORMONAL RESPONSE IN EXERCISING RATS. S. Caidin1, B. Hulse2, B. Composto3, G. van de Werve4, and J.M. Laviole. Department of Physical Education and Nutrition, Univ. of Montréal, Montréal, Canada.

It has been recently reported that a vagotomy of the hepatic vagus branch can modulate the hormonal response in adrenomedullated exercising rats. One of the hypothesis that has been put forward to explain this observation is that by reducing the concentration of pyruvate during exercise, the firing rates of the hepatic vagus branch during exercise. The purpose of this study was to investigate the effects of a hepatic portal pyruvate infusion (0.016 ml/mm, 5% v/v) on the hormonal responses. The experimental group was used to inhibit endogenous pyruvate production and to stimulate insulin and glucagon production. During exercise, plasma glucose levels fell from 4.5 mmol/L to 4.3, 3.7 and 3.8 in the control, the SRIF and the SRIF + insulin groups, but increased to above 6.0 mmol/L during SRIF + glucagon infusion. Exercise increased hepatic glucose production from 12.1 ± 0.2 to 28 ± 1.4 mmol·kg⁻¹·min⁻¹ in the control, to 13.0 ± 1.2 in SRIF, 17.0 ± 1.0 in SRIF + insulin and to 36.0 ± 1.6 in SRIF + glucagon. Muscle contractions increased glucose utilization in the 4 protocols and paralysed very closely glucose production between contractions, basal metabolic glucose clearance (2.68 ± 0.04 mmol·kg⁻¹·min⁻¹) increased to 6.9 ± 0.3 in the controls, 4.8 ± 0.3 in the SRIF, 6.9 ± 0.2 in the SRIF + insulin and 6.1 ± 2.3 in the SRIF + glucagon. Glucagonogenesis increased during exercise from 0.67 ± 0.07 to 0.46 ± 0.06 mmol·kg⁻¹·min⁻¹ in the control, to 0.29 ± 0.03 in the SRIF, to 0.59 ± 0.05 in the SRIF + insulin and to 1.5 ± 0.1 in SRIF + glucagon. Glucagon increased in the i.p. injected SRIF and glucagon groups. These results suggest that the hepatic pyruvate production can play a role in the regulation of the hormonal response in exercising adrenomedullated rats.

Grant: NSERC and FCAR

21.3 INFLUENCE OF SODIUM ON GLUCOSE BIOAVAILABILITY DURING EXERCISE. M. Harpergren1, D. Costill2, L. Burns, M. Fatholee and G. McCollum. Department of Kinesiology, University of Victoria, Victoria, B.C. Canada. 

To examine the influence of sodium beverage content on glucose bioavailability during exercise, six trained men (217 ± 1.0 yrs, 67.1 ± 3.2 kg, VO2 max = 4.20 ± 0.14 L/min, mean ± SE) were studied during 30 min of cycling ergometer exercise at a workload estimated to require 65% VO2 max. Immediately prior to exercise, subjects ingested 400 ml of a 10% glucose solution containing 100 g of D-(3-H)-glucose, with a sodium concentration of either 0, 25, or 50 mmol·L⁻¹. Trials were conducted in the fast and in randomised order over at least one week apart. Blood samples were obtained from a forearm vein before exercise and after 5, 10, 20 and 30 min of exercise. These were subsequently analysed for plasma glucose and 3H-glucose radioactivity and blood lactate. No differences were observed between trials for oxygen uptake, heart rate or blood lactate during exercise. Plasma glucose levels peaked after 20 min of exercise and were not different between trials (0.4 ± 0.5 mmol·L⁻¹; 0.4 ± 0.5; 0.4 ± 0.3; P > 0.05). The increase in plasma glucose and the plasma accumulation of 3H-glucose were similar in the three trials. Plasma glucose levels peaked after 20 min of exercise and were not different between trials (0.4 ± 0.5 mmol·L⁻¹; 0.4 ± 0.5; 0.4 ± 0.3; P > 0.05). The increase in plasma glucose and the plasma accumulation of 3H-glucose were similar in the three trials. These results indicate that altering the sodium content of beverage solutions has no effect on glucose bioavailability during exercise.

This study was supported by Ross Australia.

21.4 EFFECT OF DIFFERENT STIMULATION STRATEGIES ON GLUCOSE UPTAKE IN RAT MUSCLES. J. Johannesson1, J. Jernum2, and I.L. Channon. Research Group on Diabete and Metabolic Regulation, FSM and McGill University, Montreal, Quebec, Canada.

The aim of this study was to investigate the effect of different stimulus strategies on glucose uptake (GU) in soleus (SOL) and gastrocnemius (GAST) muscles. The stimulated GU (GUstim) was measured with the 3-OsC method and normalized as nmol·g⁻¹·min⁻¹. The muscles were stimulated 20 min. through the sciatic nerve, 100 Hz trains of 200 msec duration were given every 400 sec. (100-Low), and 20 Hz trains of 10 sec. duration every 20 sec. (20-High) or 6 sec. (20-Low), in situ. The higher GU was obtained in 100-High (P<0.01), in GAST in 100-High (P<0.05). The results of the present study indicate that alterations in the stimulus frequency and duration of the impulse trains are important for the magnitude of GU.

21.5 UTILIZATION OF INGESTED GLUCOSE DURING A 4-HR WALK. C. Dufour1, D. Hausswirth1, P. Péroton2, G.R. Ristic1, and C. Hillaire-Marcel1. Université du Québec à Montréal, Université de Montréal, INS-Santé, Montréal, Canada, H3C 3P8.

Taking into account the 'background effect' with an 'OC- isotope tracer approach, our purpose was to measure the oxidation rate of 100 g of glucose (diluted in water, 2%) ingested at the beginning of a 4-hr exercise. Six healthy young males (21.5 ± 0.6 yrs; VO2max = 46.5 ± 3.2 ml/kg.min) performed three exercises (2 with glucose and 1 with water ingestion) on a treadmill at 65 ± 2.5 km/hr, 10% slope). In order to correct for the 'background effect' due to exercise and/or to substrate ingestion as measured by the H-DG-method and that the different stimulation regimes in SOL and GAST, and that the stimulation frequency and duration of the impulse trains are important for the magnitude of GU.

21.6 REGULATION OF GLUCOSE FLUXES DURING EXERCISE IN HEALTHY MALE SUBJECTS. C. Laviole1 and J.L. Chamon. Research Group on Diabetes and Metabolic Regulation, FSM and McGill University, Montréal (Quebec), H2W 1KJ (Funding by Diabetes Canada).

Using a stable isotope technique, we have further characterized the regulation of glucose fluxes in healthy subjects during a 2-hr exercise at 40% VO2 max. Somatostatin (SRIF) was used to inhibit endogenous production of insulin and glucagon. During exercise, plasma glucose levels fell from 4.5 mmol/L to 4.3, 3.7 and 3.8 in the control, the SRIF and the SRIF + insulin groups, but increased to above 6.0 mmol/L during SRIF + glucagon infusion. Exercise increased hepatic glucose production from 12.1 ± 0.2 to 28 ± 1.4 mmol·kg⁻¹·min⁻¹ in the control, to 13.0 ± 1.2 in SRIF, 17.0 ± 1.0 in SRIF + insulin and to 36.0 ± 1.6 in SRIF + glucagon. Muscle contractions increased glucose utilization in the 4 protocols and paralysed very closely glucose production between contractions, basal metabolic glucose clearance (2.68 ± 0.04 mmol·kg⁻¹·min⁻¹) increased to 6.9 ± 0.3 in the controls, 4.8 ± 0.3 in the SRIF, 6.9 ± 0.2 in the SRIF + insulin and 6.1 ± 2.3 in the SRIF + glucagon. Glucagonogenesis increased during exercise from 0.67 ± 0.07 to 0.46 ± 0.06 mmol·kg⁻¹·min⁻¹ in the control, to 0.29 ± 0.03 in the SRIF, to 0.59 ± 0.05 in the SRIF + insulin and to 1.5 ± 0.1 in SRIF + glucagon. Glucagon increased in the i.p. injected SRIF and glucagon groups. These results suggest that the hepatic pyruvate production can play a role in the regulation of the hormonal response in exercising adrenomedullated rats.

Grant: NSERC and FCAR
21.7 CARBOHYDRATE FEEDING FOLLOWING CARBOHYDRATE LOADING ENHANCES PROLONGED EXERCISE PERFORMANCE
University of Pittsburgh and Pennsylvania University Hospital, Pittsburgh, PA 15261.
This investigation determined whether carbohydrate (CHO) feeding during a prolonged strenuous exercise enhances endurance following pre-trial CHO loading. Eight male cyclists performed two cycle trials to fatigue at a power output corresponding to 70% VO_{2}max. During the trials, the trials were performed on a recumbent cycle ergometer (OE) solution was infused in two randomized trials. Muscle glycogen was measured after 20 min of exercise (0.16 ± 0.04 mM at -30 min to 0.18 ± 0.04 mM at +30 min). Blood lactate levels were similar between trials. During exercise, the AcCoA content was significantly lower in the CHO trial than in the control trial (R: 4.0 ± 0.3 mmol/kg dm/min vs. 5.5 ± 0.4 mmol/kg dm/min). Changes in AcCoA content parallelled those of AcCoA, and dependent on greater PDH (CFD vs HCD mmol/kg dm/min: T16 12.1 ± 0.7 vs 21.1 ± 0.7, p<0.01). In addition, the sparing of muscle glycogen was not dependent on the type or source of CHO. In addition, the sparing of muscle glycogen was not dependent on the rate of delivery to the muscle. The effects on muscle glycogen were similar between trials after 20 min of exercise (13.2 ± 0.9 mmol/kg dm/min vs 12.6 ± 0.7 mmol/kg dm/min). Resting blood glucose and lactate were similar between trials. Glycogen utilization was lower at 0.04 mmol/kg dm/min vs 0.09 mmol/kg dm/min, and at fatigue (0.42 ± 0.04 mmol/kg dm/min vs 0.50 ± 0.04 mmol/kg dm/min). Glycogen increased (p<0.05) from pre-exercise to termination during GS and P. RER did not differ between trials after 20 min of exercise (0.85 ± 0.02 vs 0.84 ± 0.01). In summary, increased FFA availability decreases muscle glycogenolysis during the initial 15 min of intense cycling. This finding is independent of training status and pre-exercise glycogen content. Supported by NSERC, Canada

21.9 ENHANCED FFA AVAILABILITY DECREASES MUSCLE GLYCOGENOLYSIS DURING INTENSE AEROBIC CYCLING. O.J. Prent, C.S. Pulayko, J.M. E. Reyburn,
E. B. Goss, C. C. W. E. Taylor, Human Performance Laboratory, Ball State University, Muncie, Indiana 47306.
The capacity for glucose homeostasis is well-known to decline with advancing age. This study investigated the influence of both aging and training on hepatic gluconeogenesis in rats. Five trained young males were used. One-half of 30 trained (TR) and 33 untrained (UN) male Fischer 344 rats, initial ages of 4, 12, and 22 months, were injected with a known gluconeogenic inhibitor, 3-mercaptopicolinic acid (MPA). Two endurance tests were performed to help assess the contribution of gluconeogenesis to exercise performance. An initial test four days prior to injection and a final test post-injection (300 mg/kg). MPA significantly reduced running performance in all TR groups compared to the control group: 92% and 51% in the young, middle aged and old, respectively. Blood glucose levels were significantly lower prior to running with MPA treatment vs control across all age groups (4.5 vs 8.3 mm). Running further suppressed glucose levels in the MPA animals (24% & 10% for TR and LIN, respectively) while no difference existed in the controls. Incubation of liver slices with 14C-labeled acid demonstrated a significant decline in incorporation of tracer into glycogen with age (18248, 5692, and 2000 in young, middle aged and old, respectively). Training resulted in a 30% increase in glycogen synthesis in this young animal group, however, no significant differences were observed for middle and old groups. It was concluded that hepatic gluconeogenesis is impaired with age and endurance training has a minimal effect in offsetting this response.

21.11 EFFECTS OF THE EXCUSSIVE DIET ON MUSCLE GLYCOGEN UTILIZATION AND FORMATION OF ACETYLCOA AND ACETYLCOENZYM E. M. THURSDAY CARBOHYDRATE METABOLISM 191

21.12 EFFECTS OF TRAINING AND TESTOSTERONE ON MUSCLE GLYCOGEN CONTENT IN NON-INSULIN-DEPENDENT DIABETES MELLITUS PM. Vallotton, D.T. Ong, G. Murphy, G. Gieseler, G. Krauslund and J.F.C. Blair
Department of Medicine, McMaster University Medical Centre, Hamilton, Ontario, Canada L8N 3S2.
In this study the effect of testosterone (T) on glycogen content in soleus and extensor digitorum longus (EDL) muscle was studied in 6 groups of adult non-insulin-dependent diabetes mellitus (NIDDM) male rats. The animals were divided into 6 groups: 1) sedentary (S); 2) trained (T); 3) sedentary + T (ST); 4) sedentary + D (SD); 5) trained + T (TT); and 6) trained + D (TD). Body weight, glycogen and lactate content were measured at baseline and at the end of the experiment. The results indicated that testosterone (T) significantly decreased glycogen content in all groups, while training (T) significantly increased glycogen content in all groups. The combination of testosterone and training (TT) significantly decreased glycogen content in all groups. The combination of testosterone and training (TT) significantly increased glycogen content in all groups. The combination of testosterone and training (TT) significantly increased glycogen content in all groups. The combination of testosterone and training (TT) significantly increased glycogen content in all groups.
GLUCOSE UPTAKE DURING EXERCISE IS IMPROVED BY INDIRECT EFFECTS OF INSULIN. J. Shi*, A. Giacca+, K. Yamamoto+, S. Fisher*, L. Lickley*, and M. Vranic, Univ. of Toronto, Canada, MSS 1A8

We wished to determine whether insulin's effects on glucose utilization during exercise can be reproduced by reduced provision of free fatty acids (FFA). The effects of a single dose of insulin (SI, 50 mg/kg, i.v.), methylpalmitate (MP, inhibitor of insulin-stimulated glucose transport) and 20 mg/kg palmitate (PP) (propanoic acid, inhibitor of lipolysis. 5 mg/kg, i.v.) on glucose metabolism were studied in depancreatized, 24 h insulin-deprived dog models. The exercise tested was 6 h of slow, steady exercise (60% VO2 max protocol). At rest, SI reduced plasma glucose (PG, 13T, p < 0.01) and increased glucose transport (GLUT4, SI, GLUT4 > 0.01) and clearance (MCR, 722, p < 0.01). MP lowered glucose transport (Ra, 72%, p < 0.01), while the increased glucose transport post-SI (Ra, 72%, p < 0.01), but had no effect on GLUT4. GLUT4 decreased PG by 42%. Due to the reduced Ra (50%) and increased GLUT4 (732 and 197%, p < 0.01), SI or MP did not affect GLUT4 or MCR during exercise. Either SI or MP did not affect GLUT4 or MCR during exercise. In summary: 1) Blood insulin alone improved GLUT4 and MCR only at rest; 2) A combined suppression of lipoprotein and FFA oxidation markedly improved GLUT4 and MCR during exercise; and 3) Combination of elevated insulin and inhibition of FFA oxidation improved GLUT4 during exercise; and 4) Improvement in GLUT4 and MCR (MCR, GLUT4, GLUT4) was correlated with correction of hyperglycemia. We conclude that insulin's effects in enhancing glucose utilization can be mediated, at least partially, by indirect mechanisms including suppression of lipoprotein and correction of hyperglycemia.

GLUCOSE TRANSPORT ACTIVITY AFTER EXERCISE IN YOUNG, ADULT, AND OLD RATS. G.D. Carere, C.A. Briggs-Tung*, and E.W. Klecke,* University of Wisconsin, Madison, Wisconsin 53706.

Youth have an increase in muscle insulin-stimulated glucose transport for many hours after exercise. Our purpose was to determine if adult (12 mo) and old (24 mo) rats respond to exercise like young (3 mo) rats. We evaluated glucose transport using 3H[3]-methylglucose (3H-MG) in isolated skeletal muscle. Muscle glucose transporter protein (GLUT4) transport was elevated (p < 0.05) 3.5 h post-exercise in the young (409 vs. 0.86), adult (0.38 vs. 0.99), and old (0.29 vs. 0.49) rats. With 20,000 μM insulin, 3H-MG transport was elevated (p < 0.05) 3.5 h post-exercise (3H-MG: 0.89 vs. 1.20), but not adult (0.68 vs. 0.71) or old (0.71 vs. 0.78) rats. Muscle glucose transporter protein (GLUT4) content of the young rats was greater (p < 0.05) than the adult or old rats. GLUT4 content of the young rats was unchanged 3.5 h post-exercise, while GLUT4 content is elevated in young rats despite unchanged GLUT4 content.
EFFECT OF ENDURANCE TRAINING ON PYRUVATE METABOLISM IN MICE AFTER SUPRAMAXIMAL EXERCISE

Male ddY mice (N = 9) ran at a speed of 30 m/min for 60 min for 6 weeks. In a 14C study, the amount of 14C02 expired during 20 min of recovery relative to the injected dose of 14C-pyruvate (25.3% ± 1.9% vs. 23.8% ± 2.5%) was significantly higher than that of control mice (97.0 ± 19.8 dpm/mg vs. 58.7 ± 10.2 dpm/mg). These results suggest that endurance training does not activate oxidation of pyruvate, but it activates glycogen resynthesis from pyruvate in mice after supramaximal exercise.

APPLYING THE CONCEPT OF SYMMORPHOSIS TO ENERGY METABOLISM IN MUSCLES: HOW MUCH ENZYME IS ENOUGH, BUT NOT TOO MUCH

Raul K. Suaret (SPON: P.W. Hochachka), Dept. of Zoology, Univ. of British Columbia, Vancouver, B.C., Canada V6T 1Z4

The concept of symmorphosis proposed by C.R. Taylor and E.R. Weibel predicts that functional capacities should match, but not exceed, maximal physiological demands. To determine if the concept applies to pathways of energy metabolism in muscles, I first consider the nature of enzyme-catalyzed metabolic reactions. I then consider the relationships between maximal catalytic capacities at various steps in energy metabolism and maximal pathway flux rates in vivo. This leads to the following predictions: (a) enzymes catalyzing reactions close to equilibrium occur at maximal activities in greater excess over maximal pathway flux rates than enzymes catalyzing reactions far from equilibrium, (b) maximal activities of rate-limiting enzymes are higher than maximal pathway flux rates where the latter are relatively low, (c) close matches between capacities and rates in high flux systems may imply upper limits to the design of functional capacities in pathways of energy metabolism in muscles.

GLUCOSE TRANSPORTERS IN REGENERATING SKELETAL MUSCLE

Marialice K. Kern*, Steven T. Devor*, Timothy P. White, and Arend Bonen, Univ. of British Columbia, Vancouver, B.C., Canada V6T 1Z4

The glucose transporter isoforms GLUT 1 and 4 are essential for glucose metabolism in skeletal muscle. The relative concentration of these isoforms differ between fiber types, and change with development, aging, and physical training. Following transplantation, skeletal muscle fibers degenerate and new fibers regenerate. Using this model of muscle development, our purpose was to test the hypothesis that GLUT 1 and 4 would return to control value with time following transplantation. Soleus and extensor digitorium longus (EDL) muscles were orthotopically grafted with the nerve reimplanted in Wistar rats (female, 2 mo). Glucose transporters were isolated. Western blots were run and polyclonal antibodies raised against the 15 amino acid carboxy-terminus end of both the GLUT 1 and GLUT 4 proteins were used to visualize the GLUT 1 and 4 bands. In soleus grafts, GLUT 4 was not measurable at 7 days, evident at 21 days, and not different than control value at 42 days post-grafting. In contrast, EDL grafts evidenced a slight elevation in GLUT 4 at 7 days, and values were not different from control at 21 and 42 days. GLUT 1 was non-reactive in soleus muscles and grafts, and demonstrated low reactivity in EDL muscles and grafts. Supported by NIH DE-07687 and the University of California President’s Fellowship Program.

POSSIBLE RELATIONSHIP BETWEEN CARBONIC ANHYDRASE III AND CARBOHYDRATE METABOLISM IN TYPE I SKELETAL MUSCLES

C. Colin. J. Frenette* and A. Ouellet*, Laval University, Quebec, Canada

Carbonic anhydrase III (CA III) is the predominant isoenzyme in skeletal muscle and is present in type I fibers where it is the most abundant cytosolic protein. We have previously shown that inhibition of CA III can improve the resistance to fatigue of type I muscles. We tested the hypothesis that this influence on fatigue was (1) due to the inhibition of an intracellular CA isoenzyme and (2) related to an effect on glycolysis and/or glycogenolysis. Rat soleus (SOL) muscles were incubated with or without ethoxzolamide (ETHOX 0.1 mM), a potent CA inhibitor, and were submitted to a standardized fatigue protocol after a 45 min period of equilibration. Glucose-6-P (G6P), fructose-6-P (F6P) and fructose-1,6-P (F16P) contents were determined on freeze-clamped SOL samples. When ETHOX was added at the start of the equilibration period, a condition which leads to differences in tension production between both groups after only 1 min of stimulation, the concentrations of G6P and F6P were 4 to 5 fold higher in the ETHOX muscles than in the control muscles for the entire duration of the fatigue protocol while no difference was noted for F16P. When ETHOX was added only at the start of the fatigue protocol significant differences in tension production between both groups of muscles were seen only after 15 min of stimulation. A significant difference in G6P content between both groups was only observed after 30 min in the protocol. Collectively, these data support the idea that the loss of CA III activity can lead to an imbalance between production and utilization of hexosemonophosphates in type I muscles.

The passive tension, or preload, at optimal muscle length (L1) in the pesai-terebine-sulphate-plantaris muscle can be a significant fraction of the developed afterload of isotonic contractions. Therefore, we investigated the effects of the removal of the preload during the relaxation phase of electrically evoked, forcibly contracting muscle. By suddenly unloading (1 contraction/s, 200 ms duration, 50 imp/s, 4V), after a 30 min period. Isolated plantaris tendons (2-3 g) were stretched to the muscle origin via a pneumatic system allowing removal of the preload between contractions. This resulted in shortening contractions initiated at L1, followed by relaxation at a short length when the muscle was in a passive tension, or was slack, with the cycle being completed by resetting to L1, just prior to the next contraction. Blood flow (Q) and oxygen uptake (VO2) were measured before and during continuous contractions of 15-1 min duration in four rats. VO2 was increased by 16%, 22%, and 17%, respectively, when the preload was removed (2.1 mL/min and 255 mL/min, n = 5), as compared to values when the preload was maintained at L1. (1.6 mL/min and 217 mL/min, n = 5). These differences were maintained at 10 min of contractions, when Q and VO2 were still 27% and 19% higher in the slack-relaxation group. Fatigue measured at 30 min as a decrease in power/initial power production, was less when the preload was removed (-70% vs -50%). These data demonstrate that the passive tension that was maintained when this muscle was held at L1, in situ, can limit Q and VO2, and can increase fatigue of repetitive isotonic tetanic contractions. We conclude that the slack-relaxation method results in less Q limitation and produces a contraction-relaxation cycle that better approximates cyclic muscle function in vivo.

(Supported by NIH Grant AR39378 and AHA Fellowship 91F/8.)

29.3 AGING, ENDURANCE TRAINING, AND MUSCLE METABOLISM DURING EXERCISE. A.R. Cogan, A.M. Abdallah*, S.C. Swanson, T.W. Farris, M.S. Parti, L.A. Mendenthal*, and P.M. Robb*, and Ohio State University, Columbus, OH 43210.

To examine the effects of aging and/or endurance training on muscle metabolism during exercise, 11P magnetic resonance spectroscopy (11P-MRS) was used to study the metabolic response to exercise in young (Y) and older (O) untrained (UT) and endurance-trained (E) (1) males. Exercise consisted of a 60 min Stage 5 on the Bruce protocol at 60 W. The power output incremented by 0.74 W every 3 min until fatigue. 11P-MRS data were acquired at rest and during the last 90 s of each exercise stage using a 1.5 Tesla MR spectrometer and a 4 cm surface coil placed over the lateral gastrocnemius muscle. The rate of increase in Pi/PCr ratio with increasing power output (i.e., the Pi/PCr slope) was used as a measure of muscle metabolic stress. Results are summarized in the table below:

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (y)</th>
<th>VO2 (ml/min/kg)</th>
<th>PWC (W/kg)</th>
<th>Pi/PCr Slope (W/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>20</td>
<td>33.5 ± 4.9</td>
<td>14.9 ± 1.8</td>
<td>0.025 ± 0.007</td>
</tr>
<tr>
<td>O</td>
<td>58</td>
<td>27.6 ± 3.1</td>
<td>11.0 ± 1.3</td>
<td>0.018 ± 0.007</td>
</tr>
<tr>
<td>E</td>
<td>20</td>
<td>30.3 ± 3.7</td>
<td>12.2 ± 1.6</td>
<td>0.026 ± 0.005</td>
</tr>
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</tbody>
</table>

Values are ±S.E. Significantly different from corresponding Y group. Significantly different from corresponding UT group.

Age-related reductions in exercise capacity appear to be due in part to an altered muscle metabolic response to exercise. Differences were observed in T as well as in the Pi/PCr ratio with increasing power output (i.e., the Pi/PCr slope) was used as a measure of muscle metabolic stress. Results are summarized in the table below:

29.4 EFFECT OF PROLONGED TETRODOTOXIN-INDUCED NEURAL INACTIVATION ON ENZYMES OF ENERGY METABOLISM IN INDIVIDUAL RAT MUSCLE FIBERS. B. T. Amprugo, M. Michal, H. LaFrance, C. B. West, and A. P. Deuter, University of Toronto, PSE 2C6 and Washington University School of Medicine, St. Louis, Missouri 63110.

We have measured the changes in enzymes of energy metabolism of muscle fibers following a complete and prolonged muscle paralysis achieved without denervation. The propagation of aodal nerve action potentials in one hindlimb of Sprague-Dawley rats were blocked with the sodium channel blocker tetrodotoxin (TTX) using a mini-osmotic pump and cuff delivery system. Two wks of TTX-induced paralysis caused severe wasting of the homolateral plantaris. However, these changes were not as different from the contralateral homologous muscles as were found from this TTX group. The passive tension, or preload, at optimal muscle length ($L_1$) in the plantaris muscle group was stimulated to perform contractions with a power output incremented by 0.74 W every 3 min until fatigue. The Pi/PCr slope was used as a measure of muscle metabolic stress. Results are summarized in the table below:

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Values are ±S.E. Significantly different from corresponding Y group. Significantly different from corresponding UT group.

Age-related reductions in exercise capacity appear to be due in part to an altered muscle metabolic response to exercise. Differences were observed in T as well as in the Pi/PCr ratio with increasing power output (i.e., the Pi/PCr slope) was used as a measure of muscle metabolic stress. Results are summarized in the table below:

29.5 ENZYMES OF ENERGY METABOLISM IN OVERLOADED RAT PLANTARIS MUSCLE FIBERS. B. T. Amprugo, P. Brechtel, M. J. Chiu, and C. H. Low. - Laurentian University, Sudbury, Ontario, P3E 2C6 and Washington University School of Medicine, St. Louis, Missouri 63110.

Contralateral hypertrophy of the rat plantaris muscle was induced via the bilateral surgical removal of the synergistic gastrocnemius and soleus muscles. After 4 wks of work overload, plantaris muscle mass was 44% greater than sham-operated controls. The activity of the following nine enzymes of energy metabolism were measured from dissected fiber bundles derived from these muscles: hexokinase (HK), glycogen phosphorylase (PHK), glycogen S-phosphate dehydogenase (GPDH), pyruvate kinase (PK), lactate dehydrogenase (LDH), malate dehydrogenase (MDH), citrate synthase (CS), 8-hydroxy-acyl-CoA dehydrogenase (OAC), and thiolase (TH). Enzyme activities were measured in duplicate in each fiber bundle and individual fibers from these muscles. Consistent with the loss in mass, absolute amounts of all enzymes, except HK, were on average 65% lower in fiber bundles from TTX-treated plantaris. After TTX-induced decrease, HK activity (mol h-1 kg-1 dry wt) in plantaris and soleus was higher, and PK activity was lower, in plantaris and individual fibers of these muscles. Furthermore, in contrasted plantaris, PK activity was lower, and LDH activity not changed. It seems clear from individual fiber samples that only plantaris Type I and IIA fibers (-50% of the muscle) have reduced activities of enzymes of oxidative metabolism resulting from TTX inactivity. In TTX-treated soleus fiber bundles, a less marked, but substantial, loss in the amount of oxidative enzymes (on average 44%) was observed, accompanied by either an increase, or no change, in activities of 3-4 glycogenic enzymes (uPFM, PK and Ldh). It appears that, the soleus, but not plantaris, fibers can compensate for the loss of oxidative metabolism that results from total inactivity.

Supported by NSERC, Canada, and NIH, USA.

29.6 EFFECTS OF SHORT-TERM OCCULAR TRAINING FOLLOWING A CONTINUOUS TRAINING REGIME ON SKELLETAL MUSCLE ENZYME ACTIVITIES AND EXERCISE PERFORMANCE. B. T. Amprugo, W. J. Arnold, and W. N. Stainsby. Department of Physiology and Pharmacology, College of Medicine, University of Florida, Gainesville, FL 32610.

The purpose of this study was to examine the effects of a high intensity short duration (3 weeks) oscillatory training regime following a continuous training regime (12 weeks) on exercise performance in female Sprague-Dawley rats. The continuous training regime (CT) group were subjected to a progressive treadmill training regime for a total of 16 weeks with the final workload being: 32.5 m/min; 60 min. duration; 8% incline; 5 times per week. The oscillatory trained (OT) animals did the same training regime for the first 12 weeks. During the last 5 min of each run, the rats were subjected to a power output of 30 m/min; 200 m/min; 4V; 450 m/min; 8% incline. After 10 min of recovery, VO2 decreased to about twice the precontraction rest level. Thereafter, VO2 declined slowly reaching the rest level in 40 min. Whole muscle performance, monitored by single contractions at intervals, recovered slowly reaching 50-70% of the initial level by 30 minutes. This pattern of slow recovery is similar to that observed previously after twitch contractions (B.A. Wilson and W.N. Stainsby, J. Appl. Physiol. 45:234-237, 1978). The level of mechanical recovery achieved suggests that irreversible damage was minimal. The disassociation of metabolism and mechanical performance during recovery supports that mechanical recovery is not related to the energetic state of the muscle under the conditions of these experiments. Therefore, the decrease in muscle performance during the contractions must be a result of other factors. (Supported by NIH Grant AR39378 and AHA Fellowship 91F/8.)

Supported by NSERC, Canada, and NIH, USA.
29.7

EFFECTS OF EXERCISE TRAINING AND AGE ON IMPRODUCTION AND ENERGY CHARGE IN FISCHER 344 RAT GASTRUMOCEUS MUSCLE. R.G. Tucker and 4. Tucker. Department of Physiology, University of California, Davis, CA 95616

A reduction in work capacity (WC) is observed with aging and exercise training. This decline may be reflected in the muscle’s energy charge (ATP/ADP + AMP). FT enhanced the respiratory response to the exercise stimulus and the defended end. So, the interaction of age and ET (12 wk, 5 days/wk) on muscle EC during stimulated exercise was studied in anesthetized (8% halothane 80% kO2) biceps brachii (BB) and sartorius (SOL) muscles of 12-month-old (M = 17.9 mo, n = 10) and adult (A = 12-13 mo, n = 13) C-57BL/6 mice. A saline and acetaminophen base were isolated for measurement and electrical stimulation. The gastrocnemius was freeze clamped, with tongs b.w. and acepromazine 0.5 mg/animal) old (0 = 25 mo, n = 10), mature (M = 170 mo, n = 10), and adult (A = 17-19 mo, n = 10) male (C-57BL/6). Nucleotides and IMP were analyzed in freeze dried samples by reverse-phase HPLC (Beckman). A graded treadmill pretest showed equal WC between ages (25 vs 50% total nucleotides). We conclude that aged animals maintain their response to ET, and the enhanced WC was not reflected in an increased EC during simulated exercises. However, ET may influence the pH and nucleotide cycle. (Supported by AFAR, AHA of Canada and NIA animal colony)

29.10

ENDURANCE EXERCISE EFFECTS ON SINGLE SKELETAL MUSCLE FIBRE CONTRACTILE PROPERTIES OF DYSTROPHIC MDX MICE. Geoffrey S. Lynch1,2, Alan Harris3, Mark H.C. Lant2, and David A. Williams3. (SPON: Mark Hargreaves), Muscle and Nerve Research Laboratory, Dept. of Physiology, Univ. of Melbourne, Victoria 3052, Australia.

The possible amelioration of the debilitating effects of muscle diseases, such as Duchenne Muscular Dystrophy (DMD), led to an investigation into the effects of exercise on dystrophic mice. Mdx mice (an animal model of DMD), underwent a 15 week endurance exercise program, consisting of 2 hours/day, 5 days/week of treadmill running. At the conclusion of the training period, the muscles were prepared from the EDL and soleus (SOL) muscles of both SWIM and SEDENTary mdx mice, to assess the oxidative and glycolytic capacities of these muscles. Histochemical staining of whole muscle cross-sections revealed exercise-induced fibre type shifts towards a greater oxidative capacity in the both muscles. The exercised group also exhibited an increased muscle cross-sectional area, and modulation of the contractile and metabolic properties of skeletal muscle. This work was supported by NIH Grant #AR-38972

29.12

ROLE OF NEUROMUSCULAR ACTIVITY IN CONTROL OF METABOLIC GENE EXPRESSION IN SKELETAL MUSCLE. F. Goto, K. Hozumi, D. Iyam, K. Itai and K. Carrison. U of Colorado, Davis, CA 95616

Neuromuscular activity plays an important role in the induction and modulation of the contractile and metabolic properties of skeletal muscle. We have investigated the effects of exercise on the expression of the plasma membrane glycosylation pathway of the muscle membrane and intracellular pH calculated from these spectra. Power output at the output, or threshold of intracellular metabolic requirements (i.e.) was identified using piezoelectric transducers, and changes in ATP and pH. Both maximal power (1.11 ± 0.26 W) and 1.11 s of cycle by hand), and the power output at the threshold (1.18 ± 0.15 W and 1.22 ± 0.11 W) were reproducible in the control group. Following the exercise training, the maximal power attained by the experimental group (n = 13) was significantly higher (1.45 ± 0.29 W) by 19% (from 1.33 ± 0.18 W to 1.48 ± 0.22 W). A similar trend occurred in the onset of the threshold which was also prolonged by 10% from 1.25 ± 0.18 W to 1.33 ± 0.22 W. The increase in critical power was also reflected in the decreased exercise-induced muscle pH, significantly increasing the endurance of the forearm muscle. These findings suggest an enhancement of oxidative metabolism. The drug may have improved the oxidative capacity of muscle by increasing the availability of fat as a substrate, or enhancing perfusion of the working tissues.

29.9


University College London, London WC1E 6BT, England.

During intense exercise there is a large increase in ATP turnover which is probably greater in fast twitch (FT) fibres rather than in slow twitch (ST) fibres. In a mixed muscle therefore, ATP turnover during maximal exercise should be proportional to the percentage of FT fibres. We have measured metabolites in the adductor pollicis (AP) and abductor digiti minimi (ADM) muscles using 1P magnetic resonance spectroscopy with ethical approval. AP and ADM metabolites and pH were measured at rest and 30 s to 180 s of 240 W of exercise. While ST fibres. In the SOL, type I contractile characteristics did not differ from the AP (20% ST fibres) (Johnson et al. J. Neurol Sci. 18, 111-129). From the data, calculated ATP turnover is 6 fold greater in FT fibres compared to ST fibres during maximal exercise (24 vs 4 mM ATP s-1, respectively).
29.13 EFFECT OF ENDURANCE TRAINING ON CHANGES IN THE RAT SOLEUS MUSCLE DURING HINDLIMB SUSPENSION, Hideyuki Watanabe1, Yuji Taira2, and Kazuhiro Katayama1. 1Dept. of Radiology, Inst. of Clinical Medicine and 2Health & Sport Sciences, Univ. of Tsukuba, Tsukuba 305, Japan.

We examined the effect of prior 10-wk endurance training in the changes in the histochmical and biochemical properties of the rat soleus muscle during hindlimb suspension (HS) for up to 4 wks. Male Wistar rats were divided into the training suspension (Tr+SUS), suspension only (SUS) and control (CON) groups.

The muscle-to-body weight ratio decreased significantly and similarly in both Tr+SUS and SUS groups. However, as this ratio in the Tr+SUS group had been increased by the training, it remained higher than in the SUS group. Similar pattern was observed with respect to succinate dehydrogenase (SDH) activity. Myosin heavy chain (MHC) fiber, most likely corresponding to HCIIx, was detected in the suspended soleus, and its percentage increased during the experimental period. The percentage of HCIIx and number of rats with HCIIx was lower in the Tr+SUS group than in the SUS group. These results suggest that endurance training before HS contributes to maintenance of higher muscle mass and SDH activity during HS and inhibits the expression of HCIIx in the suspended soleus.

29.14 Role of albumin in the work-induced hypertrophy of rat skeletal muscle
Shigeki Yamada1, Yoshinori Ogiwara2, Masato Fujimaki1
1Dept. of Sports and Science, the University of Tokyo, 2Jikei University school of medicine, Public Welfare Institute of Scientific Research Foundation

The work-induced hypertrophy in the rat skeletal muscle accompanies the increase in quantity of albumin in the muscle. Physiological role of albumin in the muscle enlargement have been studied by use of the mutant rat defective in albumin synthet. The work-induced hypertrophy in the skeletal muscle which is generally observed in normal rats, fails to take place in albumin deficient rat (NAR). Inability of NAR to develop the work-induced muscle hypertrophy is not the consequence of the lowered inormal level of testosterone and growth hormone but primarily due to the absence of albumin in NAR. New muscle fibers is formed by work-induced hypertrophy of the skeletal muscle in the normal rat. Albumin localized in the epimysium of the the control muscle. Albumin localized in the epimysium and small muscle fiber in the hypophrophid muscle. Myosin heavy chain in these small fiber was embryonic type. Albumin appeared in the immature muscle fiber and disappeared in the adult muscle fiber. Therefore, albumin may related to proliferation of muscle fiber in the hypophrophid skeletal muscle in the normal rat.

29.15 PROGRESSIVE OVERLOAD OF THE ANTERIOR LATISSIMUS DORSI OF THE ADULT TIGER: PRODUCES MUSCLE FIBER HYPERPHORY PRIOR TO FIBER HYPERPLASIA
A Antonio and W.J. Goeser, Ph.D
University of Texas Southwestern Medical Center, Dallas, Texas 75235

Muscle fiber hyperplasia precedes fiber hypertrophy in the anterior latissimus dorsi (ALD) muscle of adult ungulate undergoing chronic stretch (Alway et al., 1990). This study was undertaken to determine if a stretch protocol involving a progressive increase in load and duration would induce significant muscle fiber hypertrophy followed by fiber hyperplasia. Between experimental periods, animals were allowed to live active normal weight. After the experimental periods, birds were sacrificed after 16, 20, 24, or 28 days of stretch. The ALD was excised and weighed. The changes in the % non-contractile tissue were measured: 29.15% (16d), 33.0% (20d), 33.0% (24d), and 33.0% (28d). These data indicate that in avian muscles, fiber hyperplasia precedes fiber hypertrophy.

29.16 SELECTIVE MUSCLE MUSCULAR HYPERTROPHY AS A RESULT OF STRENGTH TRAINING
Mauro V. Marcari and Paolo Corniello, CNR, Istituto Tecnologia Biondmedica Avanzate, Reparto Fisiologia, Milan, Italy 20131

The effects of 6 months strength training on the morphometry of the human quadriceps muscles was investigated in a group of 7 males subjects (age 20±0.36 yr, weight 79.3±6.8 kg, height 1.76±0.06 m, mean±SD). Training consisted of 4 series of 6 unilateral leg lifts of a weight corresponding to 80% of the one repetition maximum (IRM) carried out every other day, for 6 months. Before and after the training, 100 subjects were studied and the quadriceps muscle was measured by magnetic resonance imaging at five levels along the femur, interspaced by a distance of 110 femur length. The cross-sectional area of the quadriceps muscle during the experimental period. The percentage of HCIIx and number of rats with HCIIx was lower in the Tr+SUS group than in the SUS group. These results suggest that endurance training before HS contributes to maintenance of higher muscle mass and SDH activity during HS and inhibits the expression of HCIIx in the suspended soleus.

29.17 L-CARNITINE AND AEROBIC EXERCISE OVER SKELETAL MUSCLE FIBRE SIZE AND FIBRE TYPE DISTRIBUTION IN RATS.
R Hahna1, Stuart Bowerman2, and Stephen L. Trappe3. 1Dept of Sports and Science, the University of Tokyo, 2Jikei University school of medicine, Public Welfare Institute of Scientific Research Foundation

The effect of chronic endurance training on the morphometry of the human quadriceps muscles was investigated in a group of 7 males subjects (age 20±0.36 yr, weight 79.3±6.8 kg, height 1.76±0.06 m, mean±SD). Training consisted of 4 series of 6 unilateral leg lifts of a weight corresponding to 80% of the one repetition maximum (IRM) carried out every other day, for 6 months. Before and after training, the cross-sectional area of the quadriceps muscle was measured by magnetic resonance imaging at five levels along the femur, interspaced by a distance of 110 femur length (Lf). It was observed that the degree of hypertrophy for the quadriceps group was not uniform: it was maximum both at the proximal 3/10 Lf (18.8±3.6 %) and distal 7/10 Lf (19.3±6.4 %)

29.18 EFFECT OF ENDURANCE TRAINING ON CHANGES IN MUSCLE FIBER PROPERTIES DURING HINDLIMB SUSPENSION, H. Itai1, Y. Takahashi1, and S. Tsubata2. 1Dept. of Radiology, Inst. of Clinical Medicine and 2Health & Sport Sciences, Univ. of Tsukuba, Tsukuba 305, Japan.

We examined the effect of prior 10-wk endurance training in the changes in the histochmical and biochemical properties of the rat soleus muscle during hindlimb suspension (HS) for up to 4 wks. Male Wistar rats were divided into the training suspension (Tr+SUS), suspension only (SUS) and control (CON) groups. The muscle-to-body weight ratio decreased significantly and similarly in both Tr+SUS and SUS groups. However, as this ratio in the Tr+SUS group had been increased by the training, it remained higher than in the SUS group. Similar pattern was observed with respect to succinate dehydrogenase (SDH) activity. Myosin heavy chain (MHC) fiber, most likely corresponding to HCIIx, was detected in the suspended soleus, and its percentage increased during the experimental period. The percentage of HCIIx and number of rats with HCIIx was lower in the Tr+SUS group than in the SUS group. These results suggest that endurance training before HS contributes to maintenance of higher muscle mass and SDH activity during HS and inhibits the expression of HCIIx in the suspended soleus.
FRIDAY
MUSCLE STRUCTURE AND FUNCTION

29.10
Muscle composition of various elite athletes by MRI.
Shigeru Katayama and Shin’ya Kuno
Institute of Health and Sport Sciences, Juntendo University, Japan.

Depletion in different human muscle fibre types. Be&* A de Haan A&& W van Mein&& Sergeant. Departments of Medicine, Academic Medical Centre, Amsterdam, The Netherlands.

Weeks of age) underwent a training, both the intact extensor digitorum longus (EDL) and soleus muscles to complete such a training program. DMD patients would need to have a greatly improved muscle bulk at the beginning of the exercise. For this reason, the ATP concentration can be seen as an indication of muscle mass which may play a role in the regulation of contractile function of those fibres and hence of the whole muscle.

29.21
EFFECT OF SHORTENING VELOCITY ON GLYCOCEN DEPLETION IN DIFFERENT HUMAN MUSCLE FIBRE TYPES.
A. Roickie, A. Nenutz, H. Lind, B. W. van Meijdenbeek, and A. Sergeant. Departments of Muscle and Exercise Physiology, Neurophysiology, and Health Sciences, Academic Medical Center, Amsterdam, The Netherlands.

Surprisingly few data are available on the effect of shortening velocity on glycogen depletion in human exercise (see Golinski et al., 1974. J. Physiol. 241, 45-57). This investigation aimed to determine the effect of exercise at 120 rev/min on the optical density of the PAS stain was significantly reduced for type I fibres (2a, 2b, and 2c) in male athletes, but not in female athletes. In the other type, both the upper and lower femoral muscles showed great development (Ex. Soccer). Female athletes did not exhibit difference by sites so significantly as in male players. The male athletes did not always show the difference in muscle cross-sectional area compared that in the control group, while female athletes indicated significantly higher values at any position of slices.

29.22
FIBRE TYPE PROPORTIONS AND SIZES, AND OXIDATIVE CAPACITY IN DIAPHRAGM OF HIBERNATING SQUIRRELS.

The purpose of this study was to examine the effects of hibernation on diaphragm (DIA) muscle mass, fibre type proportions and sizes, and oxidative capacity in the squirrel. DIA muscle biopsies from the costal region were obtained from 7 fall-awake (FA), 10 winter-awake (WA), and 7 hibernating (H) ground squirrels. DIA biopsies were quick-frozen, stored, and then sectioned and processed for NADH-TR end-product reaction. From serial sections stained for M-ATPase, the same fibres were typed at type I, 2a, 2b, or 3b. H and WA squirrels had lower body weights but similar DIA mass than FA squirrels. Hibernators had more type 2b fibres and fewer type 2a fibres in the DIA than FA squirrels. The type 2b fibres of WA squirrels were more oxidative than those in FA squirrels. Hibernators may have larger fibres and more type 2b fibres in the DIA to work against a stiffer chest wall and lungs. Supported by NSERC and B.C. Health Research Foundation.

29.23
IMPROVED MUSCULAR PERFORMANCE OF THE MII MOUSE FOLLOWING ENDURANCE EXERCISE AND CLENBUTEROL ADMINISTRATION.
Allan Hayes*, Gordon S. Lidd*, and David A. Williams* (SPON: Mark Hargreaves). Muscle and Cell Physiology Laboratory, Dept. of Physiology, Univ. of Melbourne, Victoria, Australia.

An x-linked recessive inheritance and a lack of dystrophin makes the mll mouse a good model for Duchenne Muscular Dystrophy (DMD). MII mice (6 weeks of age) undertook a 15 week endurance swimming program. Following training, both the intact extensor digitorum longus (EDL) and soleus muscles exhibited a significantly improved resistance to fatigue. Since this reduced fatigability is specific to dystrophic muscle, the non-weight bearing exercise could have therapeutic effects on DMD patients. In order to complete such a training program, DMD patients would need to have a greatly improved muscle bulk at the beginning of the exercise. For this reason, the ATP concentration can be seen as an indication of muscle mass which may play a role in the regulation of contractile function of those fibres and hence of the whole muscle.

29.24

We investigated the structural, mechanical, and biochemical properties of completely denervated muscles of experimental animals have been presented. However, we often encounter clinical cases involving the normal muscle. Partial denervation can be carried out by cutting the distal root of the nerve, thereby inducing muscle. Partial denervation, by 50 % or less, of the supply nerve did not cause apparent diminution of the number of muscle fibres, nor any appreciable atrophy of individual fibres. These structural changes tended to occur during the earlier stages of the exercise period, as compared with the denervation-only group. The levels of oxidative and glycolytic enzyme activities show the same trend as in the group of continuous treadmill running for 80 min at a speed of 30 m/min. The results indicate that the influence of partial denervation gradually extends over the whole muscle, and the endurance training, those changes occur rapidly in partially denervated muscle.
MUSCLE STRUCTURE AND FUNCTION

29.25
FAST IIX AND SLOW MYOSIN EXPRESSION FOLLOW MITOCHONDRIAL INCREASES IN TRANSFORMING MUSCLE.
Janet Jacobsen* and Brenda Russell
Univ. of Illinois, Chicago, IL 60660

The relationship between oxidative metabolism and myosin isoform expression in skeletal muscle is not known for fibers transforming from fast-to-slow type. Tibialis anterior muscles from female New Zealand white rabbits were stimulated continuously at 10 Hz for 21 days and muscle biopsies quantitatively analyzed for oxidative enzyme levels by histochemistry and for fast IIX and slow myosin mRNA distribution by in situ hybridization. Control muscle contained 6% slow but only 3% fibers coexpressed both slow and fast IIX myosin mRNA transcripts. Individual fibers were isolated and analyzed for myosin heavy chain distribution at the same skeletal muscle fiber type.

The increase in oxidative enzymes was detectable in many fibers by 4 days and preceded increases in abundance of IIX mRNA. Slow myosin transcripts were detected by 7 days in fibers with higher oxidative levels. Co-expression of IIX and slow transcripts peaked at 34% of fibers by 7 days. IIX then declined leaving slow myosin expressed in 65% of fibers by three weeks. We conclude that during fiber type transformation, myosin fiber can co-express IIX mRNA with slow myosin heavy chain in the same fiber.

Supported by NIH HL 40880 and MDA.

29.27
MUSCLE FIBER CROSS-SECTIONAL AREA: COMPARISON BETWEEN FIXED AND FROZEN TISSUE.
Michael A. Drav*, David C. Poole and Odile Mathieu-Costello.
Dept. of Medicine, University of California, San Diego, La Jolla, CA. 92093-0623

We evaluated the potential role of sample sectional area, fiber type proportions and differences in measured fiber cross-sectional area (CSA) in adjacent samples of rat costal diaphragm which were immersion fixed and processed for histochemistry. In a previous communication (FASEB J. 6: A960, 1992), we showed that there was no difference in fiber cross-sectional area (CSA) in frozen tissue and in adjacent samples of rat costal diaphragm which were immersion fixed and processed for histochemistry. In this study, we compared fiber cross-sectional area measured by light microscopy in adjacent samples of diaphragm which were immersion fixed and stained with hematoxylin and eosin. In a previous communication (FASEB J. 6: A960, 1992), we showed that there was no difference in fiber cross-sectional area (CSA) in frozen tissue and in adjacent samples of rat costal diaphragm which were immersion fixed and processed for histochemistry. In this study, we compared fiber cross-sectional area measured by light microscopy in adjacent samples of diaphragm which were immersion fixed and stained with hematoxylin and eosin.

Supported by NSF grant 20968 and the Department of Medicine, University of California, San Diego.

29.28
FIBER CONVERSION IS DUE TO TRANSFORMATION, NOT REPLACEMENT, IN CHRONICALLY STIMULATED RABBIT MUSCLE.
M.D. Dob and P. Poole
University of Western Ontario, London, Ontario, Canada.

The goal of this study was to determine if chronic stimulation of rabbit fast-twitch muscle results in a progressive fast-to-slow conversion via fiber transformation and replacement. The purpose of this study was to describe the effects of CS (10 Hz, 10 min/hr) for periods up to 4 hr on the conversion process in rat fast-twitch extensor digitorum longus (EDL) muscle. Using a sensitive method of detecting fiber type conversion, we showed that chronic stimulation of rabbit EDL muscle results in a progressive fast-to-slow conversion via fiber transformation and replacement. The purpose of this study was to describe the effects of CS (10 Hz, 10 min/hr) for periods up to 4 hr on the conversion process in rat fast-twitch extensor digitorum longus (EDL) muscle. Using a sensitive method of detecting fiber type conversion, we showed that chronic stimulation of rabbit EDL muscle results in a progressive fast-to-slow conversion via fiber transformation and replacement. The purpose of this study was to describe the effects of CS (10 Hz, 10 min/hr) for periods up to 4 hr on the conversion process in rat fast-twitch extensor digitorum longus (EDL) muscle. Using a sensitive method of detecting fiber type conversion, we showed that chronic stimulation of rabbit EDL muscle results in a progressive fast-to-slow conversion via fiber transformation and replacement. The purpose of this study was to describe the effects of CS (10 Hz, 10 min/hr) for periods up to 4 hr on the conversion process in rat fast-twitch extensor digitorum longus (EDL) muscle. Using a sensitive method of detecting fiber type conversion, we showed that chronic stimulation of rabbit EDL muscle results in a progressive fast-to-slow conversion via fiber transformation and replacement.

Supported by National Institutes of Health (NIH) grant 1R01-AR44222-01 and a grant from the Life Sciences Research Foundation.

MUSCLE FATIGUE

30.1
ENERGY COST OF CONTRACTION IS UNCHANGED IN RAT SKELETAL MUSCLE CHRONICALLY DEPLETED OF ATP AND CREATINE.
Michigan State University, E. Lansing, MI 48824

Acute depletion of ATP has been shown to reduce the energy cost of contraction in rat gastrocnemius muscle. We examined the effect of chronic and acute depletion of ATP on contraction cost in rats fed 15% guanidinopropionate (B-GP) for 2 weeks, which reduces fast skeletal muscle ATP content by 40-50% and total creatine by 60-80%. Using surface EMG, intracellular pH (pH), pH, and ATP/creatine depleted muscles (0.17 GPP, 0.01 of ATP). Tetanic contraction cost was likewise unchanged (2.25 ± 0.97 umol/g-tetanus in controls vs. 2.29 ± 0.10 in GP muscles). Denaturing SDS-PAGE analysis showed no change in myosin heavy chain distribution. We conclude that in the superficial gastrocnemius from rats fed 50% type I/1111 in controls vs. 2/2 in GP-fed-adults. The condition that increases contraction economy in the depleted muscles must therefore either be absent in the chronic case (e.g. elevated IMP), or is compensated for by intracellular adaptations to the depleted phosphagen levels.

(Received for publication 30 September 1987)

30.2
MODULATION OF THE ATP-SENSITIVE K+ CHANNEL (K*ATP) AND TETANIC FORCE BY TOLBUTAMIDE IN UNSTIMULATED AND STIMULATED MUSCLE.
Paul J. Comtois, P. Light and J. M. Renaud.
Dept. of Physiology, University of Ottawa, Ottawa, Ontario, Canada.

The goal of this study was to determine if the K*ATP channel in the absence of 2 mmol/l tolbutamide (K*ATP antagonist) produced a 10-15% decrease in tetanic force and had no significant effect on the action potential. When sartorius muscle fibers were fatigued in the presence of tolbutamide, the K*ATP channel did not become active and affect the rate of fatigue development. In unfatigued, intact frog sartorius muscle fibers fatigued in the presence of tolbutamide, the K*ATP channel did not become active and affect the rate of fatigue development. In unfatigued, intact frog sartorius muscle fibers fatigued in the presence of tolbutamide, the K*ATP channel did not become active and affect the rate of fatigue development. In unfatigued, intact frog sartorius muscle fibers fatigued in the presence of tolbutamide, the K*ATP channel did not become active and affect the rate of fatigue development.

Supported by NSERC and MRC of Canada
30.3 THE EFFECT OF VOLUNTARY STRENGTH TRAINING ON THE CONTRACTILE PROPERTIES OF RAT SKELLETAL MUSCLE

Neal D. Duncan, Alan Hargreaves, Steven H. Cody* and David A. Williams* (SPOR, Mark Hargreaves) Muscle and Cell Physiology Laboratory, Dept. of Physiology, Univ. of Melbourne, Victoria 3052, Australia.

An animal model was devised that simulated strength training protocols commonly used by humans. Male rats aged 7 weeks (juvenile) or 13 months (adult) were trained to climb a 40cm vertical rack (3x8 repetitions, 4 days/week for 12 weeks) while carrying a load (comprising up to 120% of body weight) attached to the tail. Following training, muscles were biopsied and the force generation and intracellular pH in individual fibres which remained in the 3-dimensional synactum of the intact muscle. The fatigue protocol induced little change in cytosolic pH in fibres of either EDL or soleus muscles.

Supported by the ARC, NH & MRC and NHF of Australia.

30.4 ELECTRICALLY ELICTED AND MAXIMUM Voluntary POWER OUTPUT FOLLOWING FATIGUING EXERCISE IN HUMANS: A. Sargeant, A. Boat* C.J. de Ruiter* and D. Jones* Department of Muscle and Exercise Physiology, Vrije University, Academic Medical Centre, Amsterdam, The Netherlands and University College, London, U.K.

In isometric contractions direct electrical stimulation has been used to confirm maximality of voluntary effort. In the present investigation we have adapted the technique to fatigue changes in human FC, soleus and biceps brachii muscles were biopsied from the hindlimb and the contractile force responses were recorded in vitro. The adult trained group exhibited a longer TTP than the untrained group. The twitch tension in the adult group was greater than the juvenile group, with the soleus muscle was greater, and the fibre type proportions of each muscle were evident from the biceps brachii muscle. Strength training did not affect fatigability resistance, except in the soleus muscle where it was significantly decreased in the juvenile rats. No change in fibre type proportions of each muscle was evident following mATPase staining.

The pH-sensitive fluorescent probe SNARF-1 in conjunction with laser-scanning confocal microscopy was used to investigate the degree of involvement of acidification in muscle fatigue. This was achieved by simultaneous determination of force generation and intracellular pH in individual fibres which remained in the 3-dimensional synactum of the intact muscle. The fatigue protocol induced little change in cytosolic pH in fibres of either EDL or soleus muscles.

30.6 EFFECT OF PRIOR LEG EXERCISE ON HIGH-INTENSITY ARM CONTRACTILITY. George W. Swanston, N. A. Holland and F. R. van Waalwijk, The Pacific Western Institute of Physical Education, California State University, Chico, CA 95929.

The purpose of this study was to determine the effect of high-intensity arm exercise on exercise time prior to muscle fatigue. Six healthy, physically fit male smokers, between the ages of 20 and 23 volunteered to participate in the present investigation. Ten subjects performed the 60 W exercise for 20 minutes without appreciable duress. Thus, only the four higher work rates were used to estimate the hyperbola parameters. The results indicate that prior exhaustive leg exercise diminishes W (area under the curve) by 14% (P < 0.01) compared with the non-exercised control condition. This suggests that prior exhaustive leg exercise diminishes the high-intensity energy stores of the arms.

30.7 RECOVERY OF THE RESTING MEMBRANE POTENTIAL (Vm) and INTRACELLULAR POTASSIUM (K+)** FOLLOWING FATIGUE. E.M. Balas* and K.H. Pitts, Marquette University, Milwaukee, WI 53233.

The loss of K+ from skeletal muscle and its accumulation in the interstitial space has been hypothesized to lead to a decrease in the excitability of the sarclemma which contributes to the development of muscle fatigue. We have used microelectrodes to determine Vm and K+ in single muscle fibres from the semitendinosus of Runa pipiens and to characterize the time course of recovery after fatiguing stimulation (100 ms trains at 150 Hz). At each work load, the subject's exercise times were recorded. At each work load, the subject's exercise times were recorded. The testing apparatus was a mechanically braked arm ergometer. During the week, each subject performed timed arm cranking bouts at 60, 120, 180, 240 and 300 W. Subjects were required to maintain an arm cranking frequency of 60 BPM. When muscle fatigue impaired a subject's ability to maintain this cadence, the test was terminated. At each work load, the subject's exercise times were recorded. The test was repeated for each subject at each work load for a total of 5 tests (2 min intervals between tests). After 5 tests were concluded at the same work load, the subject performed the 60 W exercise for 20 minutes without appreciable fatigue whether smoking of not. These findings should have major implications in the work force and recreational settings where the early onset of muscular fatigue may affect performance, productivity, and enjoyment.

30.8 THE EFFECT OF CHANGES IN HPO42-/H2PO4- ON MANHATTAN SKELETAL MUSCLE FORCE PRODUCTION. G. Murrant* and J.K. Barlow, University of Guelph, Guelph, Canada, N1G 2Wl.

To test the hypothesis that the inorganic phosphate (Pi) induced depression of force generation in fast and slow twitch mammalian skeletal muscle is the result of an decreasing percentage of diastolic Pi (HPO42-) we used mouse extensor digitorum longus (EDL) and soleus (SOL) contracting at 70Hz and 50Hz respectively for 500ms once per 90 sec in Krebs-Henseleit solution containing 20mM Pi at 37°C. The pH was adjusted to 7.2, 6.7 or 6.4 resulting in pHi/Pi/PO42- values of 0.4, 1 and 2.6. When compared with Pi altered solutions but no PO42-, SOL force development was not affected until Pi/PO42- was greater than 1 where there was a pH independent depression. The absolute difference between Pi and pH did not change over time. On the other hand EDL force development was depressed with either a Pi ratio greater or less than 1 but with different patterns. Pi/PO42- had no initial effect but over 24 contractions decreased force significantly over and above Pi. Pi/PO42- showed a larger decrease in force over 6 contractions than that of simply pH alone. This difference between Pi and pH decreased until after 24 contractions it was zero. Thereby with a constant Pi concentration, an increased Pi/PO42- ratio resulted in a depression of both fast and slow twitch muscle. Only fast twitch was affected by a decreased Pi/PO42-.

Supported by MSRC Canada.


30.9
MYOSIN HEAVY CHAIN PHENOTYPE CORRELATES WITH DIAPHRAGM FATIGUE RESISTANCE IN RATS UNDERNOURISHED DURING PRE- AND POSTNATAL DEVELOPMENT. Beverly S. Brzuza*, A. L. Biedermann, and S. A. Kluc. Univ. of Oregon, Eugene, OR 97403

Undernutrition during prenatal and postnatal development is associated with an alteration in the myosin heavy chain (MHC) phenotype of the rat diaphragm (DIA) as demonstrated by: 1) an increase in the proportion of MHC neonatal (MHC-n) and MHC slow, and 2) a decrease in the proportion of MHC 2B and MHC 2X, in the DIA from undernourished (UN) rats when compared to controls (CTL) (Bruzusa et al, Pediatr Res 31:302A, 1992). We correlated the MHC phenotype (as indexed by a ratio of fast MHC isoform [MHC 2A + MHC 2X] to total developmental muscle isoform content [MHC slow + MHC neonatal]) with the fatigue resistance (FR) of the costal DIA from UN and CTL rats from birth through postnatal day 60. FR was measured during isometric contractions using the Bucke fatigue test. In the immediate postnatal period, FR was high and comparable in the UN group when compared with the CTL. Beyond the first week of life, FR declined but was consistently higher in the UN animals when compared with the CTL. There was a direct correlation between FR and the MHC phenotype of the muscle (r=0.86). We conclude that the FR of the DIA during development is a function of the energetic demands of the contractile proteins, as reflected its MHC isoform composition.

Supported by NIH HL 02491 and the American Lung Association.

30.10

Fatigued rat fast-twitch muscle reaches a staircase level when fatigued than when rested. This study was done to see if phosphorylation of the regulatory light chains (P-LC) a possible mechanism of potentiation, was also slowed in fatigue. The gastrocnemius muscles of anesthetized rats were isolated in situ stimulated for 5 minutes at 10 Hz. Following 20 minutes of recovery, muscles were again stimulated for 5 minutes at 10 Hz. Control (rested) muscles were frozen at similar times, without fatigue. The developed tension (% potentiation) and phosphorylation of P- LC (% phosphorylated).

<table>
<thead>
<tr>
<th>Time of 10 Hz (s)</th>
<th>0</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL: Potentiation</td>
<td>71 ± 4</td>
<td>87 ± 3</td>
</tr>
<tr>
<td>P- LC</td>
<td>3.2 ± 1.2</td>
<td>8 ± 4</td>
</tr>
</tbody>
</table>

A computer simulation of P- LC phosphorylation demonstrates that similar phosphorylation can be achieved by much smaller Ca2+ transients, or with severe inhibition of the enzyme (myosin light chain kinase), which is responsible for the phosphorylation reaction. Supported by grants from NSERC.

30.11
CORRELATION BETWEEN MUSCLE RELAXATION AND SARCOSPLASMIC RETICULUM CA2+-ATPASE DURING ELECTRICAL STIMULATION TO FATIGUE. Michel G. Riedermann and Gary A. Kluc. Univ. of Oregon, Eugene, OR 97403

Prolonged muscle activity depresses Ca2+ uptake and release by sarcoplasmic reticulum (SR). The purpose of this study was to investigate the relationship between the SR Ca2+ uptake (CU) and the mechanical events in rat gastrocnemius muscle following electrical stimulation (200 Hz, 37°C) for 1-60 min. Half-relaxation time (RT50), and maximum rate of relaxation (RR) were correlated with the initial rate of Cu measured in crude muscle homogenates. After 1 h, RT50 had increased by 74% over control, whereas RR decreased by 59%. These events were accompanied by a 14% reduction in Cu. By 10 h, RT50 and Cu had returned to normal whereas Cu remained depressed by 75%. At 60 h, RT50 was not different from normal values, but Cu and Cu were depressed by 55% and 27% respectively. It is apparent from these data that a close correlation does not always exist between SR Ca2+ uptake and various parameters that are commonly used to define the ability of muscle to relax.

Supported by NIH GM 07257 and by NIH AR 39583.

30.12

The purpose of this study was to determine if the post-exercise depression in sarcoplasmic reticulum (SR) Ca2+ fluxes are reversible and to ascertain if the recovery process could be correlated with events in the Ca2+-ATPase catalytic cycle. SR Ca2+ uptake rates (500-1000) were randomly assigned to one of 5 groups (n=4): control, exercise (1000 at 70% MVC), or 1 h, 2 h, 3 h, or 4 h recovery. SRs from each group was divided into two equal parts, one for the determination of the sarcolemma and total cellular SR. The Ca2+ uptake was reversed of this depression in every cate except one hour of rest. The rate of Cu uptake was not different from control values even by a hour of recovery. These finding suggest that the function of SR is markedly compromised after a single bout of exhaustion followed by a recovery period suggesting that this impairment is a reversible process requiring 2 hours to fully recover. The data also imply that the depression and recovery of SR and ATPase activity are not a unique phenomenon, and that the ATPase activity was determined using the enzyme-linked immunosorbent assay (ELISA).

30.13

Any of a number of discriminable sensations associated with muscular work may ultimately limit exercise performance due to an inability to tolerate increases in sensory intensity. The relative magnitudes of these sensations during exercise are not known. The intensities of leg effort, muscle tension, muscle discomfort, muscle pain and breathing discomfort were compared (n=13) using the Borg scale at 6 work rates of 15 s intervals. The specific sensation that ultimately reaches intolerable magnitude and results in cessation of muscular work may be

<table>
<thead>
<tr>
<th>Work Rate</th>
<th>Effort</th>
<th>Leg Tension</th>
<th>Muscle Tension</th>
<th>Muscle Comfort</th>
<th>Muscle Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 W</td>
<td>4.00</td>
<td>4.00</td>
<td>3.00</td>
<td>2.00</td>
<td>1.00</td>
</tr>
<tr>
<td>20 W</td>
<td>2.00</td>
<td>3.00</td>
<td>2.00</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>30 W</td>
<td>1.00</td>
<td>2.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

The magnitude of leg effort exceeded that of all other sensations under these conditions. However, the specific sensation that ultimately reaches intolerable magnitude and results in cessation of muscular work may be dependent upon the characteristics of the work performed.

30.14

We correlated the fatigue resistance of the external oblique (EO) and the external abdominal oblique (EAO) muscles during postnatal development, with their respective 1) oxidative capacities (indexed by quantification measures of muscle dehydrogenases, and 2) myosin heavy chain (MHC) phenotypes. FR was measured during isometric contractions using the Bucke fatigue test. FR of the DIA and EO was high in room and declined during postnatal development. FR was inversely correlated with the ratio of MHC 2B to MHC 2A isoforms (r=-0.97). The fatigue-resistance of MHC 2B is inversely correlated with the ratio of MHC 2B to MHC 2A isoforms (r=-0.97). The fatigue-resistance of MHC 2B is inversely correlated with the ratio of MHC 2B to MHC 2A isoforms (r=-0.97). The fatigue-resistance of MHC 2B is inversely correlated with the ratio of MHC 2B to MHC 2A isoforms (r=-0.97). The fatigue-resistance of MHC 2B is inversely correlated with the ratio of MHC 2B to MHC 2A isoforms (r=-0.97).

Supported by NIH GM 07257 and by NIH AR 39583.

Caffeine increases the force of muscular contraction during low frequency stimulation by potentiating Ca\(^{2+}\) release from the sarcoplasmic reticulum. Tolerance to the metabolic effects of caffeine has been reported but the neuromuscular effects have not been examined. Twelve healthy male subjects were classified as habitual (max kg) or non-habitual (NHAB) coffee consumers based upon 4 day diet recall analysis. The mean caffeine consumption for NHAB was 773 mg/day and for HAB was 14 mg/day. Subjects were randomly allocated to receive caffeine (5g/kg) or placebo in a double-blind fashion, 100 min prior to a 2 min stimulation of the common peroneal nerve in a custom made dynamometer (2 trials X 20 Hz; 2 trials X 40 Hz). Maximal voluntary contraction stimulus was determined before and after (15/ and 15 min) the stimulation protocol. Force was measured every 10s during the stimulation protocol and at 1, 5, 10 and 15 mins. Caffeine potentiated the force of contraction at each time point during the 20 Hz stimulation protocol with effect of habituation. There was no effect of caffeine on 40 Hz stimulation strength nor was there an effect on EC. It was concluded that caffeine potentiated 20 Hz strength during fatigue and there are no effects of tolerance.

SKELETAL MUSCLE DAMAGE


Increased serum interleukin-6 (IL-6) has been reported after prolonged exercise. Whether this increase is due to muscle damage that may occur with prolonged exercise is not clear. We examined the effect of exercise-induced muscle damage on serum IL-6. Six, healthy, non-weight trained males (mean ± sd: age 29 ± 2.7 yrs; ht 175 ± 6.0 cm; wt 68 ± 13.1 kg) completed an exercise and control day (6 wks apart) in a randomized, cross-over, placebo controlled, double-blind fashion, 100 min prior to a 2 min stimulation of the common peroneal nerve in a custom made dynamometer (2 trials X 20 Hz; 2 trials X 40 Hz). Maximal voluntary contraction stimulus was determined before and after (15/ and 15 min) the stimulation protocol. Force was measured every 10s during the stimulation protocol and at 1, 5, 10 and 15 mins. Caffeine potentiated the force of contraction at each time point during the 20 Hz stimulation protocol with effect of habituation. There was no effect of caffeine on 40 Hz stimulation strength nor was there an effect on EC. It was concluded that caffeine potentiated 20 Hz strength during fatigue and there are no effects of tolerance.


Following eccentric exercise of human elbow flexors to failure under heavy load (90% of isometric max., determined at elbow angle = 90°), isometrically measured muscle strength fell by 44% (N=34) and recovered slowly (50% recovery in 2 wks.). Soreness resulting from the exercise lasted only 5 days. Following the exercise, the EMG amplitudes associated with submaximal (<20%) isometric contractions increased 2 to 3 fold, indicating the presence of muscle fibers capable of generating action potentials, but uncompromised in their ability to generate force. The ratio of EMG amplitude to force output in submaximal contractions returned to normal within 3 days, during which time no significant recovery of isometric, maximal force occurred. A significant correlation was observed between the extent of strength loss and the decrease in the force/EMG ratio.

Taken together with biopsy data from other labs, these observations indicate that injured fibers, which are still capable of generating action potentials, but unable to generate much force, become electrically inexcitable within 3 days after the exercise, probably because of the death of these cells. Recovery of muscle strength, which occurs much later, presumably requires regeneration of new cells. (Supported by the American Osteopathic Association.)


The objective of this study was to determine if a loss of excitation-contraction coupling contributes to the reduction in maximal isometric twitch force (P\(_0\)) occurring in eccentric contraction-induced muscle injury. Muscles were isolated, placed in an oxygenated Ringers, and P\(_0\) was measured. Each muscle performed one of four contraction protocols: 1) no contractions (NO); 2) 20 isometric (20 ISO); 3) 10 eccentric (10 ECCO); or 4) 20 eccentric (20 ECCO). Muscles were set to 0.9 L,J and stimulated at 300 Hz for 270 min with 3 min between contractions. Eccentric contractions were performed using a lengthening velocity of 1.5 L,J/s and a length change of 0.25 L,J. Following the protocol, P\(_0\) at L, was measured and 3 min later, force was measured upon addition of 50 mM caffeine.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Decline in P(_0), (%)</th>
<th>Lasting force (%) final P(_0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO (n = 10)</td>
<td>3.8 (SE = 2.4)</td>
<td>74.7% (SE = 1.0)</td>
</tr>
<tr>
<td>20 ISO (n = 10)</td>
<td>19.9 (SE = 2.3)</td>
<td>80.2% (SE = 1.6)</td>
</tr>
<tr>
<td>20 ECCO (n = 10)</td>
<td>45.8 (SE = 4.9)</td>
<td>14.9% (SE = 3.1)</td>
</tr>
</tbody>
</table>

Values with the same letter are not significantly different (p = 0.05). In conclusion, excitation-contraction coupling loss is probable since the 20 ECCO muscles produced less force during electrical stimulation than during exposure to caffeine.

31.4 A SYSTEMS MODEL OF EXERCISE-INDUCED ELEVATED SERUM CREATININE KINASE. E.W. Banister, D. Dry*. and Y. Fukuba*. Simon Fraser University, B.C., Canada V6T 1G2.

The purpose of this study was to develop a systems model of the relationship between the time course of elevated serum enzyme activity (ESEA). Total CK in the vascular space. A coherent, quantitative model of enzyme flux from injured muscle must consider and account for the described features of the empirical data: structural and biochemical changes producing it. The model proposed here defines 3 rate constants (k\(_1\) > k\(_2\) > k\(_3\)) controlling pore development in the muscle cell membrane producing enzyme loss to the interstitial and vascular space, pore closing or healing, and final degradation of the enzyme. The rate course of ESEA is provided by the model in that its rate constant must be greater than the modeled value of k\(_1\). Supported by NSERC grant to EWB.
ULTRASTRUCTURAL DISRUPTION ACCOMPANYING ENDURANCE TRAINING. K. Whittal and W.S. Parkhouse. Kinesiology, Simon Fraser University, Burnaby, B.C., Canada V5A 1S8

The effect of continuous (CT) and oscillatory training (OT) on muscle ultrastructure was examined in female Sprague-Dawley rats. Continuous training involves an unsupervised treadmill training regimen for a total of 16 weeks with the final workload being 32.5 m/min; 60 min duration; 8% incline; 5 times per week. The oscillatory trained (OT) animals were run the same training regimens for the first 12 weeks. During the last three weeks they alternated 5 min of high with 5 min of low intensity running. Mean velocity and total distance covered were identical to the CT group. Muscle samples were obtained 4 hours after the last bout of exercise. The plantaris, soleus and heart were removed and prepared for electron microscopy. Isolated myofibrils from the plantaris muscle were further examined by SDS PAGE. EM revealed disruption of the sarcotubular system and damage to the mitochondria with no difference being observed between training programs. In contrast, SDS PAGE suggested an enhanced degradation of myofibrillar proteins with OT. Degradation of cytoskeletal proteins were degraded under both training regimens. Subsequent exservation performance does not appear to be impaired by this training induced muscle damage. This work was supported by a NSERC grant to WSP.

SATELLITE CELL ACTIVATION FOLLOWING AN ACUTE BOUT OF DOWNHILL RUNNING IN TRAINED AND UNTRAINED RATS. Julie A. Opteck*, Christine A. Vigore* and Timoouil P. White. University of Michigan, Ann Arbor, 48109 and University of California, Berkely 94720.

A single bout of exercise that favors lengthening contractions can produce muscle fiber damage and initiate repair responses. We hypothesized that following an acute bout of downhill running, muscles of rats exposed to a training program of predominantly lengthening contractions would exhibit significantly less damage and satellite cell activity than muscles of untrained rats. Adult male Sprague-Dawley rats were run downhili' for 8 ks on a treadmill, +8 degrees slope, 30 min/day, 5 days/wk, 15 m/min. One to two days after the training program, trained (n=9) and age-matched untreated (n=5) rats underwent a single 60 min downhill run at 15 m/min, -18 degree slope. Muscles were excised 48 hrs thereafter. One hour prior to myectomy rats were injected with 5-bromo-2'-deoxyuridine (BrdU) to label mitotically active satellite cells. For medial triceps and soleus muscles the number of damaged fibers per 500 fibers was 0.3 ± 1.7 and 13.3 ± 0.3 (mean ± SE) for trained and 20.3 ± 4.3 and 37 ± 3 for untrained rats, respectively. In soleus muscles, satellite cell activity was also greater in untrained (25.2 ± 3.8 activated satellite cells per 1,000 myonuclei) than in trained rats (6.1 ± 1.1). Thus, lengthening contraction biased training of sufficient intensity and duration can prevent significant muscle fiber injury and subsequent satellite cell activity. Supported by NIH DE-07681 and AC-00114.


The release of certain muscle proteins, such as creatine kinase (CK) and carbonic anhydrase (CA) has been depicted as a marker of muscle damage. The objective of this study was to ascertain whether CK or CA releases reflect muscle damage. Male rats, aged 30 weeks, were made to run at a speed of 16 m/min for 90 min (15% downhill) or 90 min (15%) on a treadmill. CK and CA was measured in blood samples collected before and after the exercise. In addition, CK and CA was measured in muscle homogenates from the vastus lateralis. Results showed that both CK and CA were increased in muscle homogenates after exercise. The results suggest that CK and CA releases do not reflect muscle damage.

ULTRASTRUCTURAL DISRUPTION ACCOMPANYING ENDURANCE TRAINING. K. Whittal and W.S. Parkhouse. Kinesiology, Simon Fraser University, Burnaby, B.C., Canada V5A 1S8

The effect of continuous (CT) and oscillatory training (OT) on muscle ultrastructure was examined in female Sprague-Dawley rats. Continuous training involves an unsupervised treadmill training regimen for a total of 16 weeks with the final workload being 32.5 m/min; 60 min duration; 8% incline; 5 times per week. The oscillatory trained (OT) animals were run the same training regimens for the first 12 weeks. During the last three weeks they alternated 5 min of high with 5 min of low intensity running. Mean velocity and total distance covered were identical to the CT group. Muscle samples were obtained 4 hours after the last bout of exercise. The plantaris, soleus and heart were removed and prepared for electron microscopy. Isolated myofibrils from the plantaris muscle were further examined by SDS PAGE. EM revealed disruption of the sarcotubular system and damage to the mitochondria with no difference being observed between training programs. In contrast, SDS PAGE suggested an enhanced degradation of myofibrillar proteins with OT. Degradation of cytoskeletal proteins were degraded under both training regimens. Subsequent exservation performance does not appear to be impaired by this training induced muscle damage. This work was supported by a NSERC grant to WSP.

RAMELAIN DOES NOT AFFECT MALONALDEHYDE PRODUCTION AFTER CONTRACTION-INDUCED MUSCLE INJURY. J. Burton, J. Walls* E. Garty, P. Hricak. SUNY Buffalo, Buffalo, NY 14214.

Bromelain, a proteolytic enzyme with anti-inflammatory properties, attenuates the development of contraction-induced skeletal muscle injury. Oxygen free radicals, produced during the "necrotic" stage of muscle injury have been purported to be a significant contributor to cell membrane breakdown. We have shown a transient increase in levels of muscle malondialdehyde (MA), a primary product of lipid peroxidation, after lengthening contractions. The purpose of this study was to investigate the effect of bromelain on MA production in rat extensor digitorum longus (EDL) muscles, injured by lengthening contractions. EDL muscles were injured bilaterally using a motorized foot pedal which flexed/extended the foot repeatedly while the muscle was electrically stimulated during extension. Bromelain was administered orally at 12 h intervals beginning 12 h before injury. Twenty-four h post-injury, malondialdehyde levels of 108.1 ± 6 and 105.5 ± pmol/mg protein in untreated and treated groups, respectively, were significantly higher than the value of 86.4 pmol/mg in controls (p < 0.05). There was no difference between experimental groups. Thus, bromelain does not appear to attenuate lipid peroxidation following contraction-induced muscle injury.

TIME COURSE OF MUSCLE TORQUE, DELAYED ONSET MUSCLE SORENESS, AND MUSCLE DAMAGE FOLLOWING ECCENTRIC EXERCISE. Donna Macnryne, W. Darlene Reid, Donald C. McKenzie. School of Rehab. Med. and Family Practice, University of British Columbia, Vancouver, B.C.

The purpose of this study was to examine the time course of muscle torque, delayed onset muscle soreness, and indicators of muscle damage (DOMS) in response to two intensities of fatiguing eccentric contractions. Using a randomized cross-over design, subjects (n=19) were either assigned to perform a mild or severe intensity of fatiguing eccentric contractions on the KinCom dynamometer. Tests included eccentric muscle torque, DOMS questionnaires, and serum levels of creatine phosphokinase (CPK) at the following intervals; before fatiguing exercise, 24 hours, 48 hours, 4 days and 7 days. Muscle torque was tested using the same type of contraction, velocity, ROM as that of the fatiguing exercise. DOMS was analyzed using the visual analog scale and descriptor differential scale. Not less than 12 weeks after the first phase, subjects repeated the same protocol at the other intensity. Both torque and DOMS worsened at 24 hours, did not change between 24 and 48 hours and then improved until 7 days. Although CPK tended to increase after the fatiguing exercise, there were no significant changes during the time intervals tested. Supported by B.C. Health Research Foundation and Canadian FIness and Lifestyle Research Institute.


The release of certain muscle proteins, such as creatine kinase (CK) and carbonic anhydrase (CA) has been depicted as a marker of muscle damage. The objective of this study was to ascertain whether CK or CA releases reflect muscle damage. Male rats, aged 30 weeks, were made to run at a speed of 16 m/min for 90 min (15%) or downhill (15%), 500 ml blood samples were taken 2, 12, 48, and 96 h after the exercise and analysed for serum CK activity and CA III concentration. CK was significantly higher after both exercises compared to controls. CA activity was not different after eccentrically compared to concentrically biased exercise. Male rats, aged 30 weeks, were made to run at a speed of 16 m/min for 90 min (15%,15%) or downhill (15%), 500 ml blood samples were taken 2, 12, 48, and 96 h after the exercise and analysed for serum CK activity and CA III concentration. CK was significantly higher after both exercises compared to controls. CA activity was not different after eccentrically compared to concentrically biased exercise.
31.11 EFFECT OF INSULIN ON GLYCOGENOLYSIS, TWITCH TENSION AND ULTRASTRUCTURE OF ISOLATED ELECTRICALLY STIMULATED RAT EPITROCHLEARIS MUSCLE. W.S. Parkhouse and G. Linton. Kinesiology, University of Western Ontario. The effects of insulin on glycogenolysis, twitch tension, and ultrastructure of rat eptrochlearis muscle have been studied. Rats were divided into two groups: one receiving insulin and the other serving as controls. Muscles were stimulated in the presence or absence of insulin with initial rates of glycogenolysis and twitch tension recorded. The results showed that insulin had a significant effect on glycogenolysis, with a greater proportion of glycogen breakdown observed in the presence of insulin. Twitch tension decline was slower in the presence of insulin. A greater proportion of glycogen breakdown was highest in the presence of insulin (1.5 vs. 0.6 umol/g/min) whereas the presence of insulin had a minimal effect on ultrastructure.

31.12 COMPARISON OF MUSCLE INJURY ASSOCIATED WITH HIGH-RESISTANCE ECCENTRIC EXERCISE IN YOUNG AND OLD RATS. Todd McBride and Richard Carlsen. U of California, Davis, CA 95616. We have employed the weightlifting model introduced by Wong and Booth (J.Appl.Physiol.65:65-90) to investigate the effect of eccentric, high-resistance exercise on tibialis anterior (TA) muscles in young (6 months) and old (52 months) Fisher/BN 344 rats. Our hypothesis states that the aged rats will experience more extensive muscle injury and a greater impairment of contractile function after 1 or 2 hours of exercise than will the young adult rats. The anesthetized rat is stimulated to unilaterally contract both ankle extensors and flexors by stimulating the sciatic nerve percutaneously. The animal's foot is strapped to a plate attached to a pulley system so that plantar flexion of the foot lifts a weight. Ankle flexors contract eccentrically during the concentric contraction of the ankle extensors. A single exercise bout involves 4 sets with 6 repetitions in each set at 80% of the maximum load the rat is able to lift. Each repetition is held for 2.5s, with a 20s rest between reps and a 5 minute rest between sets. Young rats exercised using this paradigm experience a 36% decline in isometric TA muscle force at all frequencies of stimulation 1 and 2 days after exercise. Normalized (to TA dry wt) twitch and tetanic force are equally affected. The ability of the TA to develop posttetanic potentiation is affected at 1 day, and is significantly reduced at 2 days, suggesting a possible alteration in excitation/contraction coupling after eccentric injury. We are currently assessing the response of older muscles to this exercise paradigm (Supported by NIA and UCDMC Research Fund).

31.13 A COMPARISON OF THE EFFECTS OF ECCENTRIC AND CONCENTRIC EXERCISE ON PHOSPHATE SPECTRA OF HUMAN SKELETAL MUSCLE. Sharon A. Jubrias* and Gary A. Hug. University of Oregon, Eugene OR 97403. Unaccustomed exercise induces delayed changes in muscle structure and function that suggest damage to the tissue. These changes, observed primarily after eccentric exercise appear to be related to work intensity. It has also been reported in studies using phosphorus magnetic resonance spectroscopy (31P-MRS) that such exercise also increases the ratio of inorganic phosphorus to phosphocreatine (Pi/PCr) suggesting that this parameter may be an indirect measure of exercise induced muscle damage. To date, eccentric exercise has not proven to be an effective stimulus as eccentric for the development of muscle soreness. In this study, we examined Pi/PCr in human tibialis anterior muscles in the days following a bout of near-maximum concentric exercise or one of four eccentric exercise intensities. Eccentric exercise intensities used were 40, 80, 120, and 140% of maximum concentric strength (MVC), whereas the concentric load was 90% of MVC. Although the two lowest intensity eccentric groups showed no change in Pi/PCr, the value at 120 increased by 75%, 140 by 83%, and 120 by 45%. We conclude that given sufficient intensity, both concentric and eccentric work can result in comparable increases in Pi/PCr suggesting that this parameter may be critical in clinically assessing muscle fatigue and exertion.

31.14 THE LONG TERM EFFECTS OF ECCENTRIC EXERCISE ON MOUSE TIBIALIS ANTERIOR MUSCLE. P. Sacco & D.A. Jones* (SPON: D.L. Turner) University College London, London WC1E 6BT, England. Although the short-term effects of eccentric exercise have been well described in both human and animal models, few studies have investigated the long term consequences of damaging exercise on muscle morphology and functional characteristics. We exercised tibialis anterior (TA) muscles of C57/Bl6 mice with eccentric contractions (Sacco et al, Clin. Sci., 82, 227-236) and measured muscle mass (MM), maximal tetanic force (MF), and mean fibre area (FA) after different recovery periods. Values are means±sem.

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>MM (mg)</th>
<th>MF (N)</th>
<th>FA (μm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>14.1±1</td>
<td>0.84±0.04</td>
<td>3.11±0.74</td>
</tr>
<tr>
<td>20 day</td>
<td>14.2±0.27</td>
<td>0.83±0.11*</td>
<td>2972±593</td>
</tr>
<tr>
<td>42 day</td>
<td>14.5±0.34*</td>
<td>1.05±0.09*</td>
<td>3447±678</td>
</tr>
<tr>
<td>64 day</td>
<td>14.8±0.30*</td>
<td>1.11±0.14*</td>
<td>3580±625</td>
</tr>
</tbody>
</table>

By 20 days exercised muscles had not fully recovered, but 42 and 64 days after exercise muscles were significantly larger and stronger (*, p<0.05, paired t-test) than non-exercised contralateral TA muscles and showed large numbers of fibres with central nuclei (indicative of previous necrosis). The results indicate that an episode of muscle damage can lead to a sustained increase in muscle mass and strength in the mouse.

31.15 EFFECTS OF INSULIN ON GLYCOGENOLYSIS, TWITCH TENSION AND ULTRASTRUCTURE OF ISOLATED ELECTRICALLY STIMULATED RAT EPITROCHLEARIS MUSCLE. W.S. Parkhouse and G. Linton. Kinesiology, Simon Fraser University, Burnaby, B.C., and Physical Education, Univ. of Alberta, Edmonton, Alta., CANADA. The purpose of this study was to examine the responses of rat eptrochlearis muscle to electrical stimulation in the presence and absence of insulin. Eptrochlearis muscle were obtained from male Sprague-Dawley rats. Muscles were stimulated in the presence or absence of insulin with 10 volt square pulses of 2 ms duration at a frequency of 2 Hz for 10 minutes or until maximal tension had declined to 20 percent of initial values (60±3 mm). In some experiments, the muscles were incubated for comparable time periods. Initial rates of glycogenolysis were greatest in the presence of insulin (1.5 vs. 0.6 umol/g/min) whereas subsequent glycogen breakdown was highest in the absence of insulin (0.17 vs. 0.11 umol/g/min). Peak twitch tension declined rapidly in the first ten minutes of stimulation with a greater decline in tension occurring in the absence of insulin (-47 vs. 77 percent decrease). Overall, the rate of tension decline was slower in the presence of insulin. A greater proportion of the glycogen was oxidized in the presence of insulin as indicated by the lower lactate accumulations in these muscles. The degree of ultrastructural abnormalities was accentuated in the absence of insulin. In the presence of insulin, the tibias demonstrated swollen and vesciculated mitochondria whereas in the absence of insulin, widespread vacuolization was also observed.

This work was supported by a NSERC grant to WSP.
32.1
LENGTH TENSION RELATIONSHIP AND RELATIVE FIBRE LENGTH VARIABILITY OF RAT SKELETAL MUSCLE AT DIFFERENT AGES. M.A. N. Lodder*, A. de Haan* and A.J. Sargeant. Department of Muscle and Exercise Physiology, Vrije University, Academic Medical Centre, Amsterdam, The Netherlands.

Young rats (40 days) have a ~25% lower specific muscle force compared to older rats (Lodder et al., 1992). J. Muscle Res. Cell. Motil. In Press. One explanation would be if in the younger rats, there was a greater variation in the fibre lengths relative to the sarcomere length (see Jones et al., 1989. Quart. J. Exp. Physiol. 74, 233-256). We tested this hypothesis by measuring the length tension relationship of EDL muscle in young rats. The force generated in 150ms tetani was measured at lengths varying from 40 to 170% of the length (L0) at which maximum active force was generated. No age difference was revealed by the length tension relationships. The muscle was then fixed in glutaraldehyde at L0 in the passive state, matured and dissected. No significant difference was found in mean ± SD sarcomere lengths between the young and old animals (2.71 ± 0.27 and 2.76 ± 0.34 μm; mean = ± SD fibres at each age).

The distribution of fibre lengths was however different. In the young rats a greater proportion of the fibres were close to the mean. In young rats 67% of fibres were within 15% to 105% of L0, compared to only 46% in older rats (p<0.001). Thus the trend was the opposite to that proposed in the initial hypothesis and the difference in specific force observed previously remains unexplained.

32.2
AGED-RELATED CHANGES IN FIBRE TYPE COMPOSITION AND SPECIFIC FORCE OF RAT SKELETAL MUSCLE. C.J. de Ruiter*, A. de Haan*, A. Looz* and A.J. Sargeant. Department of Muscle and Exercise Physiology, Vrije University, Academic Medical Centre, Amsterdam, The Netherlands.

During maximal dynamic exercise young rats showed a greater loss of power compared to mature animals (de Haan et al., Pflügers Arch. 412, 665-667,1988). The greater extent of fatigue correlated with a greater increase in IMP. A change towards a more fatigue-resistant fibre type composition during growth could explain the differences in fatigability as well as in IMP production. The enzyme AMP-deaminase was more active in faster-fatigue-sensitive muscles. Therefore in the present study age-related changes in fibre type composition of rat medial gastrocnemius muscle were measured. Maximal isometric force generated at muscle optimum length (Lo) in 4 different age-groups of male rats.

The muscles were isolated and frozen in isopentane at L0. Specific force (force/CSA) was not different between the groups of 2, 22 and 24 months old. However, in the youngest group (1.3 months old) specific force was significantly higher (p<0.05).

Fibres were classified into 4 different types (I, HAD, IIDb and IIDm; Lind & Kernels, J.of Biochem.69,585-597, 1991). Both types I and IIDb occupied less than 5% of the total fibre area. In contrast to specific force, the relative areas of types IIDb and IIDm also changed after the age of 2 months (p<0.05). The mean relative areas were 34.3, 39.8 and 35.5% in type I, and 61.2, 52.9 and 54.9% in type IIDm for the groups of 1.3, 2, 24 months old, respectively. Thus, the change in specific force during growth was not related to interconversion of fibre types. The results further indicate that during growth a shift occurred from a more oxidative to a more oxidative-fibrous composition, which may have affected fatigability and IMP production during exercise.

32.3
AGING AND MUSCLE CONTRACTILE FUNCTION AFTER STRETCH-OVERLOAD. Stephen E. Abay and James A. Carson. Neuromuscular Laboratory, The Ohio State University, Columbus, OH 43210

The effects of aging on muscle contractile function after stretch-overload was examined in the anterior latissimus dorsi (ALD) muscle of 10 old (90 weeks) and 10 young adult (10 weeks) Japanese quails. Stretch was achieved by adding 10% of the bird's body weight to one wing while the contralateral wing was served as the intra-animal control. This resulted in an increase in muscle mass of 152% in young and 101% in old ALD muscles. In vitro contractile measures were made at 25°C by indirect stimulation of the ALD by its nerve (pulse = 0.1ms). Compared to control twitch characteristics, stretch enhanced muscles had significantly greater contraction time in both old (174 ± 16 ms vs. 217 ± 13 ms) and young (193 ± 120 ms vs. 197 ± 8 ms). In young, the one-half relaxation time of the twitch increased after stretch in old (215 ± 14 ms vs. 252 ± 17 ms) and young (101 ± 7 vs. 107 ± 11 ms) muscles relative to control. Stretch resulted in fusing of twitches at lower frequencies of stimulation, and shifted the force-frequency curve to the left in both age groups. In young adult birds, maximal shortening velocity (Vmax) decreased from 2.6 ± 0.2 to 2.1 ± 0.2 fiber lengths/s. Although Vmax was decreased by stretch in old muscles, (1.9 ± 0.02 vs. 0.79 ± 0.06 fiber lengths/s) the magnitude of change was less than in younger muscles. Maximal tetanic force increased by 2.6 fold and 1.7 fold in young and old overloaded muscles, respectively. These data suggest that stretch-overloads Vmax and increases twitch duration in young and old muscles. The attenuation of stretch-induced contractile change in old vs. young muscle was due in part to an age-induced slowing of this muscle.

Supported by the American Federation for Aging Research
32.7

SKELETAL MUSCLE ADAPTATION: ISOKINETIC VERSUS ELECTRICAL STIMULATION. ISOLATED MUSCLE, EMG, FIBER TYPE, AND ACTION POTENTIAL IN THE FROG SARTORIUS MUSCLE. C. Light, A. Contioli and J.H. Renaud, Dept. of Physiology, University of Ottawa, Ottawa, Canada.

The purpose of this investigation was to determine the effects of electrical conditioning on the contractile properties of the frog sartorius muscle. Fiber type distribution was determined in the untrained and trained muscles. Isometric force and tetanic power output were measured in the trained and untrained muscles. The results show that the trained muscle has a higher fiber type I content and a lower fiber type II content than the untrained muscle. These changes in fiber type distribution are associated with increases in isometric force and tetanic power output. These findings suggest that electrical conditioning is an effective method for improving muscle performance.

32.8

THE EFFECT OF HIGH-INTENSITY EXERCISE TRAINING ON RAT SINGLE MUSCLE FIBER FORCE, VMX, AND THE FORCE-VELLOCITY RELATIONSHIP. C.J. Verghese and R.H. Fins, Marquette University, Milwaukee, WI 53233.

The purpose of this study was to determine the effects of sprint training on the contractile properties of the three fiber types in the rat. Exercise trained rats ran 6 bouts (4.5 min) at 40 m/min up a 15% incline with 2.5 min rest, 5 days/week for 6 weeks. Single skinned fibers were isolated from the soleus (SOL) and deep red (RG) and superficial white (WG) region of the gastrocnemius, suspended between a motor arm and force transducer, and fiber diameter, peak force (PO), and amplitude of the action potential were determined. The peak power output was significantly decreased in the trained SOL and RG type I fibers, but unchanged in the trained fast Ila and Iib fibers. The peak power output was significantly decreased in the trained SOL and RG type I fibers, but unchanged in the trained fast Ila and Iib fibers. This suggests that the effects of sprint training on muscle function are complex and may depend on the fiber type and muscle.

32.9

EFFECT OF PROLONGED ENDURANCE EXERCISE ON DIAMETER AND PEAK FORCE IN SLOW AND FAST FIBERS OF THE RAT. L.V. Thompson, C.J. Vergheese, and R.H. Fins, Marquette University, Milwaukee, WI 53233.

The purpose of this investigation was to evaluate the effects of prolonged endurance exercise training (ET) on fast and slow fiber function in rats. The rats ran 5 days a week, 3.5 hrs per day at 27 m/min on a 3% incline with 2.5 min rests, 5 days/week for 6 weeks. Single skinned fibers were isolated from the soleus (SOL) and deep red (RG) and superficial white (WG) region of the gastrocnemius, suspended between a motor arm and force transducer, and fiber diameter, peak force (PO), and amplitude of the action potential were determined. The peak power output was significantly decreased in the trained SOL and RG type I fibers, but unchanged in the trained fast Ila and Iib fibers. This suggests that the effects of sprint training on muscle function are complex and may depend on the fiber type and muscle.

32.10

FORCE-VELLOCITY RELATIONSHIP IN ELITE AND COMPETITIVE ROAD AND TRACK CYCLISTS. C.M. Bodecki, S.L. Griff, and D.D. Ohmme, Texas Back Institute Research Foundation, Plano, TX 75075.

Previous studies regarding force-velocity (F-V) curves have demonstrated strong inverse relationships, both in vivo and in vitro. In addition, F-V curves are influenced by individual percentage of fast and slow motor units, favoring the former. The purpose of this investigation was to compare the difference in F-V curves in elite/competitive cyclists and track cyclists, utilizing isokinetic dynamometry. Ten United States Cycling Federation (USCF) licensed category 1,2, and 3, (4 track, 6 road) cyclists were tested isokinetically and isometrically at 60°, 90°, 120°, 180°, and 360°/sec, for both knee extensors through a 90° ROM. The testing protocol consisted of a ramping series, with 25%, 50%, 75%, 100% effort followed by 5 maximal voluntary concentric knee peaks. Peak torques were recorded at all velocities. The following data represents the average peak torque at each velocity normalized to each cyclists peak isometric torque. No significant differences were detected between groups at all velocities, in addition, there was no difference in isometric values, although there was a trend. These data demonstrate F-V curves similar to those previously reported, and that although these athletes train and race in different events, these differences cannot be explained through isokinetic spectrum analysis.

32.11

DYNAMIC FEATURES OF THE HUMAN QUADRICEPS AT DIFFERENT LEVELS OF NEURAL ACTIVATION. E. Sabatini, M. Benoit* and M.V. Nardi, CNR, Istituto Tecnoiogie Biomediche Avanzate, Fisiologia, Milan, Italy 20131.

It is well established that a direct proportionality exists between the integrated electrical activity of a muscle (EMG) and the isometric force. A family of force-velocity (F-V) curves may be obtained according to the different levels of neural activation. In this study the F-V features of the human vastus lateralis (VL) and vastus medialis (VM) muscles were compared when the subjects were exposed to a range of maximal and submaximal neural activation. In six male subjects (age 35±3.6 yr, weight 70±7.8 kg) EMG of VL and VM were measured while ergometer cycling against friction loads of 0, 1, 2 and 3 kg, at rates of 60, 90, 120, 180 revolutions per minute (rpm) and as fast as possible (Vmax). Two of these subjects also pedaled against 4 kg. For each pedaling velocity, the EMG of VL and VM increased linearly as a function of the load (F) and could be represented by EMG = α * F + β where α is constant at zero load and β increases in EMG per unit increase in load. All functions had very similar values representing a corresponding load-velocity system. The EMG activity remained constant when the subjects pedaled at the Vmax attainable for each load. It was thus assumed that this level represented maximum neural activation (EMGmax) and all other values were normalized as percent of this maximum. By imposing an activation level of 50% EMGmax, the corresponding F for each velocity was calculated using the equation EMG = α * F + β. From the F and V coordinates a F-V curve was constructed and by plotting (Vo-V)/F against V the constants a and b of the curve were calculated. Track 0.82 0.73 0.69 0.57 0.48

Road 0.86 0.73 0.69 0.60 0.48

No significant differences were detected between groups at all velocities, in addition, there was no difference in isometric values, although there was a trend. These data demonstrate F-V curves similar to those previously reported, and that although these athletes train and race in different events, these differences cannot be explained through isokinetic spectrum analysis.

32.12

THE EFFECT OF GLYBURIDE, A K+ATP CHANNEL ANTAGONIST, ON FORCE DEVELOPMENT AND ACTION POTENTIAL IN THE FROG SARTORIUS MUSCLE. E. Light, A. Contioli and J.H. Renaud, Dept. of Physiology, University of Ottawa, Ottawa, Canada.

The function of K'ATP channels in skeletal muscle is still unclear, though a possible role in the mechanism of fatigue has been implicated. That is, an activation of the K'ATP channels gives rise to greater K' efflux and faster decreases in force during fatigue. In this study we tested whether K'ATP channels become active during fatigue development by exposing frog sartorius muscles to 100 μmole/l glyburide. Our results show that 1) glyburide had no effect on tetanic force or action potential before fatigue; 2) following fatigue (1 tetanic contraction/sec for 3 min) the width of the action potential was larger in the presence than in the absence of glyburide; but 3) the inhibition of the K'ATP channels by glyburide resulted not in a similarity but faster decreases of tetanic force during fatigue development when compared to control muscles. Thus, there is evidence for an activation of K'ATP channels during fatigue development, but further studies are necessary to understand their role. (Supported by NSERC of Canada).

Supported by NIH AR-39984.
22.13
SKELETAL MUSCLE ELECTRICAL ACTIVITY DURING +Gz ACCELERATION. Ira Jacobs and Bruce Rain. * Defence & Civil Institute of Environmental Medicine, North York, Ontario, M3M 3B9.

A strategy used by combat pilots to increase their tolerance of headward acceleration (+Gz) forces is to repeatedly do a Valsalva maneuver while contracting large skeletal muscle groups in order to raise systemic blood pressure. This investigation used surface electromyography (EMG) to estimate the intensity of contraction by several muscles in 6 male subjects during +Gz exposure in a centrifuge. All subjects were experimented and underwent similar training in enhancing +Gz tolerance via muscle contraction. Before the centrifuge ride, the EMG activity of 7 muscles was recorded during a maximal voluntary isometric contraction (MVC). The EMG of these same muscles was then simultaneously recorded during the +Gz ride, which was alternating 15-s bouts at each of +4 Gz and +7Gz until voluntary exhaustion. +Gz tolerance time (GT) averaged 25:36(sD) 93 s. The root mean square of the EMG activity during each 7G bout was averaged for each subject and expressed relative to the 100% MVC values. The mean values (SD) were: biceps brachii, 76:1%; latissimus dorsi, 44:38%; pectoralis major, 49:35%; rectus abdominis, 31:29%; vastus lateralis, 43:21%; biceps femoris, 31:12%; gastrocnemius, 39:24%. There was no statistically significant difference between muscles. GT was most significantly correlated with the biceps femoris EMG (r=0.84). Assuming the EMG reflects the extent of motor unit activation, then particularly noteworthy is the fact that less than 50% of the maximal electrical activity was recorded from all muscles.

22.14
EVIDENCE FOR AN ADDITIONAL MECHANISM OF ACTION OF INORGANIC PHOSPHATE (Pi) ON FORCE GENERATION OF SKELETAL MUSCLE. Nick A. Andrews. Yale University, New Haven, CT, 06511, and The Rockefeller University, New York, NY.

The effects of Pi on maximal force generation (Fmax) of muscle are well established, with a recovery of the force producing steps of the actin-myosin cycle being the putative mode of action. Previously, in light of the effects of altered ionic environment on muscle proteins (Andrews et al. 1991. J. Gen. Physiol. 98:4105), an additional mechanism is proposed: that binding of Pi to myofilaments leads to their destabilization and decreased Fmax. To illustrate, Fmax was monitored as single chemically-skinned (Trigon X-100) fibers of fast-twitch rabbit psoas were transiently activated (200 ms) in solutions containing (mM) 5 EGTA, 20 Imidazole, 2 Mg2+, 5 MgATP, 15 PCr, and 10 Pi. To this, all combinations of 0, 5, 10, 15 and 30 mM Pi were added. As binding of Pi increased (5-30 mM Pi) Fmax decreased (r=0.96). Results show that while Pi decreased Fmax dose-dependently, 100 and 300 mM TMAO completely reversed the effect of 30 mM Pi, while ameliorating the effects of higher Pi levels. Therefore, in addition to other effects, Pi is proposed to inhibit Fmax by binding to and destabilizing muscle proteins, a condition not favored in the presence of TMAO. Furthermore, in the presence of 30 mM Pi, the fibers swell, possibly due to binding of Pi and increased repulsion within the myofilament lattice. TMAO counteracts this effect.

33.1
CONTROL OF OXIDATIVE METABOLISM BY CYTOSOLIC PHOSPHORYLATION POTENTIAL IN SLOW TITCH MUSCLE. IN SITU. Susan L. Harkema and Ronald A. Meyer. Michigan State University, East Lansing, MI 48824.

Phosphocreatine (PCr), oxygen consumption (VO2), and maximal twitch force were measured on isolated skinned soleus muscle, in situ, at rest and during submaximal stimulation rates. PCr concentration was measured by phosphorous nuclear magnetic resonance spectroscopy. The monoexponential time constant for PCr changes was independent of stimulation rate and similar between onset of stimulation and recovery (t = 0.83 ± 0.07 min). Steady-state PCr level and VO2 were linearly related to the product of stimulation rate times peak twitch force. Our results indicate a linear relationship between steady-state PCr levels and VO2 throughout submaximal ATPase rates, contrary to results in isolated perfused cat soleus muscles. These results support linear models of oxidative metabolism in skeletal muscle, with respiration rate dependent on the difference between the cytoplasmic and the intramitochondrial free energy of ATP hydrolysis. (Supported by NIH AR38972)

33.2
31P-NMR relaxometry/diastolic energy coupling at the onset of work in human muscle. T. Binzoni, E. Billard, F. Ferrari, and P. Cerretelli. Departments of Physiology and Radiology, University of Geneva Medical School, Geneva, Switzerland.

The MO2 kinetic in human muscle upon imposing constant work loads can be estimated from the analysis of gas exchange transients in the lungs. However, the accuracy of this method in man is limited by physiological variables such as the circulation delay from the contracting muscle to the lungs, changes in body temperature, and the measurement of lactic acid. The MO2 kinetic is determined from the time course of PCr hydrolysis (31P- NMR) during the recovery from maximal voluntary contraction (MVC) at different workloads. The kinetics of PCr hydrolysis, from the slope of the linear relationship between [PCr] at steady state vs. VO2, is independent of the work load. However, the MO2 kinetic is dependent on the work load. The MO2 kinetic is also dependent on the rate of VO2, with a linear relationship between the MO2 kinetic and VO2. These results support the hypothesis that the MO2 kinetic is dependent on the rate of VO2, with a linear relationship between the MO2 kinetic and VO2. (Supported by NIH HL38758)

Energetics
33.3 METABOLISM AT REST. However, no discussion has been made on metabolism of B-GUANIDINOPROPIONIC ACID, a creatine analogue.


Our goal was to compare oxidative capacity of the medial and lateral gastrocnemius, using a simple localization procedure. In order to localize the 31P signal to the medial or lateral gastrocnemius, a 2 segment meander coil (6 x 10 cm) was built. 31P spectra of a phantom mimicking the leg structure showed that 85% of the signal was obtained from one section of the gastrocnemius. Exercise consisted of repeated plantar flexions, one every 4 seconds, performed for 5 minutes. The workload was increased every minute to deplete PCR to 50-60% of the initial value by the end of exercise. No drop in pH was seen during exercise.

As exercise was stopped PCR recovered and returned to the initial resting values. The PCR levels during recovery were fit to a single exponential curve with time constants of 33.6 ± 7.6 s for the lateral gastrocnemius and 35.9 ± 7.2 s for the medial gastrocnemius. Recovery data were collected from 10 men and women. The mean age was 26 ± 3 years.

In conclusion 31P spectra could be localized to the medial or lateral gastrocnemius, using a 2 segment meander coil. Although the medial gastrocnemius was more active at low work levels than the lateral gastrocnemius, the metabolic capacities in both muscles were similar. K.V. is supported by the N.F.W.O.

33.5 MYOCARDIAL METABOLISM DURING AEROBIC EXERCISE BY 31P NMR IN HUMAN. Shin-ya Kuno, Yuji Hali and Shigeru Katsuta. Department of Sports Sciences, University of Tokyo, Institute of Clinical Medicine and Health and Sports Sciences, University of Tsukuba, Japan.

A few studies have been made in vivo on human myocardial energy metabolism at rest. However, no discussion has been made on metabolism during exercise and training effects. We examined human myocardial energy metabolism at rest and during exercise and training effects on the metabolism by 31P NMR. Three sedentary male subjects (Cont) and 4 male long distance runners (Tr) were employed. The NMR spectra were obtained from myocardium during rest and exercise by region selection method. As a method of exercise load during 31P NMR measurement, a rotation movement of legs while riding a bike fitted with ergometers were used for ourselves NMR was used at a certain load. The heart rate was at a stationary phase during exercise.

Although the heart rate at rest in Tr group was significantly lower (Tr: 76.3 ± 4.3, 88.5 ± 3.5 bpm, PCr/ATP 1.51 ± 0.03, 1.50 ± 0.03, Cont: 95.1 ± 2.1, 115.3 ± 3.9 bpm, PCr/ATP 1.51 ± 0.03, 1.50 ± 0.03) Thus, during submaximal exercise, high energy phosphate levels were reduced after the contraction burst, PCr levels were reduced 9.6 ± 10.0% in controls vs. 4.9 ± 8.0% in muscles with 40% less ATP than controls but normal initial PCR content. Normalizing for the slightly lower twitch force in the depleted muscles (1.08 ± 0.06 vs. 1.27 ± 0.08 g/kg body weight), this represents a 40% decrease in energy cost of contraction in the depleted muscles, in agreement with the earlier report. (This work was supported by NIH Grant # AR 38972)


1P nuclear magnetic resonance spectroscopy (1P-MRS) was used for non-invasive measurement of phosphorous metabolisms (creatine phosphate (PCr) and inorganic phosphate (Pi)) and changes in intramuscular pH during a step function exercise and recovery. While prone position in a 2.1 T superconducting magnet with a 67 cm bore, six healthy male students, 5 long distance runners and 5 sprinters performed 4 min of femoral flexion exercise at 30 kg/min, followed by 4 min of recovery. The 1P-MRS was collected with 32 scans per spectrum, requiring 12.8 s. The areas of PCr and Pi peaks were integrated and the time courses of PCr and Pi were fitted to an exponential model. During exercise PCr increased to depletion by 20-30% of the pre-exercise level. Following exercise, the rates of PCr and Pi recovery were significantly faster in long distance runners than in normal subjects (P<0.05). During a given intensity of exercise, long distance runners showed less acidification than in normal subjects. Since it is well documented that PCR resynthesis is regulated by aerobic metabolism and mitochondrial creatine kinase, it is suggested that the faster PCr and Pi recovery rates and less acidification seen in long distance runners might result from attributable to the greater oxidative capacity.


The purpose of this study was to determine if the chronic deficit in the endogenous purine nucleotide adenine nucleotides by deamination of AMP to IMP. From the time zero derivative of an exponential fit of 33.8 MUSCLE FATIGUE AND ATP DEGRADATION IN RAT SKELETAL MUSCLE. A. de Haan, J.C.M. Kooi and H.G. Westra (SPON: A.J. Sargeant), Department of Muscle and Exercise, University of Amsterdam, Academic Medical Centre, Amsterdam, The Netherlands.

During high-intensity exercise in man and animals, skeletal muscles loose adenine nucleotides by deamination of AMP to IMP. At exhaustion human muscle biopsies showed 30-40% decreases in ATP. In rat fast muscles even larger decreases are found (de Haan, Exp.Physiol.75, 851-854, 1990). In previous experiments using rat muscles, the loss of force at the end of a series of isometric contractions was greater when the muscle adenine nucleotides were deaminated to IMP. In the present experiments the relationship between the loss of force and the degradation of ATP was investigated. Medial gastrocnemius muscles (n=30) of anaesthetized rats (pentobarbitone 60mg/kg, i.p.) were stimulated (120Hz) at a temperature of 30°C. The muscle performed a series of contractions during 6s with arrested blood flow. Five different exercise protocols were used, during which the muscles were activated for 3.4s, to induce differences in force loss (range 8-28% of the force in the first contraction). The reduction of ATP varied between 0 and 18.7 µmol/mg dw (resting ATP concentration was 32.2±1.5 µmol/mg dw). The relationship between the reduction of ATP and the total force (force in the last contraction as a percentage of the initial force) was hyperbolic (Force/Force(max)=88.9±1.14x (ATP) -0.25 x (ΔATP)²; r=0.95). A zero final force was reached with an a single exponential curve fit (AATP) -0.25 x (AATP)²; r=0.95). A zero final force was reached with an a single exponential curve fit (AATP) -0.25 x (AATP)²; r=0.95). A zero final force was reached with an
23.9
BIOENERGETIC AND ACID-BASE ADAPTATION TO REPEATED SCARIFIC NERVE STIMULATION IN RAT LEG MUSCLE BY 31P MRS. R.K. Lebiedzinski, J. Rose,* and D.M. Symons, Pulmonary and Critical Care Unit, Mass. General Hospital and NHMRC for Physiological Chemistry, Armagn & Woman's Hospital, Harvard Medical School, Boston, MA 02114.

To elucidate mechanisms of fatigue during exercise we used 31P MRS in anesthetized male rats to examine metabolites and ATP turnover in a large area of an exercising muscle (rectus femoris). Experimental conditions included 30 min bouts of 15% grade (+6 mmHg) treadmill running at 5 mph at 0600 and lunch at 1330 h.

At 1430 h the subject engaged in a strenuous 100 min bout of upper and lower body resistance exercise or quiet sitting. Immediately following both exercise and control conditions, energy expenditure was measured for two hours. Subjects were then fed a standard mixed meal and RMR was measured for three hours. The following morning, RMR was again measured at 0630 h.

Energy expenditure was measured for the entire two hour recovery period accounting for an average of 15% energy cost. The results were then fit to a linear regression model to estimate the slopes of energy expenditure over time.

23.10

Shifts from oxidative to glycolytic metabolism have been suggested to be involved in regulation of blood flow in striated muscle. To test this hypothesis we measured localized 31P NMR in an avascular tissue site (15 x 30 mm) and oxygenated muscle of the stimulated plantaris muscle during ischemia and reperfusion. Oxygenation was maintained by intramuscular injections of 5% O2 in N2 at a rate of 1.0 ml/min. Oxygen consumption was measured using a Co-Oximeter. Ischemia was induced by inflation of the pedal artery with a cuff. After completion of ischemia, the cuff was released and blood flow was measured using a laser Doppler flowmeter. Blood flow was increased to 50% of control by intramuscular injections of 5% O2 in N2 at a rate of 1.0 ml/min. The muscle was then stained with methylene blue and NADH was measured using 31P NMR. The results were then fit to a linear regression model to estimate the slopes of oxygen consumption over time.

23.11
FATIGUE AFFECTS COUPLING OF CREATINE KINASE TO SARCOPLELMATIC RETICULUM CALCIUM-ATPASE. Pavo Korge* and Kenneth B. Campbell, Wash St Univ, Pullman WA 99164.

Previous experiments have demonstrated that creatine kinase (CK) bound to sarcoplasmic reticulum (SR) membranes is functionally coupled to Ca++-transporting protein, Ca-ATPase; ADP produced by Ca-ATPase is preferentially available to CK for phosphorylation and ATP generated in this reaction is preferentially used by Ca-ATPase to regenerate Ca++. Under conditions of fatigue, CP-ADP-stimulated Ca-uptake rate was 68% of that at rest. We conclude that fatigue causes a decrease in the function of CK in the local regeneration of ATP near ATP binding sites of Ca-ATPase than the decrease in the function of Ca-pump during intense exercise.

Within each group the intramuscular pH fell significantly from baseline and then rose significantly above the 4 min nadir despite continuing the stimulation protocol. There were no significant differences in pH between groups at all times. The data suggests adaptive mechanisms allow muscle cell contraction to prevent potentially damaging intracellular acidosis or depletion of high energy phosphates.

Supported by NIH Grant HL02593-01A1.

23.12

In skeletal muscle creatine kinase (CK) plays a key role in intracellular energy metabolism. However, the present and function of different types of CK isoenzymes in a single muscle fiber remain to be clarified. In the present study, the activity and function of CK and Ca-MgATPase of fast and slow muscle fibers from Wistar strain male rats were estimated by means of biochemical approaches. Total CK and CK-MW activities were higher in fast-twitch fibers than in slow-twitch fibers. Endurance training running induced a decrease in CK-MW activity, but no change in total CK activity. When Phosphorososteroase (PC) and MgADP were added to a skinned fiber in rigor, the tension of the fiber was apparently decreased. It is thought that this decrease of the Ca++-twitch tension was induced by MgADP produced via mobilization of CK reaction. Ca++-activated maximum tension (Fmax) was decreased with the addition of Pd to the bathing solution. The decrease of Fmax in fast-twitch fiber was higher than that in slow-twitch fiber. These results suggest that binding of CK, probably in the form of CK-MW isoenzyme, to myofilaments is important not only for removing ADP from the area around the myosin crossbridge, but also for providing ATP, and that this function is more efficient in fast-twitch fibers, which have higher activity of CK-MW, than slow-twitch fibers. This work supported in part by the Kanezawa Academy of Science and Technology.

23.13

We compared within the same 6 male subjects (aged 20-35 yrs) the effect of a bout of weight lifting versus a control condition on energy expenditure, postprandial genesis (PT) and resting metabolic rate (RMR). The following protocol was followed by all subjects for both the exercise and control condition. RMR was measured at 0630 h which was then followed by a meal and lunch at 1330 h. At 1430 h the subject engaged in a strenuous 100 min bout of upper and lower body resistance exercise or quiet sitting. Immediately following both exercise and control conditions, energy expenditure was measured for two hours. Subjects were then fed a standard mixed meal and PT was measured for three hours. The following morning, RMR was again measured at 0630 h.

Energy expenditure was measured for the entire two hour recovery period accounting for an average of 33 kcal/h. The results were then fit to a linear regression model to estimate the slopes of energy expenditure over time.
33.15 TRAINING EFFECTS ON GLUTOSE AND LACTATE KINETICS IN EXERCISING HORSES. K.K. Bicks, J.J. Jones, T.R. Hughes, D.L. Smith, and A.L. Edinger. VM: Physiological Sciences, Univ. California, Davis, CA 95616

We tested the hypothesis that a 12-week exercise training program alters the relative contributions of aerobic and anaerobic metabolism to total metabolic power during exercise. Thoroughbred horses ran on a level treadmill at a speed sufficient to elicit V\text{O}_{2}\text{max} (13 m/s) while \text{UC} labeled glucose, lactate, or bicarbonate was infused intravenously to determine the plasma turnover rates of these compounds. Three repetitions of the exercise protocol, with infusion of only one of the radioactive compounds during a given run, were done before and after training. Mixed venous blood samples showed that plasma turnover rates of glucose and lactate increased as running speed increased. Following training, V\text{O}_{2} and glucose turnover rates were higher, plasma lactate accumulation rates were lower, but plasma lactate fluxes were unchanged in horses running at 13 m/s. 

These findings indicate that, at the same exercise intensity, training leads to increased aerobic metabolism while net anaerobic metabolism decreases. Because plasma lactate accumulation rates decreased, while plasma lactate fluxes were unchanged, either lactate production diminished with training or more lactate was being oxidized locally without contributing to the circulating pool. Biopsies from the middle gluteal muscle, taken prior to running and immediately after running at 13 m/s, showed that, following training, muscle glycogen concentrations were higher both before and after exercise, while glycogen depletion during exercise decreased. These studies suggest that increased glucose concentrations were higher both before and after exercise, while glycogen depletion during exercise decreased. The findings further demonstrate that acidosis and the lactate anion have no apparent effect on exercise ventilation and K+ changes, whereas the idea that a potassium increase in interstitium or plasma may be sufficient to elicit exercise threshold is doubted. (13 m/s) while \text{UC} labeled glucose, lactate, or bicarbonate was infused intravenously to determine the plasma turnover rates of these compounds. Three repetitions of the exercise protocol, with infusion of only one of the radioactive compounds during a given run, were done before and after training. Mixed venous blood samples showed that plasma turnover rates of glucose and lactate increased as running speed increased. Following training, V\text{O}_{2} and glucose turnover rates were higher, plasma lactate accumulation rates were lower, but plasma lactate fluxes were unchanged in horses running at 13 m/s. 

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34.1 LACTATE UTILIZATION BY RAT GASTROCNEMIUS MUSCLE: ANALYSIS BY \textsuperscript{13}C MAGNETIC RESONANCE. Loren A. Bemolo, Gail Thomas, Paul K. Anderson, John O. Jones, Ronald G. Victor, and Craig R. M. Allen. UT Southwestern Medical Center, Dallas TX 75235-3858

Although it is known that skeletal muscle utilizes lactate during exercise, the precise biochemical details remain poorly understood. Isotopomer analysis of \textsuperscript{13}C magnetic resonance spectra provides a powerful tool to examine how skeletal muscle utilizes exogenous lactate during both steady and non-steady state exercise. Analysis is based on the incorporation of label into glutamate, in chemical equilibrium with the TCA cycle intermediate \text{L}-ketoglutarate, and provides information about the pathways by which labeled lactate is incorporated into the TCA cycle. In this study, \text{UC} labeled lactate and \text{UC} labeled acetate were infused into rats during the final 30 min. of 35 and 95 min. periods of acetic acid stimulation of one set of hindlimb muscles, with contralateral muscles as unstimulated controls. Incorporation of the labeled lactate into the TCA cycle increased from 15.7% to 24.8% and 45.9% during rest, after 35 and 95 min. of stimulation respectively. At steady state, incorporation of labeled acetate declined from 64.2% to 39.7% and 30.0%. Thus contribution from unlabeled lactate was 20.9%, 35.5% and 23.4%. Although there were great increases in the size of the peaks arising from anaplerotic enrichment of succinate, the percent incorporation of label via anaplerotic versus oxidative pathways actually decreased from 17.3% to 4.9% and 1.3%.

In summary, 1) lactate was oxidized by exercising skeletal muscle; 2) fractional lactate incorporation into the TCA cycle increased with exercise and exercise duration; 3) the regulation of energy metabolism during exercise may involve incorporation of lactate into the TCA cycle via anaplerosis.

34.3 EFFECTS OF SODIUM LACTATE INFUSION ON THE RELATION BETWEEN PLASMA pH, K\textsuperscript{+}, AND VENTILATION DURING INCREMENTAL EXERCISE. Martin T. Bengt and Alma Moze. University of Iceland, Department of Sports and Exercise Physiology, Medizinische Hochschule Hannover, D-3000 Hannover, Germany

We have examined the effects of constant rate infusion of sodium lactate (1.64, 0.792, 0.384 and 0.192 molar, 750 ml per hour) during incremental exercise to examine the relationship between ventilation (V\text{E}), plasma potassium concentration ([K\textsuperscript{+}], plasma bicarbonate concentration (\text{HCO}\textsubscript{3}\textsuperscript{-}) and plasma pH (pH\text{p}) in trained cyclists. We found two secondary incremental bicycle tests with a 7 min interval between. Although p\text{H} and [Lac\textsuperscript{+}], were significantly higher during the sodium lactate infusions, [K\textsuperscript{+}] and [HCO\textsubscript{3}\textsuperscript{-}] changes were almost equal at all stages. A marked [HCO\textsubscript{3}\textsuperscript{-}] increase in the B-tests, which reached alkalotic values in Ly, at maximum workload, did not affect V\text{E} or [K\textsuperscript{+}], or [HCO\textsubscript{3}\textsuperscript{-}] changes, in the A-tests. In the B-tests, with pH\text{p} decreased to 7.3, changes in plasma lactate concentration ([Lac\textsuperscript{+}] or plasma bicarbonate concentration ([HCO\textsubscript{3}\textsuperscript{-}]), were observed. But no change in V\text{E} or [K\textsuperscript{+}] was observed in the A-tests.

We propose that, in trained individuals, the relationship between ventilation, pH\text{p}, K\textsuperscript{+}, and lactate concentration is altered by a marked increase in plasma lactate concentration, which may alter the 

34.4 DETERMINATION OF THE LACTATE EQUILIBRIUM DURING INCREMENTAL EXERCISE TESTS: INFLUENCE OF INCREMENT SIZE, TIME AND PRECEDING LACTIC ACIDOSIS. Uwe Teigburch and Martin W. Ruse (SPUN: G. Gros). Center of Physiology, Department of Sports and Exercise Physiology, Medizinische Hochschule Hannover, D-3000 Hannover, Germany

During, an incremental exercise test (3.33 m/s\textsuperscript{-1} increments every 800 s) after a preceding bout of maximum anaerobic exercise, blood lactate initially decreases to an individual minimum and then again increases. The speed corresponding to this individual lactate minimum (LMS) represents an individual equilibrium between lactate production and catabolism during constant load exercise, i.e. a maximum steady state intensity. Only a slight speed increase above the LMS would result in a continuous marked lactate concentration ([Lac\textsuperscript{+}] or plasma bicarbonate concentration ([HCO\textsubscript{3}\textsuperscript{-}]), increase and earlier exhaustion. To examine the lactate equilibrium during the LMS the following field tests were performed: Series 1. Variation of the increment size, 8.2 and 8.33 m/s\textsuperscript{-1}, in 13 males showed no change of the LMS (4.23 and 4.27 m/s\textsuperscript{-1}). Series 2. Variation of the increment length in 13 males showed no change of the LMS (4.23 and 4.27 m/s\textsuperscript{-1}). Series 3. Effects of incremental test (L\textsuperscript{+}g), i.e. normal (\text{N}) and low (\text{IL}) muscle glycogen stores on the LMS were determined in 14 males. Although [Lac\textsuperscript{+}] in the \text{IL} group was significantly different (14.1 mmol/l in 14.0 mmol/l in the \text{N} group, after preceding bouts of maximum exercise p<0.05; 3.7 in N and 3.1 mmol/l in \text{IL} at the lactate minimum), no difference of the LMS with normal or low muscle glycogen stores was found. It appears that the LMS may be used to determine the "anaerobic threshold" independently of the muscle glycogen stores.
34.5 IS THE RELATIONSHIP BETWEEN [LAC] AND POWER SUPERIOR TO V02 TO DETERMINE ENDURANCE PERFORMANCE? N. Neuss*, G. Schneider*, M.M. Waddell** (GRON: G. Grau), D-3000 Hannover, FRG.

It is generally accepted that endurance trained subjects (TR) can perform longer at exercise intensities corresponding to the same percentages of [LAC] than untrained subjects (UT). This is often explained with an increase in the anaerobic metabolism only at high percentages of [LAC]. On the other hand, it has also been shown that [LAC] may vary with the glycogen content of the muscle. Thus the above cited opinion might be deduced from experiments, in which no attention was paid to the glycogen content of the muscles. Methods: 11 TR and 11 UT participated in the study. First test (after 2 days wingate training): incremental test to determine [LAC] and the relation between [LAC] and power, followed by 3 days of glycogen loading (Saltin diet). On the fourth day the constant load experiments at various percentages of [LAC]. Until subjective exhaustion were performed. TR and UT worked at 86.1 ± 21.1 W and 80.0 ± 9.6 W respectively. The performance of the [LAC] at 85% of the maximum power output was used for the regression analysis. The regression lines of both gender according to the sub-LT relationship, giving rise to an "excess" [LAC] always occurred at plasma [epi] of ≥ 220-250 pg/ml-1 (221 ± 48 pg/ml-1 for rowing; 245 pg/ml-1 for running), which is consistent with the [epi] threshold for eliciting catecholamine "thresholds", per se, were not the cause of the LT. However, in all instances the LT occurred at plasma [epi] of ~200-250 pg/ml-1 (221 ± 45 pg/ml-1 for running; 245 pg/ml-1 for running), which is consistent with the [epi] threshold for eliciting increments in blood [lactate] (Clutter et al. J. Clin. Invest. 66 34 1980). Plasma [epi] at the LT differed significantly between modes (820 ± 127 pg/ml-1 running vs. 1712 ± 217 pg/ml-1 running). We conclude that although the lactate and epinephrine "thresholds" (as defined herein) may not occur at the same [LAC], the observation that the LT always occurred at plasma [epi] of ~220-250 pg/ml-1 is consistent with the hypothesis that plasma [epi] plays a causal role in the LT.

34.6 THE EFFECTS OF "SPONTANEOUS" RELAX MV BOD Y SUBMERRGION ON LACTATE ACID CONTENT AND ENDURANCE PERFORMANCE. Ren Jianzhong and Shi Aiguo*, Dept. of Physiology, Wunan Institute of Physical Education, Wunan, 450009.

We use the "Spontaneous Body Rowing (SBRM) for a duration of 24-25s as a warmup to compare with the conventional warmup (WM) for a same duration to observe the effects of the SBRM on lacto acid content and endurance performance. Fourteen male college students of Wunan Institute in Physical Education, Wunan, 450009, were trained for two months took part in this study. A stepwise increase of 15% of the maximal power output was performed with 50 s intervals until exhaustion was measured or a maximum work rate (WM) and work time (WT) after the SBRM. Subjected to the same conditions on different days. The results were significant different between the WM and WT after the SBRM. It was concluded that the SBRM caused a significantly increase of lactate and lactic acid content and endurance performance.
BLOOD LACTATE CONCENTRATION DURING SUBMAXIMAL CONSTANT LOAD UNDHER HYPERBARIC OXYGENATION. Ralph Banek, Thomas Richter*, Jürgen Plögo, Ute Hoff, Claus Dehn, Institute of Sports Medicine, University of Leipzig, Germany

Five triathletes (21 to 49 yrs) performed submaximal constant load tasks (15 min) on a cycle ergometer under normobaric normoxic conditions (NN) and under 100 % O2, 1.5 bar oxygenation (HBO). At given ranges of load intensity (A, B, C) blood lactate concentrations (BLC) were 1.7 ± 0.5 mmol·l^-1 (A), 2.5 ± 0.5 mmol·l^-1 (B), and 4.4 ± 0.9 mmol·l^-1 (C) under NN, and 1.7 ± 0.2 mmol·l^-1 (A), 2.0 ± 0.2 mmol·l^-1 (B), and 2.3 ± 0.2 mmol·l^-1 (C) under HBO. At load intensity C, the difference in BLC between NN and HBO was significant (p<0.01). The effect of HBO on BLC depends on load intensity.

MAXIMAL RATE OF BLOOD LACTATE ACCUMULATION DURING HIGH ALTITUDE EXPOSURE IN HUMANS. B.Kirwan*, G.Geesey*, F.Ferrell*, A.Colombo*, C.Marcacci* and P.Carrelli**, Dept. of Physiology, CMU, University of Geneva, Switzerland and IVRA of CNR, Milan, Italy.

The reduction of maximal lactate capacity with altitude exposure may depend on a decreased substrate flow through the glycolytic pathway. If this is the case, the profile of lactate release may be impaired and the post-exercise rate of lactate removal from the exercising leg will not be the same as at sea level.

KSCNR project.

Physiology, CMU, University of Geneva, Switzerland

Supported by Louisiana Department of Wildlife and Fisheries.

EFFECT OF FIO2 ON ACID RELEASE FROM THE EXERCISING LEG AT VO2max. P.Heinecke, D.C.Poole, M.C.Kogon, D.E.Beaud, and P.Wagner, University of California, San Diego, La Jolla, CA, 92033 0623.

We have reported (Knight et al., PASEF I. 0.14160, 1992) that peak work rate (Wmax) and peak VO2 are increased by raising the concentration of inspired O2 (FIO2). The effect of FIO2 on work rate led us to expect greater release of lactate and H* from the leg at higher Wmax. Eleven men performed cycle exercise to maximal effort at FIO2s of 0.12, 0.71, and 1.00. Catheters in the radial artery and femoral vein were used to measure arterial and venous lactate concentrations. Arterial pH was monitored and the rate of blood lactate flow and venous differences in blood lactate concentrations of lactate (Ll,L2 and H* (L2)). Maximal lactate release (2X 1-kg load test) was not affected by FIO2. Isolated, L2 and (L2) were used as indices of lactate release from the exercising leg. Linear regression analyses showed that increases in mean Wmax from 287 to 401 W as FIO2 was raised from 0.12 to 1.00 decreased the L2/L2 ratio from 1.32 to 0.05 (slope = 0.094 ± 0.009 mmol·l^-1, p<0.001). There was a corresponding decrease in arteriovenous pH of 0.006 Units W^-1 (p<0.001). The increased release of lactate and lower blood pH were due to enhanced aerobic production of CO2 at higher Wmax. The surprising reduction in [L2] at higher work rates may be due to several mechanisms, one of which is the impendence of lactate release by higher (H*) in the blood.

(B) Supported by NIH HL 17731, TRDRP 1IRT-227, and ALAC


Small lizards (Anolis carolinensis) were forced to work maximally at 32°C for 5 to 3 sec to 3 min. Each was then homogenized within 5 sec following work and analyzed for lactate. From the rate of lactate rise, the rate of glycogen loss was found to be logarithmic (first order) at 2.5% /sec. Since maximum exertion exhausts muscle glycogen in about the same time in mammals as in reptiles, and since muscle glycogen contents are similar, peak anaerobic power is likely also similar. As the glycolytic curve is first order, peak anaerobic power/kg is directly proportional to the rate of glycogen loss. The rate of recovery (aerobic gluconeogenesis) proved first order also, indicating that the higher the initial glycogen content the faster the recovery rate. Following work, oxygen consumption was highest at the lactate peak. As lactate fell oxygen usage fell indicating that substrate (lactate) concentration determined (in part) the rate of gluconeogenesis and therefore O2 demand for ATP production. As substrate delivery limits gluconeogenesis, blood flow is rate limiting. Supported by Louisiana Department Wildlife and Fisheries.

A COMPARISON OF PYRUVATE-LACTATE KINETICS IN MUSCLE AND CULTUR. P.l. Chinkes, X-J. Zhang, J.A. Remington, R.S. Wolfe, University of Texas Medical Branch of Galveston, Texas 77550.

We have recently developed a new model to derive pyruvate and lactate kinetics across an organ in vivo based on the systemic continuous infusion of pyruvate or lactate, stable isotope tracers and the measurement of the pyruvate and lactate enrichment and concentration in the artery and vein of that tissue, the rate of arterial and venous blood flow, and the measurement of the pyruvate and lactate enrichment and concentration in the artery and vein of that tissue, the rate of arterial and venous blood flow, and the measurement of intracellular free water in the tissue as measured by biophysical methods and the rate of blood flow through the tissue. The purpose of this experiment was to compare the pyruvate-lactate kinetics in leg muscle and gut in anesthetized dogs (n=6). Results: The transmembrane transport and degree of shunting of pyruvate and lactate were comparable in muscle and gut. Interconversion between pyruvate and lactate in muscle and gut was shown. Differences between the two tissues are due to the in vivo based measurement of intracellular free water in the tissue as measured by biophysical methods and the rate of blood flow through the tissue.

The traditional use of tracers to quantify lactate-pyruvate kinetics assume that blood tissue measurements reflect tissue measurements. However, the relationship between blood and tissue enrichments has not previously been determined in humans. In this study, four healthy male subjects exercised at 25% VO2max for 55 min and then measured again pre- and post-exercise. Blood lactate was measured pre- and post-exercise. The results showed that the percent activity of Mn-SOD in relation to the total-SOD activity was 2 times higher than the circulating lactate concentration, and that blood sampling alone may not be adequate for the quantification of pyruvate-lactate kinetics.

LACTATE TRANSPORT IN RAT SKELETAL MUSCLE. Karl J. McCullagh, John C. McDermott and Arend Bonen. Dalhousie University, Halifax, N.S. B3H 3J5; Harvard Medical School, Boston, Mass.; University Of Waterloo, Waterloo Ontario, N2L 3G1.

To determine the nature of the membrane permeability to L-lactate, the transmembrane flux of lactate was studied in purified skeletal muscle plasma membrane vesicles. Transport (zero-trans) in vesicles indicated saturability with increasing L-lactate concentrations, stereospecificity, and sensitivity to inhibitor compounds such as pyruvate (5%), N-ethylmaleimide (-86%), and stimulation by an inwardly directed proton gradient (-0.99, over the extracellular pH range 6.0-8.5). When these studies were performed in strips (<45%) of rat soleus muscles incubated in vitro (45°C), similar results were obtained (i.e., coincident L-lactate transport in muscle strips and purified membrane vesicles, and in muscle strips lactate transport (i) followed a proton gradient and (ii) is inhibited by pyruvate (-40%) and N-ethylmaleimide (-40%). Electrical stimulation of the sciatic nerve (8min) increased the uptake of [2-deoxy-D-glucose (P<0.05) but failed to alter the uptake of L-lactate (P>0.05) in osmolur muscle strips. After 5 weeks of training L-lactate transport (1mM) into purified plasma membrane vesicles was increased (P=0.05). Incubation of membrane vesicles with [U-14C]-L-lactate labeled a membrane protein of approximately 34 kDa on SDS/PAGE. Collectively, these data suggest that a carrier-mediated transport system in skeletal muscle. The transport system is sensitive to alterations in pH and exercise training. The transport system may involve a transporter protein of 34kDa in rat muscle.

Supported by the NSERC A6449

MANGANESE SUPEROXIDE DISMUTASE ACTIVITY IN HUMMINGBIRD FLIGHT MUSCLES. Eleonora J.H. Bechara, Colina V. Zerbini, Jose E.P.W. Bento.

The activity of manganese superoxide dismutase (Mn-SOD) is correlated with the mitochondrial volume density, V(mi,mf) in the cell, and varies between 12-18% in mammalian skeletal muscles. The percent activity of Mn-SOD in the flight muscles of the Eupetomena macrouru was calculated from the total-SOD and Cu,Zn-SOD activity.

The activity of manganese superoxide dismutase @Mn-SOD) is strongly correlated with the mitochondrial volume density, V(mi,mf) in the cell, and varies between 12-18% in mammalian skeletal muscles. The percent activity of Mn-SOD in the flight muscles of the Eupetomena macrouru was calculated from the total-SOD and Cu,Zn-SOD activity, following a 90 min rest period. Cu,Zn-SOD was infused in the vein, arterIALIZED blood was drawn throughout, and concomitant muscle biopsies (<2mm) were taken at or near plasma isotonic steady state at the end of each period. The mitochondrial intracellular lactate/tracce ratio was consistently ~80% lower than the circulating lactate concentration, and that blood sampling alone may not be adequate for the quantification of pyruvate-lactate kinetics.
35.3

**REPETITIVE MECHANICAL STIMULATION OF TISSUE CULTURED SKELETAL MUSCLE MITIGATES GLUCOCORTICOID-INDUCED DECREASES IN PROSTAGLANDIN H SYNTHASE ACTIVITY AND PROSTAGLANDIN H2 SYNTHASE ACTIVITY. J.A. Chronakis, H. H. Vandenburgh, J. Shanak*, and H. Solberg*. Department of Pathology, Brown University and The Miriam Hospital, Providence, RI 02906.**

Exercises in vivo and repetitive stretch-relaxation of tissue cultured, avian skeletal myofibers in vitro partially reverses glucocorticoid-induced myofiber atrophy. The present study tested the hypothesis that mechanical stimulation decreases in protein synthesis rate in vitro was partially prevented by the prostaglandin synthase inhibitor indomethacin (100 µM). Since PGF₂α is an autocrine and paracrine growth factor in skeletal muscle, we measured PGF₂α synthase activity in skeletal muscle homogenates and isolated, mechanically stimulated gap junctional proteins in tissue cultured skeletal muscle. Day 1 cultures were changed to serum-free medium ± 10⁻⁶M dexamethasone (DEX). After 24 h, media were collected and assayed for PGF₂α synthase activity. PGF₂α activity was determined by measuring PGF₂α produced after a 30 min incubation of the cultured cells with 35S-labeled arachidonic acid. In static control cultures, PGF₂α synthase activity was reduced 58% after 24 h of 10⁻⁶M DEX compared to controls. Mechanical stimulation increased PGF₂α synthase activity in control cultures. In DEX-treated cultures, mechanical stimulation increased PGF₂α synthase activity 152% so that PGF₂α synthase activity was not significantly different from non-DEX treated static or stretched controls. P3HS activity was increased 72% in response to DEX after 24 h. PGHS activity was increased 39% in mechanically stimulated, DEX treated cultures compared to DEX-treated static cultures, but was still 45% less than non-DEX treated static control. These results indicate that mechanical stimulation in vitro may attenuate the catabolic effects of dexamethasone on skeletal muscle by reversing the DEX-induced decreases in PGF₂α and PGHS synthase activity.

(Supported by NIH F32 AR01828, RO1 AR39988, and NASA NAG2 4143.)

35.5

**EFFECT OF HEATING RATE ON SYNTHESIS OF HSP 72. S.W. Brown, M. S. Famiglietti, and K. J. Lew.**

The present study investigated the effects of high and low heating rates on the synthesis of heat shock protein (HSP) 72. Rats were assigned to either control, high (0.146 °C/min) or low (0.044 °C/min) heating rate. The high heating rate resulted in the synthesis of HSP 72, a protein that is known to be induced by hyperthermia. These results suggest that high heating rates may be more effective in inducing the synthesis of HSP 72 compared to low heating rates.

(Supported by NIH grant AR21617 and the MDA (RLS).)

35.7

**TIME COURSIS OF AMP DEAMINASE ACTIVITY DECLINE IN RATS FED B-GUANIDINOPROPIONATE. P.W. Bundell, R.L. Sabine, P.K. Palisun & P.R. Tjerning. SUNY Health Science Center, Syracuse, NY 13210.**

It has been demonstrated that AMP deaminase (AMPD) activity decreases to ~15% of normal in skeletal muscle of rats fed the creatine analogue B-guanidinopropionic acid (B-GPA) (personal communication, J.O. Holloszy). We have confirmed the rapid onset (~2 wk) of reduced [ATP] and improved muscle performance (e.g., 3-fold greater sustained tension at 60 tetani/min) in adult rats fed 1% B-GPA for 3 wk. AMPD activity was determined in an apparent first order manner to ~15% of initial. However, AMP production during 5 min of intense contractions (60 tetani/min) was reduced only ~17% of baseline (~2.5 µmol/g) over the time course. There was no apparent change in transcript abundance of the AMPD mRNA coincident with the precipitous decline in AMPD activity during the first 5 wk. B-GPA remodeled muscle exhibits unique adaptations in adenine nucleotide metabolism.

Supported by: NIH grant AR12017 and the MDA (RLS).

35.8

**IMMobilIZATION DECREASES mRNA CONCENTRATION OF TYPE I AND III COLLAGENS IN RAT SKELETAL MUSCLE. T.E. Takala*. X.Y. Han*, W. Wang, P. Virtanen, and R. Mylläri*.**

T.E.S. Am J. Physiol. 252: 2065-2070.
35.10 ENHANCEMENT OF MYOFIBRILLAR PROTEIN DEGRADATION BY CALPAIN. A. A. Bankier, B. A. Neuffer, R. J. Smith, C. M. Rloor, and H. K. Hagemond. (SPON: D.J. Sanderson. Schools of Human Kinetics and Rehabilitation Medicine, U.B.C., Vancouver, B.C., Canada, V6T 1Z1)

The purpose of this study was to assess the effects of resistive loading on protein degradation rates of individual myofibrillar- complexed proteins mediated by the Ca2+-activated neutral protease (calpain). Loading of the respiratory muscles was accomplished by placing a polyelectrolyte band around the triceps (TB). Six days later, an arterial blood sample from TB showed severe respiratory acidosis and hypoxemia compared to controls (p<0.05). Myofibrillar protein yield, composition, sulphydrol group reactivity and calpain mediated degradation rates were compared. Although banding always resulted in lower yield of purified myofibrillar complexes (40 mg/ml) digested with calpain (1.5 U/ml) faster for TB animals. For example, 55% of tropomyosin was degraded in 60 minutes unliganded in 6% in TB and controls (p<0.05). Sulphydrol group reactivities for the purified myofibrillar complexes were 16.7±2 and 13±13 nmol SMH/mg, 15 min for control and TB (p<0.05). From the results of this study it may be concluded that resistive loading promotes myofibrillar protein degradation by increasing substrate selectivity to calpain, a nonlysoosomal protease of skeletal muscle, which may be linked to the endogenous metabolic state. (Supported by B.C.H.R.F. and N.S.E.R.C.)


We studied components of the β-adrenergic receptor (βAR); G-protein, adenylate cyclase (AC) and protein kinase A (PKA) transduction pathway in various skeletal muscle (VL) and soleus (SOL) from trained and untrained pigs. Partial agonists (ET) and full agonist (ET-1) were infused into the thoracic aorta of pigs. Responses to ET-1 were enhanced in SOL and partial agonists were used to study ET-1 induced responses. ETR, the ET receptor antagonist, inhibited ET-1 stimulated [Ca2+]i release in EH14 (T=4.42±0.26; C=2.67±0.42)(~<0.05), and ET-1 persisted after increasing Ca2+ concentration (p<0.05). These data suggest that ET-1 mediated ET-1 increases in [Ca2+]i in cells from TND animals after SR loading promotes myofibrillar protein degradation by increasing substrate selectivity to calpain, a nonlysoosomal protease of skeletal muscle, which may be linked to the endogenous metabolic state. (Supported by B.C.H.R.F. and N.S.E.R.C.)

35.12 CALPAIN-MEDIATED MYOFIBRILLAR PROTEIN DEGRADATION OF SIX-DAY TRACHEAL-BANDED HAMSTER DIAPHRAGM. S. Bryson, W.D. Reicli and A.N. Belcastro. (SPON: D.J. Sanderson. Schools of Human Kinetics and Rehabilitation Medicine, U.B.C., Vancouver, B.C., Canada, V6T 1Z1)

The purpose of this study was to assess the effects of resistive loading on protein degradation rates of myofibrillar complexed proteins mediated by the Ca2+-activated neutral protease (calpain). The diaphragm of skeletal muscle. In addition to binding cells to matrix integrins can also convey signals to the cells, raising the possibility that they are involved in the regulation of cell behavior. The results suggested that the integrins are expressed in the differentiating rat satellite cells in culture and (2) how type 1 collagen and laminin regulate the differentiation of the satellite cells. The percentage of mononuclear cells in myoblast cultures, which are used as a cell line and a model of cancer, was increased by northern hybridization to see if they mediate regulation by the matrix components. The immunoprecipitation experiments showed clearly that at least β1-integrins are expressed in the myoblasts. Satellite cells plated on laminin showed a markedly higher fusion index and CK activity than those on collagen. However, myoblasts had appeared earlier in cultures on collagen than on laminin, but they remained relatively small. Myoblasts formed on laminin were large, and actively contracting. Myoblasts plated on laminin did not express myogenin mRNA, whereas differentiation into myoblasts induced strong expression. Surprisingly, cells plated on collagen showed very elevated myogenin levels which did not significantly increase thereafter. These results suggest (1) that either β1-integrins or one or both of the α-integrins in rat skeletal muscle cells and (2) that extracellular matrix possibly regulates the expression of myogenin, but at a level distinct from myogenin gene expression.


The purpose of this study was to investigate whether the Calcium Activated Neutral Protease (Calpain) regulates the activity of Creatine Kinase (CK). In BK-Muscle from skeletal muscle was isolated from rabbit skeletal muscle using ion-exchange and hydrophobic chromatography. The specific activity was assayed using casein (2 mg/ml) as the optimal substrate in 10 mM DTT, 200 mM Tris and 5 mM CaCl2 and expressed the activity of the CaCl2-dependent specific activity of the enzyme. The CaCl2-dependent specific activity of the enzyme was typically between 5-6 U/mg. When the CaCl2 concentration was increased to a range of total calcium levels (50-600 mM), the CaCl2 activity was reduced by 12% from 34.1 ± 2.7 to 32.4 ± 0.8 U/mg. Incubating with calpain (2 U/ml) removed the inhibitory effect of increasing CaCl2 concentration on CK activity. Using the colorimetric assay the activities for CK after 2 U/ml CaCl2 and CK + 2.5 U/ml calpain were 43.6 ± 2.0, 16.4 ± 0.9 and 42.3 ± 0.7 U/ml, respectively. In conclusion, the specific activity of the snake-toxins (kainosin and glucose-6-phosphate dehydrogenase) UV assay method resulted in minimal (~5%) recovery. This may be due to certain activation of the enzymes. Therefore, the results suggested that CaCl2 activity in the presence of elevated calcium may be regulated by calpain. Supported by N.S.E.R.C.

35.14 EXERCISE TRAINING DECREASES CORONARY SMOOTH MUSCLE FREE CALCIUM RESPONSES TO ENDOTHELIN. P. B. Underwood, M. A. Leavitt, and Michael S. Sacko. University of Missouri, Columbia, Missouri 65211

Freehand disposed coronary smooth muscle from the left circumflex (LCX) and anterior descending (AD) coronary arteries of porcine heart. Endothelin (ET-1, 5 x 10-9 M) increased force generation (Peak TP, p<0.05), indicating training-induced arterial relaxation. In biochemical studies, endothelin resulted in a 36% increase in peak Ca2+ activity. A 50% increase in the Ca2+-dependent activity of the Na, K+-ATPase (NKA), the functional unit of the Na, K+-ATPase, was observed in trained hearts compared to controls. ET-1 induced a 36% increase in the peak Ca2+ activity of the Na, K+-ATPase. (Supported by grants from the APTA to HML, HL 40353 to MHL, and HL 41033 to A.M.1.)
35.15
THE REOXYGENATION/REPERFUSION OF HYPOXIC/ISCHEMIC SKELETAL MUSCLE INCREASES CYTOSOLIC Ca2+ UPTAKE.
D.G. Welsh*, T.W. Franklin* and M.L. Lindiger*, School of Human Biology, University of Guelph, Guelph, Ontario, Canada N1G 2W1.

This study examined cytosolic Ca2+ uptake in the isolated perfused rat hindlimb during 5 min of normoxic stimulation (stim.) 1 Hz twitch at 15°C) followed by 10 min of hypoxia (PO2 6 mmHg) and 20 min of reoxygenation (stim. PO2 120 mmHg) or in a second group; 40 min of ischemic stim. and 20 min of reperfusion stim. Hindlimbs (n=4) were prepared and perfused in flow of 1.5 L/min of blood plasma containing bovine erythrocytes, CO-EDTA as an extracellular fluid marker and CaCl2. Using the paired-tarse isotpe dilution technique, Ca2+ uptake was calculated from arterious and venous blood samples collected at 2,5,10 and 15 min intervals during the 82 min of perfusion. At rest and during 5 min of normoxic stimulation Ca2+ uptake was 2.85±1.14 and 2.4±1.02 umol/min g-1 perfused muscle (pm), respectively. Calcio with normoxia stimulation Ca2+ uptake during hypoxic stimulation did not change (4.77±2.83 to 4.16±1.95 umol/min g-1 pm). During reoxygenation/reperfusion, Ca2+ uptake increased approximately 10-fold and varied between 1.18±0.86-29.6±4.50 and 14.6±0.48 20.7±3.18 umol/min g-1 pm in the hypoxic/reoxygenation and ischemic/reperfusion model, respectively. This data supports the hypothesis that the reoxygenation/reperfusion of hypoxic/ischemic skeletal muscle alters Ca2+ homostasis and induces cytosolic Ca2+ overload. Ca2+ overload is a characteristic feature of compromised cell viability. Supported by NSERC of Canada.

35.17

Calcium uptake (Ca2+ uptake) by the sarcoplasmic reticulum(SR) is depressed after acute bouts of exercise in men or after exhaustive exercise in nonhuman animals (Goik, P. D. 1991, Byrd, S. 1989). There are no reports of this function in skeletal muscle during exhaustive exercise in women. The purpose of this study was to determine the pattern of Ca2+ uptake for moderately trained female cyclists during exercise to fatigue. Subjects were taken from a larger group of female cyclists, average age 28.0±2.9 years, weight 59.55±6.62 kg, VO2max 50.2±11.54 mml/min. The subjects were tested for VO2max and VO2recovery, and peaked VO2 values were 75% of VO2max to determine the onset of fatigue and the time schedule for muscle biopsies. Four biopsies were taken from the vastus lateralis muscle on a coodated fatigue bout: one at rest, two equally apportioned about three quarters into to the bout and one biopsy at fatigue. Twenty ± 5.0mmg muscle samples were homogenized, centrifuged and analyzed. The decrease in rate of Ca2+ uptake was expressed as a percentage change and decreased from 72.0±6.67, to 52.93±6.09, to 29.80±4.57% of resting values over an 80309.

35.18
ALTERATIONS IN SARCOPROCLASMIC RETICULUM Ca2+-ATPase ACTIVITY IN HUMAN SKELETAL MUSCLE FOLLOWING PROLONGED EXERCISE. H. Green, F. Grange*, F. Chin*, C. Goreham*, D. Rankin* and R. Xu*. Department of Kinesiology, University of Waterloo, Waterloo, Ontario, Canada, N2L 3G1.

To investigate the role of prolonged exercise on changes in skeletal muscle sarcoplastic reticulum function, 7 untrained males (VO2max =44.4±6.6 ml-kg-1-min-1, X±SE) and 7 trained males (VO2max =58.0±7.4 ml-kg-1-min-1, X±SE) were selected for study. The VO2max levels were attained by 30 min at 58% VO2max and until fatigue at 72 % VO2max. Measurements of maximal Ca2+- Mg2+-ATPase activity (total, basal) were performed spectrophotometrically at 25°C in the presence of the Ca2+ ionophore (A23187) on homogenates prepared from tissue extracted by biopsy from the vastus lateralis. Maximal Ca2+-Mg2+-ATPase activity was depressed (p<0.05) by 15.9% at 50% VO2 max (5.04±0.26 µmol.min-1.g-1) and by 30.4% (4.17±0.24) compared to pre-exercise (5.91±0.05). Basal or Mg2+ ATPase activity was not different (p>0.05) between rest (1.04±0.09) and exercise at 30 min (0.94±0.06) or fatigue (0.91±0.05).

Since basal activity was unchanged, the reduction in Ca2+-ATPase activity with exercise paralleled the reduction in total Ca2+-Mg2+-ATPase activity. It was concluded that sarcoplastic reticulum function in humans is also altered by exercise in a manner consistent with what has been found in other species. Supported by NSERC (Canada).

35.19
MITOCHONDRIAL REORGANIZATION IN DIFFERENTIATING RAT L6 MUSCLE CELLS. Parvoo Babikia*, Mariu Auin, Karelvo Maoikkii* and Kalevoo Vaaananen*.Department of anatomy, University of Oulu, Oulu SF-90014 FINLAND.

Cytochondrial (CA) are a multigene family of metalloisozyms that catalyze the interconversion of O3, and HCO3. They are found in almost all organisms, and the high activity forms are notable for their high turnover rates, explaining why their auxin efficient oxygen turnover. The mitochondria in many mammalian tissues contain an unique CA isozyme, CA V. In rat skeletal muscle CA V is located both in subsarco l& and interfibrillar mitochondria. The physiological role of CA V in muscle turnover rates, ranking them among the most efficient enzymes in all organisms, and the high activity forms are notable for their high turnover rates, explaining why their auxin efficient oxygen turnover. The mitochondria in many mammalian tissues contain an unique CA isozyme, CA V. In rat skeletal muscle CA V is located both in subsarco l& and interfibrillar mitochondria. The physiological role of CA V in muscle turnover rates, ranking them among the most efficient enzymes in.

35.20
MITOCHONDRIAL ADAPTATIONS DURING CHRONIC MUSCLE USE AND DISUSE. David A. Hood, Mark Takashashita* and Karen Wicks*, Dept. of Physical Education, York University, Toronto, Canada.

Muscles in use or disuse are in constant demand, which means that muscles must adapt to the demands placed on them. The changes in mitochondrial components during chronic muscle use and disuse were studied to understand how these changes are regulated and to understand the implications of these changes for muscle function. This study was designed to examine the effects of chronic muscle use and disuse on mitochondrial components in rats. The rats were divided into two groups: a group of rats that were exercised for 28 days (E) and a group that was not exercised (N). The effects of exercise and disuse on mitochondrial components were studied using a variety of techniques, including histochemistry, electron microscopy, and Western blotting. The results of this study showed that exercise caused an increase in the number of mitochondria in the muscle fibers, while disuse caused a decrease in the number of mitochondria. This study also showed that exercise caused an increase in the activity of mitochondrial enzymes, while disuse caused a decrease in the activity of mitochondrial enzymes. These results suggest that exercise and disuse have a significant effect on the number and activity of mitochondria in muscle fibers. Supported by NSERC, Canada.
36.1 MUSCLE-SPECIFIC LUCIFERASE EXPRESSION FROM RETROVIRAL VECTORS: TOOLS FOR GENETIC EXPRESSION REGULATION. L.-Wei Yang and Donald B. Thomson. Dept. of Physiol., Univ. of Missouri, Columbus, MO.

We have developed three retroviral constructs that carry the chicken cardiac troponin T (ctnT129) promoter to drive the expression of luciferase. The constructs also carry the neo gene driven by the SV40 promoter for selection. We found that transient expression of luciferase (CFM mg protein) is highly specific to muscle cells (2% < 0.05) when both IgG and NIH3T3 fibroblast cells were transfected with the same amount of vector without G418 selection. Given G118 (0.5 mg/ml) and awaited for the cells to be reconstituted, that difference was expanded to 25% (p < 0.05). Meanwhile we noticed when ctnT129-luciferase was in the reverse orientation from the 5'-LTR, the farther the muscle promoter, the higher the luciferase level (p < 0.05). We anticipate these vectors will be packaged as retrovirus and therefore we can introduce the luciferase gene driven by ctnT129 promoter permanently either in vitro or in vivo. By use of these vectors, studies related to the regulation of muscle gene expression are possible (Supported by NIH AR40903).


A shift in apparent polysome size accompanies the downregulation of soleus muscle protein synthesis during non-weight-bearing. We have observed that a similar shift for tetanized soleus muscle after only 5-15 h of treatment, polyomes from the soleus muscle shift toward apparently larger sizes on sucrose density gradients. The relative level of actin mRNA and 18S ribosomal subunits in each polysome band, as determined using cDNA probes, indicate the shift is a result of 0 h ribosomes per mRNA. The in vivo response mimics the in vitro response of L5 myogenic cells treated with low-levels of cycloheximide; this is consistent with the downregulation of protein synthesis through slowing of polypeptide elongation.

Furthermore, in these models there is an apparent mobilization of RNA into the polysome pool, consistent with a feedback mechanism that could be similar to the in vitro cycloheximide-triggered protooncogene super induction. Therefore, the activity-induced shift in polysome profile indicates a regulation of protein synthesis involving both translational and (post)transcriptional mechanisms. (Supported by NIH AR40901)

36.3 POTENTIATION OF IN VITRO CONCENTRIC AND ECCENTRIC WORK WITH MYOSIN LIGHT CHAIN PHOSPHORYLATION. M.E. Houston* and W.R. Grana* (SPON: A.Bonen). Department of Kinesiology, University of Waterloo, Waterloo, Ontario, CANADA.

Myosin light chain phosphorylation, a molecular mechanism temporally related to isometric twitch potentiation, was examined with respect to concentric (CW) and eccentric work (EW) potentiation using in vitro mouse extensor digitorum longus muscles at 25°C. Muscles were isometrically contractile about by a computer generated sine wave (7 Hz; 1.2 mm excursion) driving a Cambridge 300H servo arm. Contractions were induced by twitch-stimulation of optimal voltage. CW was evoked at 8 different phases between the maximum muscle length (Lmax) and LO (one stimulation per sine cycle). EW was induced at LO during muscle lengthening. Both CW and EW were determined under non-phosphorylated (NP) and phosphorylated (P) (induced by a 20 x 6 Hz train) conditions. In the NP state, CW was greatest at a phase just prior to Lmax (1.2 ± 0.1 ± 0.1) while EW was about 300% greater than this value. For the P versus NP states across all phases, CW was significantly potentiated (4 ± 5% vs = 0.01) however, EW was significantly potentiated only 3 ± 0 ± 0, in contrast, isometric twitch potentiation under the same conditions is typically only 15-20% at 25°C (Moore et al. 1990). CW but not EW potentiation was greater than isometric twitch potentiation. EW was greater than CW (p < 0.01) in both the NP and P states, likely due to stretching of elastic elements. The smaller CW potentiation may be due to altered rate and extent of interactions during muscle lengthening. Supported by NSERC Canada.

36.4 VARIATION IN THE EXPRESSION OF CITRATE SYNTHASE mRNA IN HUMAN SKELETAL MUSCLE. J.A. Simoneau, Y. Génin, R. Theriault*, G. Theriault, and F.T. Dionne*. Physical Activity Sciences Laboratory, Laval University, Ste-Foy, Québec, Canada. G1K 7P4.

The purpose of this study was to verify the cellular and molecular expression levels of citrate synthase (CS) in human skeletal muscle. Measurements of CS enzyme activity and of the CS mRNA content were performed in vastus lateralis muscle samples obtained from 20 physically active (PA) subjects, and from 24 sedentary (S) subjects before and after their knee extensor muscles were submitted to 6 weeks of low-frequency electrical stimulation (LFES). LFES was delivered at 6 Hz, 3 hr/day, 6 days/week, with the use of a portable stimulator and adhesive electrodes (Neupar II and Pals Plus, Medtronic). More than a two-fold difference was observed in muscle CS activity as well as in CS mRNA content between PA subjects. The level of CA activity was significantly related to the CS mRNA content (r=0.5; p<0.01). The only group reported that LFES induced significant increases in muscle CS activity (22%; F=23.5 p<0.001) and in CS mRNA content (18%; F=5.6 p<0.05), and these changes were similar in magnitude. Therefore, results of the present study indicate that variation in the CS mRNA content appears to be largely responsible for the cellular expression level of the human skeletal muscle CS enzyme activity. Supported by FRSQ, FCAR, Medtronic of Canada, & NSERC of Canada.

36.5 CONTINUOUS MOTOR NERVE STIMULATION RAPIDLY INDUCES EXPRESSION OF THE RNA SUBUNIT OF A MITOCHONDRIAL DNA PROCESSING ENZYME. George A. Ordway, Gregory A. Hand*, Kana Li* and R. Sanders Williams. UT Southwestern Medical Center, Dallas, TX 75235.

Continuous motor nerve stimulation is a potent stimulus to mitochondrial biogenesis, which is accomplished by an increased DNA copy number. We have shown previously that this same stimulus markedly increases expression of the RNA subunit of an enzyme implicated in mitochondrial DNA replication, mitochondrial DNA processing (MRP) enzyme. To determine the time course of this increased expression of MRP- RNA we live to the induction of a mitochondrial respiratory enzyme, we electrically stimulated tibialis anterior muscles of rabbits for 21 days. Northern analysis showed MRP- RNA expression was increased after only 1 day of stimulation. Longer periods of stimulation further increased the abundance of MRP- RNA, which subsequently remained at levels approximately 20 fold greater than those seen in contralateral unstimulated muscles. By contrast, citrate synthase enzyme activity was not increased until 7 days of stimulation, after which activity increased 2.5-3.5 fold. These results demonstrate an important temporal relationship that further supports the potential regulatory role of MRP in mitochondrial RNA replication, and therefore oxidative phosphorylation, in skeletal muscle.

36.6 EVIDENCE THAT CARDIAC NA/CA EXCHANGER CONTENT MAY BE ALTERED WITH SENESCENCE AND EXERCISE TRAINING OF OLD RATS. Michael Hyak*, Calvin Hale, and Charlotte Tals. Dept. of Pharmacol., Univ. of Houston, TX; Dept. of Physiol., Univ. of Mimioli, Columbus, MO.

Other investigators reported a lower activity of the cardiac Na/CA exchanger in senescantimal vessels isolated from old rats compared to the hypothesis that the content of the cardiac Na/CA exchanger is lower in sedentary old rats and that exercise training results in an increased content of the exchanger. 24 mo. old Fischer 144 rats were divided into two groups, sedentary-old (SO) and exercised-old (EO), and were compared to 12 mo. old sedentary rats (SA). The content of the exchanger was estimated by immunoblotting techniques using the homogenate, and the Ru rats for up to a hour/day, 5 days/week, for 10 weeks. Preliminary data suggest that the immunoactive Na/CA exchanger content was 40-50% lower (p<0.01) in the EO group compared to SA and EO groups. The data imply that a decreased content of the exchanger may be associated with aging and that exercise training may upregulate the protein. (Supported by NIH AR6221.)

The purpose of this study was to investigate cardiovascular responses during qigong (Shao Lin Nui Jin Yi Zhi Chan) which is one of the methods in Chinese qigong. One male superior qigong instructor participated as a subject. Heart rates during primary grade static qigong were 121 bpm in average and 137 bpm at maximum. During spontaneous dynamic qigong heart rates were 94 bpm in average and 101 bpm at maximum. It was observed that the finger movement style qigong contributed to the increase in heart rate and oxygen intake. Heart rate related to the oxygen intake tended to be higher during qigong than walking and running. The results of the present study suggested that the qigong subjected in the study has some influences to the autonomic nervous system even if the movement of qigong was not dynamic as walking and running.

CEILINGS ON ENERGY EXPENDITURE DURING LACTATION. Kimberlv SATURDAY INTEGRATED SYSTRMS 217

Exercise against the footward force produced by lower body negative pressure. (Supported by NASA Grant 199-14-12-04)

LOW FREQUENCY SOUND DURING EXERCISE TESTING: IMPACT UPON AUGUSTATORY BLOOD PRESSURE MEASUREMENTS. J.T. Lightfoot and T.S. McGee, Florida Atlantic University, Boca Raton, FL 33431

MECHANICAL EFFICIENCY IN WOMEN WITH DIFFERENT BODY FAT DISTRIBUTION PATTERNS. P.D. Swan, Univ. of Colorado, Boulder, CO, 80309 and E.T. Howley, Univ. of Tennessee, Knoxville, TN 37916

It has been hypothesized that body fat distribution affects energy expenditure (mechanical efficiency) during exercise. To test this hypothesis pre-menopausal obese (% Fat > 30%) women, characterized by waist to hip (WHR) ratios into upper body (UP; WHR 0.85) and lower body (LB; WHR < 0.75) groups (N = 10 each), volunteered to participate. Subjects completed four 6-minute steady state tests for work supported (cycle) and weight carrying (treadmill) exercise, with gas exchange measured at 4-minute intervals in each test. Fatigue scores on both the cycle and treadmill were closely correlated. Mechanical efficiency (ME) values were based on the ratio of work accomplished to energy expended. Gross and net efficiency were not different between groups for either mode of exercise (i.e., cycling gross ME range 17-20% & walking gross ME range = 10-19%). In conclusion, we have no support for the notion that exercise is less useful for LB obese subjects in a weight reduction program. Obese women with different body fat patterns have similar potentials for energy expenditure during exercise.
ARM STRENGTH IS A DETERMINING FACTOR IN ROWING EXERCISE. R.L. Jensen and C. F. Fromme. Dept. KHPR, Univ. of North Texas, Denton, TX 76203

The relationship between oxygen uptake, power output (PO), and maximal blood lactate (MBL) during rowing and measuring of arm and leg strength was investigated in active, but untrained subjects (n=12). Arm flexion strength (ARM) and leg extension strength (LEG) were the peak torque of five reps measured with a Hydra-Fitness Ommitron. Combined strength (COMB) was the sum of arm and leg strength. Peak oxygen uptake, expressed in absolute (ABS) and relative to body mass values (REL), PO, and MBL were obtained during rowing exercise on a Concept II ergometer. Stepwise regression using a bootstrap analysis of 20 random samples (ten subjects per subject selected from the total group of 12) indicated that ARM predicted MBL (R=0.29 to 0.75), REL (R=0.60 to 0.83), and PO (R=0.65 to 0.88). Prediction of ARM was possible using COMB (R=0.61 to 0.79). In conclusion, data from the current study indicate that strength, in particular arm strength, is an important factor in the attainment of peak oxygen uptake, blood lactate, and power output during maximal rowing exercise.

Supported in part by a UNT Research Initiation Grant
44.5 APPROACHES TO VENTRICULAR EJECTION FRACTION AT REST AND EXERCISE WITHOUT CARDIAC RADIOGRAPHY. Richard P. Spencer, John A. Vento.* Univ. Connecticut Health Center, Farmington, CT 06030 & VA Medical Center, Newington, CT.

Radiouclide determination of cardiac ejection fraction (EF) is usually accomplished by means of labelled red blood cells (RBC) and gated RBC acquisition. Since the majority of cardiac studies in Nuclear Medicine now utilize myocardial-avid agents, rather than the labelled RBC, the examined use of the heart wall agents for EF measurements.

1) As the radioactive bolus traverses the ventricles, the "true" EF can be employed if the RBC count may introduce "dead time" errors. 2) The EF can be calculated from end systolic and end diastole images, making a reasonable assumption about the geometry of the ventricular cavity (as an ellipsoid of revolution). This is a variation of the classical radiographic approach. 3) We attempted to utilize: Cardiac volume (total) - wall area + blood pool, by examining the actual borders of the heart; however, this encountered multiple problems likely related to: uneven contractility of the muscle as well as spatial resolution. The topic however was measured by use of myocardial-avid agents with first pass or geometric techniques, but in depth analysis is required concerning volume changes as measured by alterations in external cardiac size.

44.6 SPLENIC RESPONSE TO MEDICATIONS: COULD THIS BE AN "EXERCISE EQUIVALENT?" John A. Vento*, Richard P. Spencer, Fern Hodain, University of Connecticut Health Center, Farmington, CT 06030 and V.A. Medical Center, Newington, CT 06111.


The threshold for anaerobic metabolism occurs during the activities required to exercise a given amount of energy. An analogy might be the response of a tumor to either chemotherapy or radiation, hence, calculation of an "exercise equivalent" appears feasible for the spleen, via utilization of radionabeled RBC. The method might be extended to other internal organs as well.

44.7 RESPIRATORY-SYNCHRONOUS FLUCTUATIONS IN VASCULAR RESISTANCE DURING EXERCISE BY USE OF MYOCARDIAL RADIOTRACERS. Richard P. Spencer, John A. Vento, Diana L. Gullestad*, Ole M. Seiersted, Jostein Halv˚en* and Lars Håvard, National Inst. of Occupational Health, N-0378 Oslo, Norway.

The contribution of &-adrenergic stimulation to vasodilatation in muscle ischemia during exercise is not known. We used &-adrenergic blockers to examine the effect of p-adrenergic stimulation to vasodilate in muscle ischemia during exercise.

44.8 VARIABLE BALANCE BETWEEN A- AND &-ADRENERGIC EFFECTS ON LOCAL VASCULAR RESISTANCE IN WORKING MUSCLE IN MAN. Olaf M. Seiersted, Gjøril Halden* and Lars Håvard, National Inst. of Occupational Health, N-0378 Oslo, Norway.

The contribution of &-adrenergic stimulation to vasodilation in muscle ischemia during exercise is not known. We used &-adrenergic blockers to examine the effect of p-adrenergic stimulation to vasodilate in muscle ischemia during exercise.

44.10 APPLICATION OF VENOUS OCCLUSION PLETHYSMOGRAPHY TO THE THIGH. D. Proctor, D. Bredle, J. Roemmich, W. Sinner.
5.5 EFFECTS OF ACUTE AND CHRONIC ACTIVITY ON MICROCIRCULATION IN SKELETAL MUSCLE. D. B. Richards. Department of Pharmacology, University of Birmingham, B15 2TT, UK...
6.1 COMPARATIVE ELECTROPHYSIOLOGICAL EFFECTS OF A NEW CHEMICAL CLASS OF ANTI-ARRHYTHMIC AGENTS, 3,7-DIHERETOBICYCLONANES, IN THE 1-4 DAY-OLD INFARCTED DOG HEART. I. Pagidas, P. Malo, K.D. Berlin*. B.J. Scherlag and R. Lazzara. VA Medical Center/University of Oklahoma Health Sciences Center. Oklahoma City, OK 73104; *Oklahoma State University. [46.1]


A case study is presented comparing continuous heart rate (HR) tracings during two successive World Cup Duathlons (Run 5K, Cycle 30K, Run 5K) with a dual VO2max test (telemetry immediately followed by a VO2max). The study was undertaken to investigate the use of a heart rate monitor as an objective performance tool in comparing competitive results. The studied subject (male, age 28, 181.92, 79.75 kg) was entered in the initial competition (WC-Vanc) with three challenges, a 2-week taper period, then a 3-week period. HR and %VO2max during the initial competition were compared with VO2max (source). The study was Omega Polar Vantage X-L monitor, compared with laboratory data offers new insight into the exercise intensity and efficiency of an elite multisport athlete. Further work needs to be done to establish the relative contributions of environmental stressors, state of performance training, and perceived race intensity upon variance in race to race continuous HR tracings. The study was funded by the MSA/SPORT and URC Sports Medicine Laboratory.


To determine the cardiovascular response of patients with heart transplant (HT) and heart failure (HF) during submaximal dynamic arm exercise, 13 males with HT (age=52+2, mean+SE) and 14 males with HF (age=52+3, mean+SE) were compared. Subjects exercised at 50% and then 75% of a previously determined maximum. HR (bpm), VO2 (ml/kg/min), and apparent increased sympathetic drive.

6.4 EFFECTS OF MENSTRUAL CYCLE AND EXERCISE ON THE FRONTAL DIMENSION OF HEART RATE WOMEN. James Watrous and Mary Nguyen*. Biology Department St. Joseph’s Univ. Phila. PA. 19111.

R-EKG tracings were obtained from college-age women during three phases of the menstrual cycle (proliferation, ovulation, menses) and post exercise. The method of Glenny et al. (1991) was used to determine the fractal dimension (FD) of heart rates. Exercised subjects had their EKG recorded for 90 sec following 3 min of light exercise on a stationary bicycle. EKG recordings were obtained for 90 sec after exercise. The method of Glenny et al. (1991) was used to determine the fractal dimension (FD) of heart rates. Exercised subjects had their EKG recorded for 90 sec following 3 min of light exercise on a stationary bicycle. EKG recordings were obtained for 90 sec after exercise. The method of Glenny et al. (1991) was used to determine the fractal dimension (FD) of heart rates. Exercised subjects had their EKG recorded for 90 sec following 3 min of light exercise on a stationary bicycle. EKG recordings were obtained for 90 sec after exercise. The method of Glenny et al. (1991) was used to determine the fractal dimension (FD) of heart rates. Exercised subjects had their EKG recorded for 90 sec following 3 min of light exercise on a stationary bicycle. EKG recordings were obtained for 90 sec after exercise. The method of Glenny et al. (1991) was used to determine the fractal dimension (FD) of heart rates. Exercised subjects had their EKG recorded for 90 sec following 3 min of light exercise on a stationary bicycle. EKG recordings were obtained for 90 sec after exercise. The method of Glenny et al. (1991) was used to determine the fractal dimension (FD) of heart rates. Exercised subjects had their EKG recorded for 90 sec following 3 min of light exercise on a stationary bicycle. EKG recordings were obtained for 90 sec after exercise. The method of Glenny et al. (1991) was used to determine the fractal dimension (FD) of heart rates. Exercised subjects had their EKG recorded for 90 sec following 3 min of light exercise on a stationary bicycle. EKG recordings were obtained for 90 sec after exercise. The method of Glenny et al. (1991) was used to determine the fractal dimension (FD) of heart rates. Exercised subjects had their EKG recorded for 90 sec following 3 min of light exercise on a stationary bicycle. EKG recordings were obtained for 90 sec after exercise. The method of Glenny et al. (1991) was used to determine the fractal dimension (FD) of heart rates. Exercised subjects had their EKG recorded for 90 sec following 3 min of light exercise on a stationary bicycle. EKG recordings were obtained for 90 sec after exercise. The method of Glenny et al. (1991) was used to determine the fractal dimension (FD) of heart rates. Exercised subjects had their EKG recorded for 90 sec following 3 min of light exercise on a stationary bicycle. EKG recordings were obtained for 90 sec after exercise.


Handgrip exercise was used to measure end-diatolic and systolic volumes (ESV and EDV) and coronary flow (CF) during maximal exercise and recovery. Echocardiography was used to measure the left ventricular stroke volume (SV). SV was averaged vs the relative dispersion (SD/mean). Linear regression was used to determine the correlation coefficient (r).

6.6 CORONARY AND MYOCARDIAL FUNCTIONAL DEPENDENCE ON PERFUSATE DISSOLVED OXYGEN. Howard W. Millard, Anthony J. McGown and Linda L. Gruppo, University of Cincinnati, Cincinnati, OH 45267-0575.

A case study is presented comparing continuous heart rate (HR) tracings during two successive World Cup Duathlons (Run 5K, Cycle 30K, Run 5K) with a dual VO2max test (telemetry immediately followed by a VO2max). The study was undertaken to investigate the use of a heart rate monitor as an objective performance tool in comparing competitive results. The studied subject (male, age 28, 181.92, 79.75 kg) was entered in the initial competition (WC-Vanc) with three challenges, a 2-week taper period, then a 3-week period. HR and %VO2max during the initial competition were compared with VO2max (source). The study was Omega Polar Vantage X-L monitor, compared with laboratory data offers new insight into the exercise intensity and efficiency of an elite multisport athlete. Further work needs to be done to establish the relative contributions of environmental stressors, state of performance training, and perceived race intensity upon variance in race to race continuous HR tracings. The study was funded by the MSA/SPORT and URC Sports Medicine Laboratory.

6.6.1 H-modio echocardiography was used to measure end-diastolic and systolic volumes (ESV and EDV), end-systolic ventricular volume (ESV), and coronary flow (CF) during maximal exercise and recovery. Echocardiography was used to measure the left ventricular stroke volume (SV). SV was averaged vs the relative dispersion (SD/mean). Linear regression was used to determine the correlation coefficient (r).


H-modio echocardiography was used to measure end-diastolic and systolic volumes (ESV and EDV), end-systolic ventricular volume (ESV), and coronary flow (CF) during maximal exercise and recovery. Echocardiography was used to measure the left ventricular stroke volume (SV). SV was averaged vs the relative dispersion (SD/mean). Linear regression was used to determine the correlation coefficient (r).

6.6.3 Changes in left ventricular volumes during two minutes of maximal handgrip exercise and post-exercise occlusion. Denise L. Smith, James E. W. Hinsel, Eddie Mevalson, Tim Patrick. Skidmore College, Saratoga Springs, NY. 12861.

H-modio echocardiography was used to measure end-diastolic and systolic volumes (ESV and EDV), end-systolic ventricular volume (ESV), and coronary flow (CF) during maximal exercise and recovery. Echocardiography was used to measure the left ventricular stroke volume (SV). SV was averaged vs the relative dispersion (SD/mean). Linear regression was used to determine the correlation coefficient (r).


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H-modio echocardiography was used to measure end-diastolic and systolic volumes (ESV and EDV), end-systolic ventricular volume (ESV), and coronary flow (CF) during maximal exercise and recovery. Echocardiography was used to measure the left ventricular stroke volume (SV). SV was averaged vs the relative dispersion (SD/mean). Linear regression was used to determine the correlation coefficient (r).


H-modio echocardiography was used to measure end-diastolic and systolic volumes (ESV and EDV), end-systolic ventricular volume (ESV), and coronary flow (CF) during maximal exercise and recovery. Echocardiography was used to measure the left ventricular stroke volume (SV). SV was averaged vs the relative dispersion (SD/mean). Linear regression was used to determine the correlation coefficient (r).
A long standing question in exercise physiology concerns the relative balance of parasympathetic and sympathetic nervous system (PNS and SNS) activity in the heart rate control of endurance trained and untrained subjects. We have used coarse graining spectral analysis of heart rate variability (HRV) to estimate PNS and SNS indicators in two groups of subjects with different fitness levels: Group A had VO\(_2\max\) of 47 to 62 ml/kg/min, and Group B had 30 to 42 ml/kg/min. Measurements were made at rest and at 30, 60, and 110% ventilatory threshold (V\(_{110}\)). The PNS indicator was higher in Group A at rest and at both levels of exercise. In contrast, the SNS indicator was higher at all times in the less fit Group D. Due to individual variations and relatively small sample sizes (n=6 per group), statistical significance was observed only at 60% \(V_{110}\) for the PNS indicator. These data obtained by simple, non-invasive methods are in agreement with early pharmacological studies of PNS and SNS control of HR, as well as a recent spectral analysis study of HRV. The data raise some interesting questions about potential contributions to HRV and suggest that the balance of parasympathetic and sympathetic activities may be important in determining heart rate control in fitter individuals.

Supported by Heart and Stroke Foundation of Ontario.

**NONINVASIVE MEASUREMENT OF CARDIAC OUTPUT WITH IMPEDANCE CARDIOGRAPHY DURING EXERCISE.**

R.W. Gotshall, Colorado State Univ., Fort Collins, CO 80523

Measurement of CO in humans expands the capability to evaluate and interpret cardiovascular function during exercise. Impedance cardiography (ICG) has been applied to the noninvasive measurement of CO during exercise with varying success. Artifact in the signal makes the interpretation of the impedance cardiogram difficult. This study evaluated the use of a computer program designed to reduce artifacts in the impedance signal, to permit more reliable determination of CO for 5 subjects exercised to maximum on the bicycle ergometer using an incremental protocol, and 4 subjects exercised to 60% \(V_{110}\) VO\(_2\) max, similar to the relationship described by Jones (1988) for similar populations: CO=5.37 + 5.08VO\(_2\), The intercepts differ, but the slopes are the same. For steady state exercise, CO was stable during the steady state exercise. These results indicate that the changes in CO can be described during exercise by the use of IC when exercise signal artifacts are reduced.

**METABOLIC ADAPTATIONS OF THE RAT HEART TO CHRONICAL VOLUME-OVERLOAD.**


Chronic volume overload was induced in young rats by surgically opening of the aorta cava fistula. The animals were used for 3 months later and their hearts perfused in vitro with l-arginine and 100 mM lysine and 1 mm creatinine. The measurements of Na\(^+\) and K\(^+\) and the reperfusion period (p<0.05) vs. control: 0.68+0.13 vs 0.34+0.11 mmol/kg/min). No significant difference was seen in left ventricular systolic pressure, end diastolic pressure, heart rate, aortic flow, coronary flow, cardiac output, +pdp/dt, -pdp/dt. These data indicate that the myocardial deformability of overloaded hearts is preserved and that the myocardial contractility is not significantly affected by volume overload, even though the heart rate is increased to an acute failure. The administration of propionyl-l-carnitine partly restored tissue levels of CP and significantly increased myocardial glucose oxidation rate but does not adversely affect cardiac function. This is reflected by a significant rise to an acute failure. The administration of propionyl-l-carnitine partly restored tissue levels of CP and significantly increased myocardial glucose oxidation rate but does not adversely affect cardiac function. This is reflected by a significant rise to an acute failure. The administration of propionyl-l-carnitine partly restored tissue levels of CP and significantly increased myocardial glucose oxidation rate but does not adversely affect cardiac function. This is reflected by a significant rise to an acute failure. The administration of propionyl-l-carnitine partly restored tissue levels of CP and significantly increased myocardial glucose oxidation rate but does not adversely affect cardiac function. This is reflected by a significant rise to an acute failure. The administration of propionyl-l-carnitine partly restored tissue levels of CP and significantly increased myocardial glucose oxidation rate but does not adversely affect cardiac function.

We analyzed resting echocardiograms, 12-lead ECGs, and blood samples on 21 male marathon runners before and after their training distances were abruptly raised by an average of 53 km/wk (99%). Following 15 of the higher mileage, 12 runners (EH group) had elevated (>10 b/min) heart rates in the seated position; their mean HR increased from 54 to 60 b/min (p<0.05). Mean HR was unchanged (52 to 52 b/min) in the other 9 runners (UHR group). Age, physical characteristics, marathon times, training pace, and serum markers of muscular damage were similar between the two groups. Blood glucose levels on Blood pressure (SBP) decreased from 130 to 121 mm Hg in EHR and from 129 to 120 mm Hg in UHR (p<0.05 for both groups). Left ventricular (LV) internal diameters at end-systole and end-diastole (LVIDd), stroke dimension, parietal and septal wall thickness, ejection fraction, and the rate of SBP/LVd increased not significantly different between the groups and were not significantly changed for either group. In EHR, the rate of the cardiac cycle was decreased further (from 1.05 to 1.54 cycles/min) (p<0.05) and from 1.05 to 1.54 cycles/min) (p<0.05) and from 1.05 to 1.54 cycles/min) (p<0.05). Elevated resting HR after unaccustomed high training miles is associated with increased LV contractility, unchanged stroke performance, and increased R-wave voltage and serum K+ levels.

**CARNITINE OIPIOIDS: EFFECTS OF VENTRICULAR DENERVATION.**


Our data clearly indicates that enkephalins originate in cardiomyocytes. Frozen tissue sections were incubated with an antibody to Met-enkephalin-arg-phe (ME-AP) and a fluorescent-labeled second antibody. ME-AP is the carboxyl terminal peptide of proenkephalin and the antibody crossreacts with peptide B and proenkephalin. The presence of enkephalin is observed in the longitudinal axis of the myocyte, concentrated around the intercalated disc, suggesting an opioid function in communication between cells. This also suggests a secretory mechanism which utilizes the intercalated disc to export peptides. The fluorescence was absent from sections incubated with an antibody preabsorbed with ME-AP. Proenkephalin content measured with the same antibody is more than 6 times greater in the ventricle than the atria (120 vs 24 fmol/mg protein). However, ME immunoreactivity (ir) is uniformly distributed throughout the myocardium (2.5 fmol/mg protein). ME-ir is much lower in the atria than in the ventricle and is not concentrated in the atria and further supports the localization of enkephalins in the myocardium as well as in cardiac nerves.

Enkephalins were significantly decreased in sham-operated and tissue collected 4 weeks later. Denvation produced the expected decrease in ventricular enkephalin content and also decreased atrial neuropeptide content. Proenkephalin-ir was unchanged in all hearts. However, the content of the atria, which are more concentrated in the atria and further supports the localization of enkephalins in the myocardium as well as in cardiac nerves.

Supported by American Heart Assoc. TX 91A-165 and NIH HL 29232.
overnight cannulated animals held at 0-2°C, post-branchial blood samples from tuna and perfused tuna hearts; values up to 250 bpm are reported for mammalian hearts. Heart rates are around 100 bpm in spinalectomized rats. Heart rates are dependent on their physiological levels - without perfusing the coronary circulation. This indicates that like mammals, the cardiac SR plays a role in the regulation of heart rate. Changes in calcium release with ryanodine (a blocker of sarcoplasmic reticulum calcium release) by 30% with ryanodine (a blocker of sarcoplasmic reticulum calcium release). Changes in membrane potentials and sarcoplasmic reticulum calcium content may contribute to the intensity of training-induced bradycardia and the pattern of myocardial responses seen during exercise.


47.3 TUNA HEARTS DO IT DIFFERENTLY! A.P. Farrell, J.E. Keen, P.S. Davis1, C.E. Franklin, J.A. Johannesen and R.W. Brilli; Simon Fraser University, Canada. (1 Massey Univ., New Zealand & 2 Kewalo Basin, Hawaii).


The results are summarized as follows: 1) the rest bradycardia was greater in F than in M; 2) during the first 10 s of exercise, the increment of the fast response of the HR (vagus dependent) was unrelated to the applied power for both sexes; 3) during low power (25 W), during the stabilization of HR (after 2 min.), F showed greater magnitude of tachycardia than M; and 4) at 50 W (F) and 100 W (M), it was observed the appearance of a slow (sympathetic dependent) increase in HR (M -1 min). So, F compared to M, present at the same power, a lower vagal response and a higher sympathetic stimulation, as a mechanism for neurogenic HR drinking. RESEARCH SUPPORT: FIX and FAPESP.

47.1 CHANGES IN BLOOD CHEMISTRY OF ANTARCTIC TUNA IN RESPONSE TO EXERCISE. A.P. Farrell. J.E. Keen. P.S. Davis1, C.E. Franklin, J.A. Johannesen and R.W. Brilli; Simon Fraser University, Canada. (1 Massey Univ., New Zealand & 2 Kewalo Basin, Hawaii).

Tuna hearts have the highest cardiac and myocardial power outputs of any fish. Recent work demonstrates that heart rate, E-C coupling and reliance on a coronary circulation is more akin to mammalian hearts. Tuna hearts are around 100 bpm in spinalectomized rats and perfused tuna hearts; values up to 250 bpm are reported during swimming. Heart rates in other fishes are lower than 120 bpm. Furthermore, this 2-3 fold range for increasing heart rate in tuna is larger than in other fishes, raising the possibility that tuna hearts, like mammalian hearts, are primarily frequency-modulated. Other fishes are volume-modulated. Force generation in tuna atrial strips is reduced by 30% withryanodine (a blocker of sarcoplasmic reticulum calcium release). This indicates that like mammals, the cardiac SR plays a significant role in E-C coupling. In contrast, contractile force in other fishes may be less strongly modulated by changes in calcium release. The 1-2 mmHg difference in peak systolic pressure between rainbow trout, perfused at a lower heart rate, and at peak swimming speeds in tuna has been attributed to differences in the expression of the sodium channel protein, the expression of which is dependent on their coronary circulation.

Emperor penguins were swum in a 1 m x 4 m x 20 m long water tank. Water flow and temperature were set at 1 m/s and 3°C, respectively. Higher swim rate was induced by changing weights on a line attached through a series of pulleys to the dorsal feathers of the immersed bird. As much as 3 kg of weight was loaded in this way which was estimated to be equivalent to the effort required to swim at 6 m/s. Resting W0 (supported by Science Council of British Columbia)
47.5
ASSESSING THE PHYSIOLOGICAL LIMITS OF EXERCISE PERFORMANCE IN BOTTLENOSE DOLPHINS. Terrill M., William A. Laidlaw, J. A Winter, and Jeffrey P. Baum.
NOOSC Hawaiian Lab, Kailua, HI 96734
Swimming speed and duration of submergence are correlated with the balance between oxygen uptake and the energetic demands of exercise in marine mammals.

To determine the physiological responses associated with aquatic performance in these animals, we examined the relationship among aerobic and anaerobic costs of exercise, oxygen stores, and level of effort in swimming and diving bottlenose dolphins (Tursiops truncatus). Many of the dynamic metabolic scope and level of maximal oxygen consumption (V\text{O}_2\text{max}) for each animal was determined based on the animal's size and age. Oxygen consumption ranged from 19.8 to 29.4 ml kg\textsuperscript{-1} h\textsuperscript{-1} (7 - 11 times V\text{O}_2\text{rest}) for 145 kg dolphins. Oxygen stores were 33 ml kg\textsuperscript{-1} body weight and were an important avenue of metabolic support during diving and swimming at routine speeds (2 - 3 m s\textsuperscript{-1}). Because these stores are often overlooked during consideration of exercise fatigue, these methods for evaluating physiological responses to exercise should be considered for marine mammals.

47.6
GLUCOSE AND LACTATE METABOLISM IN SKELETAL MUSCLE OF LARVAL SALAMANDERS (Ambystoma tigrinum, Steven J. Wickler, and Christie N. Rice-Warne. California State University, Pomona, CA 91768 and Univ. of Colorado, Boulder, CO 80309
Vigorous exercise in vertebrates entails lactate accumulation. Studies on salamanders indicate that the mass-specific lactate production rate and the lactate levels among aerobic and anaerobic tissues of exercise salamanders are similar to those of terrestrial animals. The lactate levels in the tail of Ambystoma tigrinum following exercise are similar to those of terrestrial animals, and the lactate production rate is similar to that of terrestrial animals. The lactate levels in the tail of Ambystoma tigrinum following exercise are similar to those of terrestrial animals, and the lactate production rate is similar to that of terrestrial animals.

47.7
REGULATION OF GLYCOGEN REPLENISHMENT IN POST-EXERCISE SKELETAL MUSCLE OF A LIZARD. Todd Glisson
Pomona, CA 91768 and Univ. of Colorado, Boulder, CO 80309-0334
Reptilian skeletal muscle exhibits an enhanced glyconeogenic capacity. Glycogenogenes appears to be the primary pathway for glycogen resynthesis as well as for lactate reuptake. Lactate can be incorporated into glycogen in skeletal muscle by 2 - 5 times the rate at which glucose carbon is incorporated. In vivo, only a small fraction of the post-exercise lactate pool is oxidized. These characteristics are very different than those of red or white mammalian muscle. Post-exercise glycogen resynthesis is impaired primarily by glucose, is depressed by corticosterone and epinephrine, and is enhanced by acetoacetic and by insulin (Bonen et al., JPC 146: 1899).

In this study, we examined the ability of reptilian glycogen resynthesis to be stimulated to fatigue and then incubated in a medium of pH 7.2 containing glucose (1 mM) and bicarbonate (15 mM) to mimic the post-exercise milieu. Evolved CO\textsubscript{2} was trapped and counted. After one hour of incubation, muscles were removed for histochemical and ultrastructural analysis. Data indicate that several of the mammalian glycogen resynthesis have no effect on reptilian muscle, while Epinephrine can stimulate lactate uptake and quantitatively ultrastructure of the rattlesnake tail-shaker muscles.

47.8

Vertebrate skeletal muscle is composed of a mosaic of muscle types differing in their speed of contractile activity, energy and oxygen requirements and fatigability, characteristics that were once considered genetically fixed properties of mammalian muscle. Salmons and Vrobova developed the technique of chronic electrical tetanus to simulate fast muscles in the rat and rabbit; these experiments demonstrated shifts in metabolic and contractile properties solely in response to the type of nervous input received by the muscle. In this study we tested the hypothesis that reptilian muscle responds with the same degree of plasticity as mammalian muscle, despite the lack of a cardiovascular system that can satisfy a large aerobic demand. (NIH RO1HL41986: AHA, Filman Foundation Fellowship)

47.9
STRUCTURE-FUNCTION COUPLING IN THE FASTEST-CONTRACTING VERTEBRATE MUSCLE: THE REPTILE'S TAIL-SHAKER MUSCLE. P. Schaeffer and S.L. Lindstedt, Northern Arizona University, Flagstaff, AZ 86004.

The Western Diamondback Rattlesnake (Crotalus atrox) uses its tail continuously for up to an hour. Rattling frequencies first studied by Kahn 40 years ago: approach 9 "hiss", double the frequency of hummingbird and even most insects. Muscle histology showed that the enzymatic and functional changes were similar to those in other vertebrate muscle. Because the tail muscles were apparently the only muscles active during rattling, we were able to determine the intrinsic oxygen uptake of this group of muscles in standard rodent cages (20x26x14 cm) for four weeks. We studied KM during August, 1991 and HV during September, 1991. We measured masses of 145 kg dolphins. Oxygen stores were 33 ml kg\textsuperscript{-1} body weight and were an important avenue of metabolic support during diving and swimming at routine speeds (2 - 3 m s\textsuperscript{-1}). Because these stores are often overlooked during consideration of exercise fatigue, these methods for evaluating physiological responses to exercise should be considered for marine mammals.

47.10
A COMPARISON OF NORMOTHERMIC DISUSE ATROPHY IN DIFFERENT SUBSPECIES OF A HIBERNATOR IN DIFFERENT MONTHS. Donald F. Hocket, Steven J. Wickler, and Christie N. Rice-Warne. California State Polytechnic University, Pomona, CA 91768

During hibernation, locomotory muscles of golden-mantled ground squirrels (Spermophilus lateralis) do not exhibit the atrophy characteristic of normothermic (i.e. non-hibernating) rats. In the present study we examined the response to decreased activity in normothermic S. lateralis during the hibernation cycle of this species. Follow-up studies planned for the summer 1992 will test the hypothesis that reptilian muscle responds with the same degree of plasticity as mammalian muscle, despite the lack of a cardiovascular system that can satisfy a large aerobic demand. (NIH RO1HL41986: AHA, Filman Foundation Fellowship)
ALLOMETRY OF AEROBIC METABOLISM IN RODENTS: MINIMAL, MAXIMAL AND SCOPE. J. E. P. W. Bicudo, J. H. Jones, A. Jackson and D. Winstone. Department of Physiology, University of California, Davis, CA and Department of Animal Physiology, University of Sao Paulo, Brazil.

Controversy exists as to the "true" relationship between body size and energy metabolism in mammals. We investigated whether allometric relationships for standard (Vogt) and maximal (Vogt max) rates of O2 consumption within a single order of mammals, the Rodentia, are different from those of less closely related mammals. We measured V02max and V02at in the largest rodent, the capybara (Hydrochoerus hydrochaeris, 50 kg) and another large rodent, the agouti (Dasyprocta fuliginosa, 3.7 kg), using a treadmill and a known flow-through system and combined these data with others from the literature to determine allometric equations for rodents and mammals in general. The inclusion of these large rats allowed low VO2 values to be made over a range of body size spanning 10^3. The allometric mass exponents (b in the equation V02 = kMb, where M is body mass) for rodents differed from those for non-rodents for both V02max (b = 0.687 ± 0.030 [95% CL], n = 130; b = 0.725 ± 0.021, n = 212) and V02at (b = 0.75 ± 0.01, n = 12; b = 0.8 ± 0.06, n = 24). Furthermore, the rodent regressions were displaced lower (i.e., the values of a in the allometric equations were smaller) for both V02max and V02at than those of the non-rodents. These results indicate that geometric scale (V02max/Ma) increases less with body size in rodents (M^0.67) than in non-rodents (M^0.75).

The results also suggest that the design factors that determine the allometry of metabolism may be more closely related within an order than between orders, resulting in allometric relationships that more closely resemble intraspecific relationships than interspecific. Supported by UC Davis Provost's Research Support Grant and FAFESP (Sao Paulo State Science Foundation).

ACID-BASE EVALUATION UTILISING STRONG ION DIFFERENCE (SID) IN EXERCISING HORSES, P. L. Ferrante, J. H. Williams and D. S. Koletis. Stitlaris Institute for Medical Research, School of Veterinary Medicine, University of California, Davis, CA and Department of Veterinary Medicine, University of California, Davis, CA.

An extreme situation is seen in thoroughbred horses, where the very high VO2 (up to 300 ml/kg/min) and O2 uptake requires about 85% of the body capacity to be used, making the control of oxygen transport and the removal of carbon dioxide critical for performance. The traditional use of arterial blood gas analysis is inadequate to evaluate acid-base status during exercise, as the exercise-induced changes in ion concentrations render standard methods of analysis invalid.

In this study, we investigated the acid-base status of exercising horses using the strong ion difference (SID), a method that provides a more accurate assessment of acid-base balance during exercise. SID is calculated as the difference between the strong cations (Na+ and K+) and the strong anions (HCO3- and Cl-), providing a measure of the acid-base status independent of ion concentration changes.

We performed side-by-side measurements of arterial blood gases and SID in exercising horses during and after prolonged exercise at ratings ranging from 50% to 100% of VO2max. The results showed that the SID was significantly higher during exercise compared to recovery, indicating a shift towards a more acidic state. The exercise-induced changes in SID were closely correlated with the exercise intensity, with higher ratings leading to greater increases in SID. These findings highlight the importance of monitoring SID during exercise to better understand and manage the acid-base status of exercising horses, thus optimizing performance and ensuring the welfare of these high-performance athletes.

We compared gas exchange and acid-base status in llano venous (IV) and pulmonary artery (PA) blood of horses at rest and during exercise. This was done, to infer comparisons of foreleg versus hindleg perfusion/metabolism balance, and 2) to determine whether the easier and more informative pulmonary artery cannula would reflect muscle venous blood during exercise. Physiologically insignificant (yet statistically significant) differences were found at rest and light (<40% max) exercise in PAO2, PO2, PCO2, and blood temperature, but these disappeared above 80% of VO2max. In contrast, due to higher IV (lactate) at 80% of max, IVpH was lower and base excess more negative: Data at >60% of VO2max:

IV PA
PO2 79.5 63.2
PCO2 45.1 34.6
pH 7.40 7.42
BE -7.0 -6.8
These differences indicate a greater metabolic stress on the hindlimb. In the whole horse, this difference must be attributed to differences in individual forelimb and hindlimb metabolic activity. Supported by NIH HL 17731 and TRODP 1RT 227.


Indians living in the Andes have adapted to the oxygen-poor air of high altitude by exercising economically. They can run faster on a treadmill and work harder on a bicycle while consuming oxygen at the same rate as their lowland compatriots. We asked if their domestic animal, the llama, has the same adaptation. The llama has many adaptations to a hypoxic environment in its genome (e.g., high oxygen affinity hemoglobin) and it seemed possible that exercise efficiency might be included in its repertoire. To test this hypothesis, we compared the llama with the pony, a lowland animal that lacks these adaptations. We measured steady state oxygen consumption (VO2) of three llamas and three ponies as they walked on a treadmill. The VO2 of the llamas was usually identical to that of the ponies over their range of walking speeds, 0.2 to 1.3 m/sec. The cost of transport, the oxygen cost of moving a kg of body mass one meter, reached a minimum of 0.12 ± 0.010 ml O2/kg/m in the llama and 0.11 ± 0.006 ml O2/kg/m in the pony at about 1 m/sec. We also compared their efficiency in working against gravity, i.e., work rate over total metabolic rate times 100. In both species work efficiency while walking up a 6° incline increased with speed from 9 to 18%. We concluded that efficient exercise is not among the llama's adaptations to high altitude. Supported by NIH Grant 5 RO1 AR41540-16 and NSF Grant DCR8915371.

ENHANCED DYNAMIC RESPONSE OF AVIAN INTRAPULMONARY CHEMORECEPTOR (IPC) DISCHARGE DURING VENOUS CO2 LOADING. S.C. Hempleman and D.E. Retou. Division of Physiology, U.C. San Diego, La Jolla, CA 92033.

We studied the CO2 step responses of 11 single unit IPC in the perfused, unidirectionally ventilated left lungs of 6 anesthetized pigeon ducks. Right lungs were independently ventilated with CO2 and air to produce, in turn, normal and elevated PCO2 (41.2 ± 4.8 and 78.6 ± 6.2 Torr). Left lung ventilatory flow of 0.02 HFCU, in air was adjusted to give the same IPC discharge rate under normal and CO2-load conditions (thus matching PECO2 levels, Hempleman et al., 1986). FICO2 steps, 0.02-0.06, 11 s period, were given and dynamic discharge oscillations (thus matching PECO2 levels, Hempleman et al., 1986). FICO2 in air was adjusted to PECO2 levels, Hempleman et al., 1986). FICO2 in air was adjusted to PECO2 levels, Hempleman et al., 1986). FICO2 in air was adjusted to PECO2 levels, Hempleman et al., 1986). FICO2 in air was adjusted to PECO2 levels, Hempleman et al., 1986). Average discharge frequency oscillation amplitudes (max-min) were the same under normal and CO2-load conditions (21 ± 4 and 25 ± 5 sec-1), but the frequency ratios of (max-min)/mean, reflecting the over and undershoot relative to mean discharge rate, were 3 times greater during CO2-load.

The results show that increased convection and diffusion in the lung during venous CO2 loading increases the dynamic character of IPC discharge, which may affect ventilatory control during exercise. Supported by NIH HL17731 and HL02071.
Abnormalities in Exercise Gas Exchange as Airway Obstruction

To investigate the impact of maximal expiratory airflow on ventilatory reserve during maximal exercise, we compared maximal exercise ventilation ($V_{\text{E}}$) estimated in maximally ventilated capacity (MVC) and subjects with normal pulmonary function to subjects with mild to severe airway obstruction (FEV$_1$/FVC=68 to 39%). Maximal ventilation capacity was estimated using the maximal voluntary ventilation (MVV) and a calculated ventilation capacity (MV$\text{max}_{\text{cap}}$), which was determined from each subject's maximal expiratory flow-volume curve and individual estimates of tidal volume, inspiratory duty cycle, and lung volume. All subjects performed graded cycle ergometry to exhaustion. $V_{\text{E}}$$\text{max}$ was correlated with MV$\text{max}$ and $V_{\text{E}}$$\text{max}_{\text{cap}}$ ($r=0.70$ and 0.69, respectively, $p<0.0001$); however, the $V_{\text{E}}$$\text{max}$/MV$\text{max}_{\text{cap}}$ indicated a larger ventilatory reserve than $V_{\text{E}}$$\text{max}$/$V_{\text{E}}$$\text{max}_{\text{cap}}$ ($p<0.05$). The difference between $V_{\text{E}}$$\text{max}$/MV$\text{max}_{\text{cap}}$ and $V_{\text{E}}$$\text{max}$/$V_{\text{E}}$$\text{max}_{\text{cap}}$ was significant for subjects with mild, moderate, or severe airway limitation ($p<0.05$), whereas it was not significant in subjects with normal maximal flows. These data suggest that ventilatory reserve is smaller when estimated from the maximal expiratory flow-volume curve than from the MVV, especially in subjects with mild-to-moderate airflow limitation. (Supported by AHA/Texas Affiliate, ALA/San Jacinto Area, and HL07222.)

Expiratory Flow Limitation and Regulation of EELV during Exercise. J.R. Rodarte, R. Pellegri, V. Brusco, and T.G. Babir. Baylor College of Medicine, Houston, TX 77030, Ospedale A. Carle, Cuneo, Italy, and Universita di Genova, Genova, Italy.

To investigate the impact of expiratory flow limitation (FL) on breathing pattern and end-expiratory lung volume (EELV), we studied nine volunteers (29±6 yr), six healthy and three with mild-to-moderate airway obstruction (67-71% of predicted FEV$_1$), during exercise. Six subjects showed evidence of FL, i.e., tidal expiratory flow impinging on maximal expiratory flow, at some or all exercise levels. Whenever an expiratory threshold load was imposed, mean expiratory flow ($V_{E}$/T$E$) decreased ($p<0.02$) associated with an increased expiratory time ($T_E$) ($p<0.05$). During non-FL conditions, $T_E$ increased less than expiratory flow decreased and EELV tended to increase. In contrast, during FL, $T_E$ increased more than expiratory flow decreased, subjects did not achieve maximal expiratory flow until a lower volume, and EELV decreased ($p<0.001$). Under both FL and non-FL conditions, unloading reversed the changes associated with loading. These data indicate that the increase in EELV during exercise is linked to the occurrence of FL. We suggest that compression of airways downstream from the flow-limiting segment may elicit reflexes which terminate expiration, thus increasing $F_{E_{Vmax}}$. (Supported by AHA/Texas Affiliate and ALA/San Jacinto Area.)

Maximal Exercise Flow and Ventilatory Reserve at Maximal Exercise. T.G. Babir and J.R. Rodarte. Baylor College of Medicine, Houston, TX 77030.

In exercise-induced asthma (EIA) bronchoconstriction develops after exercise. Some asthmatics report the onset of symptoms during exercise. PROTOCOL: Six asthmatics exercised (cycle ergometry) on 3 occasions: exercise only, exercise + lung deflation (negative pressure waveform applied to the nasopharynx during inspiration), and exercise + positive pressure waveform applied to the nasopharynx during inspiration. In the standing horse, the septum separating the pouches had developed during exercise, possibly due to muscular activity compressing the walls and decreasing their compliance, combined with active control of the shape of the nasopharyngeal roof. (Supported by C.N.P.Q., Travers Fund and N.Y.H.B.P.A.)

The guttural pouches, bilateral diverticula of the Eustachian tubes each holding ~0.1 l, have no established function. An endoscope was used to observe the Eustachian tube opening and to place matched tension pressure catheters in the pouches and pharynx. Many activities, swallowing (which opens the tubes), snorting or head movements, altered pouch pressures. During treadmill exercise, pressure changes in both pouches were similar, a phase, but were out of phase with, and about half the amplitude of those in the pharynx. Pouch pressure increased and pharyngeal pressure at the end of expiration and during most of inspiration. In the standing horse, the septum separating the pouches had a compliance twice the rest of a pouch wall (mainly the compliance between the pouch and pharynx). Leakage after air injection precluded pouch pressures above 2 cmH$_2$O. Much higher positive pressures were developed during exercise, possibly due to muscular activity compressing the walls and decreasing their compliance, combined with active control of the shape of the nasopharyngeal roof. (Supported by C.N.P.Q., Travers Fund and N.Y.H.B.P.A.)

The purpose of this study was to evaluate exercise capacity and gas exchange in a large cohort of patients to determine if exercise limitations were attributable to lung disease or to obesity. A total of 513 patients completed lung function and symptom limited graded maximal exercise testing (72% obstructed and 31% had abnormal spirograms using open circuit gas collection. In accordance with previous studies, our patients presented with reduced ventilatory and work capacity, increased ventilation and reduced gas exchange. Smoking history correlated weakly, yet significantly, with reductions in the FEV$_1$ (r = -0.18, p < 0.001). Spirometric measures (FVC, $FEV_1$, FEF, PEF) of pulmonary function declined with increasing severity of COPD (r > 0.8). Peak exercise flow ($V_{E_{max}}$) ($V_{E_{max}}$), which was determined from each subject's maximal expiratory flow-volume curve ($V_{E_{max}}$), became more severe as FEV$_1$/FVC decreased (r = -0.67 and 0.55, respectively, p < 0.001). The V$_{E_{max}}$ was determined from each subject's maximal expiratory flow-volume curve ($V_{E_{max}}$), which was determined from each subject's maximal expiratory flow-volume curve ($V_{E_{max}}$), which was determined from each subject's maximal expiratory flow-volume curve ($V_{E_{max}}$). The V$_{E_{max}}$ was determined from each subject's maximal expiratory flow-volume curve ($V_{E_{max}}$), which was determined from each subject's maximal expiratory flow-volume curve ($V_{E_{max}}$). This suggested that bronchoconstriction occurs only after exercise; FEV$_1$ improved during the INC protocol, but fell afterwards. In contrast, FEV$_1$ fell during both prolonged CL exercise and ICT exercise. Variable FEV$_1$ during exercise may reflect variations in balance of bronchodilating and bronchoconstricting influences. Supported in part by American Lung Association of Minnesota.

In order to study factors limiting exhaustive exercise at high altitude, four healthy males (age 34.2±0.69 yr, weight 76.1±17 kg, height 1.70±0.03 m) exercised until exhaustion at 75% VO2 max (225±27 W at sea level, SL, and 17.5±22.7 W at high altitude, HA, after one month at 3050 m). Exhaustion time at HA decreased by 51.7±9.5%. Throughout the exercise, VE increased compared to HA than at SL reaching 169±7 l/min (BTPS) at HA and 98±6 l/min at SL. In both circumstances just before the exhaustion the respiratory rate suddenly rose to a high level (103±9 breath/min in HA and 51±6 breath/min at SL). Mean inspiratory esophageal pressure decreased during exercise at HA while stayed constant or increased slightly at SL. Mean inspiratory gastric pressure became negative (4.4±3.2 cmH2O) at HA whereas positive at SL (0.2±1.3 cmH2O). As a consequence mean transdiaphragmatic pressure (Pdi) declined at exhaustion at HA. Integrated EMG of the diaphragm (IMEGD) progressively increased during the exercise at HA, but remained constant at SL. The IEMG of the vastus lateralis did not change either at SL or HA. From these data it appears that the contribution of the diaphragm to the work necessary to sustain such high levels of VE at HA is decreased. The decrease in Pdi coupled to the progressive increase in IEMGD may be the result of diaphragm fatigue occurring towards the end of the exercise at HA. Otherwise, no subjective no obvious signs of fatigue have been detected on the limb muscles.

48.8  HYPOXIC EFFECTS ON EXERCISE-INDUCED DIAPHRAGM FATIGUE. M.A. Babcock*, B.D. Johnson*, D.M. Griffin*, D. Pegelow*, O.P. Sumner* and J.A. Dempsey, John Rankin Laboratory of Pulmonary Medicine, Univ. of Wisconsin, Madison, WI 53705. 

We examined the effects of breathing a hypoxic gas mixture during heavy endurance exercise on diaphragm fatigue. Eight male subjects gave informed consent and completed two exercise tests at 85% VO2max, one normoxic (N) and one hypoxic (H). (1.5 FIO2, SeO2 end exercise = 77±3% 1.46). Supramaximal bilateral phrenic nerve stimulus (BFNS) was used to determine the force output of the diaphragm at FRC and positive end expiratory pressure (5 cmH2O) during 1 Hz breathing and tetanic stimulations at 10 Hz and 20 Hz. After N exercise a significant decrease in Pdi at 1 Hz (-22.7%, p<0.001), and 10 Hz (-22.6%, p<0.001) occurred. Pdi recovered at all levels by 60 min post-exercise. During the hypoxic exercise there was a decrease in Pdi at 1 Hz (-15.2%, p<0.01) and 10 Hz (-15.5%, p<0.04) occurred after H exercise. The Pdi at 1 Hz recovered after 90 min. In conclusion hypoxia resulted in the same amount of diaphragm fatigue as normoxic exercise but in a third less exercise time. We hypothesize that the effects of hypoxia may be due to both decreased O2 transport and to increased ventilatory work. (Supported by AHA and NHLBI.)

48.9  INFLUENCE OF MENTAL STRESS ON HYPERVENTILATION DURING INCREMENTAL EXERCISE. E. Onda, N. Hayashi*, Y. Nakamura, and J. DemDsev. Univ. of Arizona, Tucson, AZ 85721 and Univ. of Wisconsin, Madison WI 53705. 

The increase in ventilation (V̇E) evoked by hypoxia persists for several seconds after the stimulus is removed. This phenomenon, known as STP, is most pronounced when hypoxia is combined with mild exercise (Fregosi, R.F., J. Appl. Physiol. 71:982, 1991). Our purpose was to determine if hypoxic exercise evoked a STP and if end-tidal CO2 and O2 and external oblique abdominal EMG activity were recorded in six healthy subjects (5 M, 1 F). They exercised on a cycle ergometer at 80 W for 1.5 min. (control), followed by 1.5 min. of hypoxia (10% O2, balance N2). Hypoxia was terminated abruptly by changing the inspiratory back to O2, as exercise continued. Hyperventilation persisted for 3 to 5 (SE) breaths (range, 3-20) following the onset of O2 administration; abdominal activity, which was present in all subjects in hypoxic exercise, remained elevated for 2 or 3 breaths (range, 1-5). Separate experiments showed that abdominal muscle activity did not change during normoxic exercise at 90 W, but increased at 100 W to 98 ± 26% of the level observed in hypoxic exercise at 90 W (P < 0.05 vs. rest). In summary; 1) STP of abdominal muscle activity is evoked by hypoxic exercise, but the inter-subject variability is marked; 2) moderately intense normoxic exercise increases abdominal motor activity significantly. Supported by NHLBI.
40.13
ALTERATIONS IN THE VENTILATORY RESPONSES TO INCREMENTAL CYCLING FOLLOWING A REDUCTION IN MUSCLE GLYCOGEN CONTENT.
Donald A. Schneider, W. D. Fiksen, and J. M. Benzaiali, Univ. of Western Ontario (Faculty of Kinesiology, Dept. of Physiology, and the Lawson Research Institute), London, Ont. N6A 3K7.

Nine untrained female subjects were studied during incremental cycling performed in the normal glycogen state (NG) and under conditions of reduced muscle glycogen content (RG). Absolute oxygen uptake measured at the ventilatory threshold (Ve) increased by 32%, while oxygen uptake determined at an arbitrary respiratory compensation threshold (VeR) was increased by about 51% during conditions of RG compared to the NG state. The ventilatory threshold was detected using a control algorithm that deidentified a residual sum of squares of the breakpoint, whereas the RCT was determined as the first point of departure from linearity of minute ventilation plotted as a function of carbon dioxide output (VeCO2). We have demonstrated that muscle glycogen reduction resulted in a significant delay in the onset of both the ventilatory and respiratory compensation threshold. These data suggest that (1) ventilation is not solely responsible for lactate production and the onset of the blood lactate and/or ventilatory thresholds.

40.14
EFFECTS OF AGING AND FITNESS ON THE VENTILATORY RESPONSE TO CO2 IN HYPOXIA AND HYPOXIA IN HUMANS.

Although recent studies (Konovalov & Drage 1973, J. Clin. Invest. 52: 1812-1819) found the ventilatory response to hypoxia and hypercapnia to be decreased with advancing age, more recent studies (Ahmed et al. 1991, Respir. Physiol. 83:343-352; Rubin et al. 1982, J. Gerontol. 37:500-512) have found little or no age differences in these responses. In the present investigation, we examined the ventilatory responses to acute hypoxia (P30= 50 Torr) and in hyperoxia (P20= 500 Torr) in groups of young active (YA, n=7, 28.3±2.7 y, 16.5±6.1 kg/m²), elderly trained (ET, n=6, 76.3±10.9 y, 33.3±3.3 kg/m²), and elderly untrained (EU, n=5, 75.4±1.0, 20.2±0.6) subjects. A computer-controlled dynamic tidal forcing system was used to control inspired gas breath-by-breath. Two protocols were used, I. The CO2 was held constant throughout the session at 48.1±4.1 Torr. In protocol II, P20 was held at 78 Torr above rest. P30 was held at 100 Torr throughout except for two-minute periods at 500 Torr and 50 Torr. On average, no differences were found in ventilation (Vi, f min⁻¹) in response to acute hypoxia and hypercapnia, while no differences were found for Vi in response to hyperoxia. Vi was significantly lower in ET (38.5±2.5) and EU (36.5±3.6) compared to YA (52.2±3.2) in response to acute hypoxia. In hypercapnia, there were no differences between groups in ventilation, while in hyperoxia, the ventilatory response to hyperoxia, but not hypoxia, in moderate hyperoxia, suggested a decreased precordial CO2 sensitivity in the elderly.

Supported by NSERC and the Ontario Ministry of Health.

40.15
EFFECTS OF AGING ON THE SIAP AND THE CO2 THRESHOLD OF THE VENTILATORY-CO2 RESPONSE CURVES IN HYPEROXIA AND HYPOXIA.

Conflicting findings have been reported regarding the effects of fitness and aging on the human respiratory control system and its response to both hypoxia and hyperoxia. This study examined the response curve slope (S) and the CO2 threshold (Tc) of the ventilatory response curves in response to acute hypoxia (P20=50 Torr) and in hyperoxia (P20=500 Torr) in groups of young active (YA, n=7, 28.3±2.7 (S.E.) y, 16.5±6.1 kg/m²), elderly trained (ET, n=6, 76.3±10.9, 33.3±3.3), and elderly untrained (EU, n=5, 75.4±1.0, 20.2±0.6) subjects. A computer-controlled ventilatory bedside forcing system was used to control inspired gas breath-by-breath. Two protocols were used; I. The CO2 was held constant throughout the session at 48.1±4.1 Torr. In protocol II, P20 was held at 78 Torr above rest. P30 was held at 100 Torr throughout except for two-minute periods at 500 Torr and 50 Torr. In hypoxia, there were no differences between groups in the CO2 sensitivity of the respiratory system to other exercise-induced vent &sority mediators. In hyperoxia (P20=500 Torr) in groups of young active (YA, n=7, 78.3±2.7 (S.R.) y, 48.7±1.8 kg/m²), elderly trained (ET, n=6, 76.3±10.9, 33.3±3.3), and elderly untrained (EU, n=5, 75.4±1.0, 20.2±0.6) subjects. A computer-controlled dynamic tidal forcing system was used to control inspired gas breath-by-breath. Two protocols were used; I. The CO2 was held constant throughout the session at 48.1±4.1 Torr. In protocol II, P20 was held at 78 Torr above rest. P30 was held at 100 Torr throughout except for two-minute periods at 500 Torr and 50 Torr. In hypoxia, no differences were found in ventilation (Vi, f min⁻¹) in response to acute hypoxia and hypercapnia, while no differences were found for Vi in response to hyperoxia. Vi was significantly lower in ET (38.5±2.5) and EU (36.5±3.6) compared to YA (52.2±3.2) in response to acute hypoxia. In hypercapnia, there were no differences between groups in ventilation, while in hyperoxia, the ventilatory response to hyperoxia, but not hypoxia, in moderate hyperoxia, suggested a decreased precordial CO2 sensitivity in the elderly.

Supported by NSERC and the Ontario Ministry of Health.

40.16
EXERCISE VENTILATION AND GAS EXCHANGE AFTER HEART AND LUNG TRANSPLANTATION.
J. A. O’RoV, M. E. O’Brian, and J. M. Benzaiali, Univ. of Western Ontario (Faculty of Kinesiology, Dept. of Physiology, and the Lawson Research Institute), London, Ont. N6A 3K7.

The mechanisms regulating ventilation (Ve) during exercise in humans are controversial. We examined the ventilatory responses to head-down tilt while inhaling one of four gas mixtures: 1) room air (R), 2) 90% O2 (O2), 3) 90% O2, 1.25% CO2 (L), and 4) 90% O2, 2.25% CO2 (H). Ten subjects each participated in eight mixed gas sessions (2 of each gas) which consisted of 11 min of rest, 3-4 min of exercise, and 1 min recovery. Breath-by-breath measurements of Ve, ETCO2, tidal volume (Vt), and breath frequency (f) were taken. Ve and Vt for R were significantly higher (P < 0.05) than those for O2, L, and H. During exercise, Ve and Vt were not significantly different among the four gas mixtures (P > 0.05). During recovery, Ve and Vt were lower for H compared to the other mixtures. These responses indicate an increase in Ve with increased perfusion of the lungs during exercise independent of the ventilation number, which is in contrast to the findings of our previous study where CO2 flow to the lungs drives Vi.

Partly supported by FNSRS fund n. 32-078 719.
VENTILATORY RESPONSE TO MAXIMAL INCREMENTAL EXERCISE IN
HUMANS WITHOUT CHEMOSENSITIVITY. JP Andrés SA Schea BB
Ranzatic WPC Shannon, Resp. Biol. Prog., Harvard School of Public
Health, Boston, MA 02115 and 'Mass. Gen. Hosp., Boston, MA 02114

Patients with Congenital Central Hypoventilation Syndrome (CCBS) have been reported to have a
ventilatory response to chemorespiratory stimuli. Surprisingly, these patients have an appropriately
normal ventilatory response to a single level of mild, steady-state exercise (Schea et al, AABD-142-A194). We wondered whether CCBS patients, like normals, 1) Increase ventilation in proportion to
work load, and 2) Hyperventilate in response to blood lactate accumulation during heavy exercise. We studied 3 children with CCBS and 3 normal children during incremental treadmill exercise to the maximum load tolerated by the subject. We measured VE, PaCO2 (estimated from PETCO2), FE, VO2, and VCO2. During light incremental exercise (VO2 below 25 ml/kg/min) VE was proportional to VO2 in both groups; the mean change in PaCO2 from rest was less than 1 torr in both groups. All but one subject reached a VO2 of 30 ml/kg/min. At this higher level of exercise, controls hyperventilated; PaCO2 fell 8 torr from rest, evidence of lactate accumulation. In contrast, CCBS patients did not hyperventilate; their PETCO2 rose 3 torr from rest to heavy exercise. Thus, chemosensitivity is not necessary for a
proportional ventilatory response to graded moderate exercise but is needed to demonstrate the classical ventilatory response during heavy exercise.

A previous sensitivity analysis of a numerical single path model (SPM) of lung airways (Weibel A) with a blood
source emission term was used to simulate the excretion of CO2. Cardiac index, PVco2, VT and breathing frequency (f) obtained from an animal study at 3 levels of CO2 production induced by administering 2,4-DNP were used as input to the model to simulate breaths at 3 different VT and f. VCO2 normalized phase III slope, alveolar ventilation, and VCO2 change from baseline (b) were calculated at each VT. Both VCO2 and phase III slope are increased with f and VCO2, simulating many periods of the habitual study.

We conclude that the SPM is an effective tool for integrating lung airway structure with lung function.

END-TIDAL CARBON DIOXIDE VARIATIONS DURING EXERCISE
IN THE NORMAL MENSTRUAL CYCLE. Bruce Staats, Troy Williams, and Ken Beck. Mayo Clinic, Rochester MN 55905.

Ventilation is increased both at rest and during exercise in the luteal phase of the menstrual cycle when compared to the follicular phase. Progestrone appears to cause this increase. By the alveolar ventilation equation, increased ventilation would cause a reduction in alveolar (or end-tidal) Pco2 (PETCO2). Subjects have documented a reduction in PETCO2 but none have followed PETCO2 changes sequentially throughout the menstrual cycle.

METHODS: 9 females, ages 26-33 years were studied once in the follicular phase and 5-7 times 2-3 days apart in the luteal phase. Subjects performed 5-
min constant load cycle ergometry at 30, 70 and 90 Watts. PETCO2 was obtained by averaging the PETCO2 values during the last 10 seconds of each
workload. RESULTS: At all exercise levels, PETCO2 was highest in follicular and early luteal phases; e.g. the PETCO2 at 30 Watts decreased from 38.6 (follicular) to 36.9 mm Hg 5 days prior menses and tended to rise thereafter. Regardless of day of the cycle, PETCO2 increased from 30 through 90 Watts (overall mean +2.1 mm Hg). CONCLUSIONS: The PETCO2 during exercise falls and reaches a low-point in the mid-luteal phase, consistent with the increase in the level of progestrone. In spite of this fall, the PETCO2 increases as exercise level increases. Exercise studies of normal females should be controlled for day of the menstrual cycle. Supported by the American Lung Association of Minnesota.

Effect of Increased CO2 Production and Increased Breathing Frequency on Phase III Slope and Deadspace
MS Schreiner, JD Schwartz, PW Scherer, and GR Neufeld University of Pennsylvania, Philadelphia, PA 19104

We infused 2.4 dimethylfuran (2,4 DMF) into an anesthetized, mechanically ventilated 35 kg goat to examine the effect of breathing frequency (f) and CO2 production (VCO2) on phase III slope and alveolar deadspace (VDalveo) independent cardiac index (CI). We adjusted f to maintain a physiologic end-tidal CO2 at 3 VTs (10,15 and 20 ml/kg) at baseline (b) and after each of 2 doses of 2.4 DNP. After the third dose of 2.4 UNP there was a 6% decrease in CI but a 23-44% increase in VCO2 from b with increases in phase III slope and VDaw as well (table). After the second dose of 2.4 DNP there was a 21% decrease in CI and a large increase in phase III slope and VDaw (table).

We conclude that VDaw and phase III slope are influenced by f and VCO2.

Effect of Tidal Volume and Breathing Frequency on Phase III
Slope In Exercising Goats
GR Neufeld, PW Scherer, MS Schreiner
University of Pennsylvania, Philadelphia, PA 19104

We examined the effect of tidal volume and breathing frequency (f) on phase III slope during exercise. We trained 2 trimethystochemostatized goats to exercise on a treadmill and perform a 12 stage exercise protocol. We used a computerized system for breath by breath analysis of gas exchange data with phase III steepening similar to that observed in chronic obstructive pulmonary disease (COPD) (Schward et al, Ann. Biomed. Eng. 19:679-697, 1991). A least squares fitting algorithm was developed to find the optimal R values to match simulated and experimental data. Computer calculated R values for the subjects were found according to the steady state CO2 washout from 6 healthy subjects.
PULMONARY GAS EXCHANGE IMPAIRMENT IN ULTRAMARATHONERS FOLLOWING A 100 MILE RACE AT ALTITUDE.

M. W. Severinghaus, P. E. Bickler and M. W. Eldridge
CVRI and Depts of Anesthesia and Pediatrics, UCD, San Francisco, CA.

The purpose of this investigation was to determine the effect of chronic altitude (CA) on the pulmonary gas exchange capacity of 12 male endurance-trained athletes who ran a 100 mile race at 3,190 m (10,450 ft). They were divided into 2 groups: D (oral furosemide, 40 mg, the day before the race) and C (placebo). Gas exchange was measured under resting conditions in both CA and sea level (SL) before and 4 hours after completion of the race. 

In SL, the D group had a significantly greater increase in arterial oxygen tension (PaO2, C: 98.3±2.4 vs D: 94.9±3.2 mm Hg, p<0.05) and a smaller decrease in PaCO2 (C: 38.0±2.6 vs D: 40.1±3.8 mm Hg, p<0.05). However, in CA, the D group had a significantly greater increase in PaO2 (C: 70.0±7.5 vs D: 55.5±7.0 mm Hg, p<0.05) and a smaller decrease in PaCO2 (C: 52.0±8.0 vs D: 56.5±8.0 mm Hg, p<0.05). The difference in PaO2 between the groups was significant in CA (C: 70.0±7.5 vs D: 55.5±7.0 mm Hg, p<0.05). The difference in PaCO2 between the groups was significant in CA (C: 52.0±8.0 vs D: 56.5±8.0 mm Hg, p<0.05).

The results of this study indicate that chronic altitude (CA) can alter the pulmonary gas exchange capacity of endurance-trained athletes. These changes may be due to changes in the pulmonary diffusion capacity and/or changes in the respiratory muscle function. Further investigation is needed to determine the mechanisms responsible for these changes.

PULMONARY ARTERY PRESSURE AT HIGH ALTITUDE: INFLUENCE OF 8-BLOCKADE DETERMINED BY DOPPLER

Mark A. Solland, Eugene E. Woldt, John T. Reeves
Univ of Colorado Health Sciences Center, Denver, CO 80262

The purpose of this study was to determine the effect of chronic 8-blockade on the pulmonary artery pressure (PAP) during exercise at high altitude (HA). Eight male athletes were studied at rest and during exercise at an altitude of 3,470 m (11,400 ft). The athletes were divided into two groups: 8-blocked (C) and placebo (D). The PAP was measured using the Doppler technique during rest and exercise at HA.

During exercise, the C group had a significantly lower PAP compared to the D group (C: 120±10 vs D: 145±20 mm Hg, p<0.05). However, during rest, there was no significant difference in PAP between the two groups (C: 75±10 vs D: 80±10 mm Hg).

The results of this study indicate that chronic 8-blockade can reduce the pulmonary artery pressure during exercise at high altitude. Further investigation is needed to determine the mechanisms responsible for this effect.

PULMONARY VASCULAR RESISTANCE AT HIGH ALTITUDE: INFLUENCE OF 8-BLOCKADE DETERMINED BY DOPPLER

Mark A. Solland, Eugene E. Woldt, John T. Reeves
Univ of Colorado Health Sciences Center, Denver, CO 80262

The purpose of this study was to determine the effect of chronic 8-blockade on the pulmonary vascular resistance (PVR) during exercise at high altitude (HA). Eight male athletes were studied at rest and during exercise at an altitude of 3,470 m (11,400 ft). The athletes were divided into two groups: 8-blocked (C) and placebo (D). The PVR was measured using the Doppler technique during rest and exercise at HA.

During exercise, the C group had a significantly lower PVR compared to the D group (C: 120±10 vs D: 145±20 mm Hg, p<0.05). However, during rest, there was no significant difference in PVR between the two groups (C: 75±10 vs D: 80±10 mm Hg).

The results of this study indicate that chronic 8-blockade can reduce the pulmonary vascular resistance during exercise at high altitude. Further investigation is needed to determine the mechanisms responsible for this effect.

Exercise-induced pulmonary hemorrhage (EIPH) commonly occurs in the equine athlete; however, it is rarely observed in other animals. Furosemide, a diuretic, is used in the horse racing industry to prevent or attenuate EIPH. We have conducted studies on 6 Quarter Horses and Thoroughbreds to determine the causes and mechanisms of EIPH and the rationale for using furosemide. Right atrial (RAP), pulmonary arterial (PAP), and cardial arterial (CAP) pressures were measured during exercise on a high-speed treadmill to determine the magnitude of pressure changes and other hemodynamic variables during exercise. The effects of various dosages of furosemide administered 4 h before exercise were studied. During exercise, increases in treadmill speed were associated with increases in RAP, PAP, CAP, and heart rate. Furosemide (0.25 to 2 mg/kg) administered 4 h before exercise reduced RAP and PAP during exercise in a dose-dependent manner, but did not influence heart rate. Mean CAP was reduced by the 2-mg/kg furosemide dosage during exercise at 9 and 11 m/s, but not at 13 m/s. Furosemide may mediate some of its cardiopulmonary effects by vasodilatory activities that directly lower pulmonary pressure, thereby reducing venous return to the atria and cardiac filling. (Supported by the American Quarter Horse Association and the Kansas Racing Commission).

68.33
# BLOCKADE OF HORSE BRONCHIAL ARTERY BLOOD FLOW DURING EXERCISE. R. D. Ogle*, A. Dobson and B.P. Hackston*. College of Veterinary Medicine, Cornell University, Ithaca, NY 14853.

We wished to establish whether β-adrenergic vasoconstriction of the bronchial bed occurred during exercise. Blood flow was measured with an implanted acoustic transit time probe (Transonesics System Inc.) during two 2.4 Km, sub maximal periods of treadmill exercise separated by a short rest. Without blockade flow decreased at exercise began, but thereafter steadily increased. Flow peaked when the horse was slowing or had stopped after exercise. Systemic arterial pressure rose more quickly than flow during exercise and was still high when flow was maximum, but by then, pulmonary pressure had declined. The steady rise in flow during exercise was inhibited by propranolol, but the after-dilatation after exercise was invariably observed. Blockade was confirmed by the lack of effect of injection of isoprel, normally a potent dilator of the bronchial bed, and by the absence of sweating during exercise. We conclude that maximum pressure is transmitted from the artery to the bronchial capillary bed during the after-dilatation following exercise. Unlike the steady flow rise during exercise, this dilatation was insensitive to propranolol. These patterns were similar in normal horses and those with a confirmed history of bleeding into the airways. (Supported by the Zweig Memorial Fund. and N.Y.H.B.P.A.)

68.34
SHEEP AS AN EXPERIMENTAL EXERCISE MODEL. Kenneth T. Dodd*, Adolph J. Janeski, Carol A. Boucone, and Thomas G. Mundle. Walter Reed Army Institute of Research, Division of Medicine, Department of Respiratory Research, Washington D.C. 20017-5100.

One method for assessing the body’s capacity to do work is through exercise testing. Maximal exercise challenges yield valuable insight into integrated cardiopulmonary function and may be used to determine the most effective protocol for determining VO2max in sheep. Data collected during challenges included VO2, VO2:V02, time on treadmill, heart rate, cardiac output, blood gases and a variety of chemofactors. The parameters of alpha-blockers, beta-blockers, and splenectomy were evaluated using the model. The model was also used to evaluate maximal exercise capacity after a several systemic insults: four levels of pulmonary contusion injury, toxic gas inhalation (N02), and methemoglobinemia. The changes in exercise tolerance for each insult is reported. This effort has shown the sheep to be a suitable large animal model, providing insight into integrated heart/card function and decrement in performance.

68.35
THE EFFECT OF HYPOXIC EXPOSURE ON RAT LUNGS. RR Schoene, S Goldberg, D Luchtel, R Albert, and T Martin. Univ. of Washington, Seattle WA 98195.

Exercise at high altitude in some goats causes hypoxia which is characterized by a high protein content. The mechanism of the leak is not clear. We studied four groups of rats (N = 6): normoxic rest (NM), normoxic exercise (NE), hypoxic rats at rest (HR) and after 2 hrs. of exercise (HE) during 10-20 hours of normoxic hypoxia (FROM). At the time of sacrifice we studied blood for von Willebrand’s antigen (VWA) and lungs with bronchoalveolar lavage (BAL). The cells and protein in and with light (LM) and electron microscopy (EM) for morphology. BAL was similar in all groups, but both HR and HE had significantly elevated levels of VWA, indicative of endothelial damage. LM was similar in all groups, but LM showed mild interstitial edema in HR and damage of epithelial type 1 and endothelial cells (blistering and stripping from basement membrane) in NE. Results suggest that hypoxia causes early disruption of both epithelial and endothelial cells which may give insight into evolution of pulmonary edema.

68.36
THE LUNGS DO NOT RESPOND BY STRUCTURAL ADAPTATION TO INCREASED O2 DEMAND IN GUINEA PIGS. V.P. Salisbury-Navarro*, D.L. Turner*, H. Hoatabler* and E.R. Weibel. Dept. of Anatomy, University of Zurich, CH 3000 Bern 9, Switzerland.

An increase in O2 demand was induced in growing guinea pigs through endurance exercise training by running on a treadmill for 6 weeks (a high intensity intermittent stimulus) or through shortterm (6 weeks) or longterm (70 weeks) cold-exposure (a low intensity continuous stimulus). Both stimuli led to a significant increase by 1.2-fold in maximal O2 consumption, VO2max, but had different effects on the average daily O2 consumption (VO2:day), the VO2:day was significantly reduced (-14%) in the trained guinea pigs and increased in the cold-exposed group by 1.5 fold in the longterm cold-exposed guinea pigs. The morphometric analysis of the pulmonary gas exchanger showed that training had not affected the lung volume nor the internal structure of the lung. Cold-exposure, however, resulted in a higher mass-specific lung volume (V/L:Mb) in both cold-exposed groups, which could be the result of either an accelerated lung growth or a retardation in body growth due to cold-exposure. The chief morphometric parameters of pulmonary diffusing capacity (DLO, total and capillary specific), lung volume, and mass-specific lung volume (W/L:Mb) were therefore analyzed. A 1.2 fold increase in VO2:day resulting from exercise training proved insufficient to cause structural adaptation. Neither did the continuous low intensity stimulus of cold environment cause the structures that support gas exchange to increase in size, at least in guinea pigs. The lungs appear rather resistant to induced variation in functional capacity, possibly as a result of the observed redundancy in morphometric diffusing capacity.
49.1 Relationship between oxygenation of skeletal muscle and blood lactate concentration during progressive maximal bicycle exercise. Sachiko Homma, Nobuharu Fuji, Hideo Eda, and Haruo Negami. Inst. of Health and Sport Sciences, Univ. of Tsukuba, Ibaraki, 305, Japan

Using near-infrared spectroscopy (wave lengths of 780nm, 800nm and 830nm), we monitored changes in the oxy-, deoxy- and total hemoglobin concentration during progressive maximal bicycle exercise, and during inflation of a thigh cuff to 250mmHg in 8 healthy male volunteers who gave informed consent. Gas exchange parameters were measured continuously, and electrocardiograph and impedance-cardiograph were also obtained continuously. Articularized blood samples were obtained from a hand vein at every exercise intensity level. During low intensity exercise, low levels of deoxyhemoglobin and total hemoglobin were observed. These changes probably reflected increase in venous return. Adrenalin decrease in oxyhemoglobin content and increase in deoxyhemoglobin content were observed at 150-watt exercise intensity. These findings probably reflected increased O2 extraction by the exercising muscle. At the peak of exercise intensity, the mean content of oxyhemoglobin expressed by relative range from rest to cut off intensity was 55.0±2.1 15.7%. Blood lactate concentration was increased compared to the resting value at 120-watt exercise intensity. These results suggest that relatively high level of O2 is present in the vastus lateralis during exercise which is strenous enough to increase blood lactate concentration.

49.2 ERTHROPOIETIC RESPONSE TO INTERMITTENT ALTITUDE EXPOSURE. G.W. Lodhaetter, R.A. Robergs, D.A. Clark, R.C. Ruby, D.J. Liou, S.B. McDonald, T.W. Chabot. Univ. of New Mexico, Albuquerque, NM 87131

To evaluate the erythropoietic response to altitude, six subjects (3 males, 3 females) were exposed to intermittent high altitude (2.5 hrs/day at 18,000ft/5,538m) for six consecutive days. Venous blood samples were obtained prior to exposure (baseline), pre and post exposure (days 1, 3 and 5) and on alternate days for two weeks after exposure. Blood was assayed for erythropoietins (EPO), fibrinogen (FB), hemoglobin (Hb), and prepared for hematocrit (Hct) and reticulocyte (Rct) counts. The EPO level for pre-post exposures were 16.2±0.8 to 17.3±1.2, 14.8±1.0 to 15.0±1.0 and 14.8±1.2 to 18.1±1.1 for days 1, 3, and 5 respectively. Baseline EPO daily peak exposure EPO values were 16.2±0.8 and 15.0±0.8, respectively. Although EPO increased after each exposure, all values remained within the normal range (4-6mE/ml). Hemoglobin and Hct levels remained constant, whereas Rct increased significantly from baseline (1.0±0.1%) by day 4 and day 5 (1.4±0.1 and 2.5±0.3%, respectively). Therefore, RCT counts decreased gradually to 1.0±0.1% during the two week post exposure period. During exposure, day 2-5 indirect EPO levels exceeded direct EPO levels. Total Bil showed a pulsatile pattern throughout the 3 weeks of data collection. The data indicate that intermittent altitude exposure provides minimal erythropoietic stimulation, yet significantly increased Rct. It remains unclear if erythropoiesis is accompanied by increased RBC destruction or whether the elevated Etct counts increase erythrocyte counts.

49.3 PHYSIOLOGICAL RESPONSES AND ENERGY COSTS OF ROCK CLIMBING AT VARIOUS DIFFICULTY LEVELS. P. Watts, K. Drobish, and S. Rimzheim. Northern Michigan University, Escanaba, MI 49705

Sixteen experienced rock climbers completed 4 min continuous climbing bouts on a heart rate monitored, 8x12 ft rock climbing "tread" surface. Sixteen experienced rock climbers completed 4 min continuous climbing bouts on a metabolic cart recording expiratory gas volumes and oxygen consumption. Handgrip force (HG) and arterialized blood lactate (BL) were determined immediately following each climbing bout. Results are presented below:

<table>
<thead>
<tr>
<th>Angle (deg)</th>
<th>HG (N)</th>
<th>V02 (mL/min)</th>
<th>BL (mEq/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>80</td>
<td>1.06</td>
<td>37</td>
</tr>
<tr>
<td>60</td>
<td>91.5</td>
<td>1.7</td>
<td>30</td>
</tr>
<tr>
<td>80</td>
<td>66.4</td>
<td>1.7</td>
<td>29.5</td>
</tr>
<tr>
<td>100</td>
<td>63.8</td>
<td>2.0</td>
<td>31.0</td>
</tr>
<tr>
<td>120</td>
<td>127</td>
<td>3.0</td>
<td>31.0</td>
</tr>
</tbody>
</table>

These findings suggest that rock climbing at different angles is similar in oxygen uptake requirements at a given heart rate, but HG and BL levels were significantly different.

49.4 DYNAMICS OF LACTATE AND OXYGEN UPTAKE DURING EXERCISE. Marco E. Cabrera and Howard J. Chizeck. Case Western Reserve University, Cleveland, OH 44106

The dynamics of the oxygen uptake (VO2) and blood lactate concentration (LA) as it relates to exercise intensity is essential to the understanding of exercise energetics. To determine this dynamics, two responses (LA,VO2) were obtained during a 5 min protocol, i.e., the oxygen uptake was analyzed using system identification techniques. A time series model of the LA-VO2 kinetics system, with WR as its input and both VO2 and LA as its outputs was fitted to published data from experimental trials with ten different subjects (JAP 59,935, 1985). To detect potential changes in the system dynamics, a weighted inverse least-squares identification algorithm was used. The system parameters were identified as a function of time for each data set. Two major transitions, dividing the time domain into three regions, were apparent from the time courses of the estimated parameters. The average time difference between the two transitions was 4.8 min. The first transition occurred at a mean VO2 of 53.2% VO2max and a mean LA of 1.16±0.1 mEq/L. The second transition occurred at a mean VO2 of 72.9% VO2max and a mean LA of 2.96±0.9 mEq/L. These results expose the time varying nature of the LA-VO2 kinetics system during exercise. It appears that there are three main domains of exercise intensity or metabolic rate, between unloaded pedaling and peak exercise (VO2max). Each of these domains is associated with different parameter values and consequently distinctive dynamics.


This study examined transient oxygen uptake responses before and after eight weeks of specific endurance training of six competitive male cyclists. Each cyclist undertook three equal ascending transitions in power output from unloaded cycling to 180, 150, and 75 watts (T1, T2, T3), pre and post training. Expired air was collected continuously and analyzed via a Sensormedics 2900 metabolic cart. The average time difference between the two transitions were then analyzed for statistical significance (ANOVA/post hoc Scheffé F-test where appropriate). The results revealed a gradual slowing of oxygen kinetics with increasing workload, although there were only significant for T1 vs T2 and T2 vs T3 (p<0.05) as well as significantly faster t1/2 and MRT values post-training (p<0.05) for all three transitions. It would seem that, with appropriate methodological care, gas exchange kinetics may provide information concerning adaptation to training in addition to normal exercise testing procedures.

Supported by Sport Canada.
49.7 ECONOMY DURING ENDURANCE EXERCISE FOLLOWING MAGNESIUM SUPPLEMENTATION
L.K. Brits Exercise and Sport Science Laboratory, Western Washington University, Bellingham, WA 98225

The purpose of this study was to determine the possible effect on economy of endurance exercise following magnesium supplementation. In this study, fourteen trained subjects were given magnesium oxide at 8 mg per kg body weight per day, including the amount assumed in the diet. Each subject was tested on a double blind trial. All subjects completed a baseline graded exercise test on a treadmill and a 90-minute endurance run to volitional fatigue. After 4 weeks of supplementation, the subjects completed another 90-minute endurance run and observed changes up to the order of 4 weeks before completing their final 90-minute endurance run. The results indicate that the magnesium supplement is effective in maintaining oxygen consumption adjusted for body weight: 47.3 ± 6.56 ml/kg/min for the placebo group and 45.2 ± 4.9 mg kg⁻¹ min⁻¹ for those on magnesium supplementation; and minute ventilation was significantly different: 100.1 ± 22.8 L min⁻¹ versus 94.8 L min⁻¹, for placebo versus magnesium group, respectively. In this report, the data appear to be slightly more physiological due to the slightly higher, yet statistically different, oxygen consumption and ventilation in the placebo trial as compared to the magnesium supplementation condition that requires further study. There were no significant differences in ratings of perceived exertion using the Borg scale at any of the collection intervals during the 90-minute run to exhaustion indicating that magnesium did not influence the perception of effort in trained subjects when using this measurement scale.

49.9 CONTRIBUTION OF CENTRAL AND PERIPHERAL FACTORS TO THE VARIATION IN MAXIMAL OXYGEN CONSUMPTION IN PHYSICALLY ACTIVE HUMAN SUBJECTS
D. Prud'Homme, P. Boulay, M.R. Boulay, P. Barbeau and J.A. Simmoneau, Physical Activity Sciences Laboratory, Laval University, Ste-Foy, Canada.

The purpose of this study was to determine the relative contribution of the oxygen transport system and peripheral factors to maximal oxygen uptake (V0₂max) in physically active humans (n=15) (mean ± SD) (21 ± 6 ± 4.0 yrs of age; 73.6 ± 8.0 kg of body weight). V0₂max was determined during a maximal ergocycle test and maximal cardiac output was measured by a CO₂ rebreathing technique. Values of V0₂max and of maximal cardiac output reached 92.2 ± 8.5 ml/kg/min and 445 ± 73 ml/min/kg, respectively. Citrate synthase (CS) activity was also measured in muscle samples taken from the vastus lateralis and reached 16.0 ± 3.4 U/g wet weight. No significant association was observed between values of maximal cardiac output and muscle CS activity. However, maximal cardiac output (r=0.74, p<0.05) and CS activity (r=0.52, p<0.05) showed significant correlations with V0₂max/kg. Multiple regression analyses (F ratio=13.7) revealed that the relative contribution of maximal cardiac output and level of CS activity to the variation in V0₂max reached about 60% and 35%, respectively. These results suggest that both central and peripheral factors contribute to the variation in maximal oxygen uptake in physically active subjects.

49.11 EFFECTS OF BODY MASS (Mₐ) ON MITOCHONDRIAL AND CAPILLARY VOLUME DENSITIES, AND MITOCHONDRIAL INNER SURFACE AREA Sarm(mm) IN FLIGHT MUSCLE. HEART AND LIVER OF HUMMINGBIRDS.
Cecilia V. Zerdinetti, Jose E.P.W. Blicudo*, Stan L. Lindstedt*

University of Sao Paulo, 05080-000, SP, Brazil and Northern Arizona University, 8601 I-5621, Flagstaff, AZ, USA.

The slope of the allometric regression of specific oxygen consumption (VO₂/Mₐ) during hovering flight in the 7 hummingbird species of the family leiothrix was -0.6. Morphometric analysis of flight muscles - pectoralis (PC) and supracoracoideus (SC) - heart (H), liver (L) and from 2 species of hummingbird with different Mₐ revealed the following results (in %) for mitochondrial volume density:

<table>
<thead>
<tr>
<th>Animal/Tissue</th>
<th>Mₐ (g)</th>
<th>VO₂/Mₐ</th>
<th>Capillary volume density (mg/mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avian species</td>
<td>34.31</td>
<td>53.54</td>
<td>30.73</td>
</tr>
<tr>
<td>Bicudo*</td>
<td>26.19</td>
<td>32.84</td>
<td>19.01</td>
</tr>
</tbody>
</table>

* significantly different (ANOVA)

Capillary volume density was not different among the 2 species, being around 9% in PC, SC and H, and 17% in L. Sarm(mm) was also similar in the 2 species considered, but the values were twice as high than those observed previously in mammals (approx. 60 x 30 cm²/mg mitochondria). The results indicate that smaller species of hummingbirds are capable of attaining higher VO₂/Mₐ, mainly because of higher capillary density.

Supported by FAPESP, CAPES, CNPq (Brazil) and NIH (USA).

49.10 ROLE OF PULMONARY O₂ DIFFUSION FOR ARTERIAL O₂ SATURATION AND V0₂MAX
P.K. Pedersen, C. Andersen*, K. Madsen* and K. Jensen*, Dept. Physical Education, Odense University, Denmark.

The role of pulmonary O₂ diffusion for the maintenance of arterial O₂ saturation (%SaO₂) in exercise and its significance for V0₂max was examined. Young, healthy volunteers of varying fitness levels (5 trained females (TP), 5 trained males (TM) and 7 male elite road racing bicyclists (EB)) performed incremental cycle ergometer tests to exhaustion while inhaling normoxic air (NOX) or a 30% O₂ mixture (H0X). The decrease in radial artery %SaO₂ from rest to exhaustion in NOX (98.5% to 95.3%; p<0.001) disappeared in H0X where %SaO₂ remained 94-100%. Acid-base status was similar in NOX and H0X. V0₂max in NOX averaged 42, 22 and 73 ml/min/kg for TT, TM and EB, respectively, and increased by an average of 5% in H0X (p<0.001) with no significant differences between groups. The individual data, however, showed a significant correlation between the degree of desaturation in NOX and the H0X-induced increase in V0₂max. This supports that pulmonary O₂ diffusion contributes to the limitation of V0₂max in trained individuals as seen earlier in non-invasive studies (Power et al., JAP, 66: 2401-2405, 1989).

Supported by the Danish Medical Research Council and the Research Council of the Danish Sports Federation.

49.12 VO₂ AND CARDIAC OUTPUT DURING REST EXERCISE AND EXERCISE-EXERCISE TRANSIENTS
Dieter Leyk, Uwe Hofmann*, Dieter Eifeldt, Klaus Baum, Hans-G. Winderlich, Jürgen Stegmann, Physiologisches Institut der Deutschen Sporthochschule Köln, Carl-Diels-Weg, 50938 Köln, Germany.

The dynamics of external gas exchange during exercise is influenced by pulmonary, cardiovascular and metabolic factors. During rest exercise transitions the interaction of these factors is more complex than during exercise-exercise transients. In the present study we directly compared, in upright and supine body position oxygen uptake (VO₂) and cardiac output (CO) responses to step changes in exercise intensity. The results indicate that oxygen uptake and cardiac output responses showed a step in the early and late stage did not change, except for body weight which decreased (p<0.05). In conclusion, in spite of individual changes, training during the season did not change physiological profile in this group of well trained paddlers.
50.1 POST-EXERCISE CARDIAC AUTONOMIC REGULATION RELATED TO EXERCISE INTENSITY. N. Hayashi*, Y. Nakamura, and L. Murakia. Waseda Univ., Tokorozawa, Saitama, 359 JAPAN

After signifying an informed consent, performed two kinds of constant load exercises at the work rate corresponding to 20% and 100% of the individual ventilatory threshold (VT) in addition to the exhaustive incremental exercise using a cycle ergometer. Blood pressure (BP) and oxygen uptake (VO2) as well as the best-by-beat recording of R-R intervals were measured until 20 min after each exercise. Spectral analysis was applied to heart rate variability (HRV) data sets of 5 min before, last 5 min during, and 8 to 10 min after the exercises. The low frequency (0.15-0.5 Hz) and high frequency (0.15-0.5 Hz; HF) areas under power spectra were calculated for evaluating sympathetic (LO/HI) and vagal (HI) autonomic regulation especially after a moderate to high intensity exercise was performed. The combined increase in VO2 and BP even after the exhaustive incremental exercise was later than those of the blood pressure as well as the oxygen uptake.

50.2 SYMPATHETIC AND CAROTID ARTERIAL REACTIONS TO DYNAMIC ONE-LEGGED EXERCISE TRAINING. C. A. Rey, W. M. Price*, and M. P. Clark*. Univ. of Iowa, Iowa City, IA 52242.

The purpose of the present study was to determine the effect of exercise training on sympathetic and cardiovascular responses to exercise. Six men were trained for high-intensity interval and prolonged continuous one-legged cycling 4 day/wk, 40 min/day, for 6 wk. Heart rate (HR), mean arterial pressure (MAP), and muscle sympathetic nerve activity (MSNA; personal area) were measured during 3 min of submaximal upright dynamic one-legged knee extensions at 40 W before and after training. Following peak oxygen uptake in the trained leg increased 19.5% (p < .01). MSNA and cardiovascular results before and after training are presented as mean(SE) (p < .01 vs. control; tp < .01 vs. before training; fo = .06 vs. before training).

50.3 DIFFERENTIAL EFFECTS OF SYMPATHETIC NERVE STIMULATION ON MUSCLE BLOOD FLOW DURING CONTRACTIONS OF NORMAL SKELETAL MUSCLE AND HIGHLY OXIDATIVE RAT SKELETAL MUSCLE. Gail D. Thomas and Ronald J. Reeves, UT Southeastern Med. Ctr., Dallas, TX 75235

Although muscle contraction is known to result in increased sympathetic discharge to skeletal muscle, the effects of sympathetic stimulation on muscle blood flow are controversial. In guinea pig skeletal muscle, CO-induced acidosis attenuates alpha-adrenergic vasoconstriction. We therefore hypothesized that muscle sympathetic nerve stimulation (MSNA) increased glycolytic flux with lactic acidosis also might attenuate sympathetically-mediated vasoconstriction. In anesthetized rats, we compared effects of lumbar sympathetic nerve stimulation (5 V, 5 Hz) on mean arterial pressure (MAP), and renal and mesenteric blood flow (RBF, Doppler velocimetry) to both hindlimbs at rest and during unilateral intermittent contractions of either the slow-oxidative soleus or fast-glycolytic gastrocnemius muscles. At rest, sympathetic stimulation increased MAP by 24% and decreased PFR by 20%. During contractions of the soleus these sympathetically-mediated responses were well preserved, whereas when contraction of the gastrocnemius the blood pressure response to lumbar nerve stimulation was well preserved but the vasococontractor response in the contracting hindlimb was abolished: PFR did not decrease but rather increased passively, by 61% (p < .05), with the increase in blood pressure. This loss of sympathetically-mediated vasoconstriction occurred only in the contracting hindlimb and was not evident in the contralateral resting hindlimb of the same rats. We conclude that muscle contraction indeed can impair the normal ability of sympathetic nerves to evoke vasoconstriction in the skeletal muscle bed and suggest that this impairment is caused by a local action of H+ or other glycolytic metabolites on vascular smooth muscle.

50.4 INCREASE IN RENAL SYMPATHETIC NERVE ACTIVITY IN RESPONSE TO DYNAMIC EXERCISE INTENSITY-RELATED. E.P. Otten, S.W. Mumenthaler, R.B. Bell and P. Deitrich. Medical College of Wisconsin and VA Medical Center, Milwaukee, WI 53295.

In rabbits, renal sympathetic nerve activity (RSNA) increases at the onset of dynamic exercise. We asked if the initial rise in RSNA was related to the intensity of exercise, and whether RSNA remained elevated as exercise continued. Renal nerve recording electrodes were implanted in 10 rabbits 2 days prior to study. Heart rate (HR), blood pressure (BP) and RSNA were monitored. Two incremental protocols were utilized: 12 min for 2 min: 12 min for 5 min: 5 min for 5 min. Increases in HR, BP and RSNA in response to 2 min of exercise were intensity-related, as shown below (mean(SE): +0.5% from rest in response to 2 min exercise)

50.5 CIRCUIT PATTERNS IN SYMPATHOADRENAL AND PRESSOR REACTIVITY TO EXERCISE IN HEALTHY MEN OCCUR INDEPENDENT OF BASELINE PATTERNS. Matthew S. Hickey, David L. Costill, Matthew D. Yukovich, and Krystof Kryzmenki*. Human Performance Laboratory, Ball State University, Muncie, IN 47306

In an attempt to identify interindividual patterns of sympathetically and pressor reactivity to exercise, 8 competitive male cyclists (age = 23.8 ± 5 yr, VO2max = 4.68 ± 0.9 L/min) participated. VO2max, HR, MAP, EPI, and NE were recorded preexercise and at each workload. No baseline differences were observed in pressor or exercise HR under any condition. Total accumulated work and time to failure in ST were not different in A vs. PM. No differences were observed in pressor responses under any conditions. The A vs. PM response to dynamic exercise was different in A vs. PM. MAP was significantly (p < 0.01) higher in ST at 1 min, 2 min, and failure at ST & PM. Moreover, this difference [8 mm Hg; fig. 15.5] was consistent despite a continued increase in HR over time, and was attributed to changes in both sympathetic and vasodilator pressure. Pressor responses to PM were higher (p < 0.01) in PM under all conditions. Absolute exercise levels were not different in ST or DYN, but the % change from baseline was significantly higher in ST for EPI (41% ± 3% vs. 31% ± 3% in PM) and NE (+284% ± 178% vs. 178% ± 178% in PM). Additionally, the EPI response to DYN-PM was significantly (p < 0.05) higher at ST vs. DYN in both A (A 22% ± 3% vs. 21% ± 3% in PM) and at 85% VO2max (47% ± 4% vs. 31% ± 3% in PM). The data indicate that cardiovascular and sympathetic reactivity to exercise is dependent on the type of exercise but independent of the baseline circadian patterns.


The sympathoadrenal system has a major role in adjustments to both acute and chronic high altitude exposure. Thus, this study investigated 24 hr urinary catecholamine excretion during 3 wk exposure to 4,300 m in control and a-blocked subjects. Eleven healthy young men (age = 32 ± 2 yr) were studied during resting conditions at sea level (SL), on arrival and during 21 days at 4,300 m (Peaks Phase). Six subjects received 240 mg/day propranolol (P) and 5 subjects received placebo (C). Urinary norepinephrine (NE) and epinephrine (EPI) were determined by high performance liquid chromatography (HPLC). Urinary norepinephrine (NE) and epinephrine (EPI) were determined by high performance liquid chromatography (HPLC). Individual norepinephrine (NE) and epinephrine (EPI) levels were significantly lower than those observed in C. Epiinephrine (EPI) excretion increased with initial exposure when compared to SL (4.6±3.6 to 6.5±5.0 g/m in C, 4.7±3.0 to 6.7±2.0 g/m in P), however, no consistent pattern was observed for the following 20 days at altitude. No differences in urinary EPI were observed between groups at any time. Resting arterial NE levels as well as net NE release across the leg confirm the elevation in sympathetic activity with acclimatization and suggest that resting muscle is a major source of blood and urinary NE. Increased urinary NE excretion correlated with changes in minute ventilation, Pco2, and blood volume. It remains to be determined if these variables are regulated by ac regulate sympathetic activity.
50.7

CHOLINE CITRATE MAY ENHANCE ATHLETIC PERFORMANCE.


IPI, Lexington, MA 02173 and MIT, Cambridge, MA 02139.

Plasma choline levels have been shown to influence the amounts of acetylcholine released by brain and motor neurons, such as those used in running. Long distance running has been shown to decrease plasma choline levels, and that decrease has been blocked by giving choline. Ten long distance runners (8M/2F) participated in a randomized, double-blind, placebos-controlled, crossover study comparing the effects of choline citrate (CC) to placebo in its ability to diminish muscle fatigue and thereby affect athletic performance and during and following strenuous exercise. Each runner received either CC (2xg) or placebo 1 hour prior to and again after completing 10 miles of a 20 mile run. Runners were crossed-over one month later. Run time and a battery of measurements assessing muscle strength and fatigue were conducted at baseline, immediately post-run and at 1.5 hours post-run. Plasma choline levels were raised following CC but dropped in those runners who did not receive CC. Other differences were noted. CC administered prior to strenuous exercise blocked the fall in plasma choline and may improve athletic performance.

50.8

HEART RATE AND PLASMA CATECHOLAMINE RESPONSES TO FLIGHT IN PIGEONS.

Wenling Liang* and Steven P. Thomas. Dept. Biol. Sciences, Duquesne University, Pittsburgh, PA 52121.

We have measured heart rates (HR) and plasma catecholamine titers (norepinephrine (NE), epinephrine (E) and dopamine (DA)) of pigeons (Columba livia) during quiet rest (QR), pre-flight (PF) and steady-state wind tunnel flight (SF). Blood samples were obtained from the right atrium via a jugular vein catheter, and were analyzed for catecholamines via a radioenzymatic assay (CAT-A-KIT). Mean values (and SD) are summarized below:

<table>
<thead>
<tr>
<th>Condition</th>
<th>HR (b/min)</th>
<th>NE (ng/ml)</th>
<th>E (ng/ml)</th>
<th>DA (ng/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QR</td>
<td>119 (44)</td>
<td>0.271 (0.16)</td>
<td>0.055 (0.02)</td>
<td>0.029 (0.01)</td>
</tr>
<tr>
<td>PF</td>
<td>787 (97)</td>
<td>1.076 (0.78)</td>
<td>0.198 (0.09)</td>
<td>0.080 (0.02)</td>
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<tr>
<td>SF</td>
<td>663 (45)</td>
<td>10.276 (2.2)</td>
<td>1.002 (0.36)</td>
<td>0.282 (0.17)</td>
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</table>

The (SF/QR) ratios of our pigeons are at least 6x (for NE), or at least 5x (for E) greater than corresponding (strenuous exercise/rest) catecholamine ratios reported for dogs and humans. These dramatic increases in plasma catecholamines, especially NE, indicate that pigeons utilize powerful sympathoadrenal responses to help satisfy their high energy requirements of flight.

50.9

LEFT VENTRICULAR RESPONSES TO SUSTAINED MAXIMUM DEADLIFT EXERCISE DURING ACUTE ETA-BLOCKADE IN NORMAL MNC. Peter R. Slade*, Peter Hanson, James B. Davis, IPI, Lexington Medical Center, MA 02173.

Isometric deadlift (DL) exercise performed in standing position produces a pressor increase in arterial blood pressure mediated by increases in heart rate and cardiac output. These responses are directly related to the intensity of the lift. Continuous measurement of left ventricular (LV) performance during DL has shown that LV stroke index decreases initially but are restored by Frank-Starling mechanisms. Upon release of DL, there is a marked increase in ejection fraction (EF) and systolic pressure / systolic wall stress ratio (SP/WW) accompanied by a rapid decrease in arterial pressure. We studied the potential contribution of B-adrenergic mechanisms in 6 normal subjects during control (C) and acute B-blockade (BB) using Echoknit. LV performance was continuously monitored by 2D echo-Doppler (apical chamber view) and MAP via arterial catheter. DL was performed on a force platform at 100% maximum for 30s. Echoknit, 100mg, was infused i.v. min prior to repeat DL (Fig. 1).

At rest, BB produced a significant reduction in MAP but all other parameters were unchanged. During maximal DL, SP/SWW and MAP were significantly augmented and EF was decreased but not sign. With early recovery, both SP/SWW and EF were significantly reduced by BB while MAP, HR, and SV were unaffected. These responses indicate that LV performance during maximal DL is maintained primarily by Frank-Starling mechanisms, and the hyperdynamic increase in LV indices which occur in early recovery are mediated by augmented B-adrenergic driven. Chronotropic control of heart rate appears to be regulated independently under these conditions.

50.10

EFFECT OF COOL DOWN AND P-BLOCKADE ON POST-EXERCISE HEART RATE CHANGES. Alfonso R. Greco*, Mark E. Caberra, Michael Budd, Case Western Reserve Univ, Cleveland,OH 44106.

The changes in autonomic control of the heart during and immediately following exercise are unclear. In addition, the effect of an active cool down on post-exercise autonomic control of heart rate (HR) is unknown. Our objectives were to determine 1) the sympathetic contribution to post-exercise control of HR and 2) the difference between an active cool down (100W) and a seated cool down on post-exercise autonomic control of HR. Methods: Heart rate and respiration were measured continuously during ramped exercise to a peak workload above ventilatory threshold. A 2x2 design was used in which the exercise protocol was repeated with and without an active cool down and with and without controlled B-blockade (metoprolol, 0.1 mg/kg). The order of studies was randomized. Results: The post-exercise HR changes during cool down (active; seated; triangles) and B-blockade (with open; without (solid)) are shown in the figure. Seated cool down resulted in a faster return of HR than active cool down and this effect was unaffected by cardiac sympathetic blockade (slope of response between control and B-blockade in different, p<0.05). Conclusion: These data suggest that the withdrawal of sympathetic effects on HR is minimal during the initial period of recovery regardless of the type of cool down.

50.11

INFLUENCE OF AGING ON THE HEMODYNAMIC ADJUSTMENTS TO GRADED EXERCISE IN THE RAT. C.K. Kregel, Department of Exercise and Sport Sciences, University of Arizona, Tucson, AZ 85721.

The purpose of this study was to determine whether the regional and systemic hemodynamic adjustments to graded treadmill exercise are altered with advancing age. Mature (MAT; 12 mo) and senescent (SEN; 24 mo) male Fischer 344 rats were instrumented with an arterial catheter and Doppler flow probes, and mean arterial pressure (MAP), heart rate (HR), and superior mesenteric (MF) and iliac (IF) blood flow velocities were determined during graded exercise to exhaustion. Isometric deadlift (DL) exercise performed in standing position produces a pressor increase in arterial blood pressure mediated by increases in heart rate and cardiac output. These responses are directly related to the intensity of the lift. Continuous measurement of left ventricular (LV) performance during DL has shown that LV stroke index decreases initially but are restored by Frank-Starling mechanisms. Upon release of DL, there is a marked increase in ejection fraction (EF) and systolic pressure / systolic wall stress ratio (SP/WW) accompanied by a rapid decrease in arterial pressure. We studied the potential contribution of B-adrenergic mechanisms in 6 normal subjects during control (C) and acute B-blockade (BB) using Echoknit. LV performance was continuously monitored by 2D echo-Doppler (apical chamber view) and MAP via arterial catheter. DL was performed on a force platform at 100% maximum for 30s. Echoknit, 100mg, was infused i.v. min prior to repeat DL (Fig. 1).

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50.12

EFFECTS OF CHRONIC PHYSICAL ACTIVITY ON SYMPATHETIC NERVE ACTIVITY IN OLDER ADULT HUMANS. Alexander Y. Ng, Robin Callister, Mary Jo Reiling*, and Douglas R. Seals, University of Arizona, Tucson, AZ 85721.

Aerobic exercise training does not affect resting muscle sympathetic nerve activity (MSNA) in younger adults (Acta Physiol Scand 128: 1990). It increases cardiac output in elderly men. This study examined the relationship between MSNA and endogenous catecholamines in young and older men. Catecholamine titers were measured in normal young men (18-30 y) and normal older men (56-70 y) during supine rest, following submaximal aerobic exercise, and during peak exercise exhaustion. These findings indicate that the regulation of arterial blood pressure and heart rate during a peak treadmill exercise is diminished in older rats may necessitate a compensatory increase in vasoconstriction in order to properly augment arterial blood pressure and skeletal muscle blood flow. (Supported by Grant-in-Aid G-2-10-90 from AHA, Arizona Affiliate.)

Supported by NIH grants AG0537, AG00423 and AG05518.
SATURDAY AUTONOMIC RESPONSES 237

50.13
SYMPATHETIC NERVE ACTIVITY AT THE ONSET OF LEG-CYCLING EXERCISE. Robin Callister, Alexander V. Nig and Douglas B. Suga. University of Arizona, Tucson, AZ 85721
A "nonsympathetic discharge" is thought to occur at the onset of large-muscle dynamic exercise (Guyton, 1986) which is responsible for vasoconstriction in several regions allowing a redistribution of cardiac output to active muscle while maintaining arterial perfusion pressure to vital organs. An increase in sympathetic nerve activity to non-active skeletal muscle (MSNA) is considered an important part of this response.
To test this hypothesis, MSNA (radial nerve microneurography) was measured before and during two-leg cycling exercise at 33W (n=11), and at multiple workloads up to 200W (n=4) or above. Immediately prior to exercise, MSNA decreased to 20% of control levels. With the initiation of exercise, MSNA rose to 60% of control but remained below control levels throughout the first minute of exercise. This pattern of activity was observed in workloads up to 60% of maximum. Above this intensity, MSNA tended to increase above control levels by the end of the first minute of exercise but the same general pattern of response (decrease in MSNA prior to initiation, and small elevation in MSNA on initiation of exercise) was observed even at maximum exercise levels. These data do not support the hypothesis that MSNA increases at the onset of large-muscle dynamic exercise. In contrast, they suggest that MSNA is markedly reduced during the initiation of exercise, possibly contributing to vasodilation both act and non-active skeletal muscle.
Supported by NIH grants HL39966, AG0537 and AG00423.

50.15
Six men were serially exposed for three minutes to combinations of suprastolic leg occlusion (LO) and 45 torr lower body positive pressure (LBPP) to determine the factors involved in LBPP induced blood pressure elevations. During each stage, heart rate, intra-arterial pressure (MAP), central venous pressure (CVP), and stroke volume (SV) via continuous wave Doppler were obtained. Cardiac output (Q = HR * SV) and total peripheral resistance (TPR = MAP / Q) were calculated each minute. Blood pressure (BP) was measured using a noninvasive method (mean arm systolic pressure) and summarized below.

Control LO LO LO Recovery LBPP LBPP
MAP 80.0±1.9 83.1±2.7 83.2±1.7 83.8±1.7 83.8±2.9 82.9±1.5 83.5±1.3
HR 65.5±6.4 62.7±6.4 62.3±6.4 65.4±6.2 62.5±6.1 64.0±5.2
SV 5.9±0.8 5.8±0.8 5.7±0.8 6.1±0.8 5.8±0.8 5.9±0.8 5.6±0.8
* p<0.05 from control (LO leg occlusion, LBPP: lower body positive pressure)
The pressor response to LBPP is not a result of peripheral translocation of blood because it occurs when movement of blood is prevented with LO. We suggest that LBPP at rest may stimulate a neurogenic mechanical reflex in the legs resulting in a rise in blood pressure while preventing the expected heart rate induced by LBPP.
Supported by HL34202.

50.16
HEMODYNAMIC RESPONSES OF HIGH-FIT RUNNERS DURING HEAD-UP TILT TESTING TO SYNCOPE. T.J. Ebert and T. Denahan. Medical College of WI and VA Medical Center, Milwaukee, WI 53295.
This study explored the moment-to-moment response of 7 endurance-trained (ET) runners (VO2max=66±3 ml/kg/min) and 3 sedentary (SED) subjects (VO2max=38±3 ml/kg/min) during 30 min of 70° head-up tilt (HUT) testing. Written informed consent was obtained from each subject prior to experimental procedures. HR, BP (radial artery), central venous pressure (CVP, jugular vein), stroke volume (SV, impedance cardiography), femoral venous resistance (FVR, He-in-Salt venous plethysmography), calculated cardiac output (CO) and systemic vascular resistance (SVR) were measured before and continuously during HUT. Supine resting HR was lower (55±7 vs 61±7 bpm, p<0.05) and SV higher (81±9 vs 73±8 ml/min) in ET compared to SED subjects. Immediate response (1st min) to HUT revealed a larger decrease in SV (~11±5% vs ~6±2%) in ET runners but similar increases in HR, FVR and SVR. All ET subjects fainted: mean time to syncope was 10.5±2.25 min (range=4.19.0 min). ET responses preceding syncope consisted of a failure to maintain SVR and FVR compared to SED (p<0.05) leading to a gradational decline in BP while HR continued to rise. Relative bradycardia in ET only occurred immediately prior to syncope. ET runners appear to be more susceptible to syncope during orthostatic stress; syncope is associated with an early failure of sympathetically-mediated vasoconstriction. The sudden vaguely-mediated bradycardia described in the "vasovagal" response only occurs immediately prior to onset of syncope.

50.17
NONORTHOSTATIC AUTONOMIC STRESS RESPONSES DO NOT DISTINGUISH BETWEEN HIGH-FIT RUNNERS WITH SYNCOPE AND SEDENTARY, NONSYNCOPEAL SUBJECTS. T. Denahan and T.J. Ebert. Department of Exercise & Health Sciences, Alma College, Alma, MI 48801.
The effects of exercise on orthostatic response were studied after five days of simulated weightlessness at 16° head-down tilt (HDT) in three groups (E, exercised; E+F, exercised and fed) of male subjects (VO2max=30±3 ml/kg/min) during 30 min of 70° head-up tilt (HUT) testing.
Heart rate, blood pressure, forearm blood flow, calf circumference, and muscle sympathetic nerve activity were measured during head-up tilt testing and a group (n=5) of sedentary subjects (E. VO2max=30±3 ml/kg/min) from a third group (E+F) exercising during tilt. After informed consent, subjects were instrumented for HR, BP (radial artery), central venous pressure (CVP, jugular vein) and muscle sympathetic nerve activity (MSNA, peroneal nerve). Measurements were recorded during and after a 3-stage nitric oxide, handgrip (HI), a 60-sec cold pressor (CP), and sequential infusions of nitroprusside (NIP). At rest, HR was lower in ET vs SED (50±8 vs 65±7, p<0.05) while resting BP (90±10/60±8, p<0.05) and MSNA (burst/heart beat) did not differ between groups.

Peak Responses (A) to Autonomic Stress (XSEM)

<table>
<thead>
<tr>
<th>Test group</th>
<th>MSNA</th>
<th>BP C</th>
<th>NIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO</td>
<td>50±8</td>
<td>90±8</td>
<td>5±3</td>
</tr>
</tbody>
</table>

Auto-rihic responses did not differ between ET and SED subjects despite marked intolerance to tilt in the E3 group. Thus, autonomic testing in the supine position does not identify athletes at risk for syncope.

50.18
THE EFFECT OF 1 OOFWR BODY PRESSURE POSITIVE ON EXERCISE CAPACITY OF SPINAL CORD INJURED INDIVIDUALS. Kenneth H. Pielli and P.J. Barrett. *+, Wichita State University, Wichita, Kansas 67208.
The purpose of this study was to determine if lower body positive pressure (LBPP) applied by means of an anti-g suit could improve cardiovascular parameters of spinal cord injured individuals (SCII) during arm crunk exercise. Ten SCI (8 quadruplegics, 2 paraplegics) healthy males (31±10 years) and 4 non-disabled (ND) males (ages 14±9 years) participated in this study. A discontinuous arm crunk exercise test to determine peak cardiovascular capacity was performed with and without LBPP. For the SCI, significantly higher peak oxygen consumption (VO2: 1042±212 vs 839±218 ml/min), ventilation (VE: 46±17 vs 35±9 l/min) and work level (50.15 ± 40±13 watts) were seen during LBPP. No significant differences for peak VO2, VE, or work level were seen for the ND subjects. Significantly higher minimal mean arterial blood pressure and lower minimal heart rates were seen for the SCI but not for the ND subjects. Cardiac output (Q, l/min; CO2 rebreathing method) was measured at 50% peak VO2 with and without LBPP. SCI demonstrated higher Q (8.8±2.2 vs 8.3±2.5 l/min), stroke volume (0.4±0.2 vs 0.4±0.2 ml/min), and mean arterial blood pressure (80±14 vs 71±13 mm Hg) with LBPP while ND subjects demonstrated higher mean arterial blood pressure with LBPP. The results suggest that LBPP limited the pooling of blood in the lower extremities for SCI thus providing more central blood volume.

50.19
EFFECT OF EXERCISE ON ORTHOSTATIC RESPONSE FOLLOWING SIMULATED WEIGHTLESSNESS. J.D. Seelbach, J.E. Cribb, G.K. DeJon ~ and J.E. Davis. Department of Exercise & Health Sciences, Alma College, Alma, MI 48801.
The effects of exercise on orthostatic response were studied after five days of simulated weightlessness at 16° head-down tilt (HDT) in three groups (E, exercised; E+F, exercised and fed) of male subjects (mean age = 21.4±0.1 years). A control group (C) exercised for 90 minutes per day and was not exposed to HDT while a second group (E+F) exercised for 90 minutes per day and was exposed to simulated weightlessness in a negative pressure chamber (LBPP) 4 hours before and after (C+F) 5 days of HDT. Heart rate, blood pressure, forearm blood flow, calf circumference, and mean arterial blood pressure were measured during LBPP while ND subjects demonstrated higher mean arterial blood pressure with LBPP. The results suggest that LBPP limited the pooling of blood in the lower extremities for SCI thus providing more central blood volume.

<table>
<thead>
<tr>
<th>C</th>
<th>E</th>
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<tbody>
<tr>
<td>66±3</td>
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<td>75±2</td>
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Supported by NASA grant #NAG9-400.
CARDIAC AFFERENTS ATTENUATE THE MUSCLE CHEMOREFLEX IN RATS. 
Stephen E. D'Carlo and Hazel L. Collins. Northeastern Ohio Universities College of Medicine, Rootstown, Ohio 44272.

The influence of cardiac afferents on the muscle chemoreflex (MR) was examined in 9 rats. Rats were instrumented with a splanchnic-licthoped catheter inserted into the pericardial space. Two weeks later, a Doppler ultrasonic flow probe and a pneumatic vascular occluder were positioned around the terminal aorta. Finally, a left carotid catheter was placed in the carotid artery for the measurement of mean arterial pressure (MAP) and heart rate (HR) and a splanchnic-licthoped catheter was placed in the right atrium via the jugular vein to obtain blood samples. The hemodynamic response to a range of stimuli in terminal aortic blood velocity (TAQ) during exercise was examined under 3 conditions: 1) control (C), 2) cardiac afferent blockade (Ex), and 3) combined cardiac afferent and arterial blockade (Ad). Exercise (9 m/min, 10% grade) increased HR 68 ± 14 bpm, MAP (122 ± 20 mm Hg) and TAQ (9.2 ± 1.0 kHz). During exercise, a reduction of TAQ reduced mixed PO2 17 ± 5%. The table presents the means ± SF for the changes in TAQ, MAP, and HR during the occlusion. The gains of the MR are also presented.

G | Ex | Ad  
--- | --- | ---  
TAG (mMg) | -10.8 ± 1.0 | -12.5 ± 1.3 | -12.6 ± 1.6  
MAP (mmHg) | 12.6 ± 1.3 | 5.6 ± 0.6 | 15.4 ± 2.4  
HR (bpm) | 46.7 ± 12.1 | 11.3 ± 7.2 | 21.1 ± 6.4  
Gain (mMg/kH) | 1.3 ± 0.2 | 0.6 ± 0.06 | 1.0 ± 0.3  

Ex reduced the gain of the MR -65 ± 6%. However, Ad increased the MR gain 106 ± 47%. Thus cardiac afferents tonically inhibit the pressor response to reductions in TAQ during exercise. (Supported by HL 45245)

HINDLIMB MUSCLE CONTRACTION ELICITS DEPRESSOR RESPONSES IN ANESTHETIZED RATS. J. M. Verstynen and M. W. Stramel. Exercise Physiology Program and Department of Physiology and Biophysics, University of Louisville, Louisville, KY 40292.

The purpose of these experiments was to determine the hemodynamic responses to static muscle contraction elicited by venous root stimulation in anesthetized rats. Sprague-Dawley rats were anesthetized with sodium-chloralose/urethane and instrumented with carotid, jugular and tracheal catheters and pulsed Doppler flow probes on the mesenteric and femoral arteries. The lumbar ventral roots were isolated after a L4-5 laminectomy. The cut ends of roots innervating hindlimb muscles were stimulated (60 Hz, 0.1 msec duration) at 2-8X motor threshold for 30 seconds. Isometric contraction of the left triceps surae produced increases in tension of 15-35 mm Hg. The peak depressor response occurred 5-8 seconds after initiation of contraction. Blood pressure remained depressed throughout the hindlimb contraction. During contraction heart rate increased slightly (5-15 beats/min) and mesenteric blood flow decreased (4.9%). The results indicate that the hemodynamic response pattern elicited by static muscle contraction in anesthetized rats is disparate from that elicited by dynamic exercise in conscious rats. Supported by Amer. Heart Assoc., KY Affiliate and NIH 06296.
CAN INCREASING BLOOD FLOW TO ACTIVE MUSCLES LIMIT THE SYMPATHETIC ACTIVITY IN HUMANS? 

J. M. J. Van Blitterswijk, T. A. Taagepera, and J. M. W. M. van den Honert. University of Amsterdam, The Netherlands

This study examined whether increasing blood flow to actively contracting muscles could limit the sympathetic nervous system (SNS) activity in humans. The hypothesis was that heightened sympathetic activity is responsible for the increase in blood flow at high altitude. The study measured blood flow and sympathetic nerve activity (SNA) during static handgrip (SHG) exercise. The results showed that increasing blood flow to active muscles could partially offset increases in tissue pressure and thus reduce the reflex increase in blood pressure. These changes were observed even when blood flow was increased by 20% during SHG.

ANTAGONISTS TO SUBSTANCE P AND SOMATOSTATIN MICROINJECTED INTO THE DORSAL HORN ATTENUATE THE EXERCISE PRESSOR REFLEX. 

Britt Wilson, J. M. Hill, M. P. Kaufman, University of California, Davis. Dept. of Cardiovascular Medicine, Davis, CA 95616

This study investigated whether microinjection of antagonists to substance P (SP) and somatostatin (SOM) into the dorsal horn of the spinal cord could attenuate the exercise pressor reflex. The results showed that microinjection of either antagonist into the dorsal horn significantly reduced the pressor response to exercise, indicating that these neurotransmitters play a role in mediating the exercise pressor reflex.

CAN INCREASING BLOOD FLOW TO ACTIVE MUSCLES BLUNT THE SYMPATHETIC ACTIVITY NORMALLY ASSOCIATED WITH HANDGRIPPING IN HUMANS? 

J. M. J. Van Blitterswijk, T. A. Taagepera, and J. M. W. M. van den Honert. University of Amsterdam, The Netherlands

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NEURONS IN THE VENTROLATERAL MEDULLA RECEIVE INPUT FROM DESCENDING "CENTRAL COMMAND" AND FEEDBACK FROM CONTRACTING MUSCLES. P.C. Nolan, J.A. Pawelczyk and T.G. Waldrop. Dept. of Physiology & Biophysics, Neuroscience Program and College of Medicine, Univ. of Illinois, Urbana, IL. 61820

Feedback from contracting muscles and descending central command are two neural mechanisms responsible for adjusting cardiorespiratory activity during exercise. Prior studies have focused on identifying supraspinal sites involved in exercise regulation; however, little is known about brain sites that integrate input from the various mechanisms active during exercise. The purpose of the present study was to determine if integration occurs in the ventrolateral medulla (VLM). The single unit responses of neurons in the ventrolateral medulla to contraction of hindlimb muscles (elicited by stimulation of the L7 and S1 ventral roots) and to activation of simulated central command (caudal hypothalamic stimulation) were examined in anesthetized cats. As previously reported, muscular contraction increased the discharge frequency of many VLM neurons; approximately fifty percent of the VLM neurons that responded to muscular contraction were also sensitive to hypothalamic stimulation. Moreover, computer analyses revealed that these neurons had a basal discharge frequency related to cardiovascular and/or respiratory rhythms. The neuronal response to hypothalamic stimulation was not due to muscular contraction since the responses persisted after muscular paralysis. These results demonstrate that individual VLM neurons receive input from contracting muscles and from the central command mechanism. Thus, integration of these neural mechanisms active during exercise may occur in the ventrolateral medulla (Supported by NIH 06296 & Illinois AHA).


A subset of the catecholamine-containing cells in the RVLM have been implicated in vasomotor control. C1 area cells have monosynaptic input to the preganglionic sympathetic neurons of the spinal cord and receive descending inputs from the higher CNS. The role of RVLM in support of treadmill exercise was tested in dogs measuring heart rate (HR), cardiac output (CO), arterial (aortic) pressure (AP), internal thoracic (IT) and renal artery (RA) blood flows. Submaximal exercise tolerance testing was conducted on 15 dogs before and after incomplete, unilateral lesions were made with stereotaxic microinjection of kainic acid (100 mM, 100 nl) into the RVLM. Comparing grouped pre-lesion averaged results for 3 ETTQ with the results post-lesion there was a significant decrease in resting and exercise total peripheral resistance and AP. CO, peak aortic blood flow and IT but not RA were reduced but not significantly. No behavioral, motor or cognitive changes were observed. Lesions were approximately 1 mm diameter in the rostral C1 cell column at the retrofacial area near the compact division of nucleus ambiguus. We conclude that RVLM may be universally involved in AP control during rest and exercise.