Are blood flow and lipolysis in subcutaneous adipose tissue
influenced by contractions in adjacent muscles in humans?

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Running title: Spot lipolysis

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Abstract

Aerobic exercise increases whole-body adipose tissue lipolysis, but is lipolysis higher in subcutaneous adipose tissue (SCAT) adjacent to contracting muscles than in SCAT adjacent to resting muscles?

Ten healthy, overnight-fasted males performed one-legged knee extension exercise at 25% of maximal workload ($W_{\text{max}}$) for 30 minutes followed by exercise at 55% $W_{\text{max}}$ for 120 minutes with the other leg and finally exercised at 85% $W_{\text{max}}$ for 30 minutes with the first leg. Subjects rested for 30 minutes between exercise periods. Femoral SCAT blood flow was estimated from washout of $^{133}$Xe and lipolysis was calculated from femoral SCAT interstitial and arterial glycerol concentrations and blood flow.

In general, blood flow as well as lipolysis was higher in femoral SCAT adjacent to contracting than adjacent to resting muscle (time 15-30 min: blood flow: 25% $W_{\text{max}}$: 6.6 ± 1.0 vs. 3.9 ± 0.8 ml 100 g$^{-1}$ min$^{-1}$, $P < 0.05$; 55% $W_{\text{max}}$: 7.3 ± 0.6 vs. 5.0 ± 0.6, $P < 0.05$; 85% $W_{\text{max}}$: 6.6 ± 1.3 vs. 5.9 ± 0.7, $P > 0.05$; lipolysis: 25% $W_{\text{max}}$: 102 ± 19 vs. 55 ± 14 nmol 100 g$^{-1}$ min$^{-1}$, $P = 0.06$; 55% $W_{\text{max}}$: 86 ± 11 vs. 50 ± 20, $P > 0.05$; 85% $W_{\text{max}}$: 88 ± 31 vs. -9 ± 25, $P < 0.05$).

In conclusion, blood flow and lipolysis are generally higher in SCAT adjacent to contracting than adjacent to resting muscle irrespective of exercise intensity. Thus, specific exercises can induce “spot lipolysis” in adipose tissue.

Keywords: exercise, spot lipolysis, microdialysis
Introduction

Obesity can be defined as a condition where the amount of adipose tissue is increased to such a degree that it has consequences for the health of the person. In addition to the amount also the distribution of fat is important. Obesity can be diminished by increased physical activity and/or reduced caloric intake (11; 21) and, at least in the short term, the size of the negative caloric balance is the primary factor determining the weight loss (22; 28). There is evidence that exercise-induced relative loss of fat is higher in visceral and abdominal, subcutaneous adipose tissue (SCAT) than in femoral SCAT (23). This indicates that regional adipose tissue depots are regulated independently, and for many years it has been discussed whether specific exercises can reduce local adipose tissue depots, i.e. induce a “spot reduction” of adipose tissue, and thus modify fat distribution (19; 20).

A number of studies have examined the “spot reduction” theory and conclusions have been contradictory (12; 16; 19; 20). A valid study design to test the hypothesis of “spot reduction” is one in which the muscles in one part of the body are trained and the muscles in the contra lateral side are not, and the size of the adipose tissue depots adjacent to the trained respective sedentary muscles are measured before and after the study period. One study using this design (19) found a decrease in skinfold thickness of the trained arm, but in another study (20) the skinfold thickness decreased significantly in both the trained and the sedentary arm during the study period. The latter finding is essentially supported by a study in which the skinfold thickness of both arms was measured in tennis players and control subjects (12). The skinfold thickness did not differ between arms in tennis players or control subjects, but skinfold thickness of both arms was lower in tennis
players compared to controls. Krotkiewski et al. (16) had 10 healthy middle aged females exercise one leg for 5 weeks while the other leg was resting and ultrasound measurements revealed that the thickness of the femoral SCAT of the trained leg was significantly decreased whereas the thickness of the SCAT of the sedentary leg was unchanged. However, a reduced thickness of the subcutaneous tissue layer could be due to a training-induced enlargement of the underlying muscle which could result in a compression of a possibly unchanged amount of SCAT. To clarify this Krotkiewski et al. took 2 biopsies of the SCAT from each thigh and found that fat cell weight decreased non-significantly in both biopsies from the trained leg (-7% [0.60 ± 0.07 [mean ± SEM] to 0.56 ± 0.05 µg] and -26% [0.42 ± 0.07 to 0.31 ± 0.08 µg]) and increased non-significantly in both biopsies from the sedentary leg (+11% [0.54 ± 0.03 to 0.60 ± 0.03 µg] and +7% [0.46 ± 0.08 to 0.49 ± 0.08 µg]). Based on the biopsy data Krotkiewski et al. turned down the “spot reduction” hypothesis, but it may be speculated that their non-significant changes in fat cell weight could be due to a type 2 statistical error.

In the present study we evaluated one component in the “spot reduction” hypothesis namely if “spot lipolysis” occurs in SCAT overlying contracting skeletal muscle. Our subjects performed acute one-legged knee extension exercise, and by use of $^{133}$Xe washout and microdialysis techniques we estimated blood flow and lipolysis in femoral SCAT adjacent to contracting as well as adjacent to resting skeletal muscle.
Materials and methods

**Subjects.** Ten healthy, moderately active, overnight-fasted males (age: 26 ± 2 years [mean ± SEM], weight: 82 ± 3 kg, height: 183 ± 2 cm, BMI: 24.5 ± 0.8 kg m^{-2}, Vo_{2max}: 49 ± 2 ml kg^{-1} min^{-1}) gave their written consent according to the declaration of Helsinki II to participate in the study, which was approved by the Ethics Committee for Medical Research in Copenhagen (KF 11-055/03).

**Protocol.** Prior to the experiment subjects were accustomed to exercise on the knee extension ergometer and maximal work capacity (W_{max}) was determined for each leg as described by Andersen et al. (1). At least 5 days before the experimental day subjects performed a VO_{2peak} test on a bicycle ergometer using a standard progressive exercise test. Subjects were asked to refrain from vigorous physical activity for 2 days prior to the experiment. After a 12-hour fast and abstinence from coffee, tea, alcohol and tobacco, the subjects arrived at the laboratory at 8 a.m. During the experiments subjects wore shorts and t-shirt and the room temperature was 23 ± 1 °C. A catheter (Arterial Cannula with FloSwitch, Becton Dickinson, UK) was inserted in the brachial or radial artery for blood sampling. Microdialysis catheters were inserted and ^{133}Xe was injected into SCAT of both thighs (see below). After a 90-min equilibration period the experiment was initiated. The experiment consisted of a 15-min resting period and 3 consecutive periods of one-legged knee extension exercise (Fig. 1). First subjects exercised with one leg for 30 min at 25% of maximal work capacity (W_{max})(13 ± 1 watt, heart rate 81 ± 3 bpm). After a 30-min rest subjects exercised with the other leg for 120 min at 55% of W_{max} (26 ± 1 watt, heart rate 84 ± 4 bpm) and after another 30-min rest they exercised with the first leg again for 30 min but now at 85% of W_{max} (44 ± 2 watt, heart rate 107 ± 4 bpm). Selection
of the leg eligible for low-high respective moderate intensity was done by randomized stratification, such that dominant and non-dominant legs were similarly represented.

Both during the resting and the exercise periods subjects were sitting in a chair with the torso strapped to the back of the chair. Subjects had free access to water throughout the experiment. Pulmonary oxygen uptake and carbon dioxide excretion were measured regularly during exercise using an automated on-line system (Oxycon Champion, Erich Jaeger GmbH, Hoechberg, Germany).

**Microdialysis.** Microdialysis was performed in principle as described previously (27). After anesthesia of the skin (0.2 ml lidocaine, 5 mg ml\(^{-1}\)) at the sites of perforation, 2 microdialysis catheters (CMA 60, CMA/Microdialysis AB, Stockholm, Sweden) were placed in the SCAT adjacent to the vastus lateralis part of the quadriceps muscle in each thigh. Catheters were placed equidistant from the skin and the muscle fascia, 13-15 cm above the patella and with 2-3 cm between catheters. Catheters were perfused at a rate of 1.0 µl min\(^{-1}\) using high-precision syringe pumps (CMA 100, CMA/Microdialysis AB, Stockholm, Sweden). The perfusate consisted of Ringer acetate with 2 mM glucose, 5 kBq ml\(^{-1}\) \(^{3}\)H-glycerol (NEN, Zaventem, Belgium) and 5 kBq ml\(^{-1}\) \(^{14}\)C-ethanol (NEN). Seven out of 40 catheters ceased to function at some point during exercise.

The in vivo relative recovery (RR) for glycerol was determined by the internal reference calibration technique (24). This technique assumes that the relative loss of \(^{3}\)H-glycerol from the microdialysis catheter to the interstitial fluid equals the RR of glycerol from the interstitial fluid to the microdialysis catheter. The RR of glycerol was calculated as \((\text{Dpm}_p - \text{Dpm}_d) / \text{Dpm}_p\), where \(\text{Dpm}_p\) is \(^{3}\)H-disintegrations per minute in 5 µl perfusate and \(\text{Dpm}_d\) is \(^{3}\)H-disintegrations per minute in 5 µl dialysate. Interstitial concentrations
were calculated as \((C_d - C_p) / RR + C_p\), where \(C_d\) is dialysate concentration and \(C_p\) is perfusate concentration.

**Subcutaneous adipose tissue blood flow (ATBF).** ATBF was measured by the local \(^{133}\text{Xe}\) washout technique (27), which has the advantage that it is a quantitative method. At least 30 minutes before start of the resting period, 0.5-1 MBq gaseous \(^{133}\text{Xe}\) (Amersham Health, UK) in a volume of 0.05-0.1 ml was injected in SCAT adjacent to the rectus femoris part of the quadriceps muscle. The \(^{133}\text{Xe}\) depot was placed equidistant from the skin and the muscle fascia and 13-15 cm above the patella. The washout rate of \(^{133}\text{Xe}\) was measured continuously by a scintillation counter system (Oakfield Instruments, Eynsham, UK) strapped to the skin surface above the \(^{133}\text{Xe}\) depot. ATBF was determined in 15- or 30-min periods and calculated as \(-k \cdot \lambda \cdot 100\) (ml 100 g\(^{-1}\) min\(^{-1}\)), where \(k\) is the rate constant of the washout and \(\lambda\) is the tissue-to-blood partition coefficient for \(^{133}\text{Xe}\) at equilibrium. \(\lambda\) was assumed to be 10 ml g\(^{-1}\) (15).

Changes in ATBF in areas surrounding microdialysis catheters were also estimated by the microdialysis outflow/inflow technique (13; 25). The technique was originally described using ethanol as a marker of blood flow (13), but we have demonstrated that \(^{14}\text{C}\)-ethanol is a valid alternative to ethanol (25). The blood flow marker is added to the perfusate (inflow), it diffuses out through the membrane and is washed away by the blood. The higher the blood flow, the more marker is washed away, and the less marker remains in the dialysate (outflow). Accordingly, the outflow/inflow ratio of marker varies inversely with blood flow (9; 25). The advantage of the microdialysis outflow/inflow technique is that it estimates changes in blood flow in the same area as interstitial concentrations of metabolites are measured.
Sampling and analyses. Dialysate for analysis of glycerol was collected in 200-µl capped microvials at 15- or 30-min intervals, immediately frozen and kept at -20 °C until analysis. Dialysate sampling was delayed by 2 min relative to the rest of the experimental protocol to compensate for the transit time in the outlet tubing. Blood for determination of hormones and metabolites was sampled into iced tubes and immediately centrifuged. Blood was sampled immediately before as well as every 15 minutes during the first 30 minutes of the exercise periods and additionally at time 60 and 120 minutes during the 120-minute exercise period. Blood for determination of glycerol was stabilized with EDTA and plasma was kept at -20 °C until analysis. Microdialysate and plasma glycerol concentrations were determined by a CMA 600 microdialysis analyzer (CMA/Microdialysis AB, Stockholm, Sweden). Blood for determination of insulin was stabilized with trasylol and EDTA and kept at -20 °C until analysis. Arterial plasma insulin concentrations were determined by a commercial ELISA (DakoCytomation, Great Britain). Blood for determination of epinephrine was stabilized with reduced glutathione and EDTA and kept at –80 °C until analysis. Arterial plasma epinephrine concentrations were determined by a commercial radioimmunoassay (High sensitive 2 CAT RIA, Labor Diagnostika Nord, Germany).

Calculation of adipose tissue lipolysis. Adipose tissue venous glycerol concentrations were calculated based on “Ficks law of diffusion for a thin membrane” as described previously (27). Subsequently adipose tissue glycerol output was calculated as venous minus arterial glycerol concentration multiplied by ATBF (27). Adipose tissue glycerol output equals adipose tissue lipolysis as glycerol is not reused to any significant extent in adipose tissue (3).
Statistics. The computer program SigmaStat for Windows version 2.03 (SPPS Inc., Chicago, Ill., USA) was used for statistical analysis. All data are presented as means ± SEM. A two-way repeated measures analysis of variance (RM ANOVA) with leg and time as factors was used to test for differences between legs and changes with time in ATBF and microdialysis-associated variables. A one-way RM ANOVA was used to test for changes with time in plasma concentrations. If a difference was present according to the ANOVA, a Student-Newman-Keuls test was used post hoc to locate the difference. A one-sample t-test was used to test if incremental lipolysis differed from 0. A significance level of 0.05 in two-tailed testing was chosen a priori.
Results

Adipose tissue blood flow (ATBF). Knee extension exercise with one leg at 25%, 55% and 85% Wmax increased (P < 0.05) femoral subcutaneous ATBF in both legs (Fig. 2A). In general, blood flow was higher in adipose tissue adjacent to working muscle than in adipose tissue adjacent to resting muscle. At 25% and 55% Wmax the ATBF difference between legs (rest vs. exercise) was significant, but this was not the case at 85% Wmax. The changes in ATBF detected by the microdialysis 14C-ethanol technique were similar to changes detected by the 133Xe washout technique (Fig. 2A and 2B).

Adipose tissue interstitial and arterial plasma glycerol concentrations. Knee extension exercise with one leg at 55% and 85% Wmax increased (P < 0.05) the femoral SCAT interstitial glycerol concentration compared to rest (Fig. 3A). At 85% Wmax the interstitial glycerol concentration was higher (P < 0.05) in adipose tissue adjacent to working muscle than in adipose tissue adjacent to resting muscle. At all 3 intensities knee extension exercise with one leg increased (P < 0.05) the arterial plasma glycerol concentration compared to rest (Fig. 3B).

Adipose tissue lipolysis. During knee extension exercise with one leg at 25% and 85% Wmax the lipolysis was significantly higher in femoral SCAT adjacent to working muscle than in adipose tissue adjacent to resting muscle (Fig. 4). During the first 60 minutes of exercise with one leg at 55% Wmax the lipolysis seemed higher in adipose tissue adjacent to working muscle than in adipose tissue adjacent to resting muscle, but the difference was not significant. The difference in adipose tissue lipolysis between the two legs (lipolysis in exercising minus resting leg) during time 0-30 minutes showed that lipolysis
was larger (P < 0.05) than zero at 25% and 85% $W_{\text{max}}$, but the not at 55% $W_{\text{max}}$ (Fig. 5). Incremental lipolysis did not change with exercise intensity (P > 0.05).

**Arterial plasma hormone concentrations.** Knee extension exercise with one leg at 55% as well as at 85% $W_{\text{max}}$ decreased (P < 0.05) the arterial plasma insulin concentration compared to rest (Table 1). Exercise with one leg at 85% $W_{\text{max}}$ increased (P < 0.05) the arterial plasma epinephrine concentration compared to rest (Table 1).
**Discussion**

Specific exercises can induce “spot lipolysis” as we found blood flow (Fig. 2) and lipolysis (Fig. 4 and 5) to be higher in SCAT adjacent to contracting than adjacent to resting muscle. Based on the present results it cannot be foreseen if specific exercises can induce “spot reduction” as triacylglycerol (TG) stores could be fully replenished or even super compensated between exercise sessions.

During exercise temperature increases in the contracting muscles (10) and this would increase temperature also in the tissues adjacent to the contracting muscles. An increase in adipose tissue temperature induces an increase in ATBF (9), and this mechanism could potentially explain the increased blood flow in the adipose tissue adjacent to the contracting muscle in the present study (Fig. 2). During knee extension exercise the increase in temperature of the contracting quadriceps muscle has been found to be approximately 2 ºC (10). Felländer et al. (9) heated SCAT and increased the temperature in the tissue by 4 ºC which elicited an increase in ATBF of approximately 1.5 ml 100 g⁻¹ min⁻¹. We did not measure the temperature of the adipose tissue adjacent to the contracting muscles, but assuming that the adipose tissue temperature increased 1 ºC this could according to the data by Felländer et al. (9) at most explain an increase in ATBF of 0.4 ml 100 g⁻¹ min⁻¹.

Circulating epinephrine and norepinephrine are potent stimulators of ATBF and lipolysis (17; 26), and in the present study we found the plasma epinephrine concentration to increase significantly at the highest exercise intensity (Table 1). Circulating hormones influence all adipose tissue depots and not selectively adipose tissue adjacent to contracting muscles. However, due to the relatively increased blood flow in adipose
tissue adjacent to contracting muscles, a larger amount of the circulating epinephrine will be delivered to this tissue. This would increase the interstitial concentration of epinephrine in the adipose tissue, which could be one of the mechanisms behind the higher lipolysis in SCAT adjacent to contracting than adjacent to resting muscle.

Norepinephrine is not only a hormone but also a neurotransmitter in the sympathetic nervous system, and a selective stimulation of adipose tissue adjacent to contracting muscles could also be via local sympathetic nerves. In favor of this mechanism studies in humans have demonstrated that regional differences are present in sympathetic nervous activity (5) and that direct stimulation of a cutaneous sympathetic nerve increases lipolysis in the adipose tissue innervated by the stimulated nerve (6). Also, denervation of a rat retroperitoneal fat pad induces an increase in fat pad weight and adipocyte volume 1 week after denervation indicating that lipolysis is diminished when no sympathetic innervation is present (4).

Another mechanism to explain the increase in ATBF (Fig. 2) and lipolysis (Fig. 4 and 5) adjacent to contracting muscles could be release of paracrine substances from the contracting muscles, which could diffuse from the muscle to the adipose tissue to stimulate blood flow and lipolysis. Contracting skeletal muscle has been shown to release the myokine interleukin-6 (8), which among other things has been shown to stimulate adipose tissue lipolysis (18).

It is evident that several potential mechanisms can explain the increased ATBF (Fig. 2) and lipolysis (Fig. 4 and 5) in adipose tissue adjacent to contracting muscles, but it is more difficult to understand the rationale for the increase. The muscle and the SCAT superficial to the muscle have separate blood supplies and drainages. Accordingly, fatty
acids released from adipose tissue during exercise are transported to the heart and reaches all parts of the body and not specifically the muscle beneath the subcutaneous tissue from which the fatty acids were released.

In the present study we measured changes in ATBF by two independent methods, the $^{133}$Xe washout technique (27) and the microdialysis $^{14}$C-ethanol outflow/inflow technique (25), and findings were similar (Fig. 2). Both methods showed a general increase in ATBF during exercise and that blood flow was higher in adipose tissue adjacent to contracting muscle than in adipose tissue adjacent to resting muscle. The $^{133}$Xe washout and the microdialysis ethanol outflow/inflow techniques have previously shown comparable results in adipose tissue during external heating of the skin (9).

We found lipolysis to be higher in adipose tissue adjacent to contracting muscles than in adipose tissue adjacent to resting muscle (Fig. 4 and 5), but in contrast to findings for ATBF (Fig. 2) we did not find a general exercise-induced increase in femoral adipose tissue lipolysis. Cycle exercise of moderate intensity increases lipolysis in abdominal SCAT (2; 14), but in accordance with our findings Horowitz et al. found that exercise at 50% of $V_{o_2}$max did not increase femoral SCAT lipolysis (14). We examined femoral SCAT because this tissue has a contra lateral tissue site that can be used as control, which abdominal SCAT clearly do not.

Reliability of techniques used in the study should be considered. We placed the microdialysis probes and the $^{133}$Xe depot in the femoral SCAT equidistant from skin and muscle fascia. We did not measure the thickness of the femoral SCAT, but in studies of similar subjects we found the femoral skinfold to be approximately 10 to 30 millimeters (unpublished results). We believe that measurements of lipolysis and blood flow in
adipose tissue depots of this thickness are reliable. Theoretical predictions (7) suggest that a microdialysis probe estimates the metabolite concentration in a radius of a few millimeters from the probe, and probes thus should mirror adipose tissue metabolism and not metabolism in skin or muscle. In theory also the $^{133}$Xe depot could come into contact with skin or muscle, but if this had occurred, the washout curve for $^{133}$Xe would have become multiexponential, and this was not the case.

More calories are expended during aerobic, whole-body exercise than by exercise with local muscle groups, and accordingly a person seeking to loose fat must be advised to perform whole-body exercise. However, the present study has shown that blood flow (Fig. 2) and lipolysis (Fig. 4 and 5) are stimulated more in adipose tissue adjacent to contracting muscles than in adipose tissue adjacent to resting muscles. The incremental femoral SCAT lipolysis (Fig. 5) showed no clear connection with exercise intensity and amounted to 22 – 80 nmol 100 g$^{-1}$ min$^{-1}$ during the first 30 minutes of the exercise bout. Assuming a molecular weight of 860 g mol$^{-1}$ for TG this corresponds to an extra breakdown of 0.6 – 2.1 mg of TG in 30 minutes per 100 g of adipose tissue adjacent to contracting muscles. These figures are comparable to the increase in lipolysis induced by cycle exercise at 50% of VO$_{2}\max$, which was found to be approximately 50 nmol 100 g$^{-1}$ min$^{-1}$ in femoral SCAT and 200 nmol 100 g$^{-1}$ min$^{-1}$ in abdominal SCAT (time 15-40 min) (14) corresponding to a breakdown of 1.3 and 5.2 mg of TG in 30 minutes per 100 g of femoral and abdominal adipose tissue, respectively.

In conclusion, an acute bout of exercise can induce “spot lipolysis” and increased blood flow in adipose tissue adjacent to contracting skeletal muscle.
Acknowledgements

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Figure legends

Fig. 1
Experimental protocol. Ten males performed knee extension exercise with one leg (leg 1) at 25% $W_{\text{max}}$ for 30 minutes while the other leg (leg 2) was resting. After a short rest subjects exercised with the other leg (leg 2) at 55% $W_{\text{max}}$ for 120 minutes while the first leg (leg 1) was resting. After another short rest subjects exercised with the first leg (leg 1) at 85% $W_{\text{max}}$ for 30 minutes while the other leg (leg 2) was resting. Arterial blood samples were obtained as indicated with arrows whereas microdialysis samples and $^{133}$Xe washout readings were collected across sampling periods indicated by brackets.

Fig. 2
Adipose tissue blood flow. Ten healthy, overnight-fasted males performed one-legged knee extension exercise at 25% of $W_{\text{max}}$ for 30 minutes followed by exercise at 55% $W_{\text{max}}$ for 120 minutes with the other leg and finally exercised at 85% $W_{\text{max}}$ for 30 minutes with the first leg. Subjects rested for 30 minutes between exercise periods. Femoral, subcutaneous adipose tissue blood flow of both legs was measured using the $^{133}$Xe washout (A) and the microdialysis $^{14}$C-ethanol outflow/inflow (B) techniques. Adipose tissue blood flow is inversely related to $^{14}$C-ethanol outflow/inflow. * P < 0.05 versus rest. (*) P < 0.1 versus rest. + P < 0.05 between legs. (+) P < 0.1 between legs.

Fig. 3
Glycerol concentrations. Ten healthy, overnight-fasted males performed one-legged knee extension exercise at 25% of $W_{\text{max}}$ for 30 minutes followed by exercise at 55% $W_{\text{max}}$ for
120 minutes with the other leg and finally exercised at 85% W_max for 30 minutes with the first leg. Subjects rested for 30 minutes between exercise periods. The interstitial glycerol concentration in femoral, subcutaneous adipose tissue of both legs was measured by microdialysis technique (A) and the plasma glycerol concentration was measured in arterial blood (B). * P < 0.05 versus rest. + P < 0.05 between legs.

Fig. 4
Adipose tissue lipolysis. Ten healthy, overnight-fasted males performed one-legged knee extension exercise at 25% of W_max for 30 minutes followed by exercise at 55% W_max for 120 minutes with the other leg and finally exercised at 85% W_max for 30 minutes with the first leg. Subjects rested for 30 minutes between exercise periods. Femoral, subcutaneous adipose tissue lipolysis of both legs was calculated from the interstitial and arterial glycerol concentrations and adipose tissue blood flow. * P < 0.05 versus rest. + P < 0.05 between legs. (+) P < 0.1 between legs.

Fig. 5
Incremental adipose tissue lipolysis. Ten healthy, overnight-fasted males performed one-legged knee extension exercise at 25% of W_max for 30 minutes followed by exercise at 55% W_max for 120 minutes with the other leg and finally exercised at 85% W_max for 30 minutes with the first leg. Subjects rested for 30 minutes between exercise periods. The difference in mean femoral, subcutaneous adipose tissue lipolysis between exercising and resting legs were calculated for the time period 0 to 30 minutes for each exercise period (25, 55 and 85% W_max). * P < 0.05 versus 0.
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Table 1

Arterial plasma hormone concentrations.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Time</th>
<th>Insulin (pM)</th>
<th>Epinephrine (nM)</th>
</tr>
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<tbody>
<tr>
<td>Rest</td>
<td>Rest</td>
<td>45 ± 6</td>
<td>1.1 ± 0.3</td>
</tr>
<tr>
<td>25% $W_{\text{max}}$</td>
<td>15 min</td>
<td>41 ± 8</td>
<td>0.8 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>30 min</td>
<td>37 ± 5</td>
<td>0.9 ± 0.2</td>
</tr>
<tr>
<td>55% $W_{\text{max}}$</td>
<td>15 min</td>
<td>35 ± 5*</td>
<td>0.8 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>30 min</td>
<td>31 ± 4*</td>
<td>0.8 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>60 min</td>
<td>30 ± 4*</td>
<td>0.7 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>120 min</td>
<td>25 ± 3*</td>
<td>0.8 ± 0.1</td>
</tr>
<tr>
<td>85% $W_{\text{max}}$</td>
<td>15 min</td>
<td>29 ± 5*</td>
<td>1.1 ± 0.3</td>
</tr>
<tr>
<td></td>
<td>30 min</td>
<td>31 ± 4*</td>
<td>1.3 ± 0.1*</td>
</tr>
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* P < 0.05 versus rest.
Fig. 1

Minutes:

Blood samples:

Microdialysis and $^{133}$Xe washout:
Adipose tissue lipolysis: exercising minus resting leg

Glycerol release (nmol 100 g⁻¹ min⁻¹)

- 25% Wmax
- 55% Wmax
- 85% Wmax

* Significant difference from resting leg