Escola de Educação Física e Esporte
Fisiologia da Atividade Motora I
EFB0105

Adaptações no músculo esquelético frente ao treinamento aeróbio

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Bloco II - Objetivos

1) **Utilização de substratos**
2) **Adaptações estruturais e funcionais**

2

A utilização de substratos

FONTES DE ENERGIA PARA A REALIZAÇÃO DE EXERCÍCIOS

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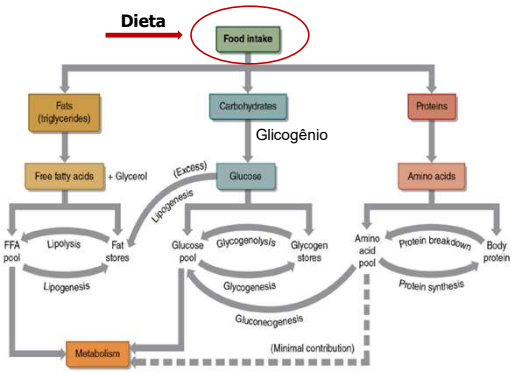

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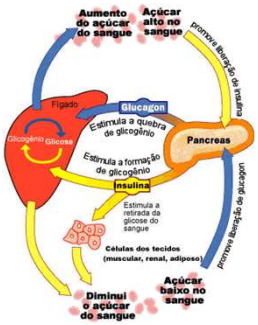
Glicose circulante?



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Substratos

- Glicogênio muscular/hepático
- Glicose sanguínea
- TAG no tecido adiposo – AG plasma
- TAG no músculo esquelético

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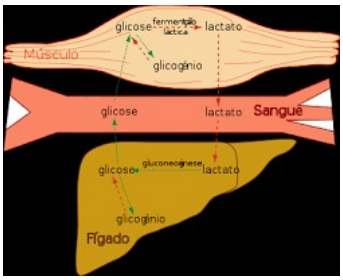
Glicogênio muscular x Glicogênio hepático



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Duração do exercício

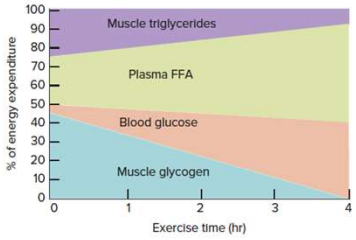

Figure 4.15 Percentage of energy derived from the four major sources of fuel during submaximal exercise (i.e., 65% to 75% $\dot{V}O_2$ max). Data are from trained endurance athletes.

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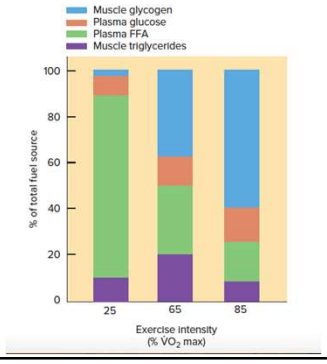
Intensidade do exercício



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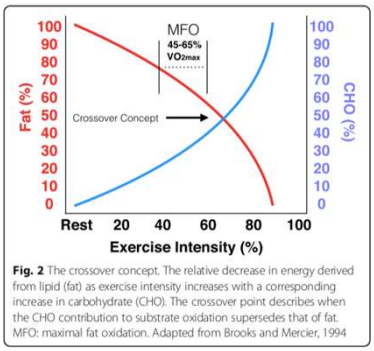

Fig. 2 The crossover concept. The relative decrease in energy derived from lipid (fat) as exercise intensity increases with a corresponding increase in carbohydrate (CHO). The crossover point describes when the CHO contribution to substrate oxidation supersedes that of fat. MFO: maximal fat oxidation. Adapted from Brooks and Mercier, 1994

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Causas da diminuição da oxidação de AG com aumento da intensidade

- Redução na entrega de ácidos graxos no músculo esquelético
- Captação prejudicada na mitocôndria
- Indisponibilidade de carnitina

Van Loon et al. (2001)

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L-Carnitina? Mas o que é isso?

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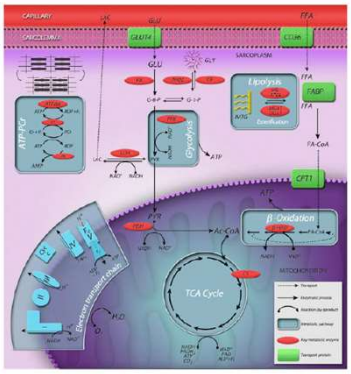

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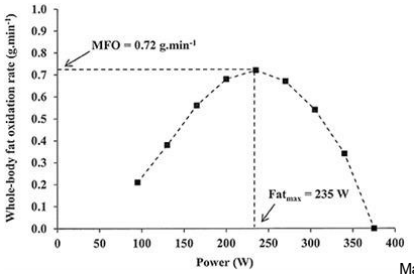
Máxima oxidação de gordura



Maunder et al. (2018)

Figure 1. Representative illustration of fat oxidation (g.min⁻¹) against exercise intensity (W) during a graded, cycling Fat_{max} test, where MFO, maximal rate of fat oxidation (g.min⁻¹) and Fat_{max}, the intensity at which MFO occurs (W).

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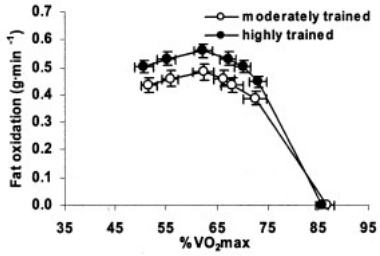
Oxidação de substrato: efeito crônico



Achten e Jeukendrup (2004)

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Population	N	Mean MFO (g.min^{-1})
Endurance-trained, lean males	201	0.53 ± 0.16
Recreationally-active, lean males	105	0.46 ± 0.14
Recreationally-active, lean females	68	0.35 ± 0.12
Overweight/obese males	193	0.28 ± 0.14
Overweight/obese females	144	0.16 ± 0.05

For example, measurement of MFO at 0.67 g.min^{-1} in an endurance-trained, lean male

TABLE 2 | Normative percentile values for Fat_{max} (%VO_{2max}) in different subject

Population	N	Mean Fat_{max} (%VO_{2max})
Endurance-trained, lean males	201	56 ± 8
Recreationally-active, lean males	67	51 ± 8
Recreationally-active, lean females	38	50 ± 10
Overweight/obese males	190	43 ± 18
Overweight/obese females	27	61 ± 10

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TF aeróbio

Mudança na utilização de substratos energéticos

SEDENTÁRIO

CARBOIDRATO

TREINADO

-usa preferencialmente LIPÍDEOS
-Poupa GLICOGÊNIO

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Porque?

- Atividade aumentada de enzimas oxidativas;
- Aumento do número de mitocôndrias;
- Densidade capilar aumentada;

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Importância de maximizar a oxidação de gordura ?

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Déficit calórico

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Maximizar a oxidação de gordura

- Estoque de glicogênio é limitado;
- Depleção associada a redução da liberação de cálcio – importante para contração muscular;

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TABLE 2.1 **Body Stores of Fuels and Associated Energy Availability**

Location	g	kcal
Carbohydrate		
Liver glycogen	110	451
Muscle glycogen	500	2,050
Glucose in body fluids	15	62
Fat		
Subcutaneous and visceral	7,800	73,320
Intramuscular	161	1,513
Total	7,961	74,833

Note. These estimates are based on a body weight of 65 kg (143 lb) with 12% body fat.

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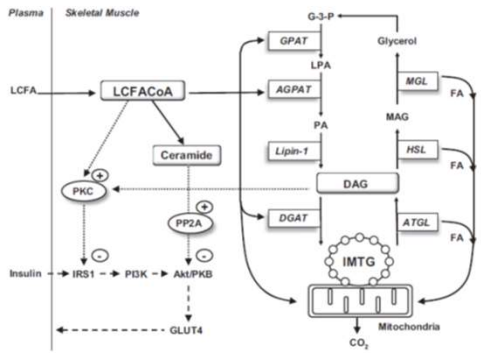
Resistência a insulina



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HIIT (extensivo e intensivo)

- 10 de 16 estudos reportaram aumento de oxidação de gordura (62%);
- Volumes maiores e intervenções mais longas parece ser mais benéficos;
- 10 a 26%

Changes in fat oxidation in response to various regimes of high intensity interval training (HIIT)

Todd Anthony Astorino[1] · Matthew M. Schubert[1]

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Qual é melhor?

RESEARCH Open Access

Effect of interval training intensity on fat oxidation, blood lactate and the rate of perceived exertion in obese men

Shaea A Alkahtani[1*], Neil A King[2], Andrew P Hills[3] and Nuala M Byrne[2]

4 semanas de HIIIT (intervalado intensivo ou hiit curto)- 30s a 90% VO_{2max} : 3os pausa passiva ***vs*** contínuo de intensidade moderada

Na oxidação de gordura mesma magnitude

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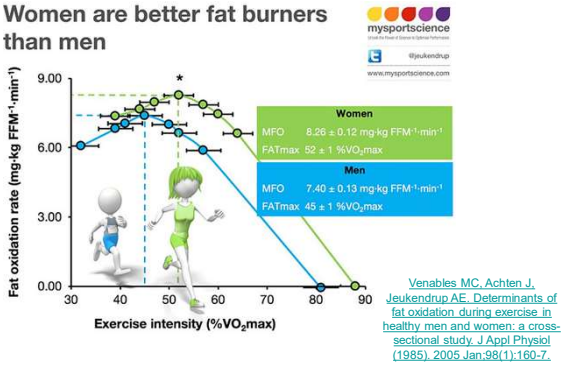
Curiosidade....



Venables MC, Achten J, Jeukendrup AE. Determinants of fat oxidation during exercise in healthy men and women: a cross-sectional study. J Appl Physiol (1985). 2005 Jan;98(1):160-7.

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Concluindo

- Oxidação de carboidratos aumenta com a intensidade do exercício mas diminui com a duração;
- Oxidação de gordura aumenta com treinamento a longo prazo;
- Importante para o desempenho e para a saúde metabólica;

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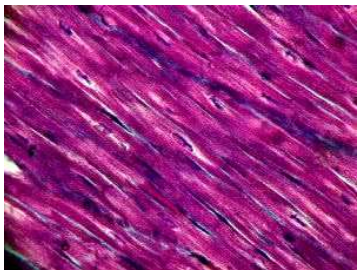
Adaptações estruturais e funcionais



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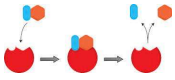
- Mitocôndria
- Tipos de fibras
- Área de secção transversa, síntese de proteínas, glicogênio e triacilglicerol no músculo esquelético
- Atividade enzimática



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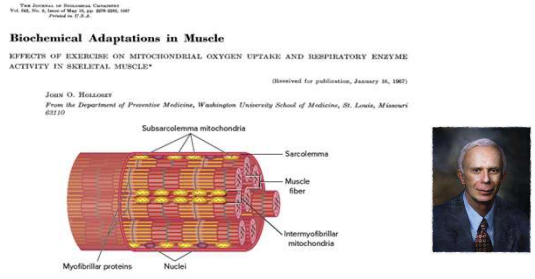
Mitocôndria



John Holloszy,1967

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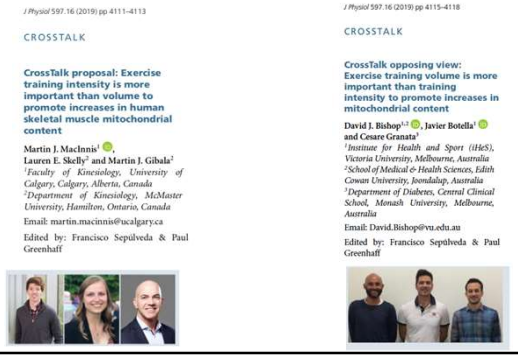
Cross-talk - intensidade ou volume?



J Physiol 597.16 (2019) pp 4111–4113

CROSSTALK

CrossTalk proposal: Exercise training intensity is more important than volume to promote increases in human skeletal muscle mitochondrial content

Martin J. MacInnis[1], Lauren E. Skelly[2] and Martin J. Gibala[2]

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Email: martin.macinnis@ucalgary.ca

Edited by: Francisco Sepúlveda & Paul Greenhaff

J Physiol 597.16 (2019) pp 4115–4118

CROSSTALK

CrossTalk opposing view: Exercise training volume is more important than training intensity to promote increases in mitochondrial content

David J. Bishop[1,3], Javier Botella[1] and Cesare Granata[3]

[1]Institute for Health and Sport (iHeS), Victoria University, Melbourne, Australia
[2]School of Medical & Health Sciences, Edith Cowan University, Joondalup, Australia
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Edited by: Francisco Sepúlveda & Paul Greenhaff

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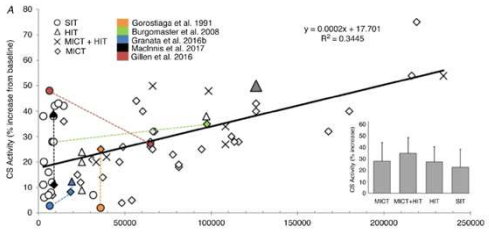

Correlação significante e positiva entre volume e aumento da mitocôndria

Não teve correlação significante entre intensidade e aumento da mitocôndria

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Cross-talking

- Segmentou para HIIT (extensivo e intensivo) (excluindo exercícios máximo - SIT)
- Exercício de moderada intensidade a 66 % (45 a 80%) $iVO_{2máx}$ = 28%
- HIIT 80% (65 a 90%) $iVO_{2máx}$ = 27%
- Volume 60% menor no HIIT

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Importante!

- Estudo da mitocôndria
  - Microscopia: volume da organela
  - Marcadores bioquímicos: enzimas localizadas na mitocôndria

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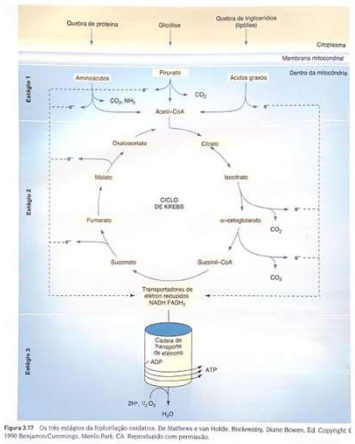

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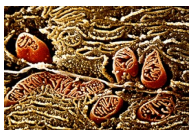
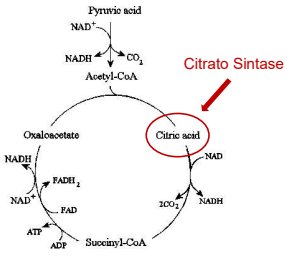
Adaptação enzimática pós TF aeróbio





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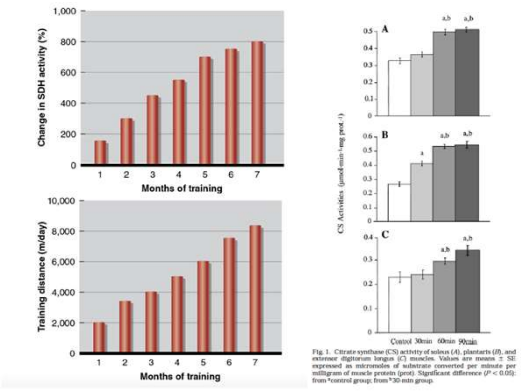

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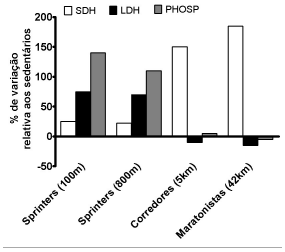
VARIAÇÕES NA ATIVIDADE ENZIMÁTICA

Tipo de modalidade praticada
(Vastus lateralis)



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Tipos de fibras

TABLE 1.1 **Percentages and Cross-Sectional Areas of Type I and Type II Fibers in Selected Muscles of Male and Female Athletes**

Athlete	Sex	Muscle	% type I	% type II
Sprint runners	M	Gastrocnemius	24	76
	F	Gastrocnemius	27	73
Distance runners	M	Gastrocnemius	79	21
	F	Gastrocnemius	69	31
Cyclists	M	Vastus lateralis	57	43
	F	Vastus lateralis	51	49
Swimmers	M	Posterior deltoid	67	33
Weightlifters	M	Gastrocnemius	44	56
	M	Deltoid	53	47
Triathletes	M	Posterior deltoid	60	40
	M	Vastus lateralis	63	37
	M	Gastrocnemius	59	41
Canoeists	M	Posterior deltoid	71	29
Shot-putters	M	Gastrocnemius	38	62
Nonathletes	M	Vastus lateralis	47	53
	F	Gastrocnemius	52	48

Adapted, by permission, from W.L. Kenney, J.H. Wilmore, and D.L. Costill, 2015, *Physiology of sport and exercise*, 6th ed. (Champaign, IL: Human Kinetics), 45.

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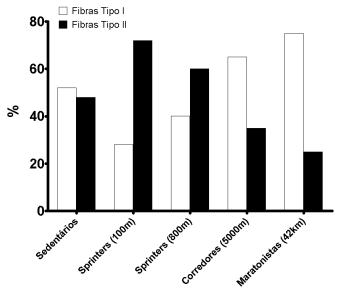
Variações na % de distribuição de fibras

Tipo de fibra de acordo com modalidade praticada
(Vastus lateralis)



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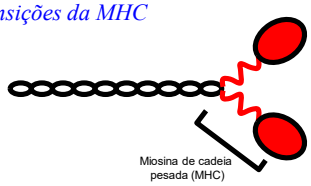
Transições da MHC



O TF de endurance leva a mudança na expressão da miosina de cadeia pesada de fibra do tipo I

Demirel HA et al. J Appl. Physiol. 1999, 86:1002-8

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Treinamento aeróbio e área de secção transversa

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Estudo com humanos – mulheres idosas

- Treinamento aeróbio durante 12 semanas
- 60-80% da FC de reserva
- 3/4 sessões por semana (30-45 minutos cada)

	Pre	Post	% Change
Aerobic capacity, $L \cdot min^{-1}$	1.1±0.1	1.4±0.1*	29±6
$ml \cdot kg^{-1} \cdot min^{-1}$	15.9±1.0	20.5±0.9*	30±6
Maximum heart rate, bpm	154±7	157±6	N/A
Body weight, kg	68.0±4.8	67.2±4.5	N/A
BMI, $kg \cdot m^{-2}$	25.2±1.8	25.1±1.8	N/A
Body fat, %	40.7±3.4	39.8±3.5†	−2.4±1.0
Fat mass, kg	27.6±4.3	26.4±4.1†	−3.9±1.6
Fat-free mass, kg	39.2±1.4	39.6±1.4†	0.9±0.4
Quadriceps muscle volume, cm^3	587±55	654±60*	12±2
Knee extensor power, W	241±42	296±43*	33±7
Normalized power, $W \cdot cm^2$	5.8±0.8	6.5±0.8*	14±4
Knee extensor peak isometric force, Nm	199±25	261±27*	35±7
Normalized force, $Nm \cdot cm^2$	4.9±0.4	5.9±0.5*	22±7

Harber et al., 2009

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Massa muscular e treinamento aeróbio? Qual a relação?

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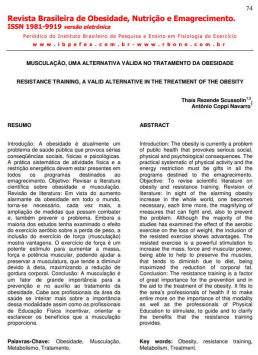
No controle de peso:

- Aumento do metabolismo basal
- Aumento do déficit calórico
- Potencialização das vias da insulina para síntese proteica



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MUSCULAÇÃO, UMA ALTERNATIVA VÁLIDA NO TRATAMENTO DA OBESIDADE

RESISTANCE TRAINING, A VALID ALTERNATIVE IN THE TREATMENT OF THE OBESITY

Thaís Resende Scussolin[1], António Coppi Navarro[2]

RESUMO

ABSTRACT

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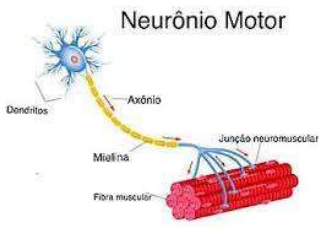
No rendimento de atletas de Endurance:

- Recrutamento de fibas Tipo IIa e IIx de alto potencial de excitabilidade.
- Resistência à fadiga



Berne & Levy, 2018

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- Preservação da reserva de glicogênio muscular.
- Sprint final de provas de longa duração.

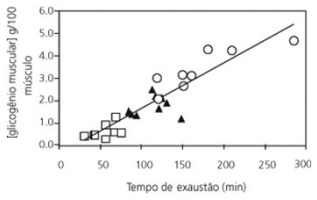

Figura 1. Relação entre a concentração inicial de glicogênio muscular e o tempo de *performance*. □ após dieta baixa em carboidrato, ▲ após dieta balanceada e ○ após dieta alta em carboidrato.
Fonte: adaptado de Bergstrom et al.[1].

https://doi.org/10.1590/S1415-52732007000400009

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Aerobic Exercise Training Increases Muscle Water Content in Obese Middle-Age Men

0195-9131/16/4805-0822/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

RICARDO MORA-RODRÍGUEZ[1], ALICIA SANCHEZ-RONCERO[1], VALENTIN EMILIO FERNÁNDEZ-ELÍAS[1], AMELIA GUADALUPE-GRAU[1], JUAN FERNANDO ORTEGA[1], FLEMING DELA[2], and JORN WULFF HELGE[2]

- 18 homens obesos com síndrome metabólica
- 4 meses
- 3 x por semana
- 4 séries de 4 minutos a 90% FCmáx: 3 minutos a 70% FCmáx - intervalado extensivo
- Bicicleta
- Dexa
- Biópsia

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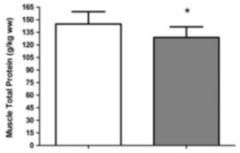
TABLE 1. Exercise and anthropometric changes with 4 months of aerobic interval training.

	Pretraining	Posttraining	% Change	*P* value
VO_{2peak} ($mL \cdot O_2 \cdot kg^{-1} \cdot min^{-1}$)	28.8 ± 7	32.1 ± 8	11%	0.001*
FO_{max} ($g \cdot min^{-1}$)	0.24 ± 0.09	0.32 ± 0.11	33%	0.003*
$Workload_{max}$ (W_{max})	232 ± 67	255 ± 75	10%	0.001*
Body weight (kg)	95.21 ± 10	93.36 ± 10	−1.9%	0.022*
BMI ($kg \cdot cm^{-2}$)	33.4 ± 3	32.7 ± 2	−2.2%	0.013*
Waist circumference (cm)	109 ± 5	107 ± 5	−1.8%	0.016*
Fat mass (kg)	31.9 ± 4.3	30.1 ± 5.1	−5.4%	0.044*
FFM (kg)	59.9 ± 9	60.3 ± 8	0.5%	0.477
Right leg FFM (kg)	9.84 ± 1.84	10.02 ± 1.85	1.8%	0.023*

Data are mean ± SD for 18 subjects. *Significantly different from pretraining.



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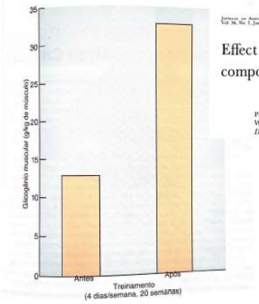

Effect of training on enzyme activity and fiber composition of human skeletal muscle

P. D. GOLLNICK, R. B. ARMSTRONG, B. SALTIN, C. W. SAUBERT IV, W. L. SEMBROWICH, AND R. E. SHEPHERD

Department of Physical Education for Men, Washington State University, Pullman, Washington 99163

13 a 15g/kg e aumento 2,5x

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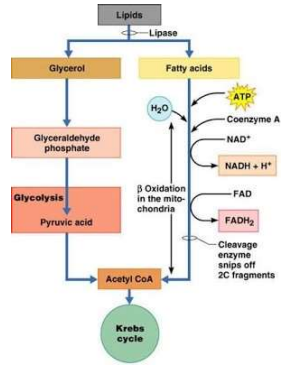
Nas vias de Beta-oxidação...

↑ Aumento dos AG intramusculares



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Triacilglicerol intramuscular

The Ultrastructure of the Normal Human Skeletal Muscle

A Morphometric Analysis on Untrained Men, Women and Well-Trained Orienteers*

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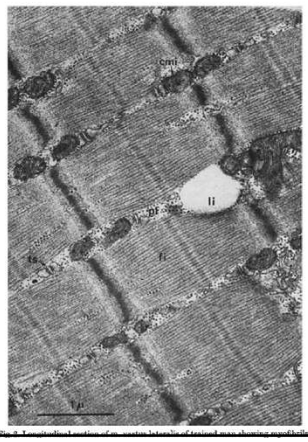

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Concluindo....

- Aumento da densidade mitocondrial
- Aumento da atividade de enzimas oxidativas
- Aumento da proporção de Fibras do tipo I
- Aumento de glicogênio e lipídio intramuscular

❖Mesmo em protocolos de exercício mais intenso

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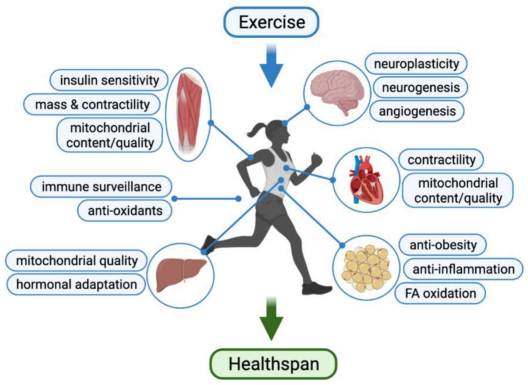

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Obrigada!

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