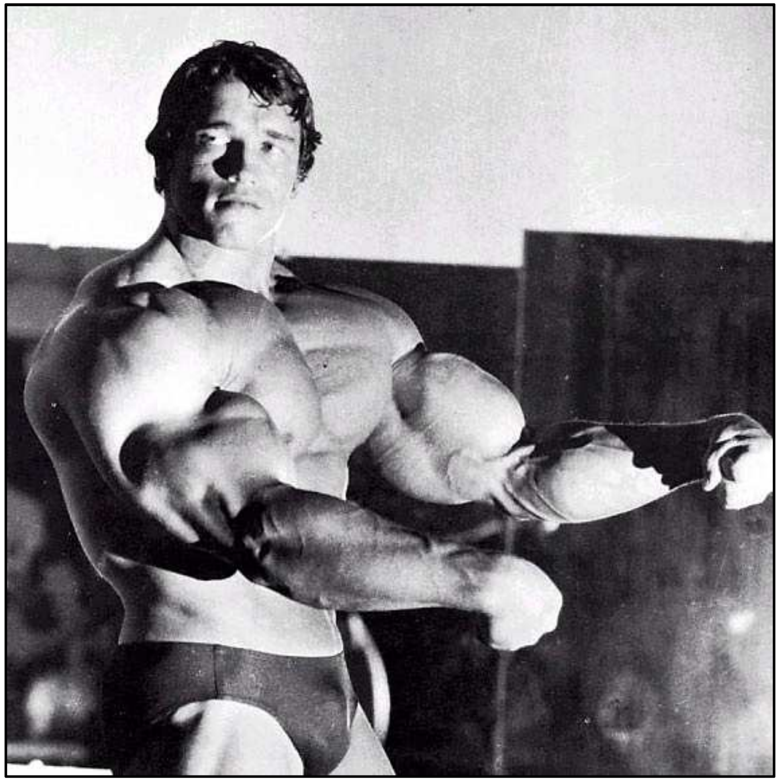
"BY 1967, ARNOLD WAS ALREADY FRONT PAGE NEWS"

TEORÍAS SOBRE LA HIPERTROFIA MUSCULAR



CURSO de ENTRENADOR SUPERIOR de CULTURISMO y MUSCULACIÓN

APECED

Prof. Mintxo Lasaosa

NUEVOS ESTUDIOS EN LOS JOURNALS

J Strength Cond Res

Sports Med

Eur J Appl Physiol

Med Sci Sports Exerc

http://www.ncbi.nlm.nih.gov/pubmed

Med Sci Sports Exerc. 2009 Mar;41(3):687-708.

American College of Sports Medicine position stand. Progression models in resistance training for healthy adults.

American College of Sports Medicine.

In order to stimulate further adaptation toward specific training goals, progressive resistance training (RT) protocols are necessary. The optimal characteristics of strength-specific programs include the use of concentric (CON), eccentric (ECC), and isometric muscle actions and the performance of bilateral and unilateral single- and multiple-joint exercises. In addition, it is recommended that strength programs sequence exercises to optimize the preservation of exercise intensity (large before small muscle group exercises, multiple-joint exercises before single-joint exercises, and higher-intensity before lower-intensity exercises). For novice (untrained individuals with no RT experience or who have not trained for several years) training, it is recommended that loads correspond to a repetition range of an 8-12 repetition maximum (RM). For intermediate (individuals with approximately 6 months of consistent RT experience) to advanced (individuals with years of RT experience) training, it is recommended that individuals use a wider loading range from 1 to 12 RM in a periodized fashion with eventual emphasis on heavy loading (1-6 RM) using 3- to 5-min rest periods between sets performed at a moderate contraction velocity (1-2 s CON; 1-2 s ECC). When training at a specific RM load, it is recommended that 2-10% increase in load be applied when the individual can perform the current workload for one to two repetitions over the desired number. The recommendation for training frequency is 2-3 d x wk(-1) for novice training, 3-4 d x wk(-1) for intermediate training, and 4-5 d x wk(-1) for advanced training. Similar program designs are recommended for hypertrophy training with respect to exercise selection and frequency. For loading, it is recommended that loads corresponding to 1-12 RM be used in periodized fashion with emphasis on the 6-12 RM zone using 1- to 2-min rest periods between sets at a moderate velocity. Higher volume, multiple-set programs are recommended for maximizing hypertrophy. Progression in power training entails two general loading strategies: 1) strength training and 2) use of light loads (0-60% of 1 RM for lower body exercises; 30-60% of 1 RM for upper body exercises) performed at a fast contraction velocity with 3-5 min of rest between sets for multiple sets per exercise (three to five sets). It is also recommended that emphasis be placed on multiple-joint exercises especially those involving the total body. For local muscular endurance training, it is recommended that light to moderate loads (40-60% of 1 RM) be performed for high repetitions (>15) using short rest periods (<90 s). In the interpretation of this position stand as with prior ones, recommendations should be applied in context and should be contingent upon an individual's target goals, physical capacity, and training status.

Sports Med. 2009;39(9):765-77. doi: 10.2165/11315230-000000000-00000.
Rest interval between sets in strength training.
de Salles BF, Simão R, Miranda F, Novaes Jda S, Lemos A, Willardson JM.
Laboratory for Clinical and Experimental Research in Vascular Biology (BioVasc), Biomedical Center, State University of Rio de Janeiro, Rio de Janeiro, Brazil.
Strength training has become one of the most popular physical activities for increasing characteristics such as absolute muscular strength, endurance, hypertrophy and muscular power. For efficient, safe and effective training, it is of utmost importance to understand the interaction among training variables, which might include the intensity, number of sets, rest interval between sets, exercise modality and velocity of muscle action. Research has indicated that the rest interval between sets is an important variable that affects both acute responses and chronic adaptations to resistance exercise programmes. The purpose of this review is to analyse and discuss the rest interval between sets for targeting specific training outcomes (e.g. absolute muscular strength, endurance, hypertrophy and muscular power). The Scielo, Science Citation Index, National Library of Medicine, MEDLINE, Scopus, Sport Discus and CINAHL databases were used to locate previous original scientific investigations. The 35 studies reviewed examined both acute responses and chronic adaptations, with rest interval length as the experimental variable. In terms of acute responses, a key finding was that when training with loads between 50% and 90% of one repetition maximum, 3-5 minutes' rest between sets allowed for greater repetitions over multiple sets. Furthermore, in terms of chronic adaptations, resting 3-5 minutes between sets produced greater increases in absolute strength, due to higher intensities and volumes of training. Similarly, higher levels of muscular power were demonstrated over multiple sets with 3 or 5 minutes versus 1 minute of rest between sets. Conversely, some experiments have demonstrated that when testing maximal strength, 1-minute rest intervals might be sufficient between repeated attempts; however, from a psychological and physiological standpoint, the inclusion of 3- to 5-minute rest intervals might be safer and more reliable. When the training goal is muscular hypertrophy, the combination of moderate-intensity sets with short rest intervals of 30-60 seconds might be most effective due to greater acute levels of growth hormone during such workouts. Finally, the research on rest interval length in relation to chronic muscular endurance adaptations is less clear. Training with short rest intervals (e.g. 20 seconds to 1 minute) resulted in higher repetition velocities during repeated submaximal muscle

J Strength Cond Res. 2008 Jan;22(1):146-52.

The effect of different rest intervals between sets on volume components and strength gains.

Willardson JM, Burkett LN.
Kinesiology and Sports Studies Department, Eastern Illinois University, Charleston, Illinois, USA.
jmwillardson@eiu.edu

The purpose of this study was to compare squat strength gains and volume components when resting 2 minutes vs. 4 minutes between sets over multiple mesocycles. After the first squat 1 repetition maximum, 15 trained men were matched and randomly assigned to either a 2-minute ($n = 7$) or a 4-minute ($n = 8$) rest interval group. Each group performed the same training program, with the only difference being the length of the rest interval between sets. Subjects performed two squat workouts per week; one was labeled as Heavy and the other was labeled as Light. The squat workouts varied in the intensity, number of sets, and repetitions performed per set in a nonlinear periodized manner throughout each mesocycle. Differences in strength gains and volume components (the load utilized per set, the repetitions performed per set, the intensity per set, and the volume performed per workout) were compared between groups. Both groups demonstrated large strength gains; however, these differences were not significant between groups ($P = 0.47$). During all mesocycles, the 4-minute group demonstrated significantly higher total volumes for the Heavy workouts ($P < 0.05$). The findings of the present study indicate that large squat strength gains can be achieved with a minimum of 2 minutes' rest between sets, and little additional gains are derived from resting 4 minutes between sets. Therefore, athletes attempting to achieve specific volume goals may need longer rest intervals initially but may later adapt so that shorter rest intervals can be utilized without excessive fatigue, leaving additional time to focus on other conditioning priorities.

J Strength Cond Res. 2010 Jan;24(1):37-42.

Chronic effects of different between-set rest durations on muscle strength in nonresistance trained young men.

Gentil P, Bottaro M, Oliveira E, Veloso J, Amorim N, Saiuri A, Wagner DR.
College of Physical Education, University of Brasilia, Brasilia, Brazil College of Health Science, University of Brasilia, Brazil. paulogentil@hotmail.com

The purpose of the study was to investigate the effects of different between-set rest interval durations on muscle strength after 12 weeks of resistance training. After baseline tests, 34 nonresistance trained college-aged men were matched and randomly assigned to 2 groups. Both groups trained twice a week and performed the same exercises and the same work output with 2 sets of 8 to 12 repetitions until volitional fatigue. One group (n = 18, 21.4 +/- 3.2 yr; 73.8 +/- 14.0 kg; 175.9 +/- 7.8 cm) used short-rest intervals (SR) with a work rest ratio of approximately 1:3; the other (n = 16, 22.4 +/- 2.6 yr; 73.1 +/- 13.6 kg; 171.9 +/- 8.2 cm) used long-rest intervals (LR) with a work rest ratio of approximately 1:6. Leg press and bench press 1 repetition maximum (1RM) were measured at baseline and after the end of the training period. The increases in 1RM for bench press were 14.4 +/- 8.1% for the SR group and 10.5 +/- 6.4% for the LR group ($p < 0.05$). For the leg press, the increases were 17.5 +/- 9.2% with SR training and 17.8 +/- 12.3% for the LR group ($p < 0.05$). The results did not reveal significant differences between SR and LR for the bench press or leg press 1RM ($p > 0.05$). Our data suggest that gains in maximum strength in nontrained men are not dependent on the length of the rest interval between sets. Therefore, personal trainers and strength coaches can advise beginning lifters to use short rest intervals to make best use of their time in the weight room.

J Strength Cond Res. 2009 Sep;23(6):1890-901.
Single versus multiple sets of resistance exercise: a meta-regression.
Krieger JW.
Journal of Pure Power, Colorado Springs, CO, USA. jim@jopp.us
There has been considerable debate over the optimal number of sets per exercise to improve musculoskeletal strength during a resistance exercise program. The purpose of this study was to use hierarchical, random-effects meta-regression to compare the effects of single and multiple sets per exercise on dynamic strength. English-language studies comparing single with multiple sets per exercise, while controlling for other variables, were considered eligible for inclusion. The analysis comprised 92 effect sizes (ESs) nested within 30 treatment groups and 14 studies. Multiple sets were associated with a larger ES than a single set (difference = 0.26 +/- 0.05; confidence interval [CI]: 0.15, 0.37; $p < 0.0001$). In a dose-response model, 2 to 3 sets per exercise were associated with a significantly greater ES than 1 set (difference = 0.25 +/- 0.06; CI: 0.14, 0.37; $p = 0.0001$). There was no significant difference between 1 set per exercise and 4 to 6 sets per exercise (difference = 0.35 +/- 0.25; CI: -0.05, 0.74; $p = 0.17$) or between 2 to 3 sets per exercise and 4 to 6 sets per exercise (difference = 0.09 +/- 0.20; CI: -0.31, 0.50; $p = 0.64$). There were no interactions between set volume and training program duration, subject training status, or whether the upper or lower body was trained. Sensitivity analysis revealed no highly influential studies, and no evidence of publication bias was observed. In conclusion, 2 to 3 sets per exercise are associated with 46% greater strength gains than 1 set, in both trained and untrained subjects.

J Strength Cond Res. 2010 Mar 17. [Epub ahead of print]

Single vs. multiple sets of resistance exercise for muscle hypertrophy: A Meta-Analysis.

Krieger JW.
Vivacity, Mountlake Terrace, Washington.

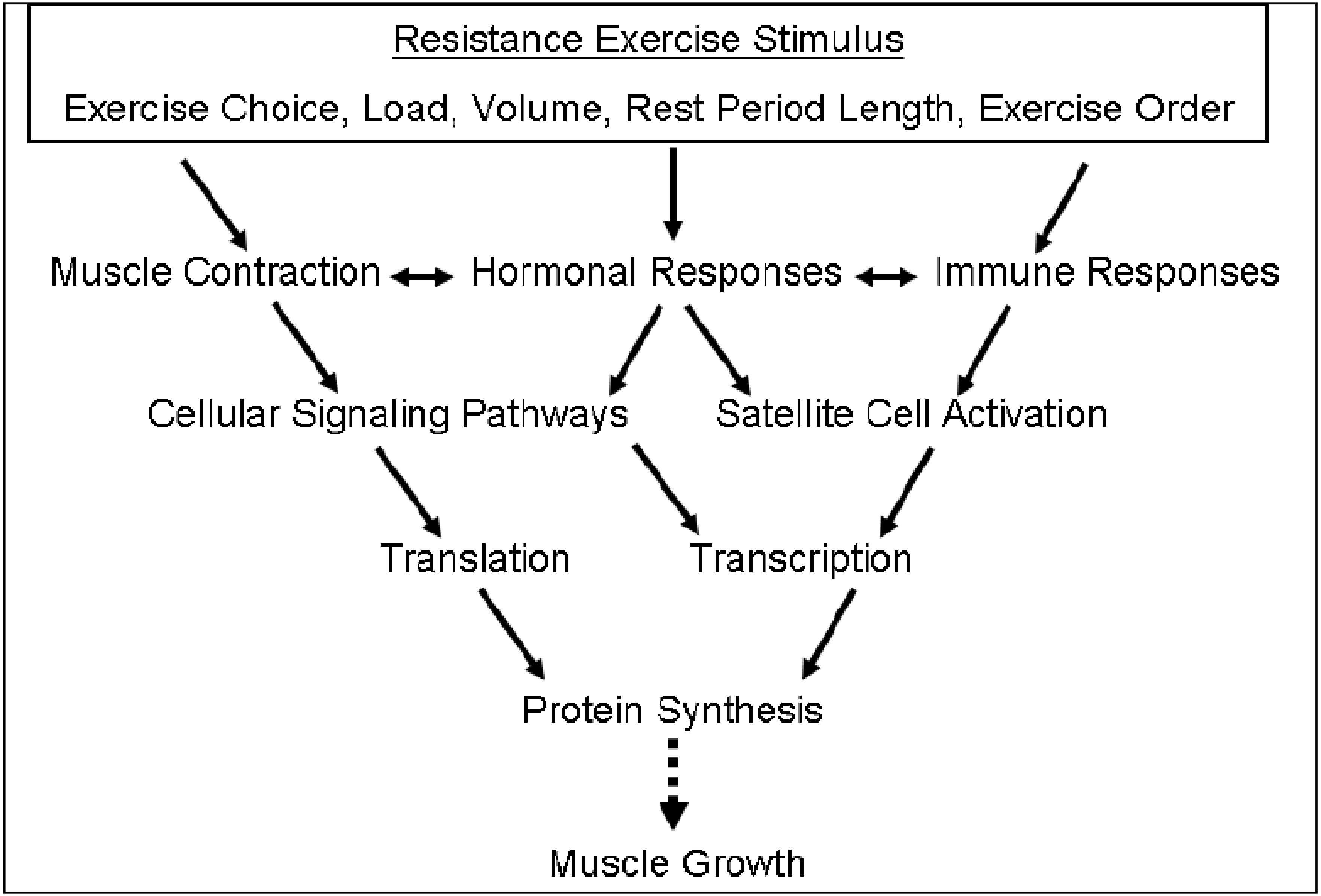
Krieger, JW. Single vs. multiple sets of resistance exercise for muscle hypertrophy: a meta-analysis. J Strength Cond Res 24(4): 1150-1159, 2010-Previous meta-analyses have compared the effects of single to multiple sets on strength, but analyses on muscle hypertrophy are lacking. The purpose of this study was to use multilevel meta-regression to compare the effects of single and multiple sets per exercise on muscle hypertrophy. The analysis comprised 55 effect sizes (ESs), nested within 19 treatment groups and 8 studies. Multiple sets were associated with a larger ES than a single set (difference = 0.10 +/- 0.04; confidence interval [CI]: 0.02, 0.19; p = 0.016). In a dose-response model, there was a trend for 2-3 sets per exercise to be associated with a greater ES than 1 set (difference = 0.09 +/- 0.05; CI: -0.02, 0.20; p = 0.09), and a trend for 4-6 sets per exercise to be associated with a greater ES than 1 set (difference = 0.20 +/- 0.11; CI: -0.04, 0.43; p = 0.096). Both of these trends were significant when considering permutation test p values (p < 0.01). There was no significant difference between 2-3 sets per exercise and 4-6 sets per exercise (difference = 0.10 +/- 0.10; CI: -0.09, 0.30; p = 0.29). There was a tendency for increasing ESs for an increasing number of sets (0.24 for 1 set, 0.34 for 2-3 sets, and 0.44 for 4-6 sets). Sensitivity analysis revealed no highly influential studies that affected the magnitude of the observed differences, but one study did slightly influence the level of significance and CI width. No evidence of publication bias was observed. In conclusion, multiple sets are associated with 40% greater hypertrophy-related ESs than 1 set, in both trained and untrained subjects.

J Strength Cond Res. 2010 Mar 17. [Epub ahead of print]

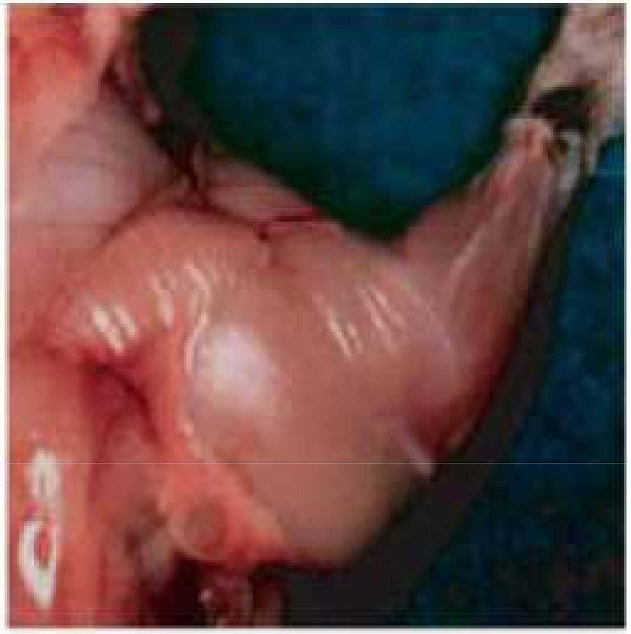
The Metabolic Costs of Reciprocal Supersets vs. Traditional Resistance Exercise in Young Recreationally Active Adults.

Kelleher AR, Hackney KJ, Fairchild TJ, Keslacy S, Ploutz-Snyder LL.
Musculoskeletal and Human Performance Laboratories, Department of Exercise Science, Syracuse University, Syracuse, New York.

Kelleher, AR, Hackney, KJ, Fairchild, TJ, Keslacy, S, and Ploutz-Snyder, LL. The metabolic costs of reciprocal supersets vs. traditional resistance exercise in young recreationally active adults. J Strength Cond Res 24(4): 1043-1051, 2010-An acute bout of traditional resistance training (TRAD) increases energy expenditure (EE) both during exercise and in the postexercise period. Reciprocal supersets (SUPERs) are a method of resistance training that alternates multiple sets of high-intensity agonist-antagonist muscle groups with limited recovery. The purpose of this study was to compare the energy cost of SUPERs and TRAD both during and in the postexercise period. We hypothesized that SUPERs would produce greater exercise EE relative to the duration of exercise time and greater excess postexercise oxygen consumption (EPOC) than TRAD of matched work. Ten recreationally active, young men each participated in 2 exercise protocols: SUPER, followed 1 week later by TRAD matched within using a 10-repetition maximum load for 6 exercises, 4 sets, and repetitions. Participants were measured for oxygen consumption and blood lactate concentration during exercise and 60 minutes postexercise after each exercise bout. No significant differences were observed in aerobic exercise EE between trials (SUPER 1,009.99 +/- 71.42 kJ; TRAD 954.49 +/- 83.31 kJ); however, when expressed relative to time, the exercise EE was significantly greater during SUPER (34.70 +/- 2.97 kJ.min) than TRAD (26.28 +/- 2.43 kJ.min). Excess postexercise oxygen consumption was significantly greater after SUPER (79.36 +/- 7.49 kJ) over TRAD (59.67 +/- 8.37 kJ). Average blood lactate measures were significantly greater during SUPER (5.1 +/- 0.9 mmol.L) than during TRAD (3.8 +/- 0.6 mmol.L). Reciprocal supersets produced greater exercise kJ.min, blood lactate, and EPOC than did TRAD. Incorporating this method of resistance exercise may benefit exercisers attempting to increase EE and have a fixed exercise volume with limited exercise time available.


Resistance Exercise Stimulus
Exercise Choice, Load, Volume, Rest Period Length, Exercise Order
Muscle Contraction
Hormonal Responses
Immune Responses
Cellular Signaling Pathways
Satellite Cell Activation
Translation
Transcription
Protein Synthesis
Muscle Growth

RATÓN KNOCKOUT Y CONTROL



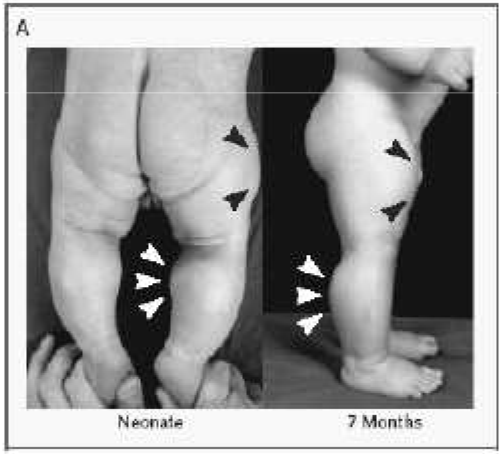
McPherron et al. (1997). Nature. 387,83-90.

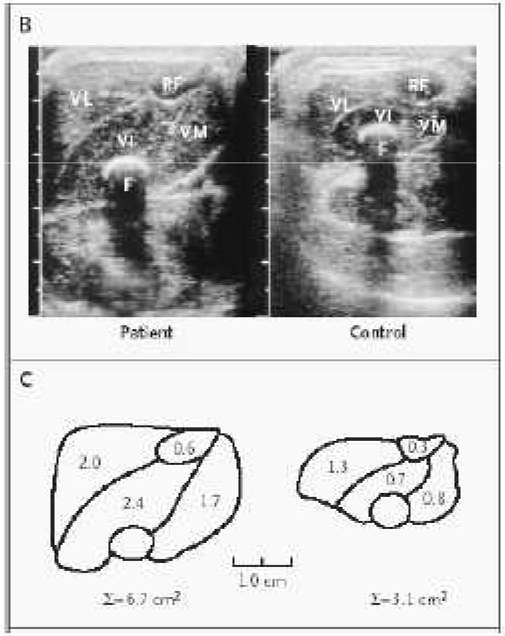
Hiperplasia muscular: Aumento en el número de células musculares con respecto al número de células normales.

Hipertrofia muscular: Aumento en la masa muscular, aumento del tamaño de las células musculares.

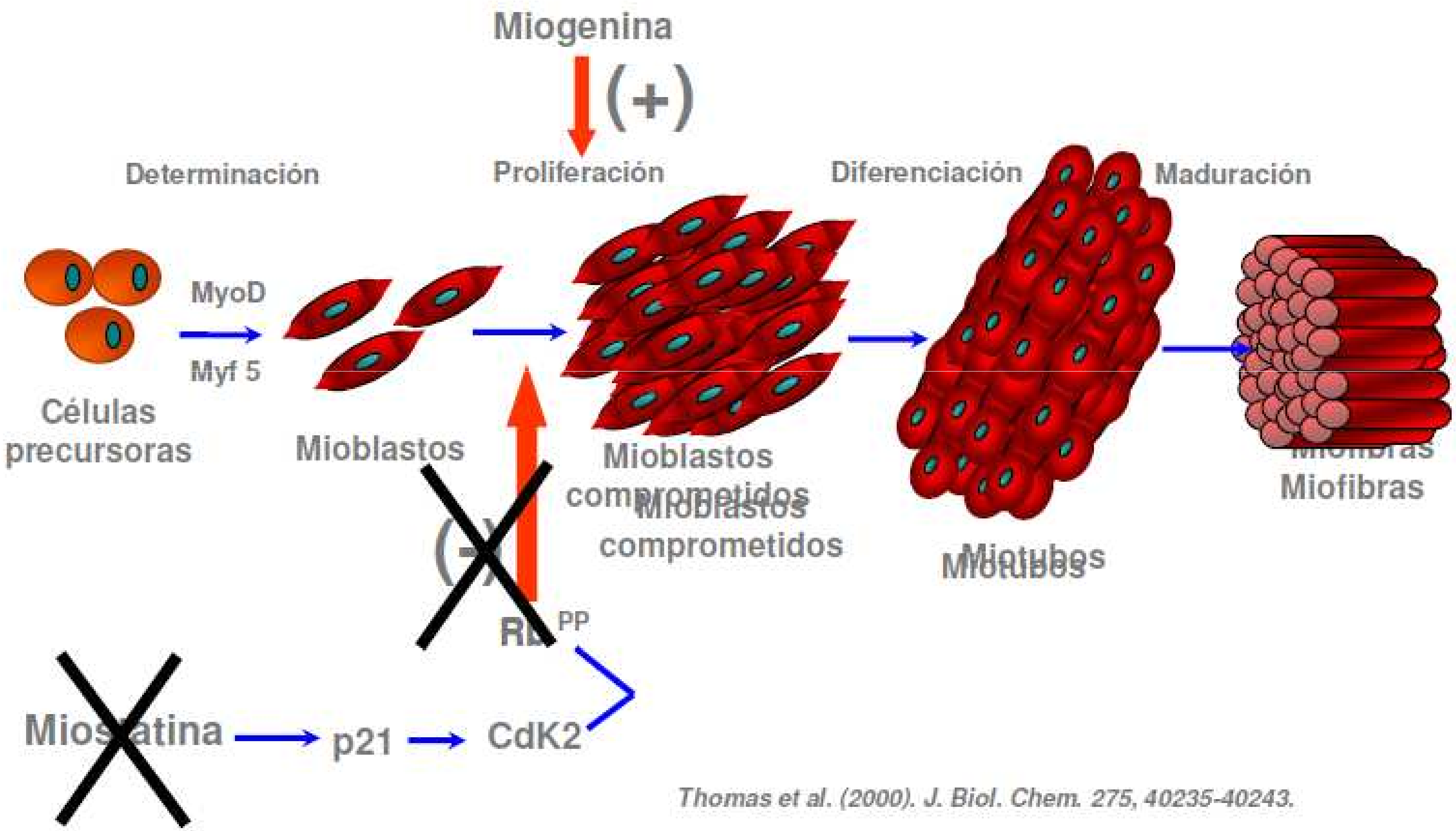
Myostatin Mutation Associated with Gross Muscle Hypertrophy in a Child

Markus Schuelke, M.D., Kathryn R. Wagner, M.D., Ph.D., Leslie E. Stolz, Ph.D., Christoph Hübner, M.D., Thomas Riebel, M.D., Wolfgang Kömen, M.D., Thomas Braun, M.D., Ph.D., James F. Tobin, Ph.D., and Se-Jin Lee, M.D., Ph.D.



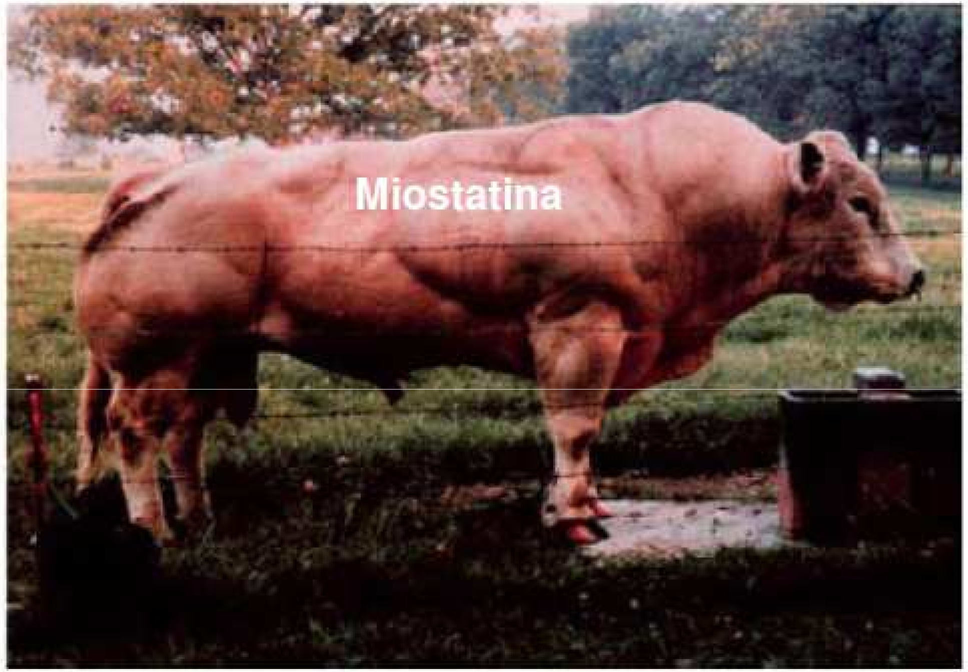


MECANISMO DE ACCIÓN DE LA MIOSTATINA



Thomas et al. (2000). J. Biol. Chem. 275, 40235-40243.

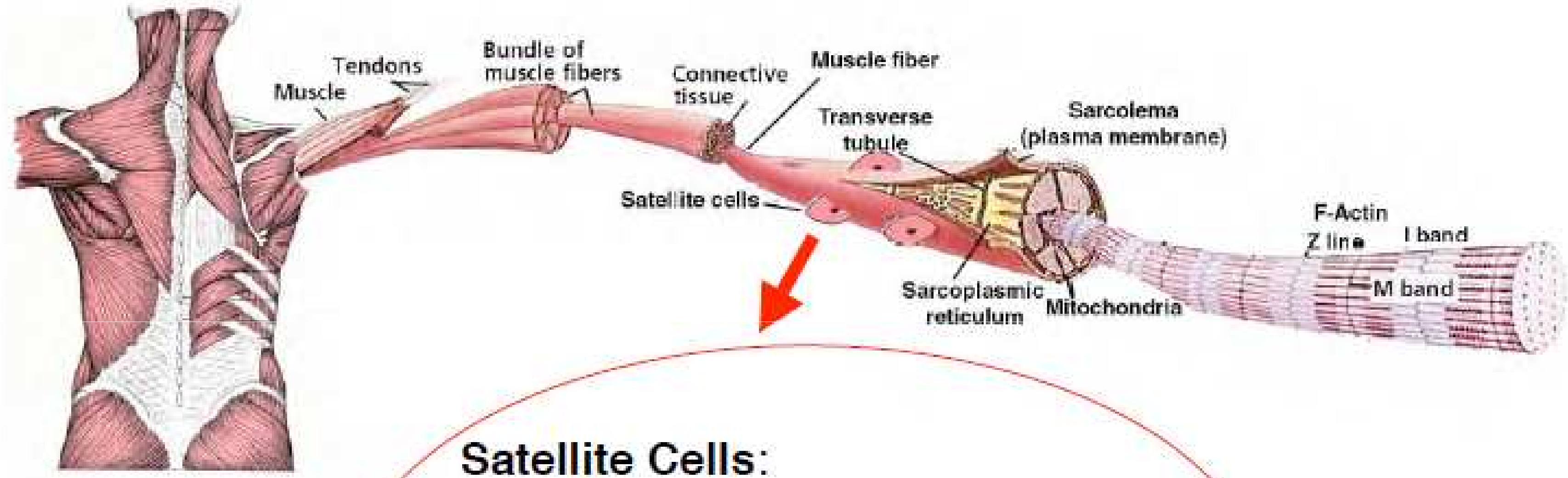
FENOTIPO MUSCULATURA DOBLE



McPherron A. & S. Lee (1997). PNAS. 11;94(23):12457-61.

SEGURO QUE NO EXISTE LA HIPERPLASIA????

Skeletal Muscle



Satellite Cells:

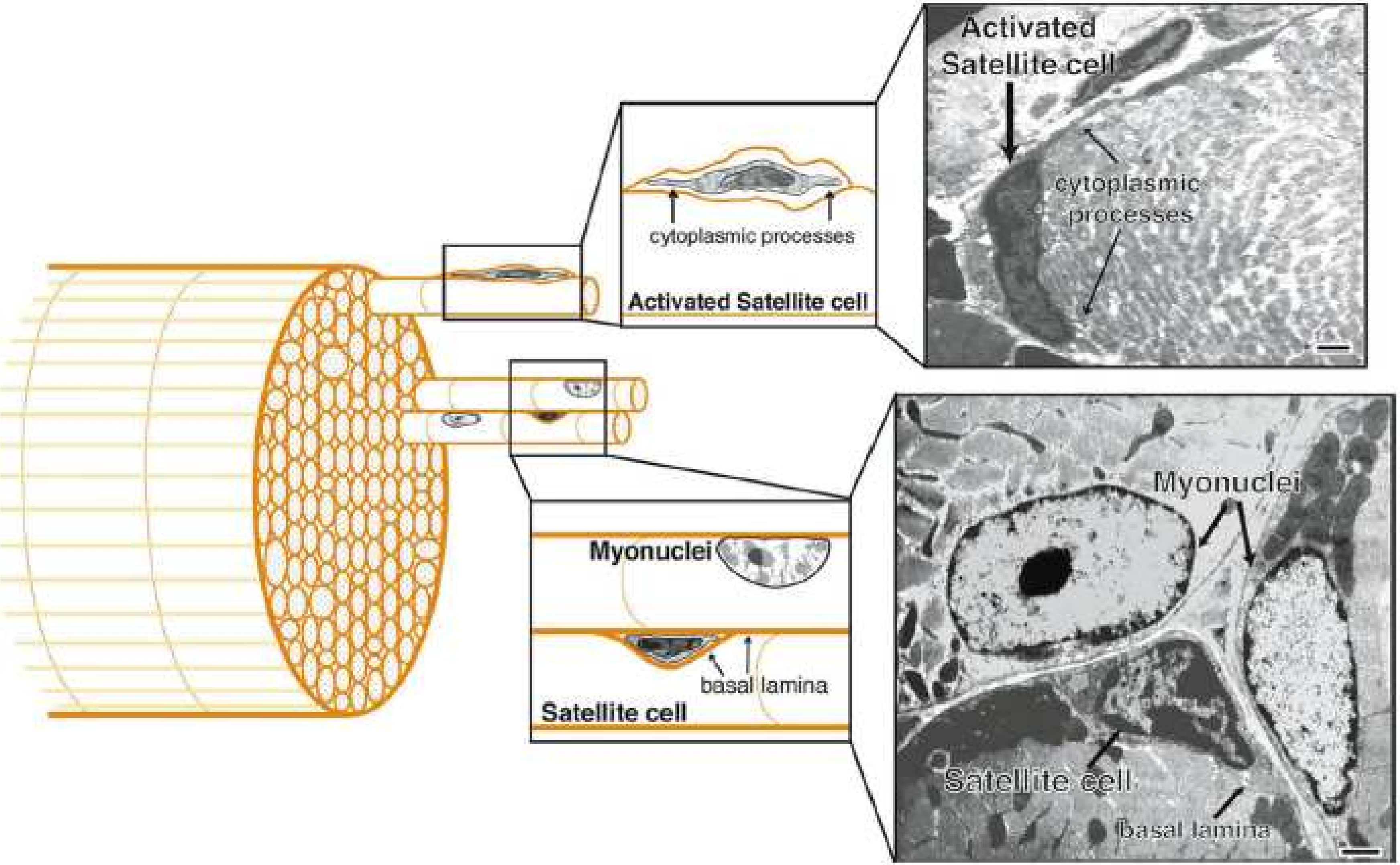
Muscle "stem" cells

Outside of the muscle fiber
but inside the basal lamina

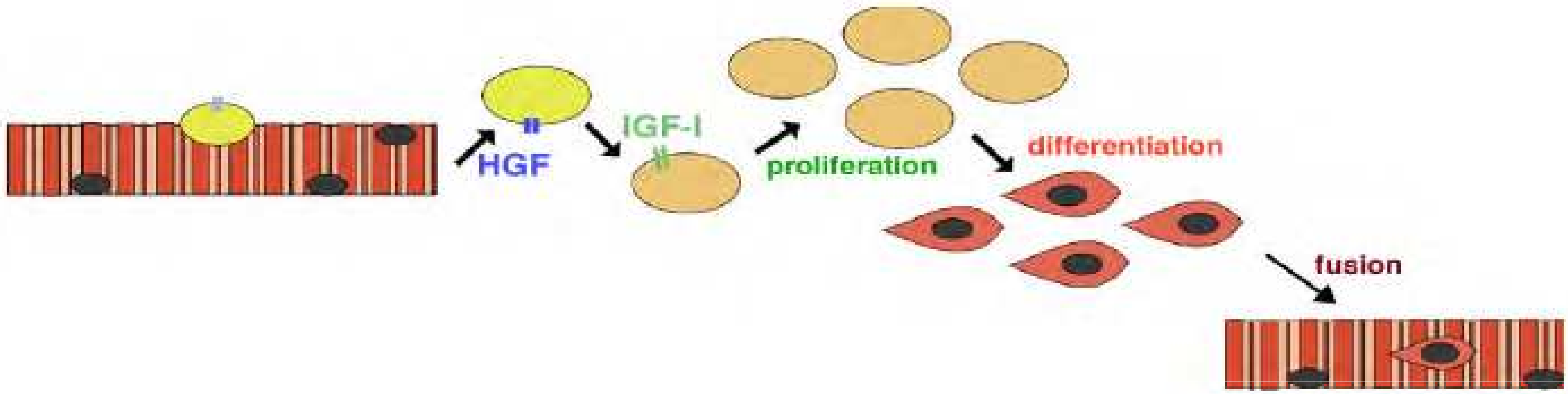
Source of nuclei for muscle repair

1 - 5 % muscle nuclear content

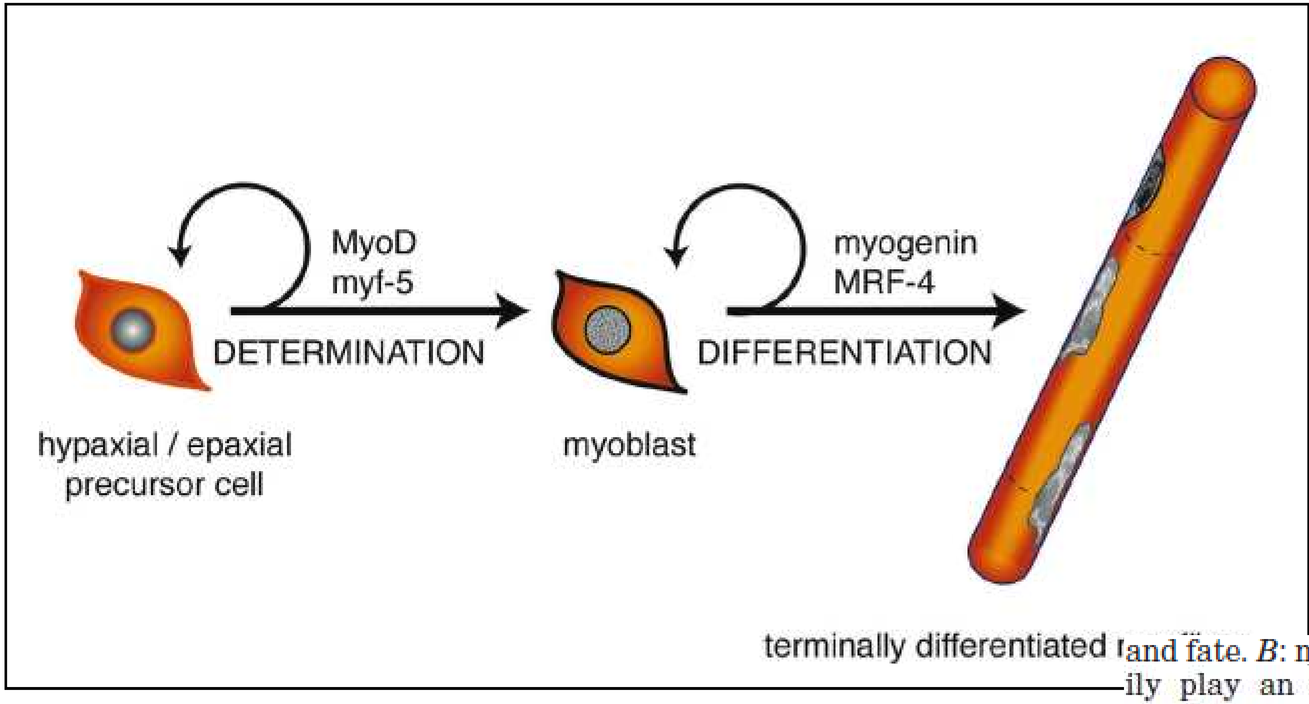
Células satélite y mionúcleos



Satellite cell activation

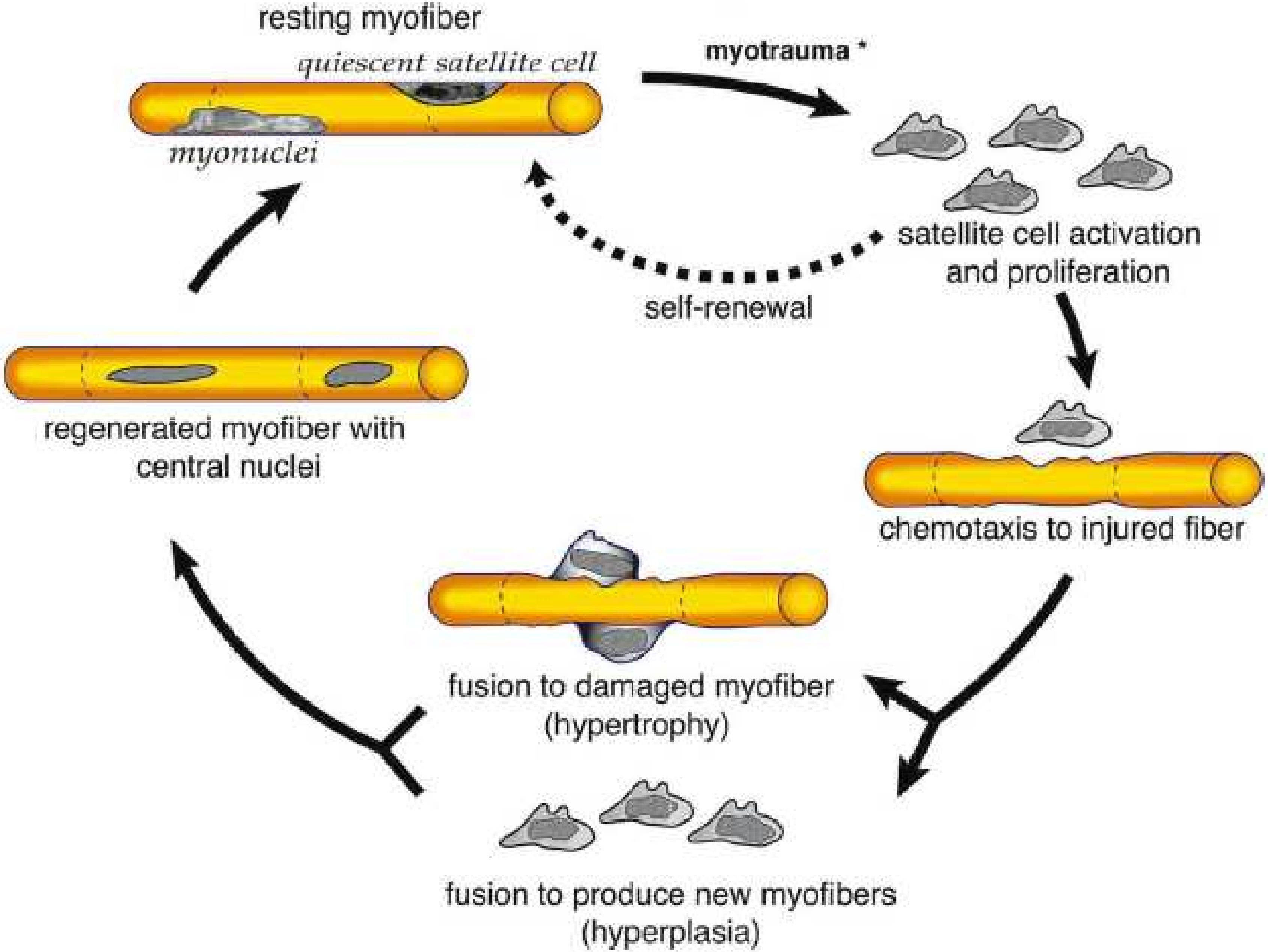


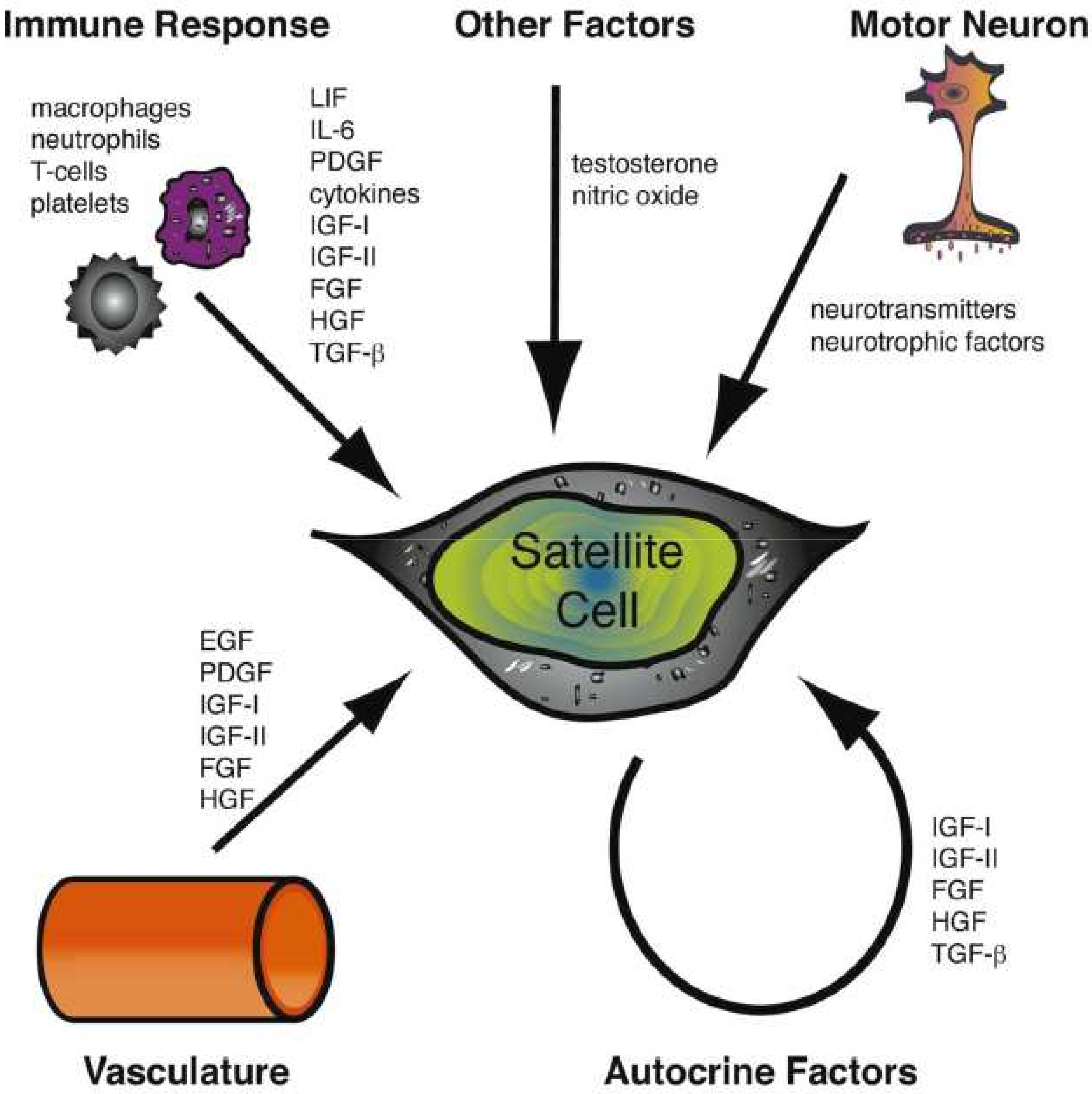
Mechanism for gaining muscle mass
Necessary for muscle repair
Activated process in muscle disease
Diminished process with age



and fate. *B*: members of the MyoD family play an integral role in skeletal muscle myogenesis. MyoD and myf5 expression is involved in determination of precursor cells to a myogenic fate, whereas myogenin and MRF4 expression is associated with terminal differentiation.

THOMAS J. HAWKE[1] AND DANIEL J. GARRY[1,2]
[1]*Department of Internal Medicine and* [2]*Department of Molecular Biology, University of Texas Southwestern Medical Center, Dallas, Texas 75390*



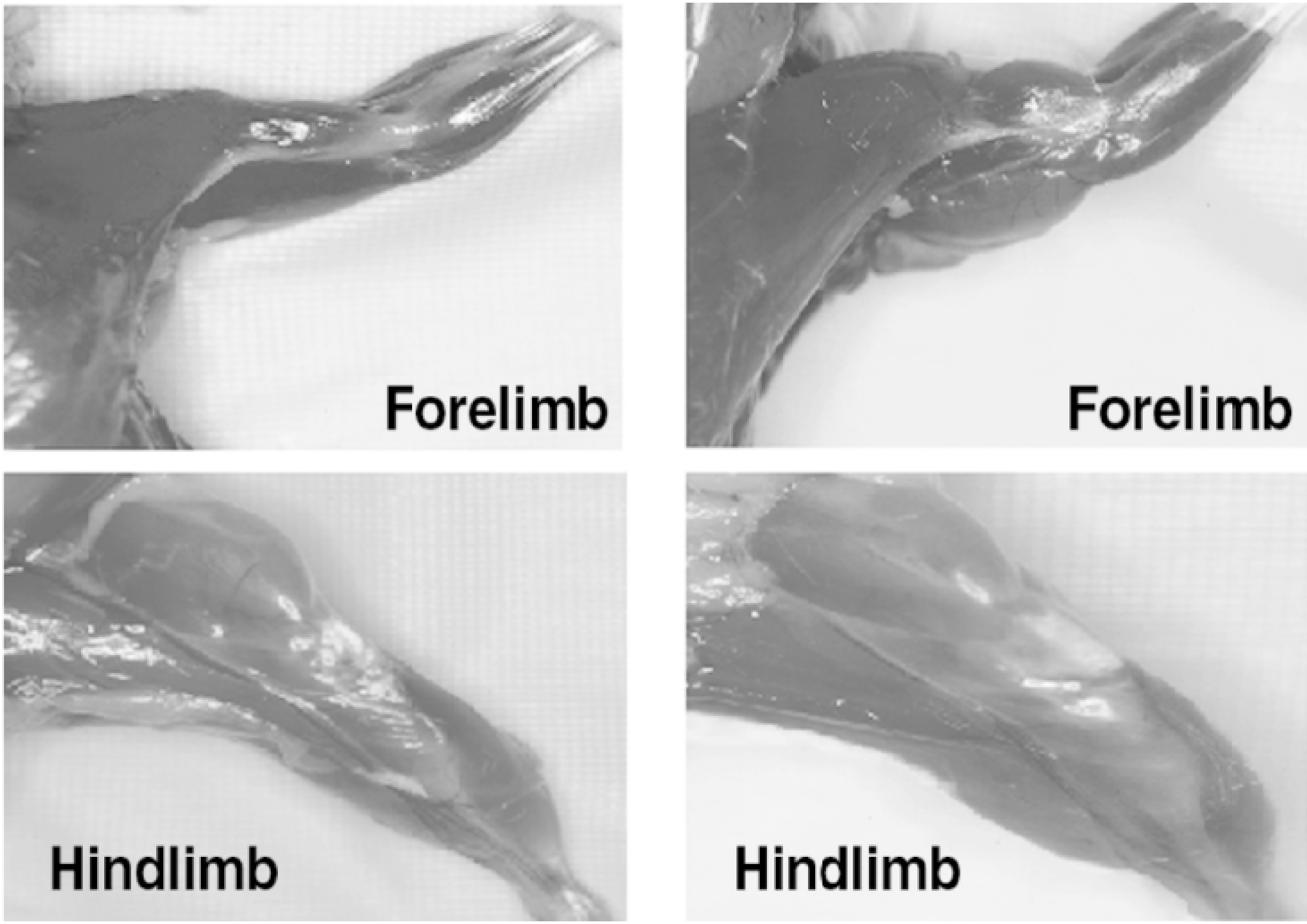

Immune Response
Other Factors
Motor Neuron
macrophages
neutrophils
T-cells
platelets
LIF
IL-6
PDGF
cytokines
IGF-I
IGF-II
FGF
HGF
TGF-β
testosterone
nitric oxide
neurotransmitters
neurotrophic factors
Satellite Cell
EGF
PDGF
IGF-I
IGF-II
FGF
HGF
IGF-I
IGF-II
FGF
HGF
TGF-β
Vasculature
Autocrine Factors

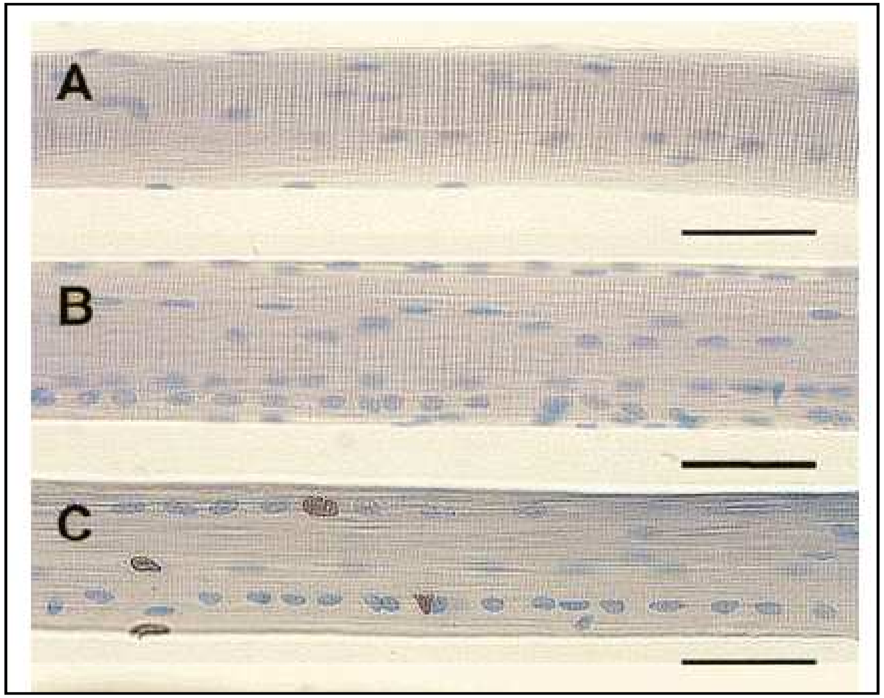
Exercise-enhanced satellite cell proliferation and new myonuclear accretion in rat skeletal muscle
Heather K. Smith, Linda Maxwell, Carol D. Rodgers, Nancy H. McKee and Michael J. Plyley
J Appl Physiol 90:1407-1414, 2001.

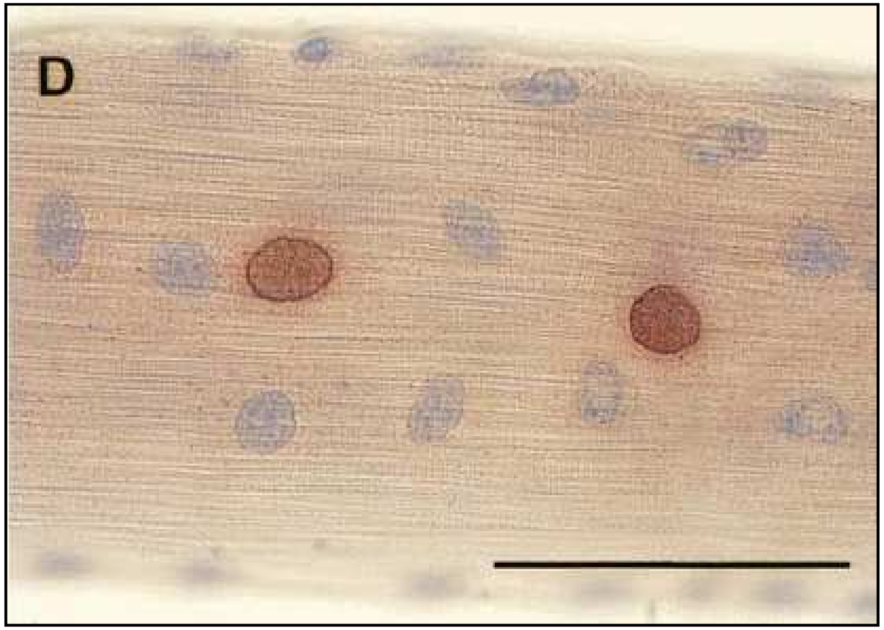
El ejercicio diario provoca la liberación de células satélite para el mantenimiento del adecuado ciclo celular.

Con ello se aumenta el número de núcleos, seguramente para regular la reparación, regeneración y aumento del tamaño de las fibras musculares dañadas.

Esto abre la posibilidad de nuevas adaptaciones de los músculos a diferentes tipos de ejercicio y quizás pueda tener implicaciones de otros tipo…nutricionales, médicas, etc…


Forelimb
Forelimb
Hindlimb
Hindlimb





Proliferación de mionúcleos a causa del ejercicio con cargas

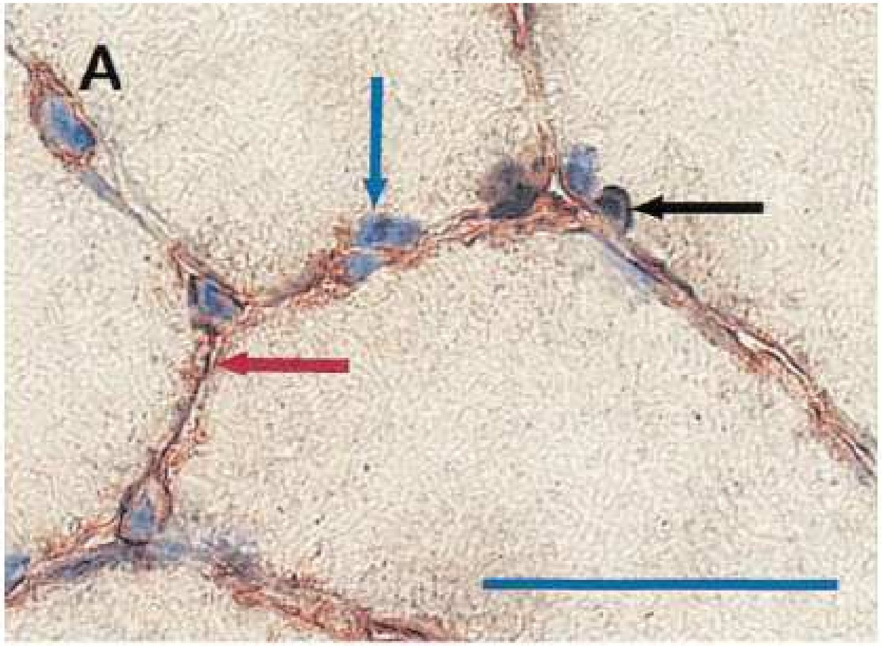
En un período de entrenamiento de 14 días nuevos núcleos musculares han aparecido.

Es debido a la ´fusión de células satélite a la fibra dañada.

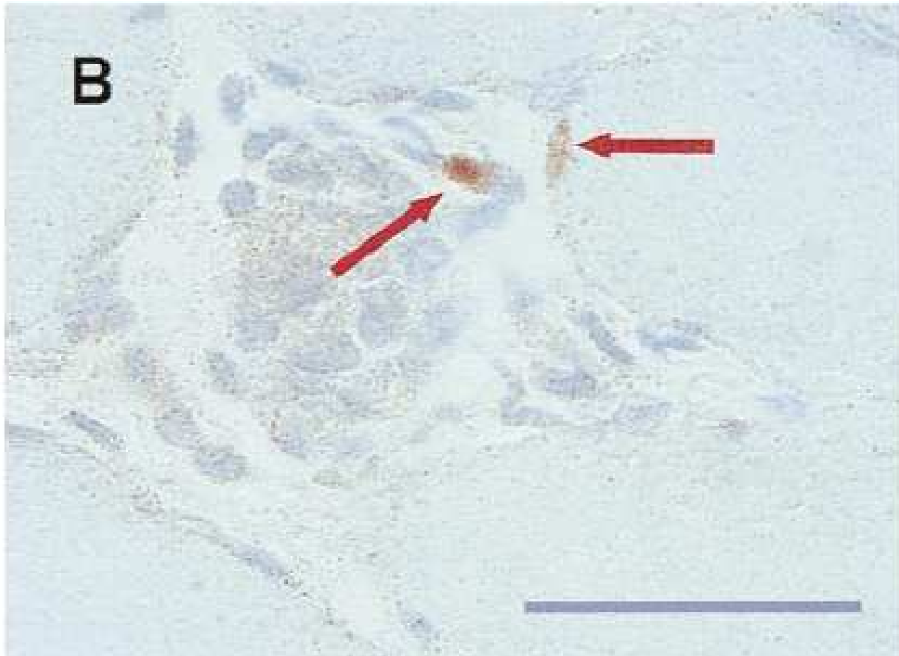
La causa más probable de la proliferación de células satélite es:

1º el efecto devastador del ejercicio físico con cargas

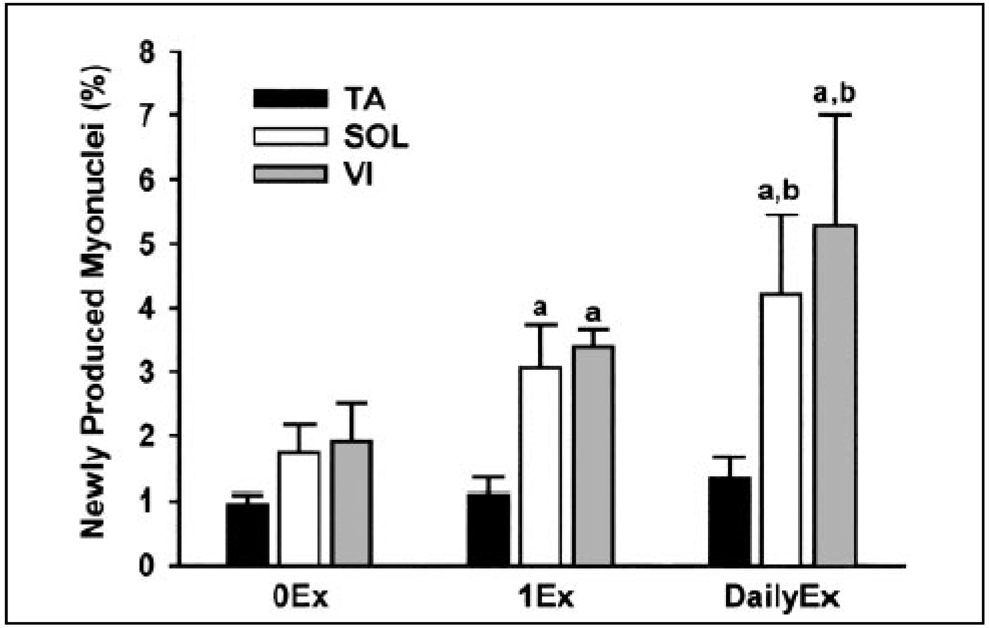
2º la liberación de factores hormonales de crecimiento



A Proliferación de células satélite desde la lámina basal en el sarcolema muscular



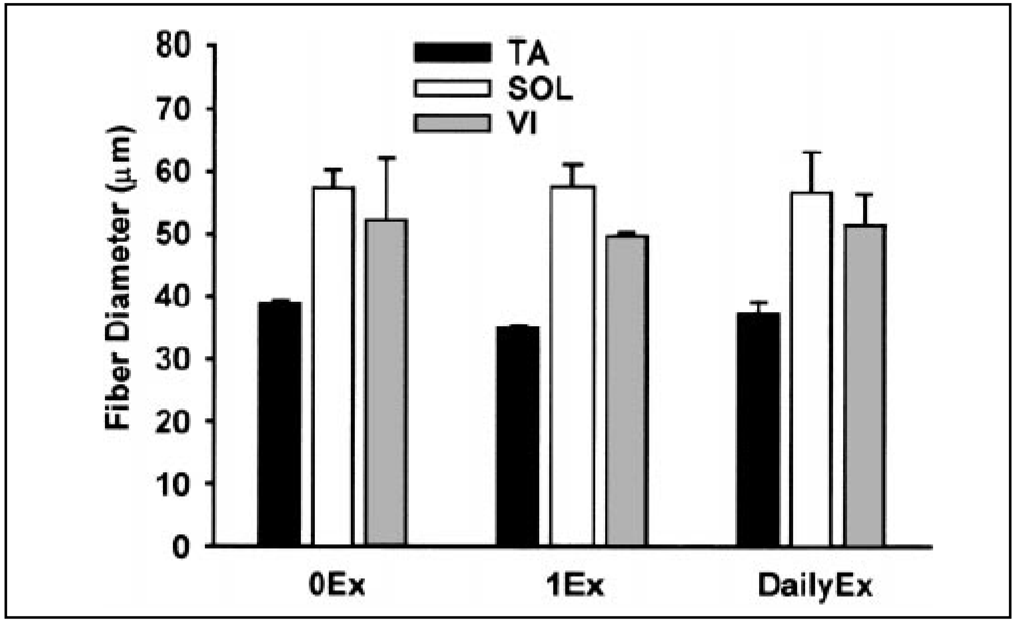
B Proliferación de mionúcleos en el sarcolema muscular



Aumento de núcleos comprobado en cada uno de los músculos entrenados.

No necesariamente aumento directo del tamaño muscular.

Las posibilidades están abiertas al aumento de tamaño. Pero harán falta otros factores añadidos.



Myonuclei acquired by overload exercise precede hypertrophy and are not lost on detraining

J. C. Bruusgaard, I. B. Johansen, I. M. Egner, Z. A. Rana, and K. Gundersen[1]

Department of Molecular Biosciences, University of Oslo, 0371 Oslo, Norway

Edited by Gerald D. Fischbach, The Simons Foundation, New York, NY, and approved July 16, 2010 (received for review December 4, 2009)

Las mejoras obtenidas por el entrenamiento de fuerza pueden durar toda la vida, aún después de tiempo de inactividad.

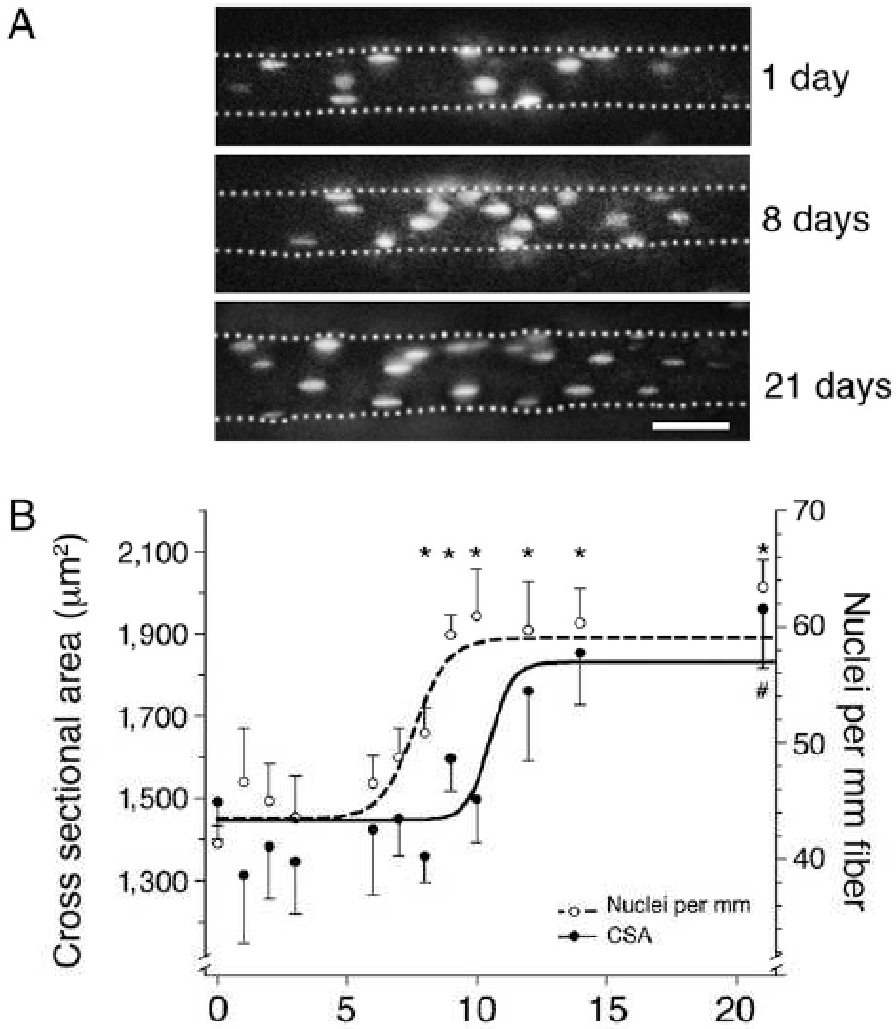
• La vuelta al entrenamiento y recuperación de la fuerza y el tamaño muscular se llamó “memoria muscular”.

• Se pensó que esto era debido a factores nerviosos, pero parece ser más debido a factores hipertróficos.

• El trabajo de hipertrofia genera nuevos núcleos celulares y estos parecen estar protegidos al efecto del desentrenamiento .

• La capacidad de regenerar células musculares por creación de mionúcleos parece ser que acompaña a la pérdida de músculo propia de la edad.

•El uso de andrógenos y anabolizantes parece ser una gran causa del aumento de núcleos en las células musculares.



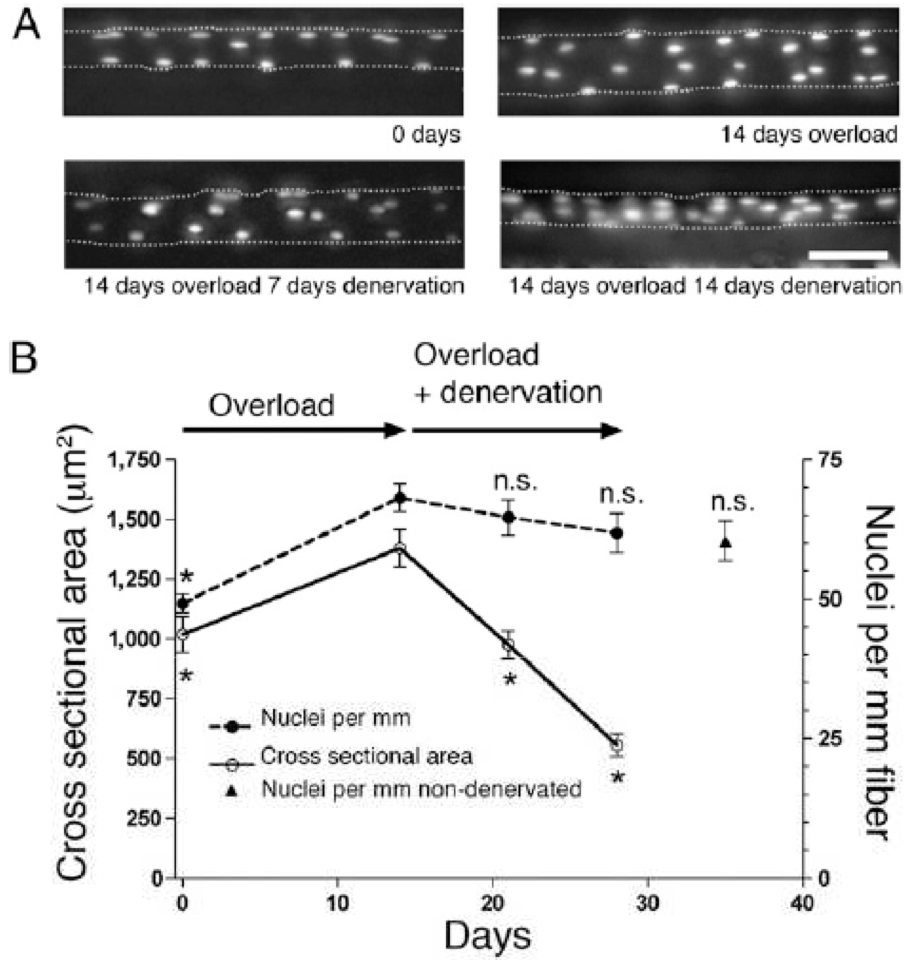
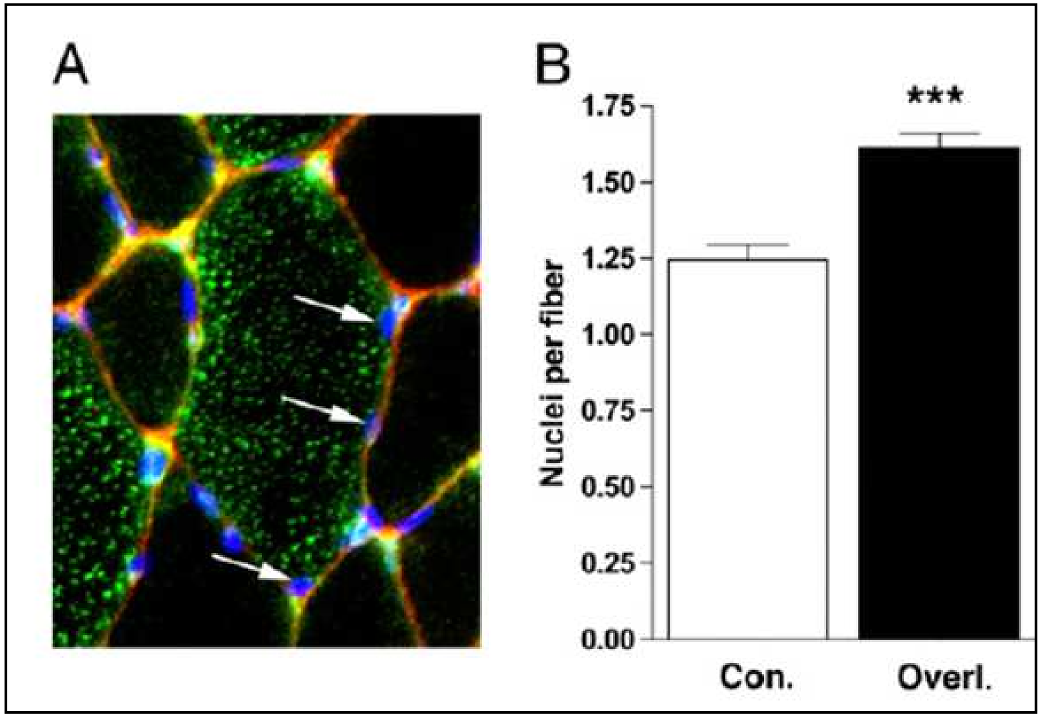
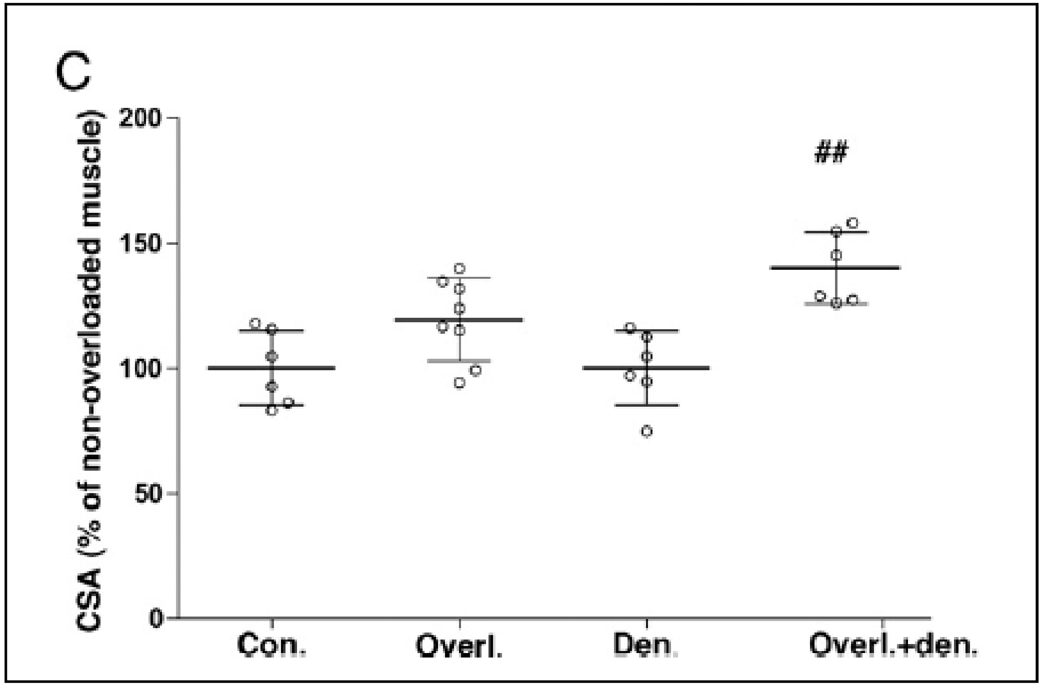


Fig. 2. Effect of denervation on overloaded muscles studied in vivo. (*A*) Micrographs of fibers after overload and subsequent denervation. Nuclei are labeled with fluorescent oligonucleotides. Illustrations represent merged

A Aumento de núcleos por el entrenamiento, y aumento de grosor en célula muscular.

B Al dejar de entrenar, pérdida de tamaño muscular, pero no tanto de número de núcleos.





La hipertrofia anterior del músculo retrasa la atrofia propia del desentrenamiento.

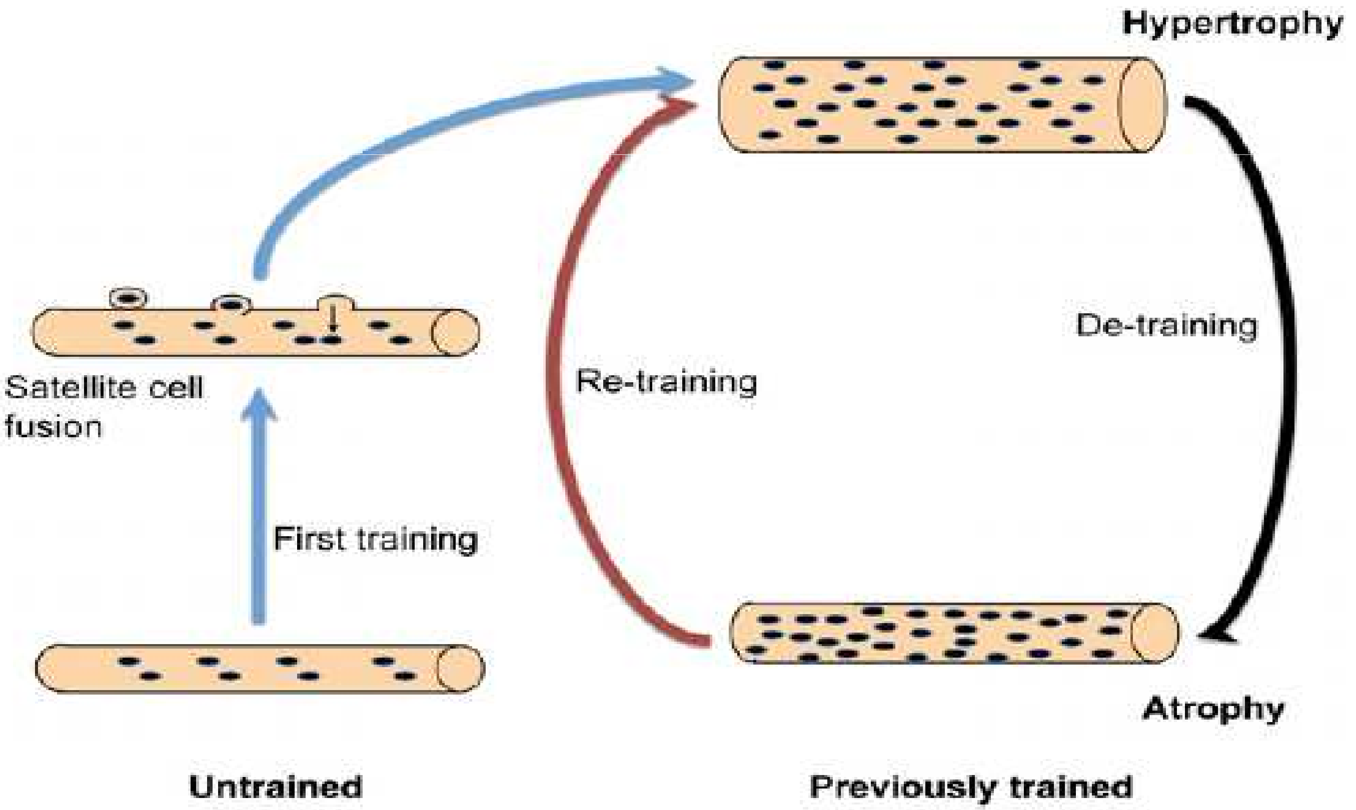
A Núcleos multiplicados.

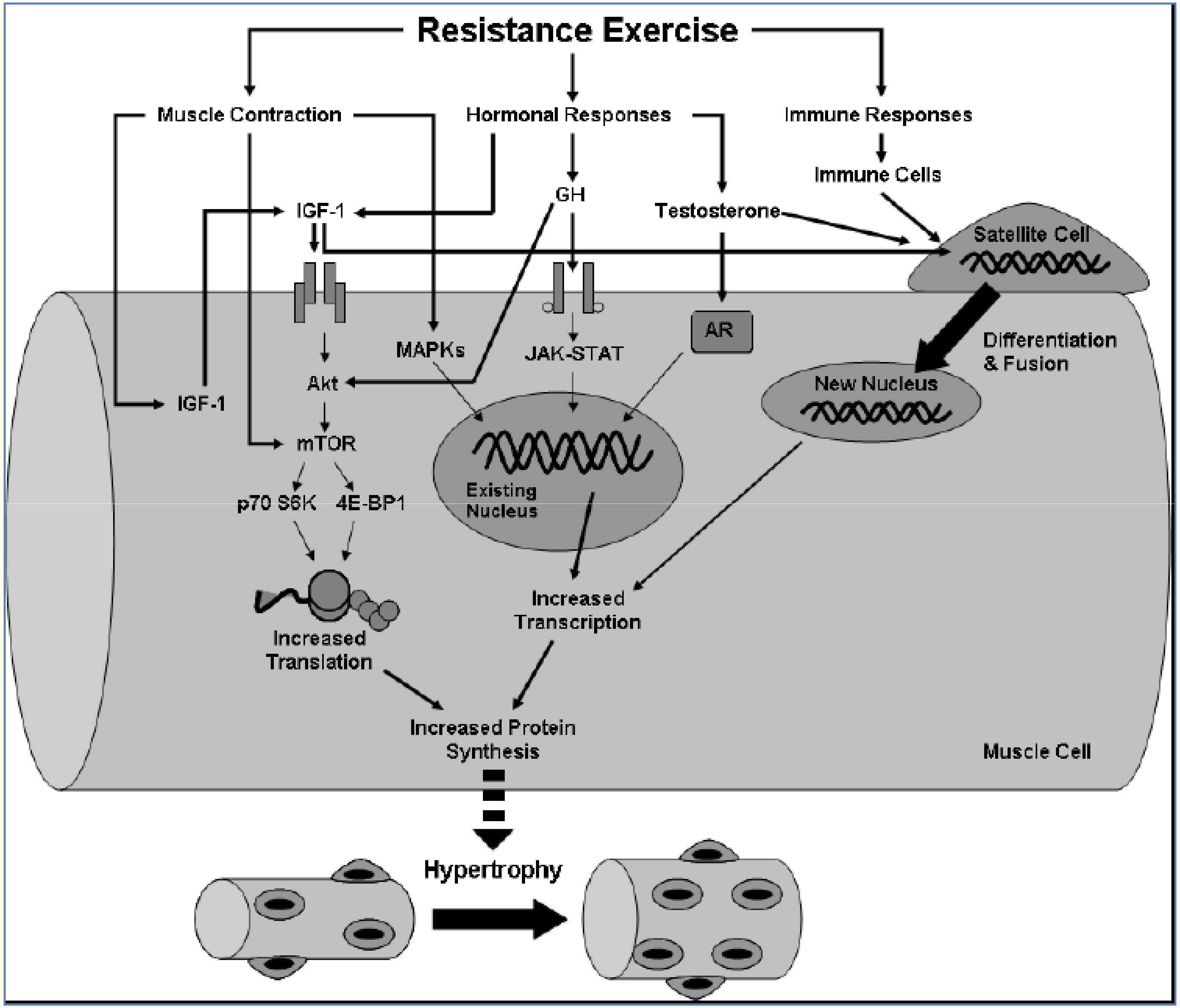
B Músculo entrenado comparado con músculo desentrenado.

C Pérdida de tamaño menor en músculos previamente entrenados.

Teoría de aumento de núcleos por el entrenamiento desde la teoría de aumento de la masa muscular por la fusión de las células satélite.

La hipertrofia debida a la reparación por la células satélite puede remitir debido al desentrenamiento, pero vuelve fácilmente al estado anterior con la vuelta a la actividad.




Resistance Exercise
Muscle Contraction
Hormonal Responses
Immune Responses
Immune Cells
GH
IGF-1
Testosterone
Satellite Cell
MAPKs
JAK-STAT
AR
Differentiation & Fusion
New Nucleus
Akt
IGF-1
mTOR
p70 S6K
4E-BP1
Existing Nucleus
Increased Transcription
Increased Translation
Increased Protein Synthesis
Muscle Cell
Hypertrophy

ADAPTACIONES MOLECULARES AL ENTRENAMIENTO DE FUERZA

Para entender---añadir imágenes

Una de las adaptaciones más evidentes al entrenamiento de fuerza es **aumento de la masa muscular**, que es debido principalmente a la **hipertrofia muscular**.

El aumento del tamaño muscular en respuesta al entrenamiento de fuerza es resultado de una serie de eventos que comprenden:

(1) activación del músculo;

(2) señalización procedente de la deformación mecánica de las fibras musculares,

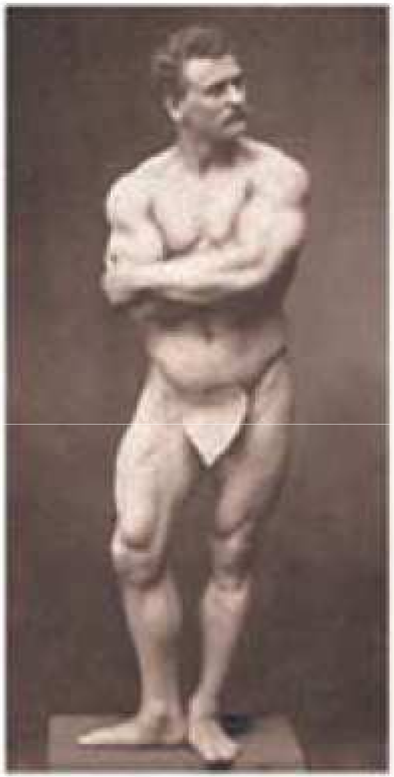
(3) síntesis proteica debida a una mayor trascripción y traducción; y

(4) hipertrofia de la fibra muscular.

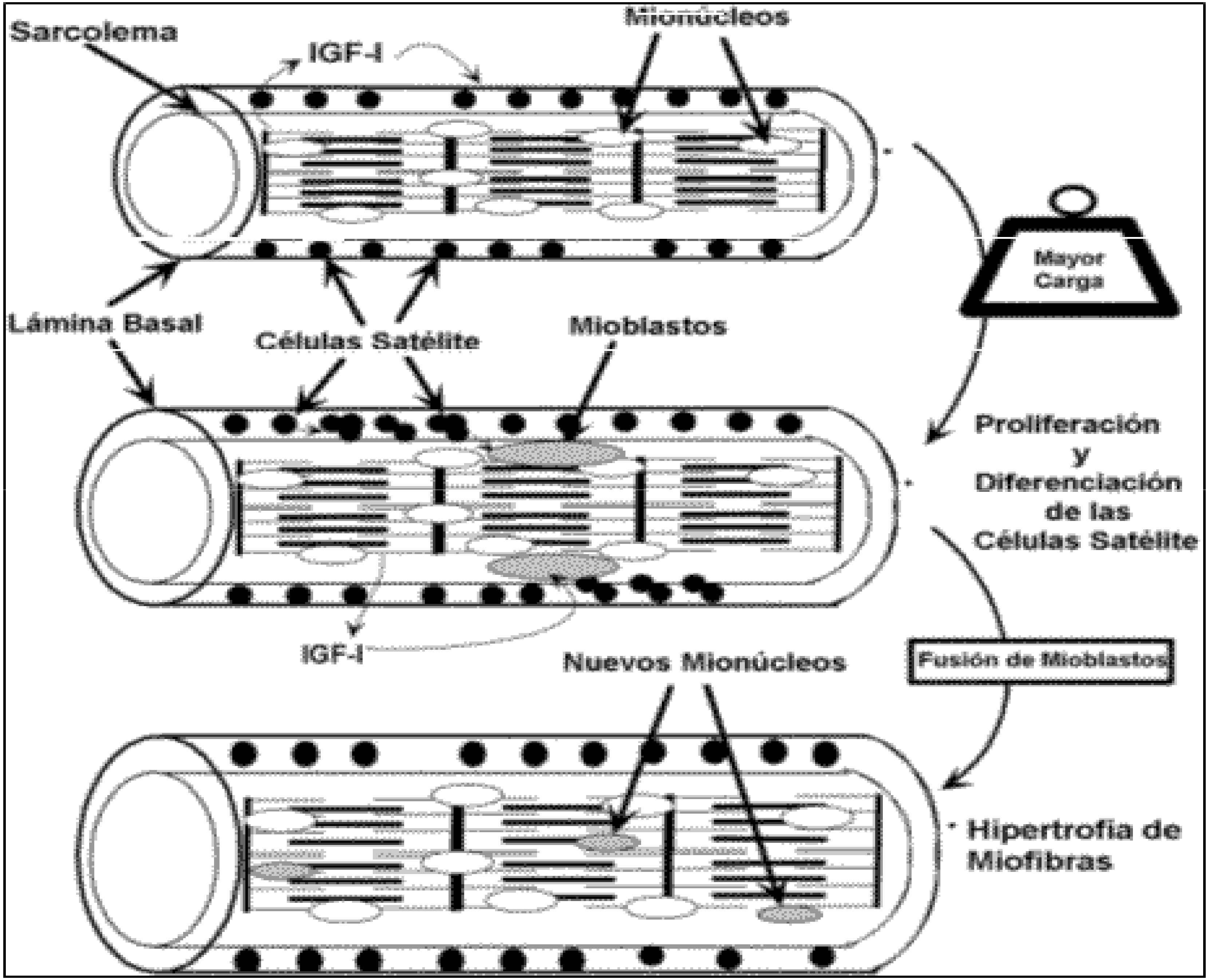
José Antonio López Calbet

La señalización procedente de deformación mecánica de las fibras musculares, ya sea por contracción o estiramiento, estimula varias vías de señalización en el músculo que son independientes de los cambios hormonales y factores de crecimiento. En concreto, la deformación mecánica activa las vías de señalización de la proteína quinasa B (Akt), de la proteína quinasa de mamíferos diana de la rapamicina (mTOR), la proteina quinasa activada por adenosin monofosfato (AMPK), y la proteína quinasa activada por mitógenos (MAPK). La vía mTOR es crucial para las adaptaciones al entrenamiento de fuerza; sin embargo, el papel de la señalización por AMPK y MAPK no ha sido aclarado del todo. Cuando las fibras musculares se contraen, la señalización por Akt-mTOR aumenta de manera marcada y esta respuesta es crítica para incrementar la síntesis proteica en el músculo y su consiguiente hipertrofia. Akt fosforila y activa mTOR durante la sobrecarga muscular, pero, la señalización de mTOR tras la estimulación mecánica puede también ocurrir independientemente de Akt. Esta señalización inducida por estimulación mecánica independiente de Akt ocurre a través de la producción de ácido fosfatídico. La cascada de señalización de mTOR incrementa la síntesis proteica mediante la mejora de la eficacia de la traducción (por ejemplo, aumentando la cantidad de ARNm traducido por ribosoma). Una vez activada, mTOR fosforila a dos dianas principales: la proteína ribosómica de 70 kDa (p70 S6K) y la proteína de unión 1 del factor eucariótico de iniciación de la traducción 4E (4E-BP1). A la par que mTOR, Akt también fosforila a la quinasa de la proteína glucógeno sintasa-3β (GSK-3β) y a la familia de factores de transcripción "*fork-head box O*" (FOXO). Akt fosforila e inhibe a GSK-3β, la cual libera la inhibición de eIF2B. La activación de eIF2B resulta en la interacción methionyl-ARNm con la subunidad 40S para el inicio de la traducción y la síntesis de proteínas. La fosforilación de FOXO mediada por Akt impide que la primera estimule la transcripción de ubiquitin-ligasas proteolíticas. Por lo tanto Akt promueve la síntesis de proteínas al tiempo que inhibe la destrucción de proteínas.

Síntesis de proteínas depende en parte de las respuestas endocrinas, paracrinas y autocrinas provocadas por el entrenamiento de fuerza, así como de factores genéticos y ambientales (aporte suficiente y adecuado de aminoácidos, vitamina D, etc.). Los cambios hormonales del tejido muscular al entrenamiento de fuerza pueden influir en los efectos locales del entrenamiento de fuerza. La evidencia más solida al respecto nos la ha proporcionado el estudio de la respuesta hipertrófica al entrenamiento de fuerza en presencia o ausencia de testosterona. No obstante, también influyen en la respuesta hipertrófica al entrenamiento de la hormona del crecimiento (GH) y los factores de crecimiento similares a la insulina (IGF-1 y 2), la miostatina y la folistatina. La unión de la GH con su receptor de membrana inicia la cascada de señalización de JAK2. JAK2 activa PI3K, que a su vez activa Akt y ésta última a mTOR. El entrenamiento de fuerza produce un incremento de las concentraciones de IGF-1 circulante y muscular. Además, el entrenamiento de fuerza altera las concentraciones de las proteínas de unión a IGF, que influencian la actividad biológica de IGF-1. Además de esta vía IGF-1 estimula la proliferación y diferenciación de unas células madre localizadas en la periferia de las fibras musculares y que reciben el nombre de células satélite. La activación, proliferación y diferenciación de las células satélite contribuye de forma significativa al crecimiento muscular tras un entrenamiento a largo plazo. La Testosterona ejerce sus efectos sobre la síntesis proteica en el músculo esquelético a través de los receptores de andrógenos (AR). La testosterona se une al AR y lo transforma en un factor de trascripción capaz de translocarse al núcleo y asociarse con el ADN para regular la expresión de determinados genes que poseen elementos de respuesta a andrógenos (ERA) en su región promotora. El bloqueo de este receptor atenúa la ganancia de proteínas musculares, lo cual muestra la importancia fisiológica de las interacciones testosterona-AR en la hipertrofia muscular. Además, de forma similar a IGF-1, la Testosterona ejerce su influencia en el crecimiento muscular a través de las células satélite. Dosis suprafisiológicas de testosterona incrementan el número de células satélite de una forma

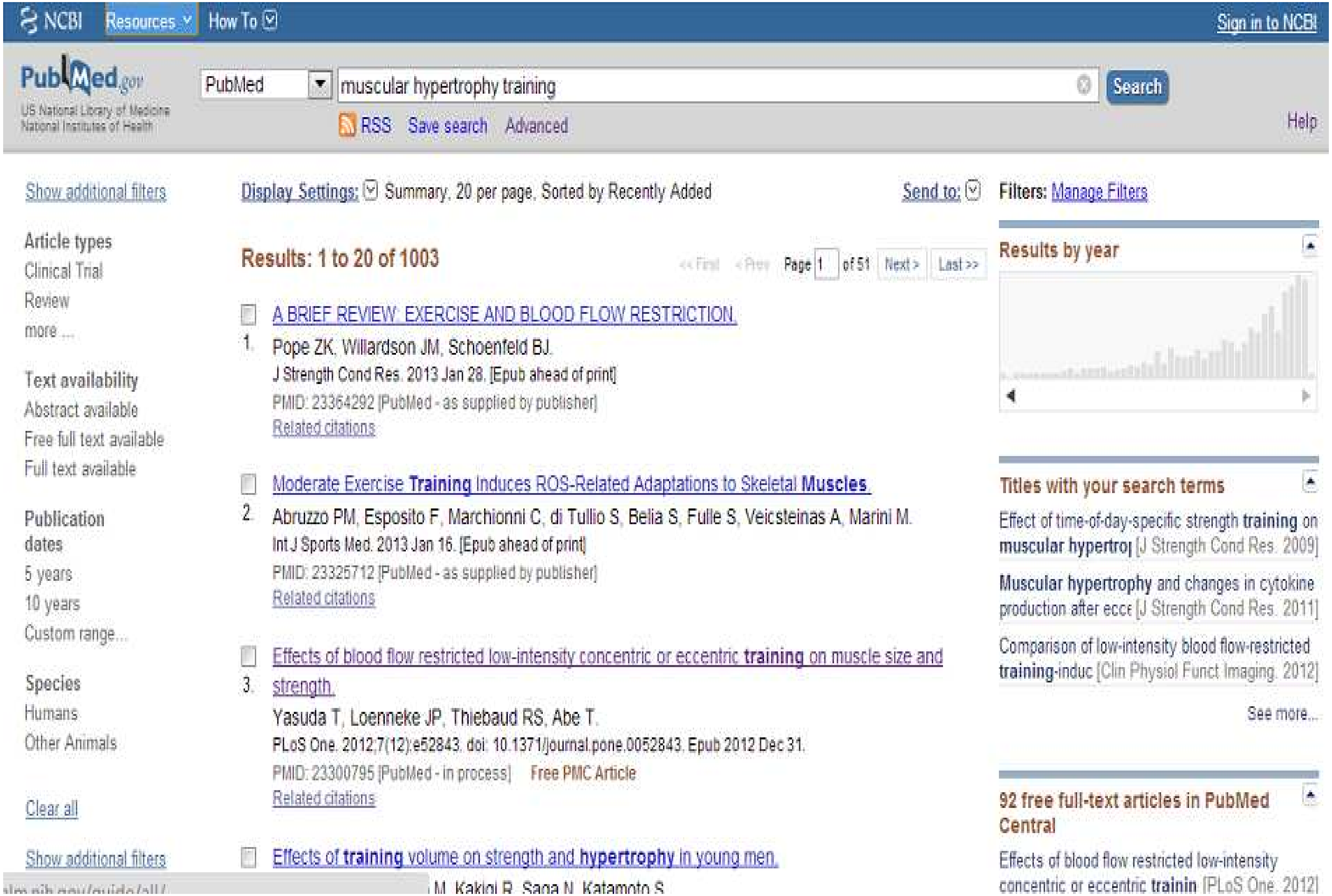




(Juha Aitiainen, 2006)


Sarcolema
IGF-I
Mionúcleos
Lámina Basal
Células Satélite
Mioblastos
Mayor Carga
Proliferación y Diferenciación de las Células Satélite
IGF-I
Nuevos Mionúcleos
Fusión de Mioblastos
Hipertrofia de Miofibras

NUEVOS ESTUDIOS SOBRE HIPERTROFIA MUSCULAR 2012 y 2013

Entrenamiento **musculación**
para el crecimiento muscular


NCBI
Resources
How To
Sign in to NCBI
PubMed.gov
US National Library of Medicine
National Institutes of Health
PubMed
muscular hypertrophy training
Search
RSS
Save search
Advanced
Help
Show additional filters
Article types
Clinical Trial
Review
more ...
Text availability
Abstract available
Free full text available
Full text available
Publication dates
5 years
10 years
Custom range...
Species
Humans
Other Animals
Clear all
Show additional filters
Display Settings: Summary, 20 per page, Sorted by Recently Added
Send to:
Results: 1 to 20 of 1003
<< First
< Prev
Page 1 of 51
Next >
Last >>
A BRIEF REVIEW: EXERCISE AND BLOOD FLOW RESTRICTION.
1. Pope ZK, Willardson JM, Schoenfeld BJ.
J Strength Cond Res. 2013 Jan 28. [Epub ahead of print]
PMID: 23364292 [PubMed - as supplied by publisher]
Related citations
Moderate Exercise Training Induces ROS-Related Adaptations to Skeletal Muscles.
2. Abruzzo PM, Esposito F, Marchionni C, di Tullio S, Belia S, Fulle S, Veicsteinas A, Marini M.
Int J Sports Med. 2013 Jan 16. [Epub ahead of print]
PMID: 23325712 [PubMed - as supplied by publisher]
Related citations
Effects of blood flow restricted low-intensity concentric or eccentric training on muscle size and strength.
3. Yasuda T, Loenneke JP, Thiebaud RS, Abe T.
PLoS One. 2012;7(12):e52843. doi: 10.1371/journal.pone.0052843. Epub 2012 Dec 31.
PMID: 23300795 [PubMed - in process]
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M, Kakigi R, Sasa N, Katamoto S
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Muscular hypertrophy and changes in cytokine production after ecce [J Strength Cond Res. 2011]
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Effects of blood flow restricted low-intensity concentric or eccentric trainin [PLoS One. 2012]

Eur J Appl Physiol. 2012 Oct 6. [Epub ahead of print]

Comparison of muscle hypertrophy following 6-month of continuous and periodic strength training.

Ogasawara R, Yasuda T, Ishii N, Abe T

Abstract

To compare the effects of a periodic resistance training (PTR) program with those of a continuous resistance training (CTR) program on muscle size and function, 14 young men were randomly divided into a CTR group and a PTR group. Both groups performed high-intensity bench press exercise training [75 % of one repetition maximum (1-RM); 3 sets of 10 reps] for 3 days per week. The CTR group trained continuously over a 24-week period, whereas the PTR group performed three cycles of 6-week training (or retraining), with 3-week detraining periods between training cycles. After an initial 6 weeks of training, increases in cross-sectional area (CSA) of the triceps brachii and pectoralis major muscles and maximum isometric voluntary contraction of the elbow extensors and 1-RM were similar between the two groups. In the CTR group, muscle CSA and strength gradually increased during the initial 6 weeks of training. However, the rate of increase in muscle CSA and 1-RM decreased gradually after that. In the PTR group, increase in muscle CSA and strength during the first 3-week detraining/6-week retraining cycle were similar to that in the CTR group during the corresponding period. However, increase in muscle CSA and strength during the second 3-week detraining/6-week retraining cycle were significantly higher in the PTR group than in the CTR group. Thus, overall improvements in muscle CSA and strength were similar between the groups. The results indicate that 3-week detraining/6-week retraining cycles result in muscle hypertrophy similar to that occurring with continuous resistance training after 24 weeks.

J Gerontol A Biol Sci Med Sci. 2012 Oct 22. [Epub ahead of print]

Skeletal Muscle Autophagy and Protein Breakdown Following Resistance Exercise are Similar in Younger and Older Adults.

Fry CS, Drummond MJ, Glynn EL, Dickinson JM, Gundermann DM, Timmerman KL, Walker DK, Volpi E, Rasmussen BB.**Source**
Department of Nutrition and Metabolism, Division of Rehabilitation Sciences, University of Texas

Abstract

BACKGROUND:

The loss of skeletal muscle mass and strength during aging, sarcopenia, increases the risk for falls and dependency. Resistance exercise (RE) training is effective at improving muscle mass and strength in older adults; however, aging is associated with reduced training-induced hypertrophy. Recent research has illustrated an impaired muscle protein synthetic response following an acute bout of RE in older adults but much less is known regarding the effect of acute RE on muscle protein breakdown (MPB). We hypothesize that the ubiquitin proteasome system and the autophagosomal-lysosomal system may regulate the overall rate of MPB during postexercise recovery.

METHODS:

Muscle biopsies of the vastus lateralis were sampled from 16 older (age = 70±2 years) and 16 younger (age = 27±2 years) participants at baseline and at 3, 6, and 24 hours following an acute bout of RE. In conjunction with stable isotopic techniques to measure MPB, we utilized immunoblotting and RT-PCR to examine protein and mRNA expression for key signaling molecules in both the ubiquitin proteasome system and the autophagosomal-lysosomal system.

RESULTS:

MuRF1 mRNA expression increased, whereas GABARAP mRNA decreased after RE in both younger and older adults ($p < .05$). The LC3B-II/LC3B-I protein ratio decreased in both groups after RE ($p < .05$), but MPB was not different 24 hour post-RE in either group ($p > .05$).

CONCLUSIONS:

Aging does not influence skeletal MPB, autophagy, or the ubiquitin proteasome system following an acute bout of RE. Therefore, targeting the muscle protein synthesis response to exercise may hold more promise in

Entrenamiento **muscular/aeróbico** para el crecimiento muscular

Eur J Appl Physiol (2010) 110:665–694
DOI 10.1007/s00421-010-1545-0

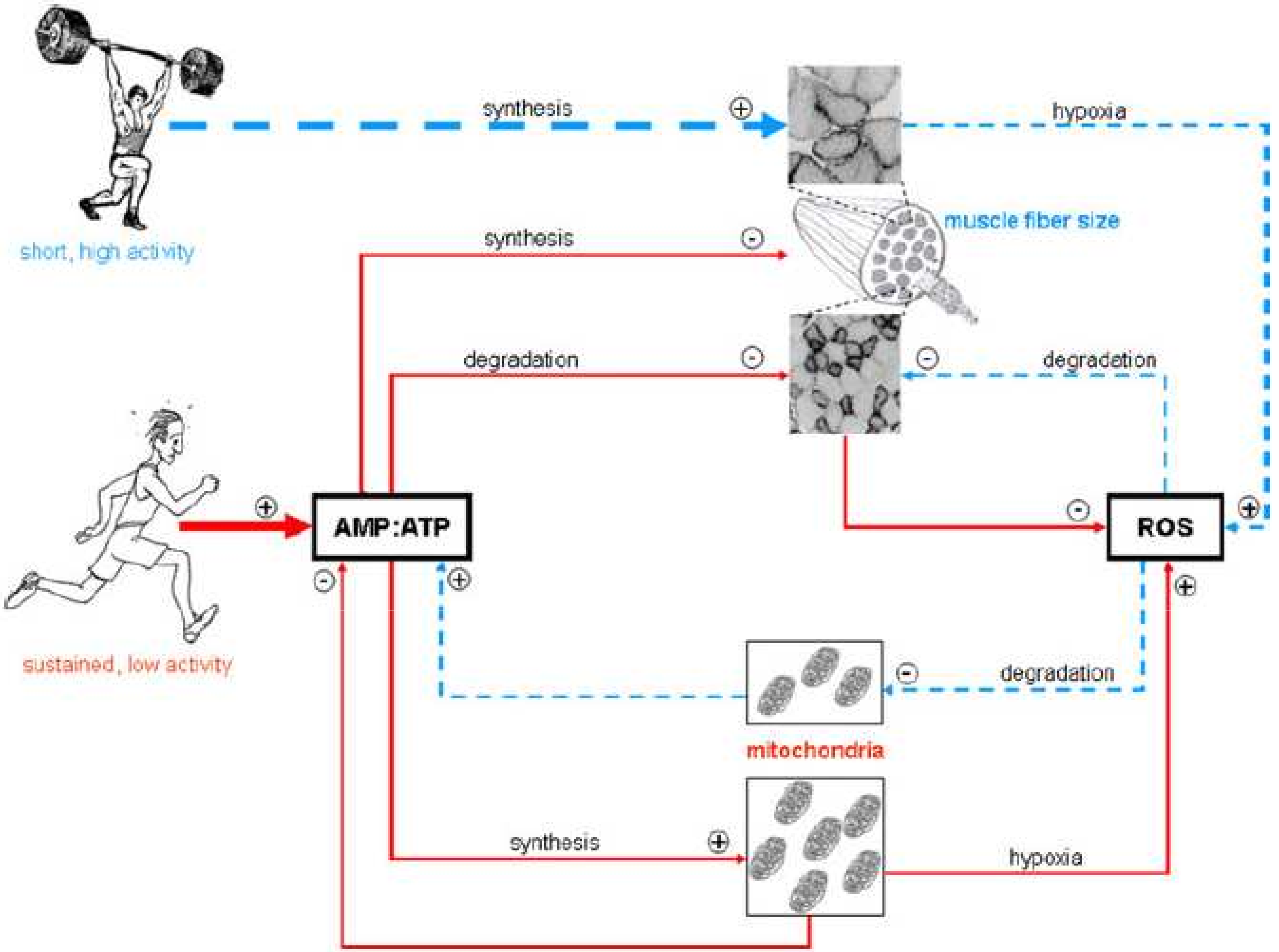
REVIEW ARTICLE

The muscle fiber type–fiber size paradox: hypertrophy or oxidative metabolism?

T. van Wessel · A. de Haan · W. J. van der Laarse ·
R. T. Jaspers

Ever since the classical training experiments of Hickson (1980), we know that human skeletal muscles have limited capacity to improve strength and fatigue resistance at the same time. This observation is valid for striated muscle tissue, in general, as an inverse relationship exists between muscle fiber size and its oxidative capacity (Fig. 1). This relationship suggests that striated muscle cells are evolved in such a way that anoxic cores are prevented. The central question addressed in this review is: 'why do the high oxidative fibers remain small compared to the low oxidative fibers'?

(Fig. 3). The rate of synthesis is largely regulated by the Akt–mTOR pathway, which induces hypertrophy in response to short contractions, mechanical loading and regulation and presence or absence of growth factors such as IGF-I and myostatin, respectively. In contrast, hypoxia and sustained contractile activity, associated with low cellular energy levels, activate Ca^{2+}-calcineurin and AMPK. Both calcineurin and AMPK stimulate oxidative metabolism and slow-type gene expression through PGC-1α, while AMPK simultaneously attenuates protein synthesis by inhibiting mTOR, via activation of TSC-2. Akt



thereby regulating the fiber size. *Solid lines* are dominant processes i high oxidative fibers, whereas *dashed lines* are dominant in low oxidative fibers. The *plus and minus signs* reflect the effects of th different processes (e.g., synthesis, degradation, hypoxia) on fiber siz and mitochondrial density (for details see text)

Eur J Appl Physiol. 2012 Apr;112(4):1457-66. doi: 10.1007/s00421-011-2112-z. Epub 2011 Aug 11.

High volume of endurance training impairs adaptations to 12 weeks of strength training in well-trained endurance athletes.

Rønnestad BR, Hansen EA, Raastad T.

Source

Lillehammer University College, PB. 952, 2604 Lillehammer, Norway. bent.ronnestad@hil.no

Abstract

The purpose of the present study was to compare the effect of 12 weeks of strength training combined with a large volume of endurance training with the effect of strength training alone on the strength training adaptations. Well-trained cyclists with no strength training experience performed heavy strength training twice a week in addition to a high volume of endurance training during a 12-week preparatory period (S + E; n = 11). A group of non-strength trained individuals performed the same strength training as S + E, but without added endurance training (S; n = 7). Thigh muscle cross-sectional area, 1 repetition maximum (1RM) in leg exercises, squat jump performance, and peak rate of force development (RFD) were measured. Following the intervention period, both S + E and S increased 1RM strength, thigh muscle cross-sectional area, and squat jump performance ($p < 0.05$), and the relative improvements in S were greater than in S + E ($p < 0.05$). S increased peak RFD while S + E did not, and this improvement was greater than in S + E ($p < 0.05$). To the best of our knowledge, this is the first controlled study to demonstrate that the strength training response on muscle hypertrophy, 1RM strength, squat jump performance, and peak RFD is attenuated in well-trained endurance athletes during a period of concurrent endurance training.

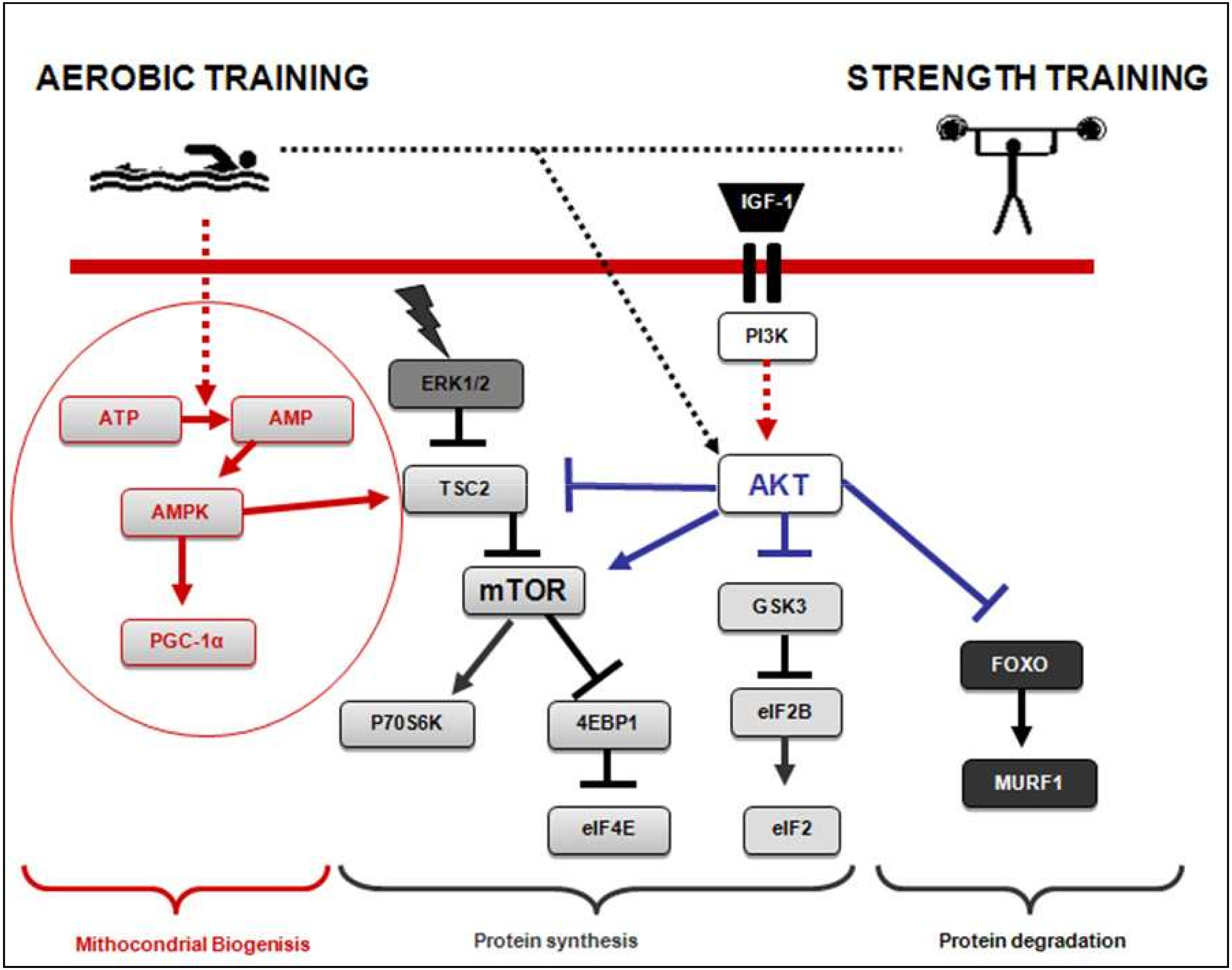
Signaling Pathways that Mediate Skeletal Muscle Hypertrophy: Effects of Exercise Training

T Fernandes, ÚPR Soci, SFS Melo, CR Alves… - 2012

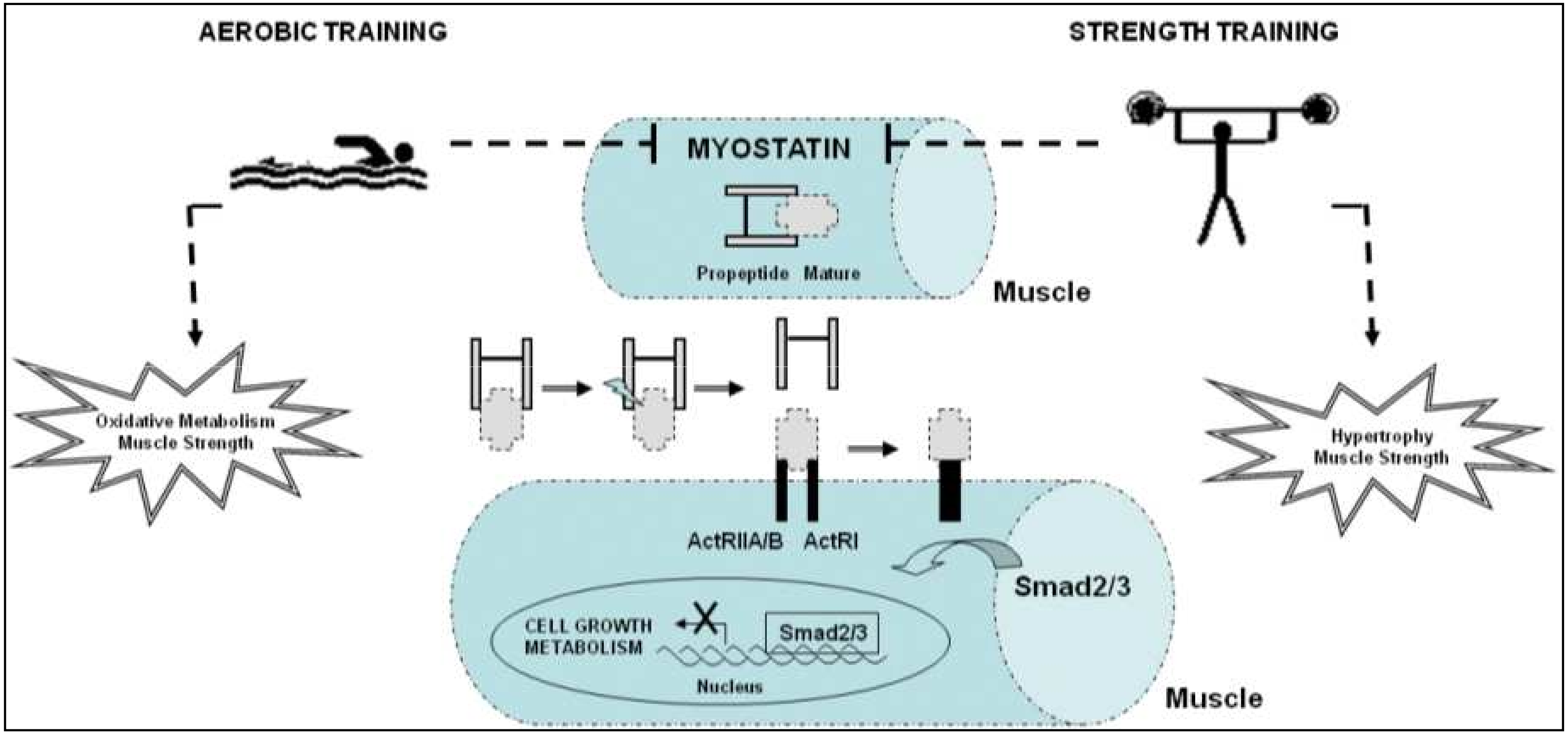
Skeletal **muscle** accounts for approximately 50% of total body weight, and is known to be the largest tissue in the human body, mainly responsible for force generation, movement and breathing [1, 2]. The **muscles** consist of four main types of fibers, type 1, 2A, 2D/X and 2B, **...**

The objective of this review was to identify and discuss the main factors in the literature as capable of generating the hypertrophic response, ie the various intracellular signaling pathways that produce the biochemical responses promoters of increasing muscle fiber size.

Certainly, there are other avenues to be considered, but these identified here may be regarded as the most studied and best representing the complex signaling system responsible for the intracellular skeletal muscle trophism induced by exercise training.



AEROBIC TRAINING
STRENGTH TRAINING
IGF-1
PI3K
ERK1/2
ATP
AMP
AMPK
PGC-1α
TSC2
AKT
mTOR
GSK3
FOXO
P70S6K
4EBP1
eIF2B
MURF1
eIF4E
eIF2
Mithocondrial Biogenisis
Protein synthesis
Protein degradation


AEROBIC TRAINING
STRENGTH TRAINING
MYOSTATIN
Propeptide Mature
Muscle
Oxidative Metabolism
Muscle Strength
Hypertrophy
Muscle Strength
ActRIIA/B
ActRI
Smad2/3
CELL GROWTH
METABOLISM
Smad2/3
Nucleus
Muscle

Conclusion

Considerable progress has been made in understanding the signaling pathways that mediate the hypertrophy and atrophy of skeletal muscle. The present literature supports the role of activation of signaling pathways intracellular Akt- mTOR, myostatin and skeletal muscle miRNAs in regulating hypertrophic by increasing muscle protein synthesis induced by exercise training.

However, the mechanisms that regulate this process are quite complex and sometimes controversial in the literature, requiring greater effort and future studies to further elucidation.

As already mentioned, the objective of this review was to identify and discuss the main factors in the literature as capable of generating the hypertrophic response, ie the various intracellular signaling pathways that produce the biochemical responses promoters of increasing muscle fiber size.

Certainly, there are other avenues to be considered, but these

identified here may be regarded as the most studied and best representing the complex signaling system responsible for the intracellular skeletal muscle trophism induced by exercise training.

J Appl Physiol. 2012 Oct 25. [Epub ahead of print]

Aerobic exercise does not compromise muscle hypertrophy response to short-term resistance training.

Lundberg TR, Fernandez-Gonzalo R, Gustafsson T, Tesch PA.1Mid Sweden University.

Abstract

This study tested the hypothesis that chronic aerobic and resistance exercise (AE+RE) would elicit greater muscle hypertrophy than resistance exercise only (RE). Ten men (25±4 yrs) performed 5 wks unilateral knee extensor AE+RE. The opposing limb was subjected to RE. AE completed 6 hrs prior to RE, consisted of ~45 min one-legged cycle ergometry. RE comprised 4 x 7 maximal concentric-eccentric knee extensions. Various indices of in vivo knee extensor function were measured before and after training. Magnetic resonance imaging (MRI) assessed m. quadricep femoris (QF) cross-sectional area (CSA), volume, and signal intensity (SI). Biopsies obtained from m. vastus lateralis determined fiber CSA, enzyme levels and gene expression of myostatin, atrogin-1, MuRF-1, PGC-1α and VEGF. Increases ($P < 0.05$) in isometric strength and peak power, respectively were comparable in AE+RE (9 and 29%) and RE (11 and 24%). AE+RE showed greater increase (14%; $P < 0.05$) in QF volume than RE (8%). Muscle fiber CSA increased 17% after AE+RE ($P < 0.05$) and 9% after RE ($P > 0.05$). QF SI increased (12%; $P < 0.05$) after AE+RE, but not RE. Neither AE+RE nor RE showed altered mRNA-levels. Citrate Synthase activity increased ($P < 0.05$) after AE+RE. The results suggest that the increased aerobic capacity shown with AE+RE, was accompanied by a more robust increase in muscle size compared with RE. While this response was not carried over to greater improvement in muscle function, it remains that intense AE can be executed prior to RE without compromising performance outcome.

Las **respuestas hormonales**
para el crecimiento muscular

Eur J Appl Physiol. 2009 Mar;105(5):695-704. Epub 2008 Dec 9.

Acute hormonal and neuromuscular responses to hypertrophy, strength and power type resistance exercise.

McCaulley GO, McBride JM, Cormie P, Hudson MB, Nuzzo JL, Quindry JC,

The purpose of the current study was to determine the acute neuroendocrine response to hypertrophy (H), strength (S), and power (P) type resistance exercise (RE) equated for total volume. Ten male subjects completed three RE protocols and a rest day (R) using a randomized cross-over design. The protocols included (1) H: 4 sets of 10 repetitions in the squat at 75% of 1RM (90 s rest periods); (2) S: 11 sets of three repetitions at 90% of 1RM (5 min rest periods); and (3) P: 8 sets of 6 repetitions of jump squats at 0% of 1RM (3 min rest periods). Total testosterone (T), cortisol (C), and sex hormone binding globulin (SHBG) were determined prior to (PRE), immediately post (IP), 60 min post, 24 h post, and 48 h post exercise bout. Peak force, rate of force development, and muscle activity from the vastus medialis (VM) and biceps femoris (BF) were determined during a maximal isometric squat test. A unique pattern of response was observed in T, C, and SHBG for each RE protocol. The percent change in T, C, and SHBG from PRE to IP was significantly ($p \leq 0.05$) greater in comparison to the R condition only after the H protocol. The percent of baseline muscle activity of the VM at IP was significantly greater following the H compared to the S protocol. These data indicate that significant acute increases in hormone concentrations are limited to H type protocols independent of the volume of work competed. In addition, it appears the H protocol also elicits a unique pattern of muscle activity as well. RE protocols of varying intensity and rest periods elicit strikingly different acute neuroendocrine responses which indicate a unique physiological stimulus.

Early-phase neuroendocrine responses and strength adaptations following eccentric-enhanced resistance training.

Yarrow JF, Borsa PA, Borst SE, Sitren HS, Stevens BR, White LJ.
Department of Applied Physiology and Kinesiology, Center for Exercise Science, University of Florida, Gainesville, Florida, USA. jfyarrow@ufl.edu

The purpose of this study was to evaluate the early-phase muscular performance adaptations to 5 weeks of traditional (TRAD) and eccentric-enhanced (ECC+) progressive resistance training and to compare the acute postexercise total testosterone (TT), bioavailable testosterone (BT), growth hormone (GH), and lactate responses in TRAD- and ECC+-trained individuals. Twenty-two previously untrained men (22.1 +/- 0.8 years) completed 1 familiarization and 2 baseline bouts, 15 exercise bouts (i.e., 3 times per week for 5 weeks), and 2 postintervention testing bouts. Anthropometric and 1 repetition maximum (1RM) measurements (i.e., bench press and squat) were assessed during both baseline and postintervention testing. Following baseline testing, participants were randomized into TRAD (4 sets of 6 repetitions at 52.5% 1RM) or ECC+ (3 sets of 6 repetitions at 40% 1RM concentric and 100% 1RM eccentric) groups and completed the 5-week progressive resistance training protocols. During the final exercise bout, blood samples acquired at rest and following exercise were assessed for serum TT, BT, GH, and blood lactate. Both groups experienced similar increases in bench press (approximately 10%) and squat (approximately 22%) strength during the exercise intervention. At the conclusion of training, postexercise TT and BT concentrations increased (approximately 13% and 21%, respectively, $p < 0.05$) and GH concentrations increased (approximately 750-1200%, $p < 0.05$) acutely following exercise in both protocols. Postexercise lactate accumulation was similar between the TRAD (5.4 +/- 0.4) and ECC+ (5.6 +/- 0.4) groups; however, the ECC+ group's lactate concentrations were significantly lower than those of the TRAD group 30 to 60 minutes into recovery. In conclusion, TRAD training and ECC+ training appear to result in similar muscular strength adaptations and neuroendocrine responses, while postexercise lactate clearance is enhanced following ECC+ training.

J Strength Cond Res. 2010 Mar 17. [Epub ahead of print]

Anabolic and Catabolic Hormones and Energy Balance of the Male Bodybuilders During the Preparation for the Competition.

Mäestu J, Eliakim A, Jürimäe J, Valter I, Jürimäe T.
1Institute of Sport Pedagogy and Coaching Sciences, Center of Behavioral and Health Sciences, University of Tartu, Tartu, Estonia; 2Department of Pediatrics, Meir Hospital, Kfar Saba, Sackler School of Medicine, Tel Aviv University, Tel Aviv, Israel; and 3Center for Clinical and Basic Research, Tallinn, Estonia.
Mäestu, J, Eliakim, A, Jürimäe, J, Valter, I, and Jürimäe, T. Anabolic and catabolic hormones and energy balance of the male bodybuilders during the preparation for the competition. J Strength Cond Res 24(4): 1074-1081, 2010-The purpose of the study was to investigate simultaneous effects of energy balance, caloric intake, and the hormonal anabolic-catabolic balance in bodybuilders prior to competition. Fourteen male bodybuilders took part in an 11-week energy-restricted period to reduce body fat. The subjects were divided into the energy-restricted group (ERG) (n = 7), who were preparing for the competition, or the control group (CG) (n = 7) who continued to train regularly and did not change their dietary or training pattern. Participants were tested at 11 weeks (T1), 5 weeks (T2), and 3 days (T3) before competition for diet, body composition, and fasting hormonal assessment. Body mass and body fat percentage of ERG were significantly ($p < 0.05$) decreased during the study period. In ERG, insulinlike growth factor-1 (IGF-1) and insulin decreased significantly during the 11-week weight-reduction period ($p < 0.05$). Testosterone was decreased only from week 11 to week 5 (from 20.3 +/- 6.0 to 18.0 +/- 6.8 nmol/L). Changes in IGF-I concentration were significantly related to changes in insulin ($r = 0.741$), fat mass ($r = 0.705$), lean body mass ($r = 0.696$), and body mass ($r = 0.652$). Changes in insulin concentrations were significantly related to changes in fat mass ($r = 0.630$) and lean body mass ($r = 0.725$). These data indicate that severe energy restriction to extremely low body energy reserves decreases significantly the concentrations of 3 anabolic pathways despite high protein intake. Monitoring of insulin and IGF-1 concentration is suggested to prevent losses in muscle mass in energy-restricted conditions. Other nutritional strategies might be needed to prevent possible catabolic effect during preparation of bodybuilders to competition.

Sport Sciences for Health
December 2012, Volume 8, Issue 2-3, pp 59-65

Hormonal responses to acute and chronic resistance exercise in middle-age versus young men

Hamid Arazi

Abstract
To examine the responses of the endocrine system to moderate-resistance training in younger (YO) verses middle-aged (MI) men, two groups of men (21 and 49 years-old) participated in 8-week moderate-resistance training program three times per week. Blood was obtained before, immediately after, and 30 min after exercise at before and after training period for analysis of total testosterone, cortisol, GH, lactate and ACTH. Squat and bench press strength, and circumference of thigh and arm increased for both groups. After training, resting testosterone and GH increased in YO; testosterone concentrations were also increased for YO and MI from pre-training values. However, GH values decreased in MI after training period. Cortisol and ACTH values were lower compared to similar times in pre-training. These data indicate that middle-aged men do respond with an enhanced hormonal profile in the early phase of a resistance training program, but the response is different from that of younger men.

El entrenamiento con **oclusión vascular** para el crecimiento muscular

Int J Sports Med. 2010 Jan;31(1):1-4. doi: 10.1055/s-0029-1239499. Epub 2009 Nov 2.
A mechanistic approach to blood flow occlusion.
Loenneke JP, Wilson GJ, Wilson JM.
Source
Southeast Missouri State University, Health, Human Performance, and Recreation, Cape Girardeau, USA. jploenneke1s@semo.edu
Abstract
Low-Intensity occlusion training provides a unique beneficial training mode for promoting muscle hypertrophy. Training at intensities as low as 20% 1RM with moderate vascular occlusion results in muscle hypertrophy in as little as three weeks. The primary mechanisms by which occlusion trainingis thought to stimulate growth include, metabolic accumulation, which stimulates a subsequent increase in anabolic growth factors, fast-twitch fiber recruitment (FT), and increased protein synthesis through the mammalian target of rapamycin (mTOR) pathway. Heat shock proteins, Nitric oxide synthase-1 (NOS-1) and Myostatin have also been shown to be affected by an occlusion stimulus. In conclusion, low-intensity occlusion trainingappears to work through a variety of mechanisms. The research behind these mechanisms is incomplete thus far, and requires further examination, primarily to identify the actual metabolite responsible for the increase in GH with occlusion, and determine which mechanisms are associated to a greater degree with the hypertrophic/anti-catabolic changes seen with blood flow restriction.

Int J Sports Physiol Perform. 2010 Dec;5(4):497-508.

Hypoxia increases muscle hypertrophy induced by resistance training.

Nishimura A, Sugita M, Kato K, Fukuda A, Sudo A, Uchida A.

Abstract

PURPOSE:

Recent studies have shown that low-intensity resistance training with vascular occlusion (kaatsu training) induces muscle hypertrophy. A local hypoxic environment facilitates muscle hypertrophy during kaatsu training. We postulated that muscle hypertrophy can be more efficiently induced by placing the entire body in a hypoxic environment to induce muscle hypoxia followed by resistance training.

METHODS:

Fourteen male university students were randomly assigned to hypoxia (Hyp) and normoxia (Norm) groups (n = 7 per group). Each trainingsession proceeded at an exercise intensity of 70% of 1 repetition maximum (RM), and comprised four sets of 10 repetitions of elbow extension and flexion. Students exercised twice weekly for 6 wk and then muscle hypertrophy was assessed by magnetic resonance imaging and muscle strength was evaluated based on 1RM.

RESULTS:

Muscle hypertrophy was significantly greater for the Hyp-Ex (exercised flexor of the hypoxia group) than for the Hyp-N (nonexercised flexor of the hypoxia group) or Norm-Ex flexor ($P < .05$, Bonferroni correction). Muscle hypertrophy was significantly greater for the Hyp-Ex than the Hyp-N extensor. Muscle strength was significantly increased early (by week 3) in the Hyp-Ex, but not in the Norm-Ex group.

CONCLUSION:

This study suggests that resistance training under hypoxic conditions improves muscle strength and induces muscle hypertrophy faster than under normoxic conditions, thus representing a promising new training technique.

Scand J Med Sci Sports. 2012 Jun 27. doi: 10.1111/j.1600-0838.2012.01489.x. [Epub ahead of print]

Effects of low-intensity, elastic band resistance exercise combined with blood flow restriction on muscle activation.

Yasuda T, Fukumura K, Fukuda T, Iida H, Imuta H, Sato Y, Yamasoba T, Nakajima T.

Source

Graduate School of Medicine, The University of Tokyo, Tokyo, Japan.

Abstract

We examined the effects of blood flow-restricted, low-intensity resistance exercise (termed kaatsu) using an elastic band for resistance on muscle activation. Nine men performed triceps extension and biceps flexion exercises (four sets respectively) using an elastic band for resistance with blood flow restriction (BFR) or CON (unrestricted blood flow). During a BFR session, subjects wore pressure cuffs inflated to 170-260 mmHg on the proximal region of both arms. Surface electromyography (EMG) was recorded from the triceps brachii and biceps brachii muscles, and mean integrated EMG (iEMG) was analyzed. Blood lactate concentration was obtained before (Pre) and immediately after two exercises (Post). During triceps extension and biceps flexion exercises, muscle activation increased progressively ($P < 0.05$) under BFR (46% and 69%, respectively) but not under CON (12% and 23%, respectively). Blood lactate concentration at Post was higher ($P < 0.05$) under BFR than under CON (3.6 and 2.1 mmol/L, respectively). Blood lactate concentration at Post was significantly correlated with increased iEMG in both triceps extension ($r = 0.65$, $P < 0.01$) and biceps flexion exercises ($r = 0.52$, $P < 0.05$). We conclude that kaatsu training using elastic bands for resistance enhances muscle activation and may be an effective method to promote muscle hypertrophy in older adults or patients with a low level of activity.

PLoS One. 2012;7(12):e52843. doi: 10.1371/journal.pone.0052843. Epub 2012 Dec 31.

Effects of blood flow restricted low-intensity concentric or eccentric training on muscle size and strength.

Yasuda T, Loenneke JP, Thiebaud RS, Abe T.Department of Ischemic Circulatory Physiology, University of Tokyo, Tokyo, Japan.

Abstract

We investigated the acute and chronic effects of low-intensity concentric or eccentric resistance training with blood flow restriction (BFR) on muscle size and strength. Ten young men performed 30% of concentric one repetition maximal dumbbell curl exercise (four sets, total 75 reps) 3 days/week for 6 weeks. One arm was randomly chosen for concentric BFR (CON-BFR) exercise only and the other arm performed eccentric BFR (ECC-BFR) exercise only at the same exercise load. During the exercise session, iEMG for biceps brachii muscles increased progressively during CON-BFR, which was greater ($p<0.05$) than that of the ECC-BFR. Immediately after the exercise, muscle thickness (MTH) of the elbow flexors acutely increased ($p<0.01$) with both CON-BFR and ECC-BFR, but was greater with CON-BFR (11.7%) ($p<0.01$) than ECC-BFR (3.9%) at 10-cm above the elbow joint. Following 6-weeks of training, MRI-measured muscle cross-sectional area (CSA) at 10-cm position and mid-upper arm (12.0% and 10.6%, respectively) as well as muscle volume (12.5%) of the elbow flexors were increased ($p<0.01$) with CON-BFR. Increases in muscle CSA and volume were lower in ECC-BFR (5.1%, 0.8% and 2.9%, respectively) than in the CON-BFR and only muscle CSA at 10-cm position increased significantly ($p<0.05$) after the training. Maximal voluntary isometric strength of elbow flexors was increased ($p<0.05$) in CON-BFR (8.6%), but not in ECC (3.8%). These results suggest that CON-BFR training leads to pronounced acute changes in muscle size, an index of muscle cell swelling, the response to which may be an important factor for promoting muscle hypertrophy with BFR resistance training.

Table 1. Changes in cross-sectional area and volume of elbow flexors muscles.

	CON-BFR				ECC-BFR			
Muscle	**Pre**	**Post**	**%Δ**	**ES**	**Pre**	**Post**	**%Δ**	**ES**
CSA at mid-upper arm (cm^2)	8.9 (0.8)	9.8 (0.7)*	$10.0^{\#}$	1.1^{c}	9.9 (0.9)	9.7 (1.2)	−2.0	−0.2
CSA at 10 cm above the elbow joint (cm^2)	14.7 (1.0)	16.4 (1.4)**	$12.0^{\#\#}$	1.7^{c}	15.4 (1.7)	16.2 (2.0)*	5.1	0.5^{b}
Volume (cm^3)	219 (16)	246 (17)**	$12.5^{\#\#}$	1.6^{c}	228 (21)	235 (23)	2.9	0.3^{a}

Values are means ± SD. ES, effect size. Significant differences between CON-BFR training and ECC-BFR training:
$^{\#\#}p<0.01$. Significant differences between pre- and post-training:

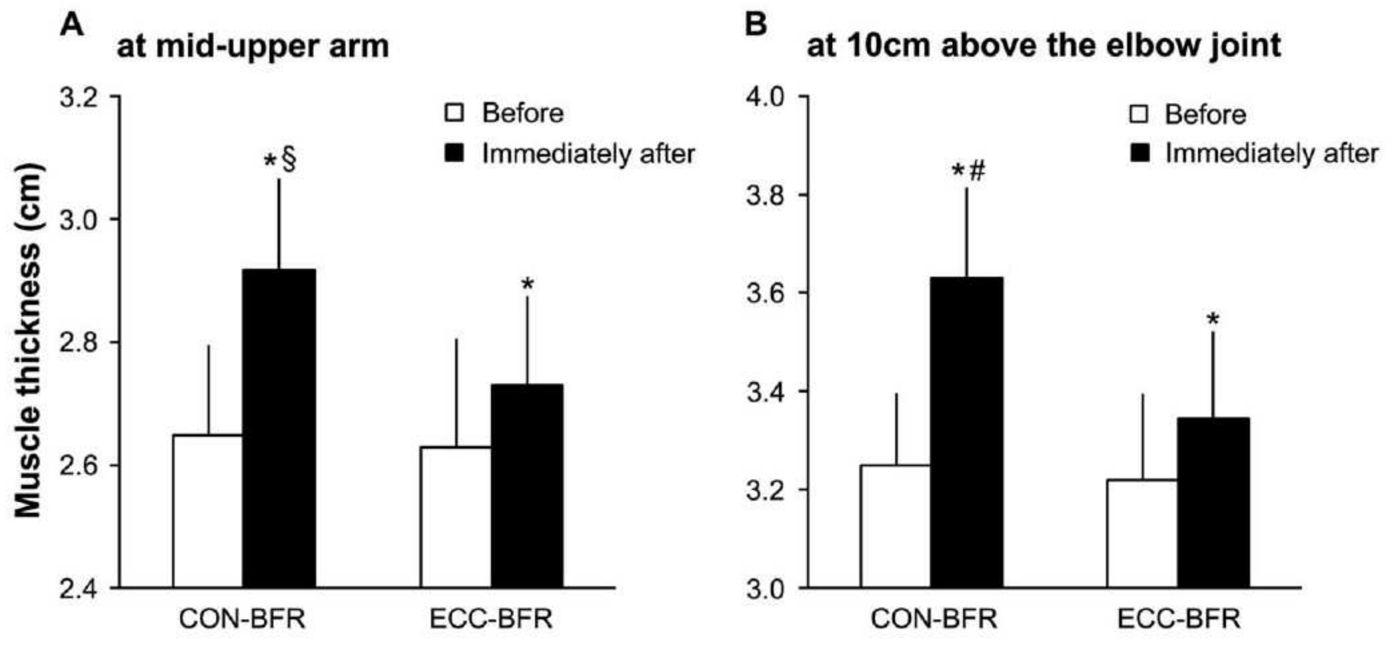


Figure 2. Muscle thickness (MTH) of the elbow flexors before and immediately after exercise session. Values are means and SD. *Different from before, $P<0.05$. #Different from ECC-BFR, $P<0.05$. §Different from ECC-BFR, $P=0.07$.

J Strength Cond Res. 2012 Sep;26(9):2523-9. doi: 10.1519/JSC.0b013e31823f2b0e

Occlusion training increases muscular strength in division IA football players.

Yamanaka T, Farley RS, Caputo JL
.Department of Health and Human Performance, Middle Tennessee State University, Murfreesboro, Tennessee.yamanaka.tetsuo@gmail.com

Abstract

The purpose of this study was to investigate the effectiveness of 4 weeks of low-intensity resistance training with blood-flow occlusion on upper and lower body muscular hypertrophy and muscular strength in National Collegiate Athletic Association Division IA football players. There were 32 subjects (average age 19.2 ± 1.8 years) who were randomized to an occlusion group or control group. The athletes performed 4 sets of bench press and squat in the following manner with or without occlusion: 30 repetitions of 20% predetermined 1 repetition maximum (1RM), followed by 3 sets of 20 repetitions at 20% 1RM. Each set was separated by 45 seconds. The training duration was 3 times per week, after the completion of regular off-season strength training. Data collected included health history, resting blood pressure, pretraining and posttraining bench press and squat 1RM, upper and lower chest girths, upper and lower arm girths, thigh girth, height, and body mass. The increases in bench press and squat 1RM (7.0 and 8.0%, respectively), upper and lower chest girths (3 and 3%, respectively), and left upper arm girth were significantly greater in the experiment group ($p < 0.05$). Occlusion training could provide additional benefits to traditional strength training to improve muscular hypertrophy and muscular strength in collegiate athletes.

Las activación de **células satélite** para el crecimiento muscular

Multipotency and physiological role of skeletal muscle interstitium-derived stem cells

T Tamaki - The Journal of Physical Fitness and Sports Medicine, 2012

... Skeletal **muscle**, the largest organ in the body compris- ing about 40-50% of total body mass, is known for its multipotent response to various postnatal events such as regular strength training induced **muscle hypertrophy**, dis- use induced atrophy, growth dependent fiber

Multipotent stem cells, other than satellite cells, that can give rise to primary myoblasts postnatally, are present in the interstitial spaces of skeletal muscle. These stem cells show differentiation potential into mesodermal and ectodermal cell lineages, and, thus, are called skeletal muscle interstitium-derived multipotent stem cells (Sk-MSCs). They are $Pax7^-$ at initial isolation; and colony-forming units of these cells typically include non-adherent type myogenic cells, while satellite cells are known to be adherent in cell culture. In these colonies, both $Pax7^-$ and $Pax7^+$ myogenic cells are produced depending on asymmetric cell division. A large number of myotubes are also formed in each colony associated with putative $Pax7^+$ satellite cells. Interestingly, $Pax7^-$/non-adherent myogenic cells showed basal lamina (BL) formation during cell culture, whereas $Px7^+$ myogenic cells did not. In in vivo analysis, interstitial myogenic cells showing BL formation were detected at early stages of myogenesis in the compensatory enlarged muscle, while myogenic cells in the parent fiber BL cylinder, probably satellite cells, did not form BL. Production of BL, associated with satellite cells, is essential for the in vivo establishment of new muscle fiber formation in the interstitium with, of course, innervation and capillary supply. Thus, the multipotency of Sk-MSCs that can give rise to peripheral nerve and vascular-related cells, such as Schwann cells, perineurial cells, endothelial cells, pericyte, and vascular smooth muscle cells, may have advantages over satellite cells. Therefore, the physiological role of Sk-MSCs, as a source for postnatal new muscle fiber formation (hyperplasia) and extension of nerve-vascular networks following growth and/or severe heavy resistance exercise, needs to be further investigated.

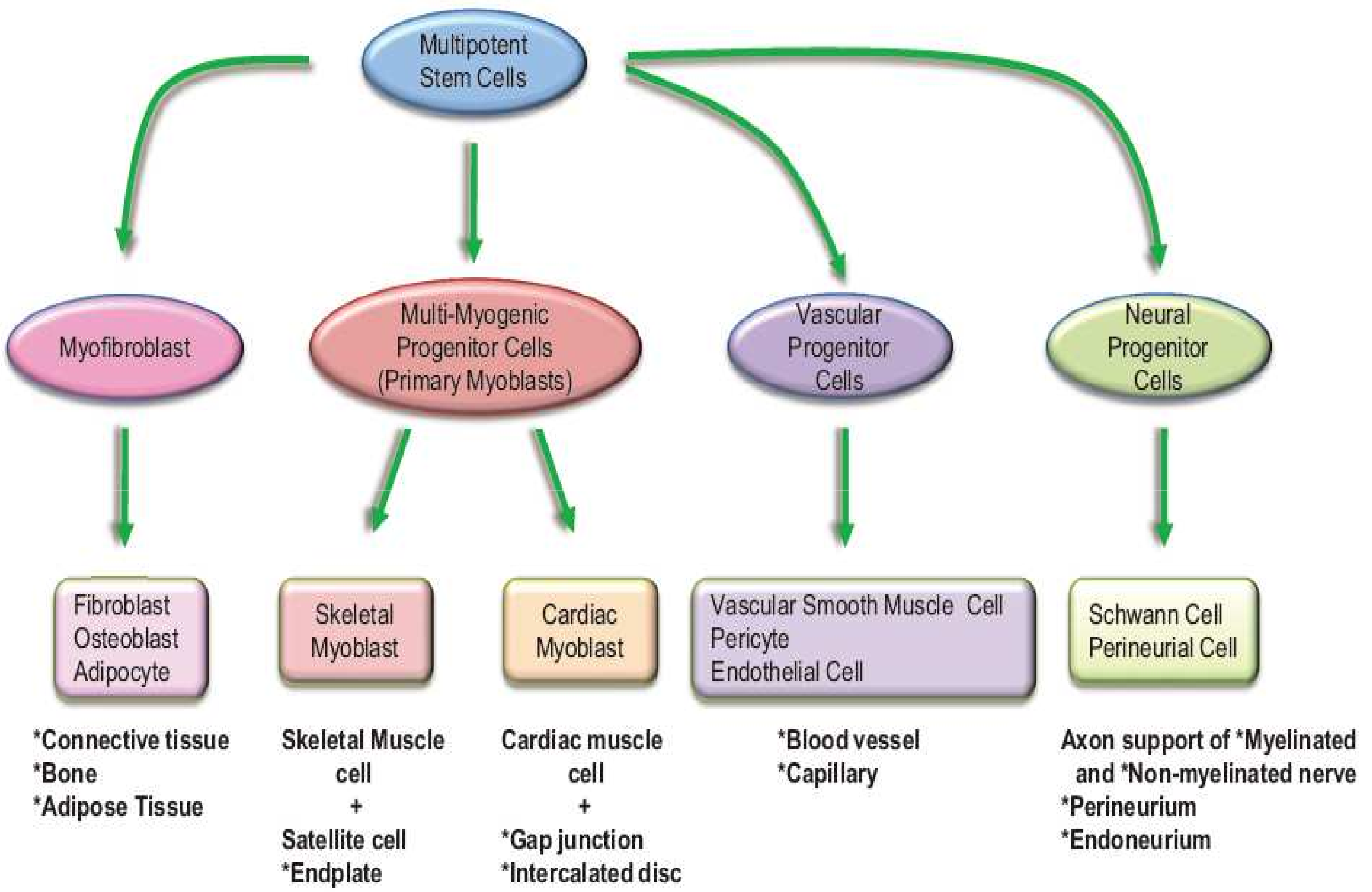


Fig. 3 In vivo differentiation potential diagram of Sk-MSCs.
*contribution to tissue constructs. Data are based on references 10, 14-18, 21, 44, 49, 52, 63.

Exercise and skeletal muscle regeneration

M Kurosaka, S Machida - The Journal of Physical Fitness and Sports Medicine, 2012
... Interleukin-6 is an essential regulator of satellite cell-mediated
skeletal **muscle hypertrophy**. Cell
Metab 7: 33-44. **...** 1992. Gamma irradiation prevents compensatory **hypertrophy** of
overloaded mouse
extensor digitorum longus **muscle**.
J Appl Physiol 73: 2538-2543.

Skeletal muscle injury is generally caused by stimuli, such as intense resistance training, eccentric muscle contraction, muscle strain and bruising. Injured skeletal muscles are repaired within several weeks after injury, because skeletal muscle has a remarkable capacity for muscle regeneration.
Cellular and molecular events underlying the regenerative processes are mainly regulated by myogenic stem cells and inflammatory cells.
The aim of this review is to summarize the current understanding of the cellular and molecular mechanisms responsible for muscle regeneration. I
n this review, focus will be given to the critical roles of satellite cells and macrophages during muscle regeneration. In addition, the satellite cell responses to exercise are also discussed.

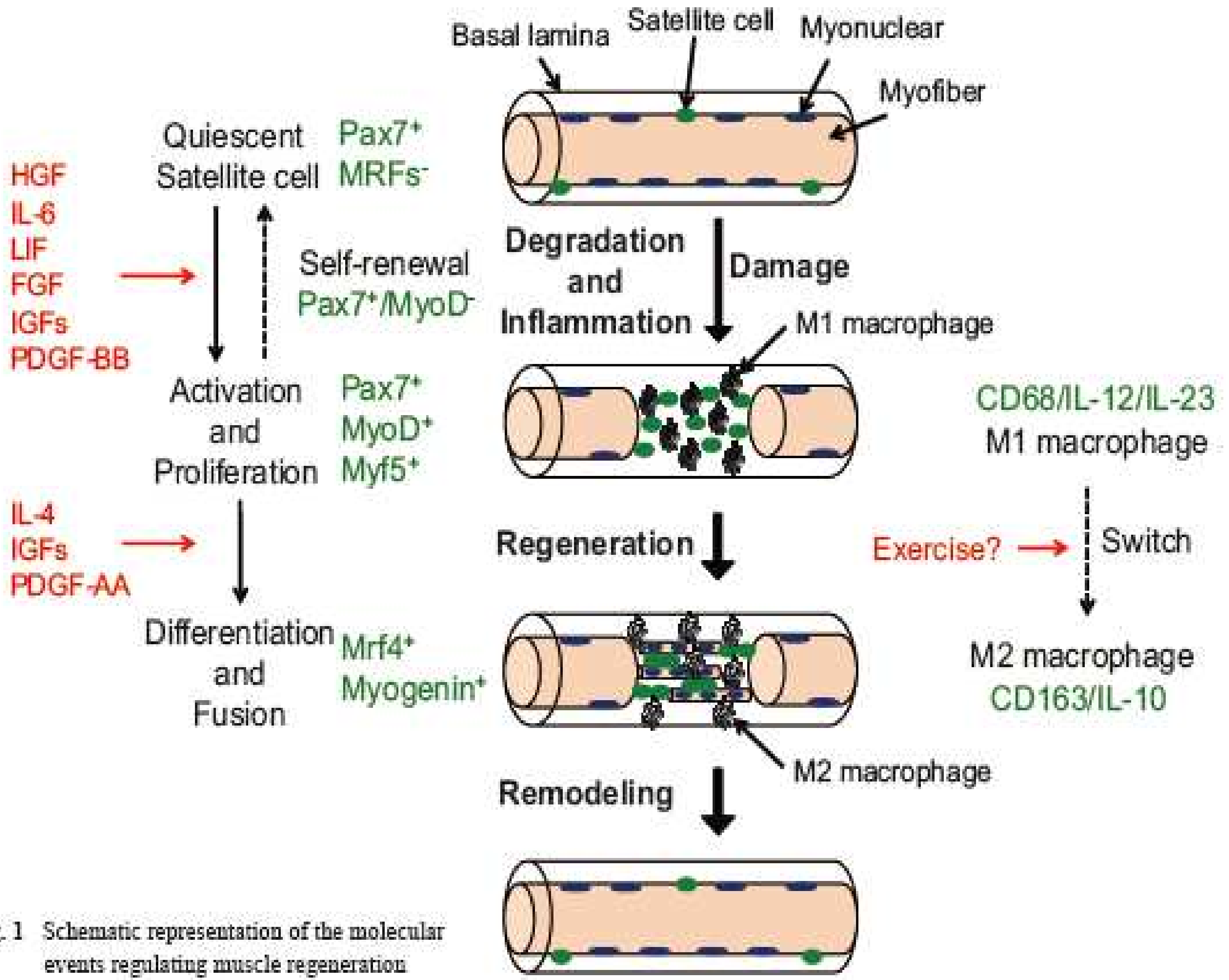


Fig. 1 Schematic representation of the molecular events regulating muscle regeneration

El **stress metabólico**
para el crecimiento muscular

1

. Sports Med. 2013 Jan 22. [Epub ahead of print]

Potential Mechanisms for a Role of Metabolic Stress in Hypertrophic Adaptations to Resistance Training.

Schoenfeld BJ.Department of Health Sciences, Program of Exercise Science, APEX Building, Room # 265, Lehman College, CUNY, 250 Bedford Park Blvd West, Bronx, NY, 10468, USA, brad@workout911.com.

Abstract

It is well established that regimented resistance training can promote increases in muscle hypertrophy. The prevailing body of research indicates that mechanical stress is the primary impetus for this adaptive response and studies show that mechanical stress alone can initiate anabolic signalling. Given the dominant role of mechanical stress in muscle growth, the question arises as to whether other factors may enhance the post-exercise hypertrophic response. Several researchers have proposed that exercise-induced metabolic stress may in fact confer such an anabolic effect and some have even suggested that metabolite accumulation may be more important than high force development in optimizing muscle growth. Metabolic stress pursuant to traditional resistance training manifests as a result of exercise that relies on anaerobic glycolysis for adenosine triphosphate production. This, in turn, causes the subsequent accumulation of metabolites, particularly lactate and H(+). Acute muscle hypoxia associated with such training methods may further heighten metabolic buildup. Therefore, the purpose of this paper will be to review the emerging body of research suggesting a role for exercise-induced metabolic stress in maximizing muscle development and present insights as to the potential mechanisms by which these hypertrophic adaptations may occur. These mechanisms include increased fibre recruitment, elevated systemic hormonal production, alterations in local myokines, heightened production of reactive oxygen species and cell swelling. Recommendations are provided for potential areas of future research on the subject.

J Physiol. 2012 Jul 16. [Epub ahead of print]

Proliferation of myogenic stem cells in human skeletal muscle in response to low-load resistance training with blood-flow restriction.

Nielsen JL, Aagaard P, Bech RD, Nygaard T, Hvid LG, Wernbom M, Suetta C, Frandsen U.**Source**
University of Southern Denmark;

Abstract

Low-load resistance training with blood-flow restriction has been shown to elicit substantial increases in muscle mass and muscle strength; however the effect on myogenic stem cells (MSC) and myonuclei number remains unexplored. Ten male subjects (22.8±2.3 yrs) performed 4 sets of knee extensor exercise (20% 1RM) to concentric failure during blood-flow restriction (BFR) of the proximal thigh (100 mmHg), while eight work-matched controls (21.9±3.0 yrs) trained without BFR (CON). 23 training sessions were performed within 19 days. Maximal isometric knee extensor strength (MVC) was examined pre and post training, while muscle biopsies were obtained at baseline (Pre), after 8 days intervention (Mid8) and 3 (Post3) and 10 days (Post10) post training to examine changes in myofibre area (MFA), MSC and myonuclei number. MVC increased by 7.1% (Post5) and 10.6% (Post12) ($P<0.001$) with BFR-training, while type I and II MFA increased by 38% (Mid8), 35-37% (Post3) and 31-32% (Post10) ($P<0.001$). MSC per myofibre increased with BFR-training from 0.10±0.01 (Pre) to 0.38±0.02 (Mid8), 0.36±0.04 (Post3) and 0.25±0.02 (Post10), respectively ($P<0.001$). Likewise, myonuclei per myofibre increased from 2.49±0.07 (Pre) to 3.30±0.22 (Mid8), 3.20±0.16 (Post3) and 3.11±0.11 (Post10), respectively ($P<0.01$). Although MFA increased in CON at Mid8, it returned to baseline at Post3. No changes in MSC or myonuclei number were observed in CON. This study is the first to show that short-term low-load resistance exercise performed with partial blood-flow restriction leads to marked proliferation of myogenic stem cells and resulting myonuclei addition in human

Efectos sobre el **sistema inmune** para el crecimiento muscular

Exerc Immunol Rev. 2004;10:75-90.

Changes in inflammatory mediators following eccentric exercise of the elbow flexors.

Hirose L, Nosaka K, Newton M, Laveder A, Kano M, Peake J, Suzuki K.

Source

Abstract

The aims of this study were to examine the plasma concentrations of inflammatory mediators including cytokines induced by a single bout of eccentric exercise and again 4 weeks later by a second bout of eccentric exercise of the same muscle group. Ten untrained male subjects performed two bouts of the eccentric exercise involving the elbow flexors (6 sets of 5 repetitions) separated by four weeks. Changes in muscle soreness, swelling, and function following exercise were compared between the bouts. Blood was sampled before, immediately after, 1 h, 3 h, 6 h, 24 h (1 d), 48 h (2 d), 72 h (3 d), 96 h (4 d) following exercise bout to measure plasma creatine kinase (CK) activity, plasma concentrations of myoglobin (Mb), interleukin (IL)-1beta, IL-1 receptor antagonist (IL-1ra), IL-4, IL-6, IL-8, IL-10, IL-12p40, tumor necrosis factor (TNF)-alpha, granulocyte colony-stimulating factor (G-CSF), myeloperoxidase (MPO), prostaglandin E2 (PGE2), heat shock protein (HSP) 60 and 70. After the first bout, muscle soreness increased significantly, and there was also significant increase in upper arm circumference; muscle function decreased and plasma CK activity and Mb concentration increased significantly. These changes were significantly smaller after the second bout compared to the first bout, indicating muscle adaptation to the repeated bouts of the eccentric exercise. Despite the evidence of greater muscle damage after the first bout, the changes in cytokines and other inflammatory mediators were quite minor, and considerably smaller than that following endurance exercise. These results suggest that eccentric exercise-induced muscle damage is not associated with the significant release of cytokines into the systemic circulation. After the first bout, plasma G-CSF concentration showed a small but significant increase, whereas TNF-alpha and IL-8 showed significant decreases compared to the pre-exercise values. After the second bout, there was a significant increase in IL-10, and a significant decrease in IL-8. In conclusion, although there was evidence of severe muscle damage after the eccentric exercise, this muscle damage was not accompanied by any large changes in plasma cytokine concentrations. The minor changes in systemic cytokine concentration found in this study might reflect more rapid clearance from the circulation, or a lack of any significant metabolic or oxidative demands during this particular mode of exercise. In relation to the adaptation to the muscle damage, the anti-inflammatory cytokine IL-10 might work as one of the underlying mechanisms of action.

Cytokine. 2010 Jan;49(1):102-8. doi: 10.1016/j.cyto.2009.10.007. Epub 2009 Nov 30.

Exercise training changes IL-10/TNF-alpha ratio in the skeletal muscle of post-MI rats.

Batista ML Jr, Rosa JC, Lopes RD, Lira FS, Martins E Jr, Yamashita AS, Brum PC, Lancha AH Jr, Lopes AC, Seelaender M.

Source
Cell and Developmental Biology Department, Institute of Biomedical Sciences I, University of São Paulo, São Paulo, Brazil. migueljr@usp.br

Abstract
Heart failure (HF) is associated with changes in the skeletal muscle (SM) which might be a consequence of the unbalanced local expression of pro- (TNF-alpha) and anti- (IL-10) inflammatory cytokines, leading to inflammation-induced myopathy, and SM wasting. This local effect of HF on SM may, on the other hand, contribute to systemic inflammation, as this tissue actively secretes cytokines. Since increasing evidence points out to an anti-inflammatory effect of exercise training, the goal of the present study was to investigate its effect in rats with HF after post-myocardial infarction (MI), with special regard to the expression of TNF-alpha and IL-10 in the soleus and extensor digitorum longus (EDL), muscles with different fiber composition. Wistar rats underwent left thoracotomy with ligation of the left coronary artery, and were randomly assigned to either a sedentary (Sham-operated and MI sedentary) or trained (Sham-operated and MI trained) group. Animals in the trained groups ran on a treadmill (0% grade at 13-20 m/min) for 60 min/day, 5 days/week, for 8-10 weeks. **The training protocol was able to reverse the changes induced by MI, decreasing TNF-alpha protein (26%, P<0.05) and mRNA (58%, P<0.05) levels in the soleus, when compared with the sedentary MI group. Training also increased soleus IL-10 expression (2.6-fold, P<0.001) in post-MI HF rats. As a consequence, the IL-10/TNF-alpha ratio was increased. This "anti-inflammatory effect" was more pronounced in the soleus than in the EDL, suggesting a fiber composition dependent response.**

J Strength Cond Res. 2011 Aug;25(8):2283-92. doi: 10.1519/JSC.0b013e3181f1592e.

Muscular hypertrophy and changes in cytokine production after eccentric training in the rat skeletal muscle.

Ochi E, Nakazato K, Ishii N.

Source

Laboratory of Health and Sports Sciences, Center for Liberal Arts, Meiji Gakuin University, Kanagawa, Japan. ochi@gen.meijigakuin.ac.jp

Abstract

We investigated the time course effects of eccentric training on muscular size, strength, and growth factor/cytokine production by using an isokinetic-exercise system for rats. Male Wistar rats (n = 34) were randomly assigned into 4 groups: 5 session eccentric-training group (ECC5S, n = 10); 5 session sham-operated group (CON5S, n = 10); 10 session eccentric-training group (ECC10S, n = 7); 10 session sham-operated group (CON10S, n = 7). In each group, a session of either training or sham operation was performed every 2 days. The training consisted of 4 sets of forced dorsiflexion (5 repetitions) combined with electric stimulation of plantar flexors. The wet weight of medial gastrocnemius muscle did not increase significantly after 5 sessions of training, whereas that after 10 sessions of training significantly increased with a concomitant increase in the cross-sectional area (CSA) of muscle fibers (weight, $p < 0.05$; fiber CSA, $p < 0.001$). Interleukin (IL)-6 in ECC5S and ECC10S groups showed significant increases ($p < 0.01$), whereas those of tumor necrosis factor (TNF)-α and IL-10 did not. The phospho-stat-3 showed a significant increase in ECC10S ($p < 0.001$) but not in ECC5S. Myostatin and follistatin also showed significant differences only between ECC10S and CON10S ($p < 0.05$).

The results showed that repeated sessions of eccentric training for 20 days cause increases in muscular size and strength associated with increases in IL-6, follistatin, phospho-stat-3, and a decrease in myostatin. The delayed responses of IL-6, myostatin, phospho-stat-3, and follistatin would be due to the chronic effects of repeated training and possibly important for muscular hypertrophy.

El **aporte proteico**
para el crecimiento muscular

J Int Soc Sports Nutr. 2012 Dec 14;9(1):54. doi: 10.1186/1550-2783-9-54.

Protein timing and its effects on muscular hypertrophy and strength in individuals engaged in weight-training.

Stark M, Lukaszuk J, Prawitz A, Salacinski A.

Source

Abstract

ABSTRACT: The purpose of this review was to determine whether past research provides conclusive evidence about the effects of type and timing of ingestion of specific sources of protein by those engaged in resistance weight training. Two essential, nutrition-related, tenets need to be followed by weightlifters to maximize muscle hypertrophy: the consumption of 1.2-2.0 g protein.kg -1 of body weight, and ≥44-50 kcal.kg-1 of body weight. Researchers have tested the effects of timing of protein supplement ingestion on various physical changes in weightlifters. In general, protein supplementation pre- and post-workout increases physical performance, training session recovery, lean body mass, muscle hypertrophy, and strength. Specific gains, differ however based on protein type and amounts. Studies on timing of consumption of milk have indicated that fat-free milk post-workout was effective in promoting increases in lean body mass, strength, muscle hypertrophy and decreases in body fat. The leucine content of a protein source has an impact on protein synthesis, and affects muscle hypertrophy. Consumption of 3-4 g of leucine is needed to promote maximum protein synthesis. An ideal supplement following resistance exercise should contain whey protein that provides at least 3 g of leucine per serving. A combination of a fast-acting carbohydrate source such as maltodextrin or glucose should be consumed with the protein source, as leucine cannot modulate protein synthesis as effectively without the presence of insulin. Such a supplement post-workout would be most effective in increasing muscle protein synthesis, resulting in greater muscle hypertrophy and strength. In contrast, the consumption of essential amino acids and dextrose appears to be most effective at evoking protein synthesis prior to rather than following resistance exercise. To further enhance musclehypertrophy and strength, a resistance weight- training program of at least 10-12 weeks with compound movements for both upper and lower body exercises should be followed.

Curr Opin Clin Nutr Metab Care. 2012 May;15(3):226-32..

Nutrient interaction for optimal protein anabolism in resistance exercise.

Breen L, Phillips SM.

Abstract

PURPOSE OF REVIEW:

The rapid muscle loss that accompanies varying diseased states (cachexia) is due to an imbalance between muscle protein synthesis (MPS) and muscle protein breakdown In the current review, we will discuss and summarize recent evidence in order to provide practical recommendations on exercise and nutrient interventions for cachectic populations.

RECENT FINDINGS:

Resistance exercise is a potent stimulus for MPS, but cachexia patients may not be best placed to lift the heavy loads that, it was previously assumed, were a prerequisite for muscle hypertrophy. However, recent evidence from our lab shows that lower loads can effectively stimulate MPS and lead to hypertrophy. Protein ingestion potentiates resistance exercise-induced rates of MPS. The source and dose of the ingested protein are important to consider when attempting to maximize postresistance exercise MPS. Specifically, rapidly digested, leucine-rich protein sources may stimulate greater postexercise rates of MPS than other protein sources, as leucine acts as a key anabolic signal for mRNA translation. Furthermore, individuals undergoing relatively slow muscle atrophy (i.e., in sarcopenic elderly) respond positively to larger doses (40 g) of amino acids following exercise, whereas the response appears to plateau after moderate doses (20 g) in healthy, young adults.

SUMMARY:

Emerging evidence shows that manipulating traditional exercise loading and nutrient strategies may ameliorate cachexia.

Protein Supplementation Increases **Muscle** Mass Gain During Prolonged Resistance-Type Exercise Training in Frail Elderly People: A Randomized, Double-Blind, …

M Tieland, ML Dirks, N van der Zwaluw, LB Verdijk… - Journal of the American …, 2012

Protein supplementation has been proposed as an effective dietary strategy to augment the skeletal muscle adaptive response to prolonged resistance-type exercise training in elderly people. Our objective was to assess the impact of protein supplementation on muscle mass, strength, and physical performance during prolonged resistance-type exercise training in frail elderly men and women.

Design/setting/participants

A randomized, double-blind, placebo-controlled trial with 2 arms in parallel among 62 frail elderly subjects (78 ± 1 year). These elderly subjects participated in a progressive resistance-type exercise training program (2 sessions per week for 24 weeks) during which they were supplemented twice daily with either protein (2 ∗ 15 g) or a placebo.

Results

Lean body mass increased from 47.2 kg (95% CI, 43.5–50.9) to 48.5 kg (95% CI, 44.8–52.1) in the protein group and did not change in the placebo group (from 45.7 kg, 95% CI, 42.1–49.2 to 45.4 kg, 95% CI, 41.8–48.9) following the intervention (*P* value for treatment × time interaction = .006). Strength and physical performance improved significantly in both groups (*P* = .000) with no interaction effect of dietary protein supplementation.

Conclusions

Prolonged resistance-type exercise training represents an effective strategy to improve strength and physical performance in frail elderly people. Dietary protein supplementation is required to allow muscle mass gain during exercise training in frail elderly people.

Efecto de la **testosterona**
para el crecimiento muscular

Effects of Sustanon on the Distribution of Satellite Cells and The Morphology of Skeletal Muscle Fibers During Maturation

Mohammed Z. Allouh and Mohammed H. Aldirawi
Department of Anatomy, Faculty of Medicine,
Jordan University of Science and Technology, Irbid, Jordan

Abstract: Sustanon is one of the most commonly used anabolic androgenic drugs to increase skeletal muscle mass and strength. This drug is a blend of four esterized testosterone derivatives: Testosterone propionate, testosterone phenylpropionate, testosterone isocaproate and testosterone decanoate. Little is known about the effects of this drug on skeletal muscle at the cellular level. This study aimed to investigate the influence of Sustanon on the morphology of skeletal muscle fibers and the distribution of myogenic stem cells known as Satellite Cells (SCs) during postnatal growth. We hypothesized that Sustanon-induced skeletal muscle hypertrophy is associated with an increase in the number of SCs. Robust immunocytochemical techniques and morphometric analyses were used to calculate the numbers of SCs and myonuclei within the pectoralis muscle of chickens. Also, DNA concentration and Pax7 protein levels were measured to confirm immunocytochemical findings. Sustanon significantly increased pectoralis mass and fiber size. All SC indices and the number of myonuclei increased significantly by Sustanon administration. In addition, greater DNA concentration and Pax7 protein expression were found in Sustanon-treated birds. This study indicates that Sustanon can induce avian skeletal muscle hypertrophy and that this is correlated with increased numbers of SCs and myonuclei.

Skeletal Muscle Fibers During Maturation
MZ Allouh… - 2012

Table 1: Skeletal muscle wet weights (g) in control and Sustanon-treated chickens

Muscle	Pectoralis	Tibialis anterior
Control	134.66±8.97	9.23±0.65
Sustanon-treated	207.23±7.36**	17.57±1.02**

Values are expressed as mean weight±SE, of n = 5, ** p<0.01 (t-test)

Size of muscle fiber: The mean ellipse minor axis±SE in the Sustanon-treated group was 93.78±3.79 µm, compared to 59.42±2.57 µm in the control group. Fibers of the pectoralis muscle were significantly ($p<0.01$) larger in the Sustanon-treated group than in control group by about 57% (Fig. 1).

Table 2: Occurrence of giant fibers in Sustanon-treated chicken pectoralis

	Total fibers		Giant fibers	
Animal	No.	Mean diameter (µm)	No.	Mean diameter (µm)
1	520	97.17±1.80	5	155.74±7.78
2	518	91.14±1.47	3	136.30±6.00
3	536	102.67±2.15	6	161.55±4.21
4	505	97.44±1.65	7	140.40±4.43
5	528	80.49±1.66	5	133.83±8.73

Formation of giant fibers: Giant fibers are unusually large fibers that possess circular transverse sectional areas (Fig. 2). These fibers are scattered throughout the muscle as a very small proportion that is usually less than 1% of the total fiber population (Handel and Stickland, 1986). In this study, no giant fibers were found in the control group. However, in Sustanon-treated birds, the mean frequency of giant fibers was 1.00±0.13% (SE). This

Table 3: Satellite cell distribution in control and Sustanon-treated chickens

Group	SC nuclei Frequency (%)	Length (μm)	SC mm⁻¹	Surface area of sarcolemma/SC ($\mu m^2 \times 10^3$)
Control	3.14±0.45	10.29±0.24	5.67±0.83	37.13±7.23
Sustanon-treated	9.33±0.57**	10.30±0.23	27.78±1.54**	10.68±0.56**

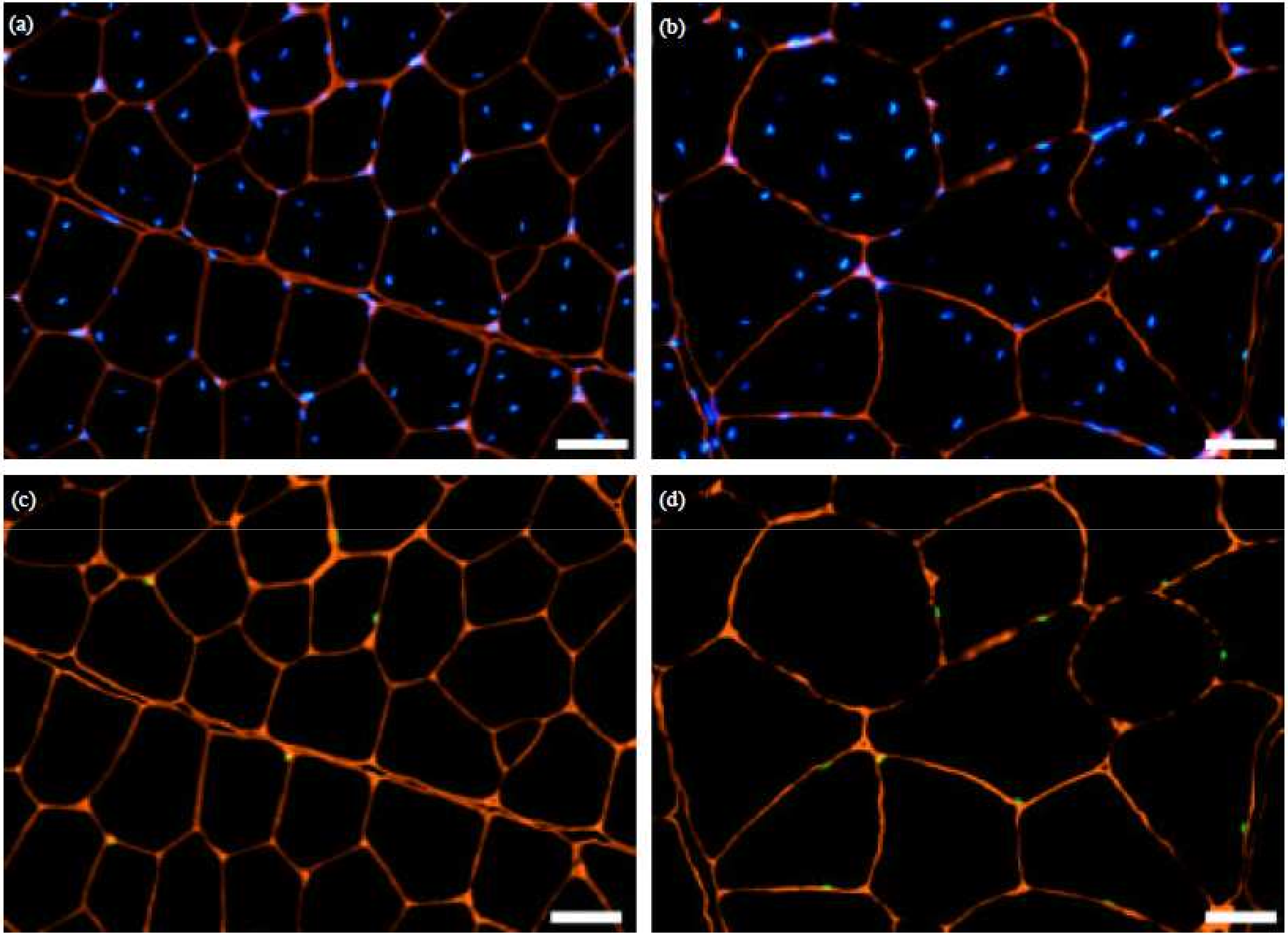
SC: Satellite cell, Values are expressed as mean±SE, of n = 5, ** p<0.01 (t-test)

Satellite cells: There were approximately 22 more SCs per millimeter of fiber in the Sustanon-treated group than in the control group (Table 3). The frequency of SCs was significantly (p<0.01) greater in Sustanon-treated birds

Table 4: Myonuclear distribution in control and Sustanon-treated chickens

Group	Myonuclei/fiber profile	Length of MN (µm)	Myonuclei/mm	Myonuclear domain ($\mu m^3 \times 10^3$)
Control (n = 5)	3.53±0.03	10.54±0.12	172.06±1.61	16.23±1.38
Sustanon-treated (n = 5)	5.56±0.48*	10.61±0.18	269.87±23.29*	26.19±2.38**

Myonuclei: There were approximately 98 more myonuclei per millimeter of fiber in the Sustanon-treated group than in the control group (Table 4). The mean number of myonuclei per fiber cross section was significantly ($p<0.05$) higher in Sustanon-treated birds than in controls.



Núcleos y láminas basales SIN y CON Sustanón