Jump Training: ¿Why and How?: an Exhaustive Review

Biological Bases for Jump Training

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Jump training exercises usually implicate an eccentric muscle action rapidly followed (after a short amortization/transition time period) by a concentric muscle action.

Stemm, J.D., Jacobson, B.H. Comparison of land- and aquatic-based plyometric training on vertical jump performance. J Strength Cond J 21(2):568-571, 2007.

SSC: Myotatic Reflex

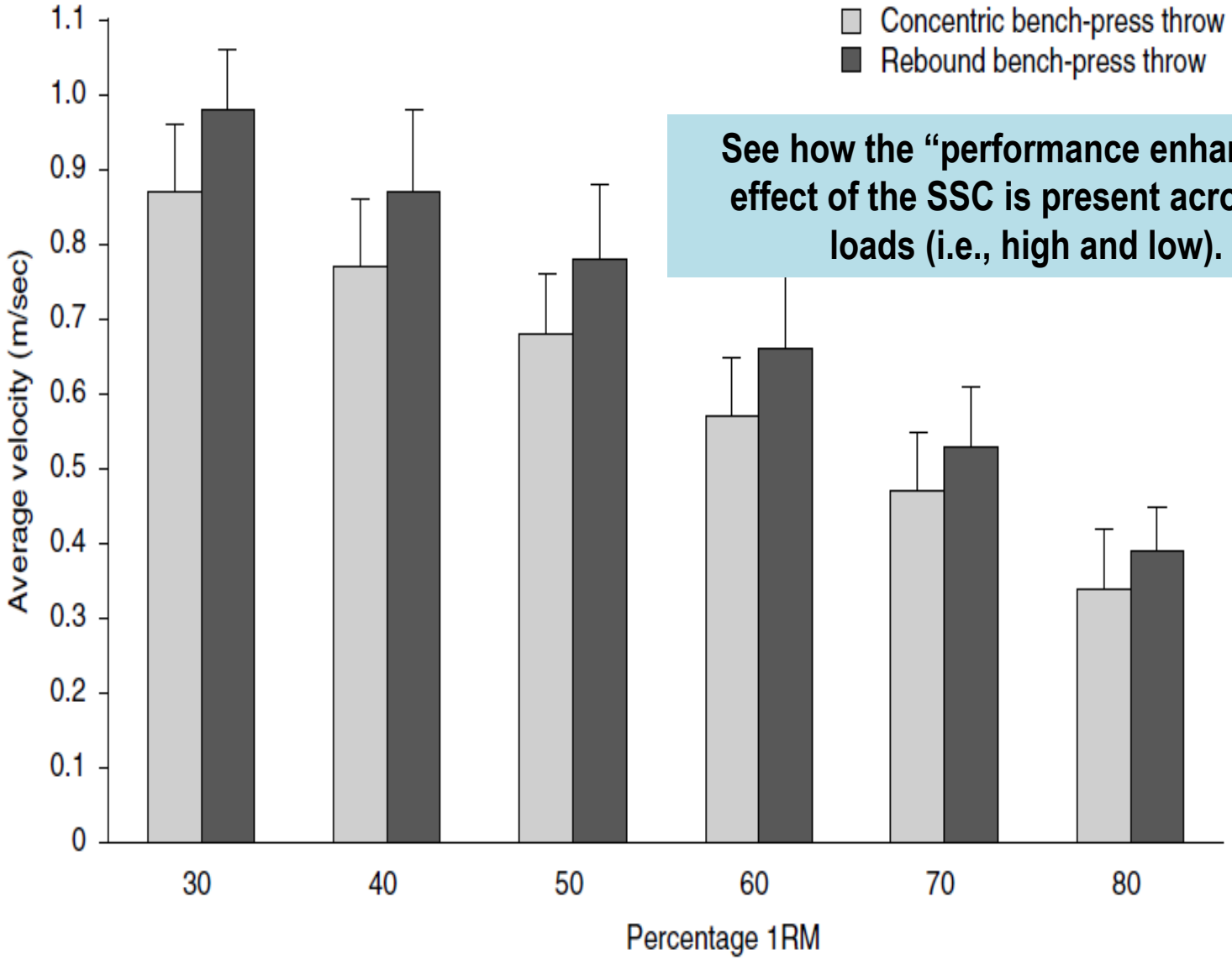
A rapid stretch of the muscle during the eccentric portion of the SSC may stimulate the myotatic reflex.

Stemm, J.D., Jacobson, B.H. Comparison of land- and aquatic-based plyometric training on vertical jump performance. J Strength Cond J 21(2):568-571, 2007.

The myotatic reflex implicates the activation of muscle propioceptors (e.g., muscle spindles; sensitive to muscle stretch), which might facilitate the activation of muscle fibers during a brief time period….

Shah, S. Plyometric Exercises. 2012. International Journal of Health Sciences and Research, 2(1): 115-126.

…therefore, facilitating "explosive" performance trough a potentially greater number of muscle fibers activated during the concentric portion of the SSC.



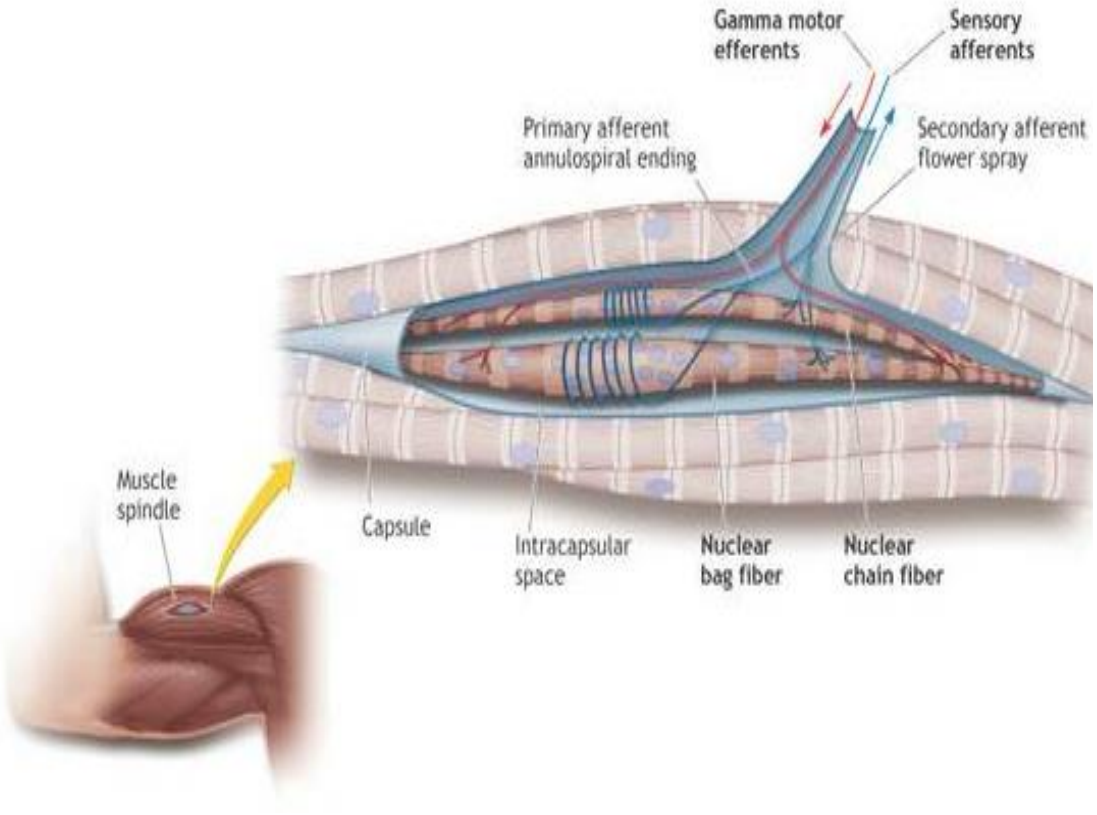
See how the "performance enhancing" effect of the SSC is present across all loads (i.e., high and low).

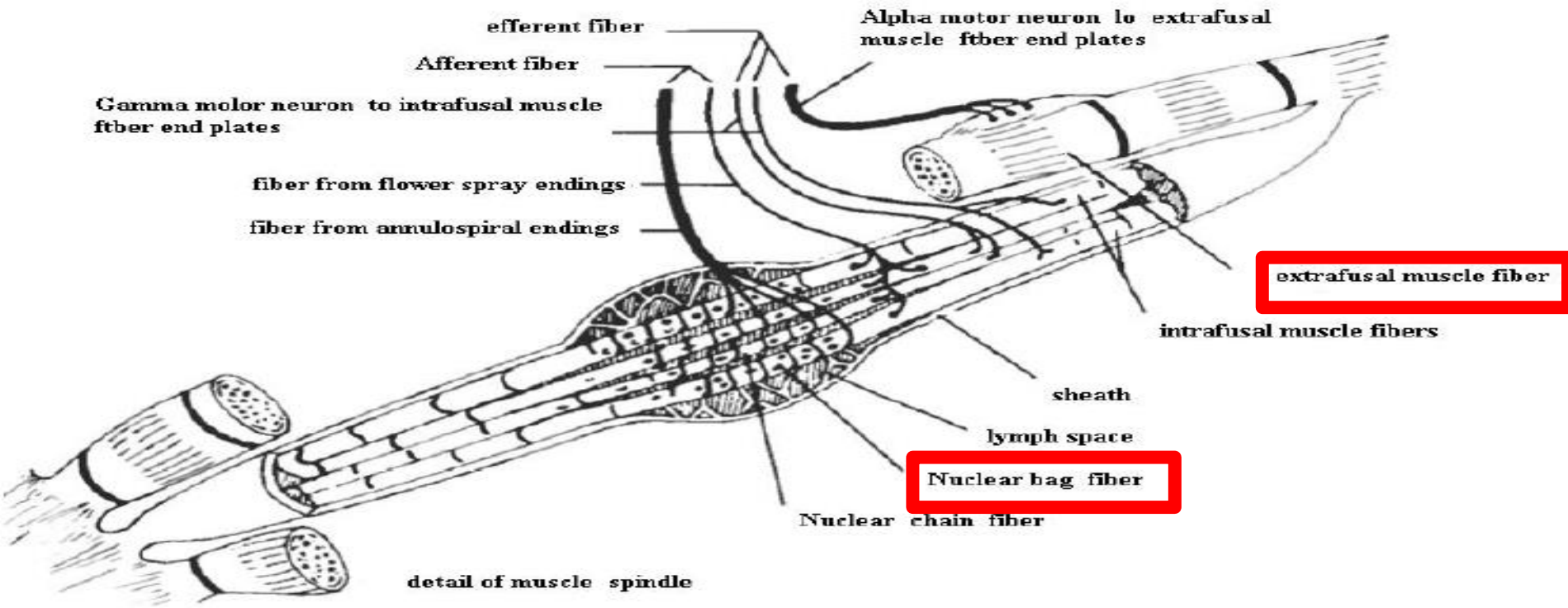
Fig. 1. Average velocities and standard deviations associated with the concentric bench-press throw and the rebound bench-press throw over a range of loading intensities (30–80% one repetition maximum [1RM]).

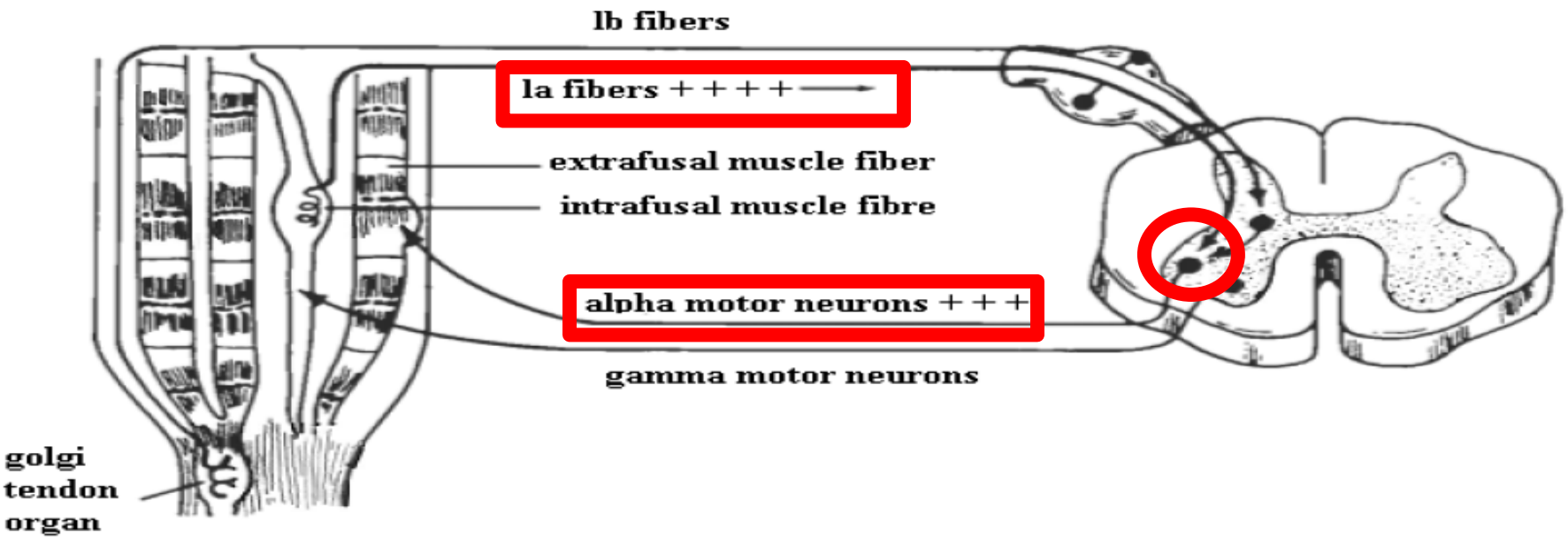
Cronin J, Sleivert G. Challenges in understanding the influence of maximal power training on improving athletic performance. Sports Med. 2005;35(3):213-34.

In the muscle spindle, NUCLEAR BAG intrafusal muscle fibers are especially sensitive to changes in muscle velocity (e.g., stretch velocity).

Shah, S. Plyometric Exercises. 2012. International Journal of Health Sciences and Research, 2(1): 115-126.







Shah, S. Plyometric Exercises. 2012. International Journal of Health Sciences and Research, 2(1): 115-126.

The myotatic reflex (i.e., monosinaptic reflex) implicates 3.5 ms in the spinal cord.

Shah, S. Plyometric Exercises. 2012. International Journal of Health Sciences and Research, 2(1): 115-126.

Muscle force inhibition through Golgi tendon organ synaptic cycle (nervous fiber type 1b) requires more time than the myotatic monosynaptic reflex from muscle spindles (nervous fiber type 1a), which can explain the muscle facilitation during SSC muscle actions (aside from the fact that Golgi tendon organ can reduce its sensitivity through training).

Shah, S. Plyometric Exercises. 2012. International Journal of Health Sciences and Research, 2(1): 115-126.

Although training may not improve myotatic reflex velocity, it might improve muscle force during the myotatic reflex, potentially improving the SSC velocity.

Robinson, L.E. The effects of land versus aquatic plyometrics on power torque velocity, and muscle sorenes. Master Thesis. Graduate School of The Ohio Stete University, 2002.

Therefore, the myotatic reflex may facilitate the concentric performance (i.e., velocity, power, force) during an acute SSC muscle action…….which may help to achieve greater training adaptations in the long-term.

Stemm, J.D., Jacobson, B.H. Comparison of land- and aquatic-based plyometric training on vertical jump performance. J Strength Cond J 21(2):568-571, 2007.

SSC: Muscle Elastic Energy

Aside from the myotatic reflex, the muscle ability to use the energy-force from muscle elastic components, may also improve the explosive performance during SSC muscle actions.

In this way, during the eccentric portion of the SSC, the load is transferred to the muscle elastic components, storing elastic energy in the process, which can be used during the concentric portion of the SSC.

Shah, S. Plyometric Exercises. 2012. International Journal of Health Sciences and Research, 2(1): 115-126.

The ability of the muscle to use elastic energy might depend on the transition period of the SSC, stretch magnitude and stretch velocity, and may be greater after a rapid eccentric phase and a short transition period.

Shah, S. Plyometric Exercises. 2012. International Journal of Health Sciences and Research, 2(1): 115-126.

The role of muscle elastic energy on explosive performance was demonstrated in early experiments from……

Acta physiol. scand. 1974. 91. 385—392

From the Laboratory for the Theory of Gymnastics, August Krogh Institute, University of Copenhagen, Denmark

Storage of Elastic Energy in Skeletal Muscles in Man

By

Erling Asmussen and Flemming Bonde-Petersen

	Peso (kg)	SJ	CMJ	DJ, 23 cm	DJ, 40 cm	DJ, 69 cm
$\bar{X}$	71.0	0.366	0.386	0.396	0.408	0.389

Values in meters

SSC: Energy Efficiency

The biological mechanisms implicated in the SSC may also implicate a reduced energy cost during the concentric portion of the cycle…..

Jamurtas, A.Z., Fatouros, I.O., Buckenmeyer, P., Kokkinidis, E., Taxildaris, K., Kambas, A., Kyriazis, G. Effects of plyometric exercise on muscle sorenes and plasma creatine kinase levels and its comparison with eccentric and concentric exercise. J Strength Cond Res 14(1):68-74, 2000

…and this acute energy-saving mechanism may have long-term positive transference…..as several studies had demonstrated that jump training might improve "movement economy"….

9 weeks of JT

Elite runners from 20 to 30 y of age (VO2max 68 ml/kg/min)

Increased 8% RE and 3% a 5-km time trial

Paavolainen, L, Hakkinen, K, Hamalainen, I, Nummela, A, and Rusko, H. Explosive-strength training improves 5-km running time by improving running economy and muscle power. J Appl Physiol 86: 1527–1533, 1999.

6 weeks of JT

Runners (VO2max 57 ml/kg/min)

Increased 4-7% RE and 3% a 3-km time trial

Spurrs, RW, Murphy, AJ, and Watsford, ML. The effect of plyometric training on distance running performance. Eur J Appl Physiol 89: 1–7, 2003.

9 weeks of JT

Elite runners from 20 to 30 y of age (VO2max 68 - 70 ml/kg/min)

Increased 4% RE

Saunders, P, Pyne, D, Teldorf, R, and Hawley, J. Factors affecting running economy in trained distance runners. Sports Med 34: 465–485, 2004.

6 weeks of JT

Male and female runners (mean VO2max = 65 ml/kg/min)

Increased 2.8% a 2.4-km time trial

Ramırez-Campillo, R, Alvarez, C, Henrıquez-Olguın, C, Baez, EB, Martınez, C, Andrade, DC, and Izquierdo, M. Effects of plyometric training on endurance and explosive strength performance in competitive middle- and long-distance runners. J Strength Cond Res 28(1): 97–104, 2014.

…..and these improvements are independent from changes in VO2max…

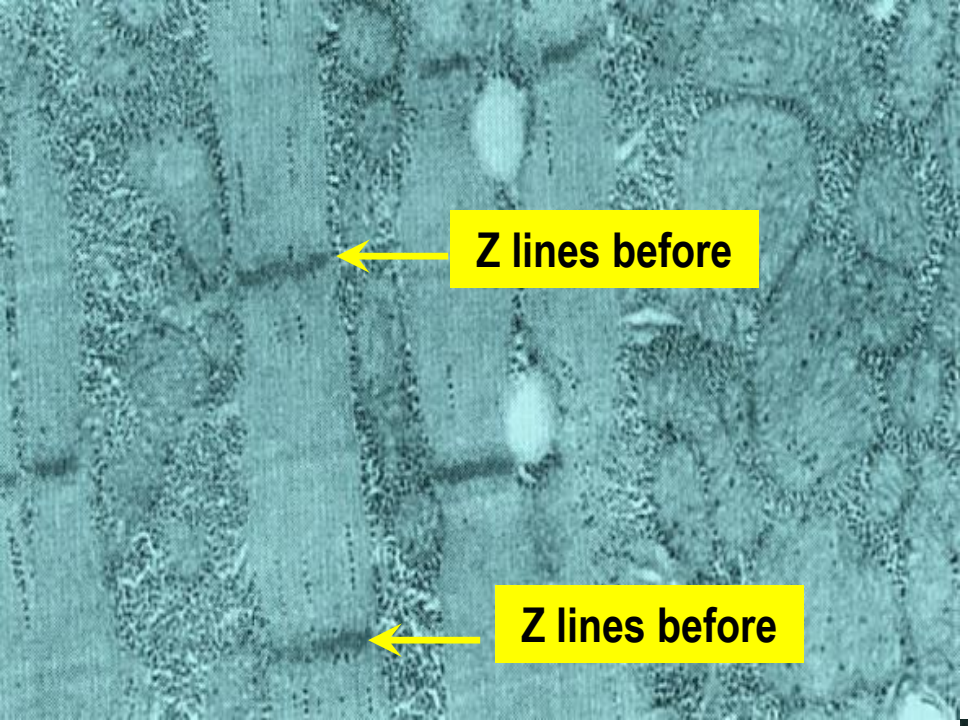
Although the physiological mechanism of the increased RE are not clear…

Pellegrino J, Ruby BC, Dumke CL. Effect of Plyometrics on the Energy Cost of Running and MHC and Titin Isoforms. Med Sci Sports Exerc. 2016 Jan;48(1):49-56.

SSC: Muscle Damage

It must be considerated that during the eccentric portion of the SSC a greater muscle-fiber tension can be developed, due to altered motor-unit recruitment pattern and utilization of muscle fibers, which may favor myofibrillar damage.

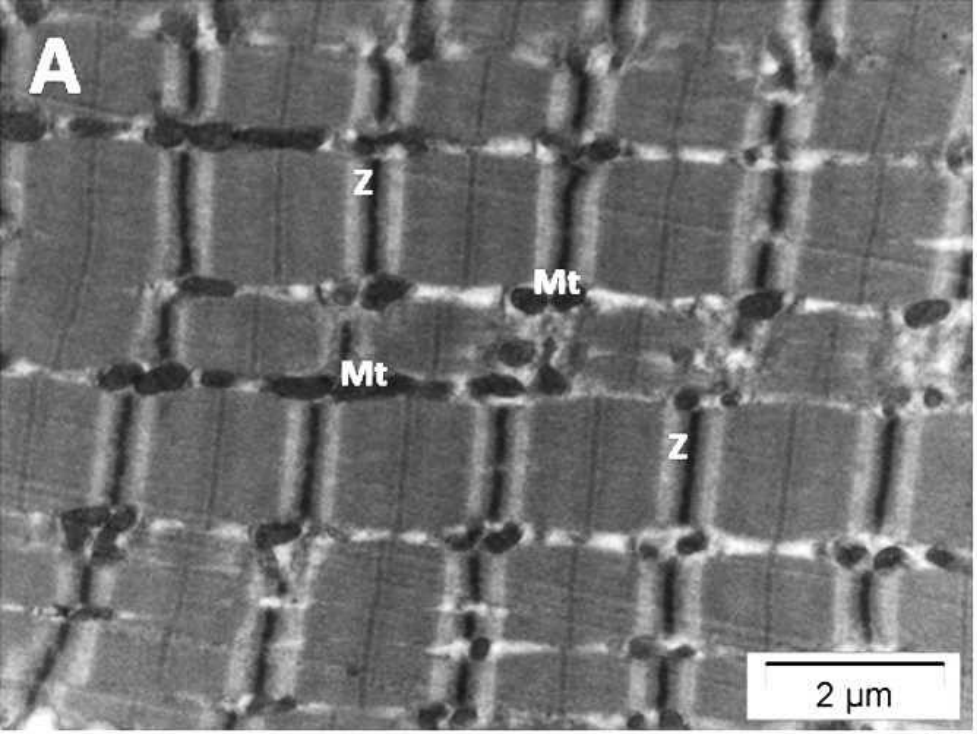
Jamurtas, A.Z., Fatouros, I.O., Buckenmeyer, P., Kokkinidis, E., Taxildaris, K., Kambas, A., Kyriazis, G. Effects of plyometric exercise on muscle zorréense and plasma creatine kinase levels and its comparison with eccentric and concentric exercise. J Strength Cond Res 14(1):68-74, 2000.



Skeletal muscle fibers before marathon

Skeletal muscle fibers after marathon

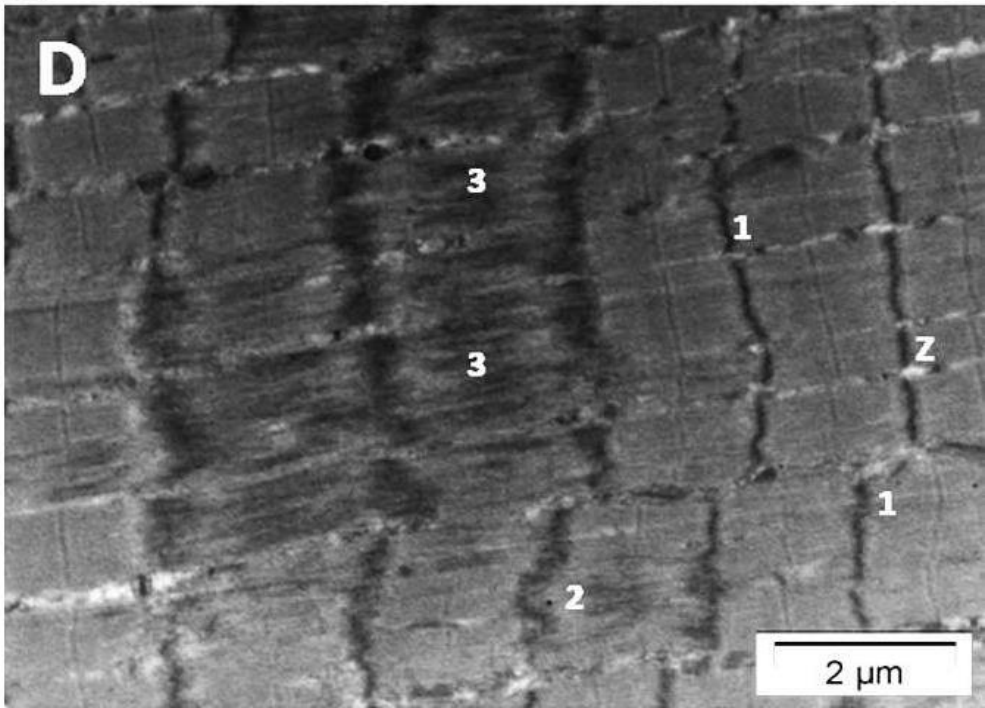
Wilmore, J., Costill, D. (2004). Fisiología del esfuerzo y del deporte. Barcelona: Editorial Paidotribo.



Normal sarcomeres, with intact patterns of lines and bands, before JT

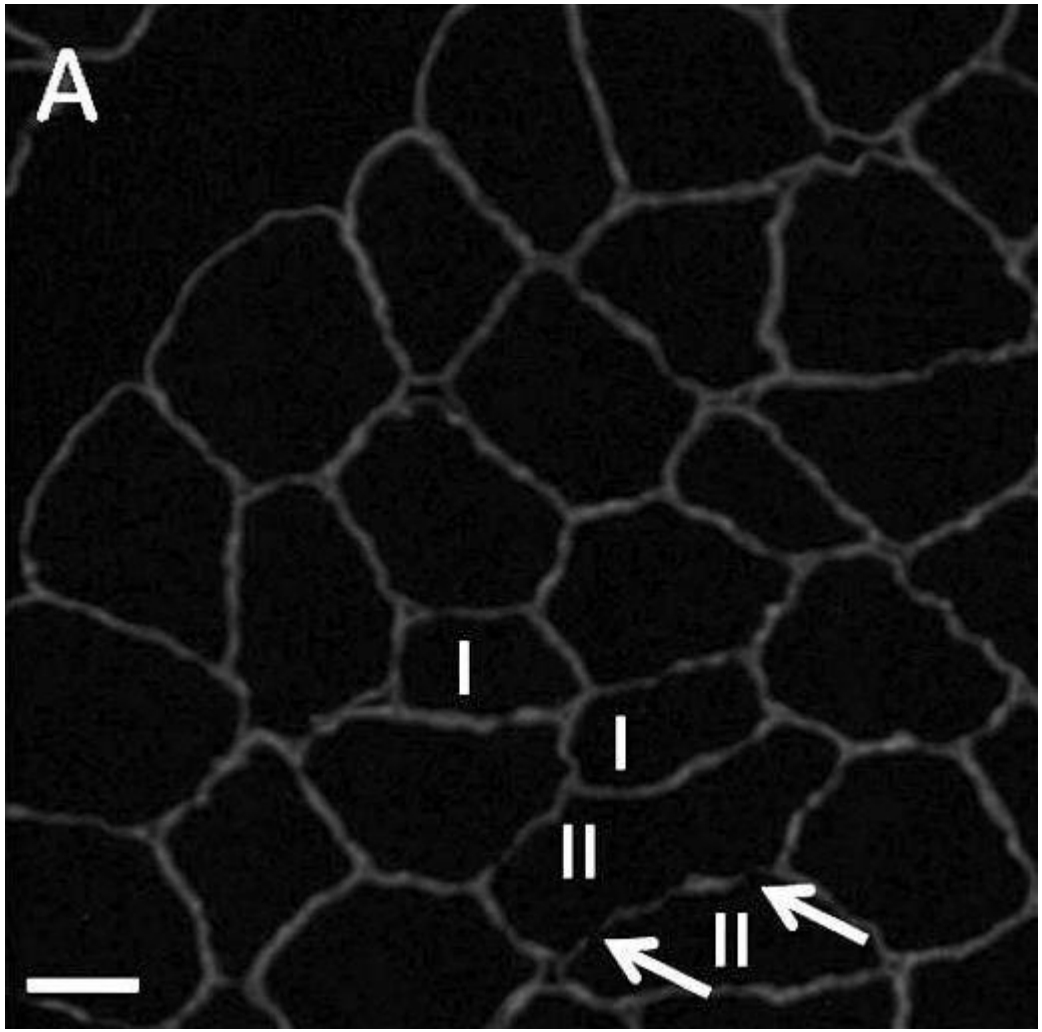
Z: normal Z line
Mt: mitochondria
1: small damage to Z line
2: moderate damage to Z line
3: rupture of Z line

Damaged sarcomeres (i.e., Z line and, also, mitochondria) after JT



Macaluso F, Isaacs AW, Myburgh KH. Preferential Type II Muscle Fiber Damage From Plyometric Exercise. Journal of Athletic Training 2012;47(4):414–420.

Diminished dystrophine staining (see arrows) as marker of muscle damage, 3 days after PT (i.e. 100 SJ).



Damage was greater in type II muscle fibers (75% vs. 25%).

Macaluso F, Isaacs AW, Myburgh KH. Preferential Type II Muscle Fiber Damage From Plyometric Exercise. Journal of Athletic Training 2012;47(4):414–420.

However, repeated JT protect against muscle damage.

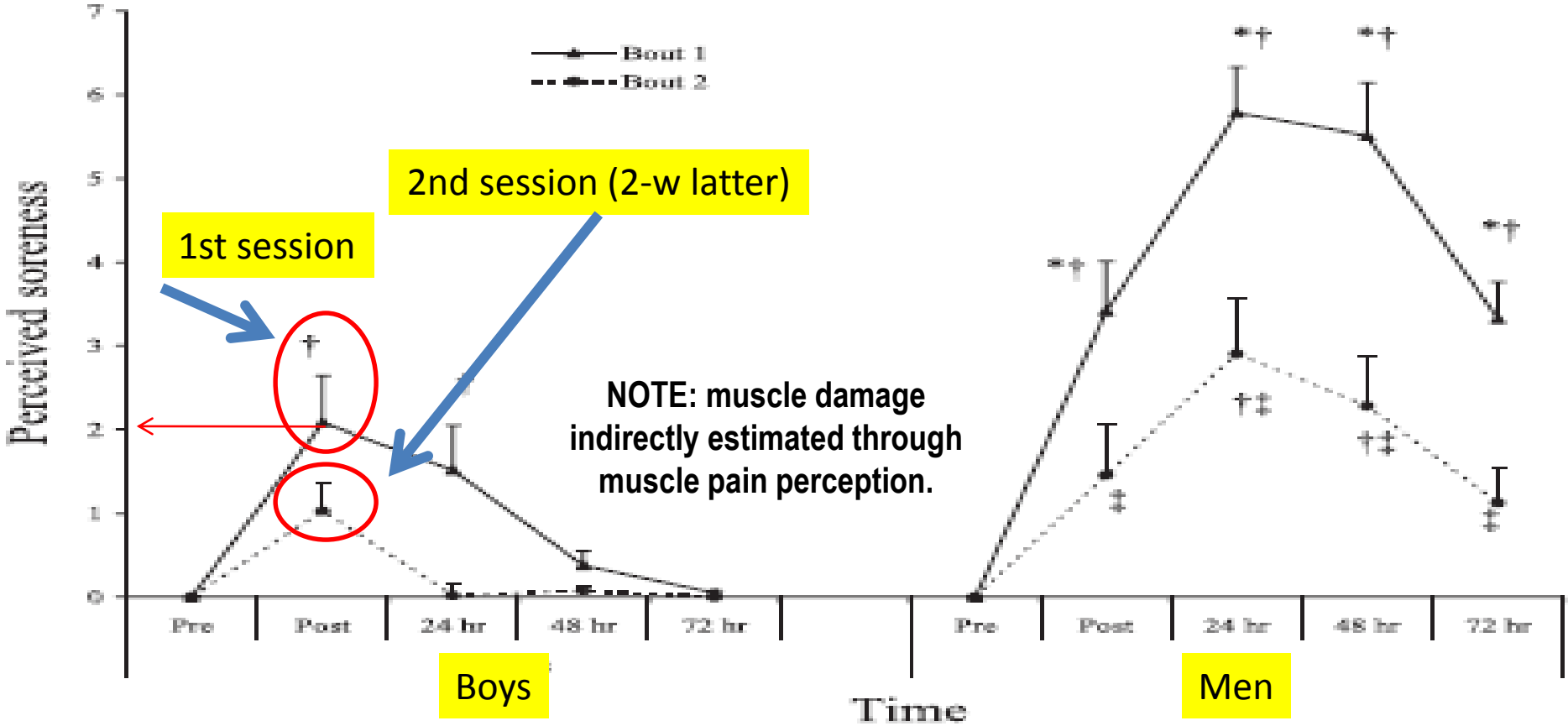


Fig. 3. Comparison of soreness in men and boys after 2 bouts of plyometric exercise. Bouts were separated by 2 wk. Values are means ± SE. *Significant difference between groups in *bout 1* ($P < 0.05$). †Significant difference across time within bout; ‡significant difference across bout, within time ($P < 0.05$).

Macaluso F, Isaacs AW, Di Felice V, Myburgh KH. Acute change of titin at mid-sarcomere remains despite 8 wk of plyometric training. J Appl Physiol 2014, 1;116(11):1512-9.

Marginson, V., Rowlands, A.V., Gleeson, N.P., Eston, R.G. Comparison of the symptoms of exercise-indiced muscle damage alter an initial and repeated bout of plyometric exercise in men and boys. J Appl Physiol 99: 1174-1181, 2005

SSC: Vertical vs. Horizontal Jumps and Elastic Energy Utilization

Compared with horizontal jumps, vertical jumps allow a greater utilization of muscle elastic energy (e.g., greater difference between a SJ and CMJ).

Maulder, P., Cronin, J. Horizontal and vertical jump assessment: reliability, symmetry, discriminative and predictive ability. Phys Ther Sport 6: 74-82, 2005.

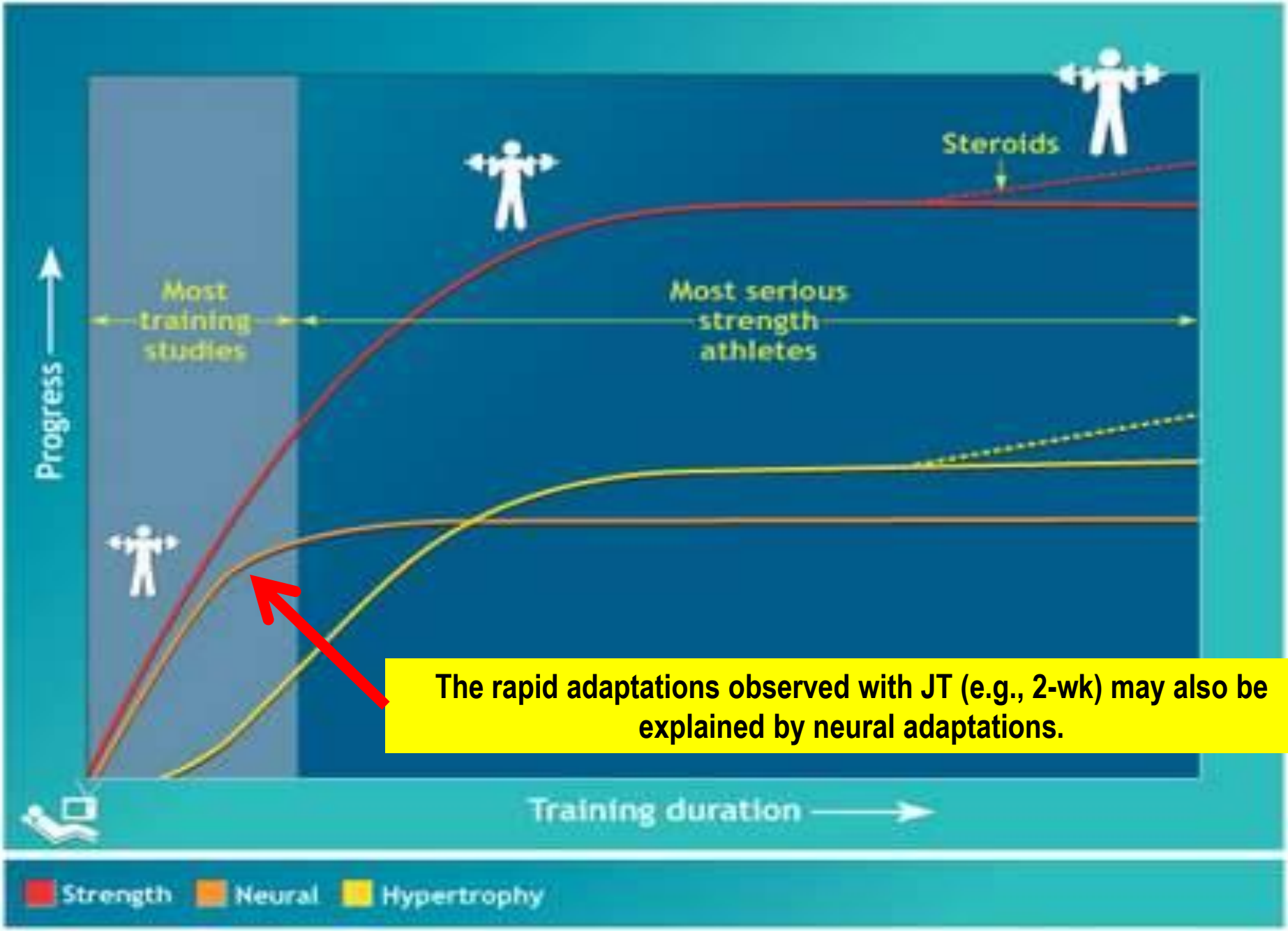
SSC: Neural vs. Hypertrophic Adaptations

"Fast" SSC muscle actions (e.g., DJ with ground contact time <250 ms) would induce mainly neural adaptations.

This may be related with the short amplitude (and duration) of the eccentric muscle action (i.e., muscle-tendon complex is stretched, but reduced stretch is generated on individual muscle fibers).

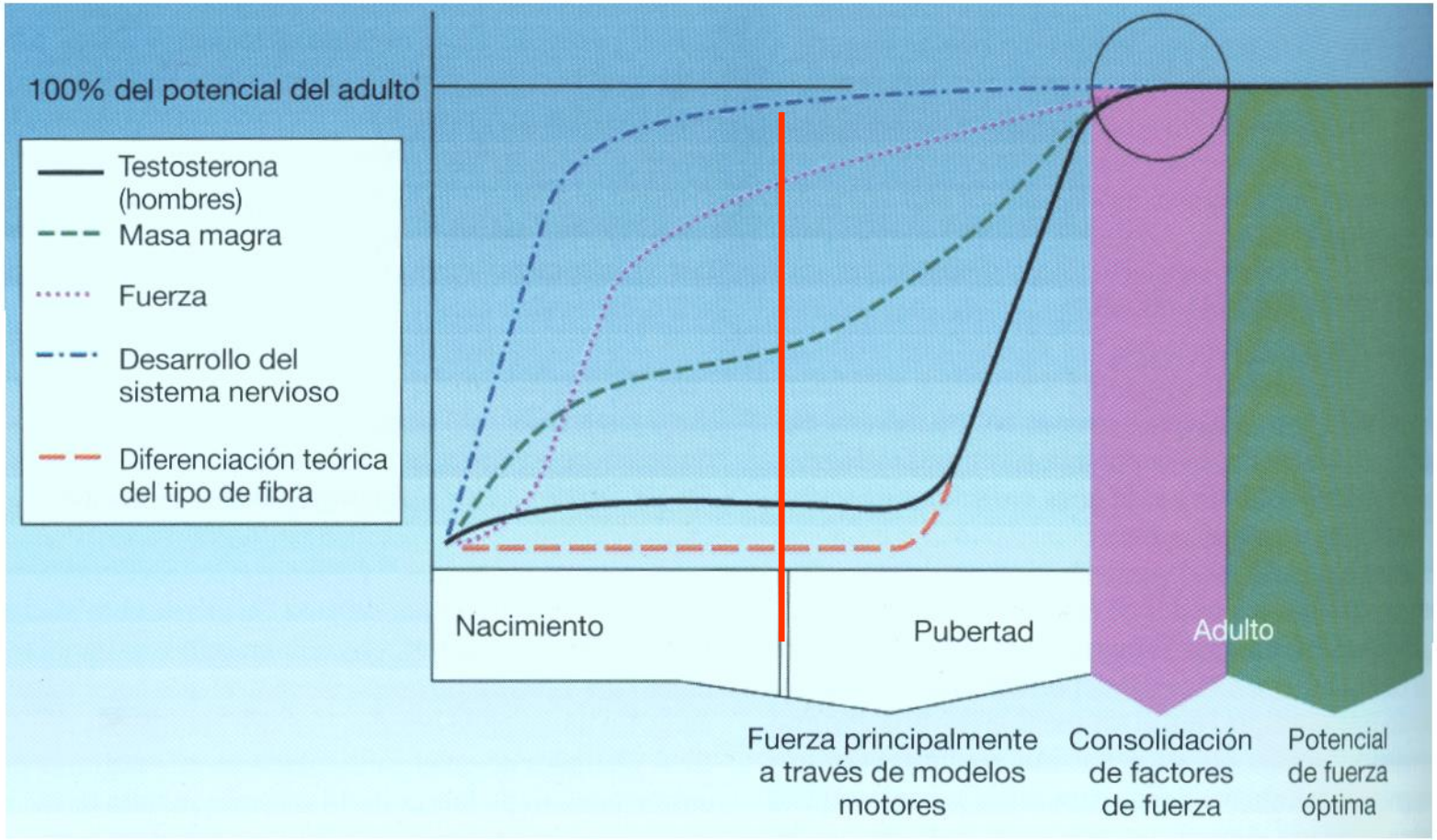
Also, the short duration of the muscle action would reduce the metabolic stress, and this may reduce the hypertrophic stimulus.

Markovic, G., Mikulic, P. Neuro-Musculoskeletal and performance adaptations to lower-extremity plyometric training. Sports Med 40(10):859-895, 2010



The rapid adaptations observed with JT (e.g., 2-wk) may also be explained by neural adaptations.

McArdle, W. Exercise physiology: energy, nutrition and human performance. Lippincott Williams and Wilkins, 2002



Wilmore, J., Costill, D. Fisiología del esfuerzo y del deporte. Barcelona: Editorial Paidotribo, 2004.

In addition, it is interesting to note that youths are very responsiveness to JT (especially before PHV), and this might be related with their greater rate of neural development…….

Lloyd RS, Radnor JM, De Ste Croix MB, Cronin JB, Oliver JL. Changes in Sprint and Jump Performances After Traditional, Plyometric, and Combined Resistance Training in Male Youth Pre- and Post-Peak Height Velocity. J Strength Cond Res. 2016 May;30(5):1239-47.

……for example, we have observed significant adaptations in youth soccer players after only 6-7 weeks……in adults also, but the rate of improvement may be slower ……
(Rodrigo Ramirez-Campillo, unpublished data)

Rodrigo Ramirez-Campillo, Andrade, DC, and Izquierdo, M. Effects of plyometric training volume and training surface on explosive strength. J Strength Cond Res 27(10): 2714–2722, 2013.

Rodrigo Ramírez-Campillo, David C. Andrade, Cristian Álvarez, Carlos Henríquez-Olguín, Cristian Martínez, Eduardo Báez-San Martín, Juan Silva-Urra, Carlos Burgos and Mikel Izquierdo. The Effects of Interset Rest on Adaptation to 7 Weeks of Explosive Training in Young Soccer Players. Journal of Sports Science and Medicine 13, 287-296, 2014.

Rodrigo Ramırez-Campillo, Meylan C, Alvarez C, Henrıquez-Olguın C, Martınez C, Canas-Jamett R, Andrade D, Izquierdo M. Effects of in-season low-volume high-intensity plyometric training on explosive actions and endurance of young soccer players. J Strength Cond Res 28(5): 1335–1342, 2014.

Rodrigo Ramírez-Campillo, César M.P. Meylan, Cristian Álvarez-Lepín, Carlos Henriquez-Olguín, Cristian Martinez, David C. Andrade, Mauricio Castro-Sepúlveda, Carlos Burgos, Eduardo I. Baez, Mikel Izquierdo. The effects of interday rest on adaptation to 6-weeks of plyometric training in young soccer players. Journal of Strength and Conditioning Research. In press.

Rodrigo Ramírez-Campillo, González-Jurado JA, Martínez C, Nakamura FY, Peñailillo L, Meylan CM, Caniuqueo A, Cañas-Jamet R, Moran J, Alonso-Martínez AM, Izquierdo M. Effects of plyometric training and creatine supplementation on maximal-intensity exercise and endurance in female soccer players. J Sci Med Sport. IN PRESS.

Rodrigo Ramírez-Campillo, Vergara-Pedreros M, Henríquez-Olguín C, Martínez-Salazar C, Alvarez C, Nakamura FY, De La Fuente CI, Caniuqueo A,Alonso-Martinez AM, Izquierdo M. Effects of plyometric training on maximal-intensity exercise and endurance in male and female soccer players. J Sports Sci. 2016;34(8):687-93. doi: 10.1080/02640414.2015.1068439. Epub 2015 Jul 22.

Rodrigo Ramírez-Campillo, Alvarez C, Henríquez-Olguín C, Baez EB, Martínez C, Andrade DC, Izquierdo M. Effects of plyometric training on endurance and explosive strength performance in competitive middle- and long-distance runners. J Strength Cond Res. 2014 Jan;28(1):97-104.

Review of the Day

Muscle Stretch-Shortening Cycle (SSC): Theoretical-Biological Bases for Jump Training

SSC muscle actions are usually related with the activation of the myotatic reflex, muscle elastic energy, and movement efficiency (at short and long term).

SSC muscle actions with high load (volume, intensity) and relatively new to the athlete (especially adults), may increase muscle damage and delayed onset of muscle soreness (DOMS).

Although with potential effects on muscle hypertrophy, JT usually induce neural adaptations (especially through fast SSC muscle actions), which seems to appear in relatively brief (i.e., <8 weeks) time periods.

In youths, their greater rate of neural development (compared to adults), may help to explain their rapid and elevated responsiveness to JT through SSC muscle actions, both, fast and slow.