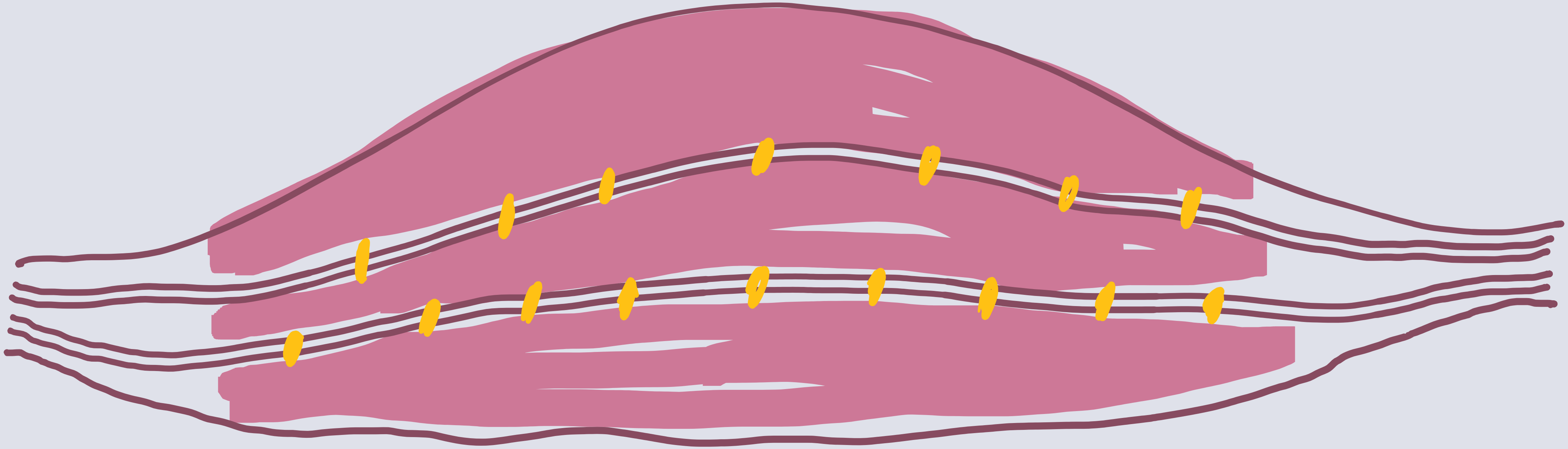
The physiology of strength training



BREATHE EDUCATION

Learning goals

- Why strength & hypertrophy are not the same thing
- The primary stimulus for hypertrophy is high levels of mechanical tension on individual muscle fibers, the primary stimulus for strength is high levels of mechanical tension on the MTU
- 1-20 RM builds strength, 6-30RM builds muscle
- To maximize strength, stop 2-3 reps before failure, to maximize hypertrophy go to failure
- Things NOT required for strengthening

BREATHE EDUCATION

Learning goals

- **Why strength & hypertrophy are not the same thing**

Why strength & hypertrophy are not the same thing

Strength: The ability to exert force against an object

Hypertrophy: Muscle growth

Strength gains are a result of increased:

1. Muscle fiber size (hypertrophy)

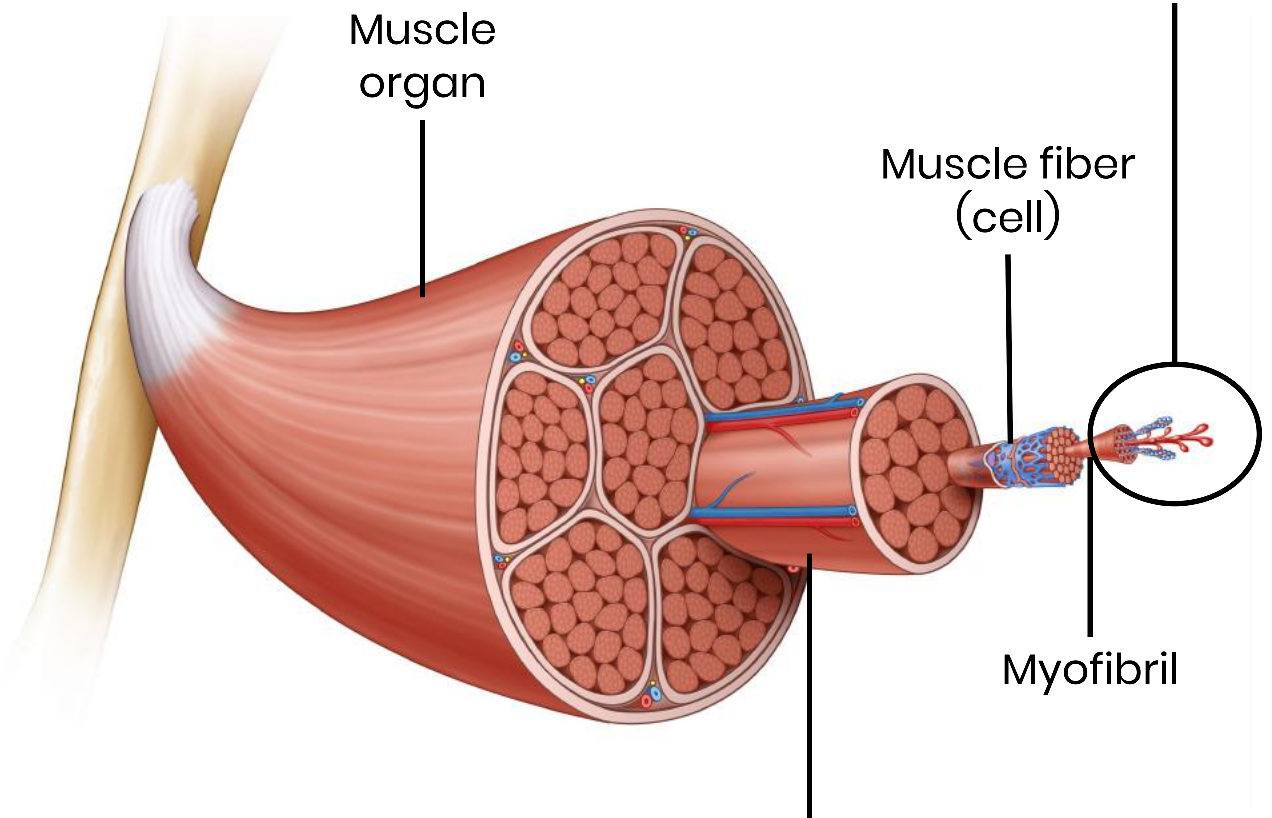
2. Lateral force transmission

3. Tendon stiffness

4. Load-specific muscle coordination

5. Load-specific motor skill

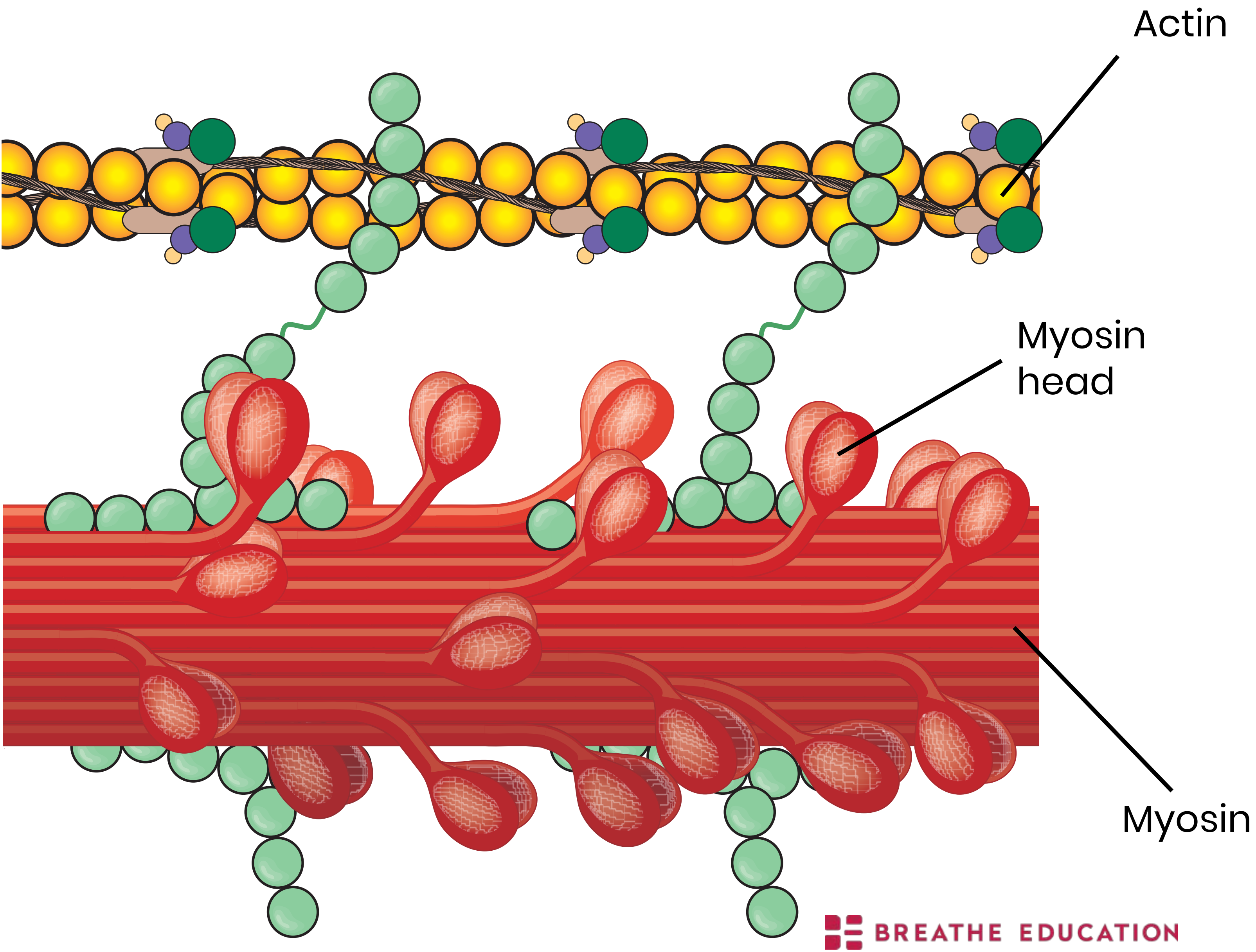
Lee Winroth lifts 170kg at 67kg bodyweight.
https://www.newyorker.com/sports/sporting-scene/the-accidental-weight-lifting-world-record-holder



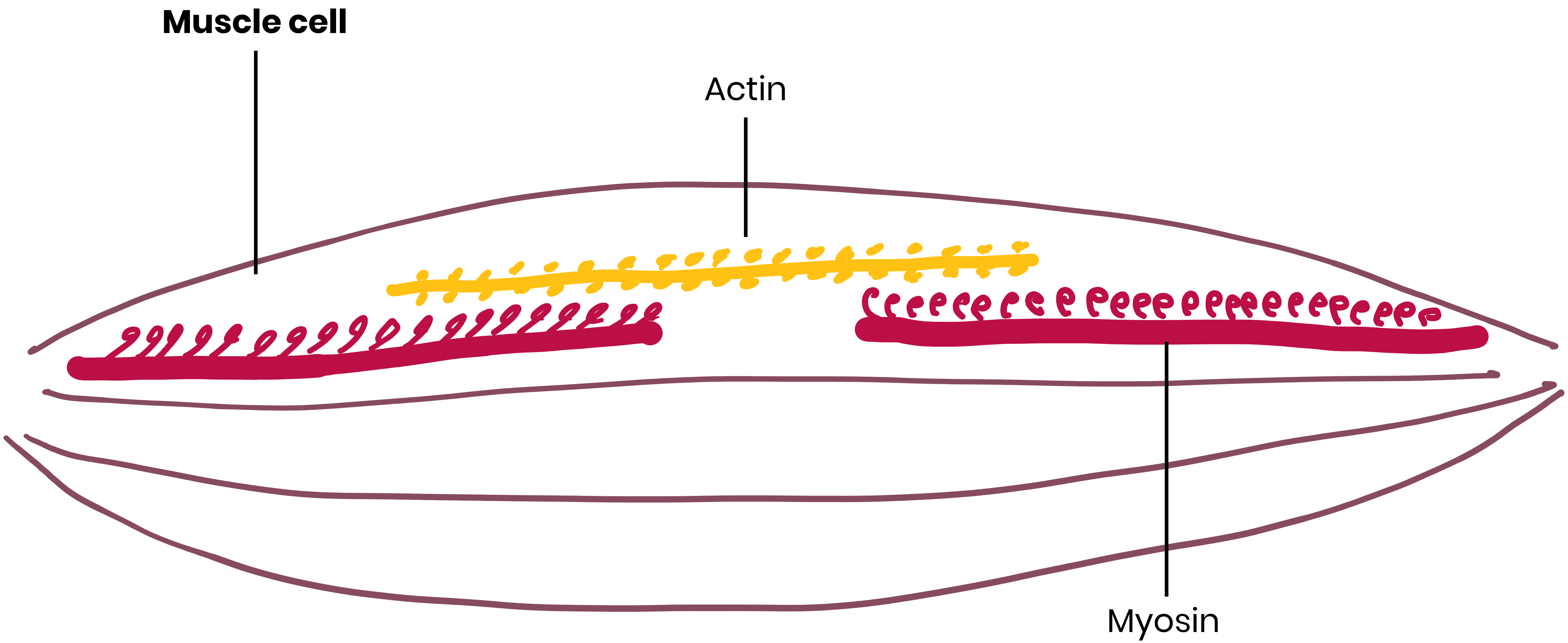
1. Increased muscle fiber size

- Mechanical tension on individual muscle fibers (cells)
- Stimulates the fiber to build more contractile proteins
- Making the muscle thicker & stiffer

Erskine, R. M., Fletcher, G., & Folland, J. P. (2014). The contribution of muscle hypertrophy to strength changes following resistance training. European journal of applied physiology, 114(6), 1239-1249. https://breathe-edu-downloads.s3.amazonaws.com/Erskine-2014.pdf

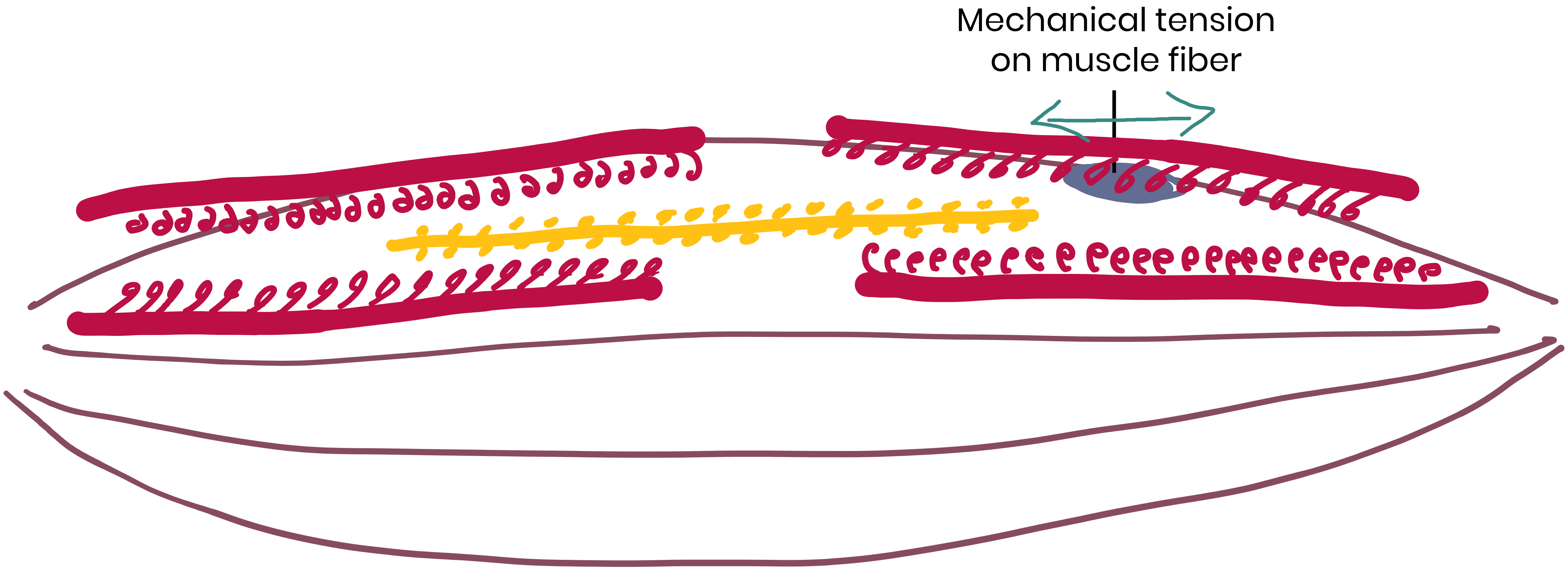


Contractile proteins



Muscles contract by the myosin heads pulling along the actin

When stimulated by mechanical tension the nucleus builds more proteins



Before strength training

After strength training

2. Increased tendon stiffness

- Tendons are elastic
- Mechanical tension on the tendon
- Stimulates collagen production & organization
- Making the tendon thicker and stiffer

Bohm, S., Mersmann, F., & Arampatzis, A. (2015). Human tendon adaptation in response to mechanical loading: a systematic review and meta-analysis of exercise intervention studies on healthy adults. Sports medicine-open, 1(1), 7. https://breathe-edu-downloads.s3.amazonaws.com/Bohm-2015.pdf

Kubo, K., Komuro, T., Ishiguro, N., Tsunoda, N., Sato, Y., Ishii, N., . . . Fukunaga, T. (2006). Effects of low-load resistance training with vascular occlusion on the mechanical properties of muscle and tendon. Journal of Applied Biomechanics, 22(2), 112-119. https://breathe-edu-downloads.s3.amazonaws.com/Kubo-2006.pdf

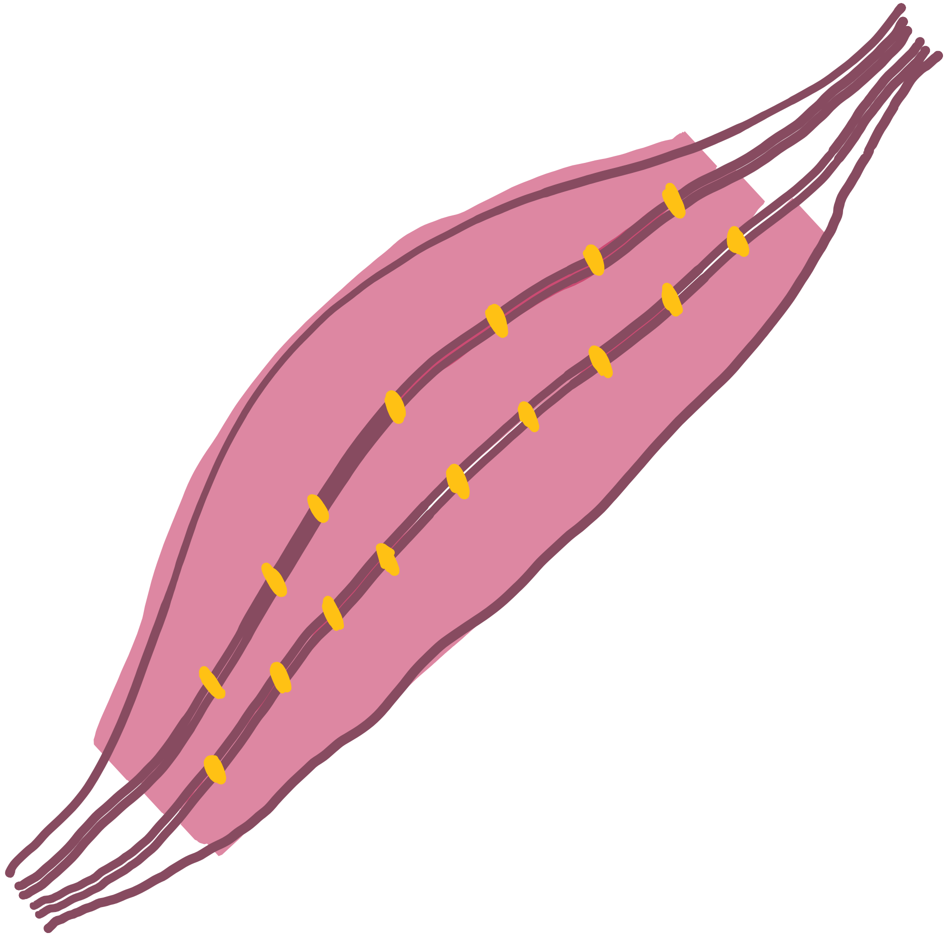
How increased tendon stiffness contributes to strength gains

- A stiffer tendon stretches less when the muscle contracts
- So, more force is transmitted directly to the bone

Bohm, S., Mersmann, F., & Arampatzis, A. (2015). Human tendon adaptation in response to mechanical loading: a systematic review and meta-analysis of exercise intervention studies on healthy adults. Sports medicine-open, 1(1), 7. https://breathe-edu-downloads.s3.amazonaws.com/Bohm-2015.pdf

Kubo, K., Komuro, T., Ishiguro, N., Tsunoda, N., Sato, Y., Ishii, N., . . . Fukunaga, T. (2006). Effects of low-load resistance training with vascular occlusion on the mechanical properties of muscle and tendon. Journal of Applied Biomechanics, 22(2), 112-119. https://breathe-edu-downloads.s3.amazonaws.com/Kubo-2006.pdf

Tendons are **elastic**



3. Increased lateral force transmission

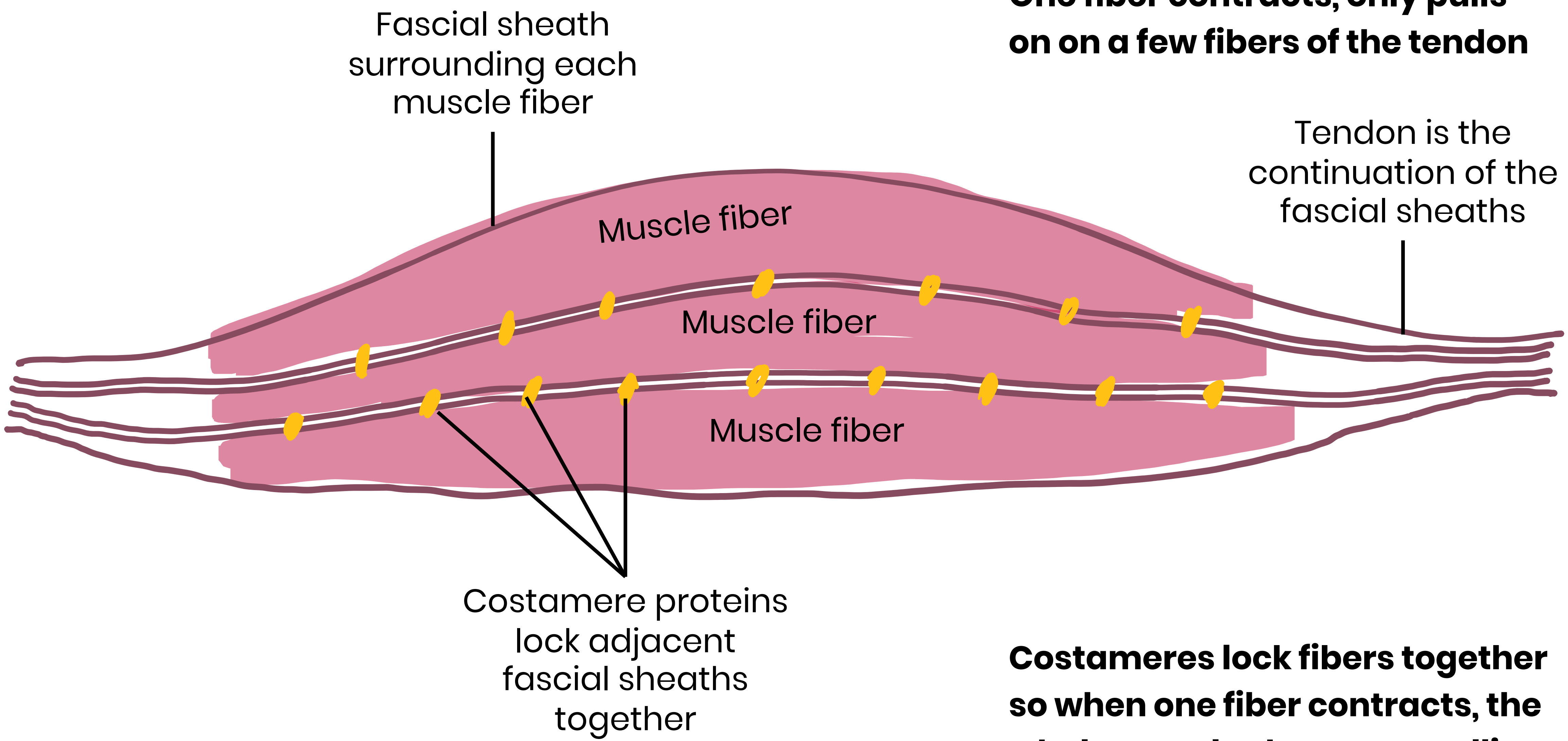
High levels of mechanical tension on the whole muscle organ stimulate production of more costameres.

Costameres lock adjacent muscle fibers to each other, making the whole muscle stiffer.

Erskine, R. M., Jones, D. A., Maffulli, N., Williams, A. G., Stewart, C. E., & Degens, H. (2011). What causes in vivo muscle specific tension to increase following resistance training? Experimental physiology, 96(2), 145-155. https://breathe-edu-downloads.s3.amazonaws.com/Erskine-2011.pdf

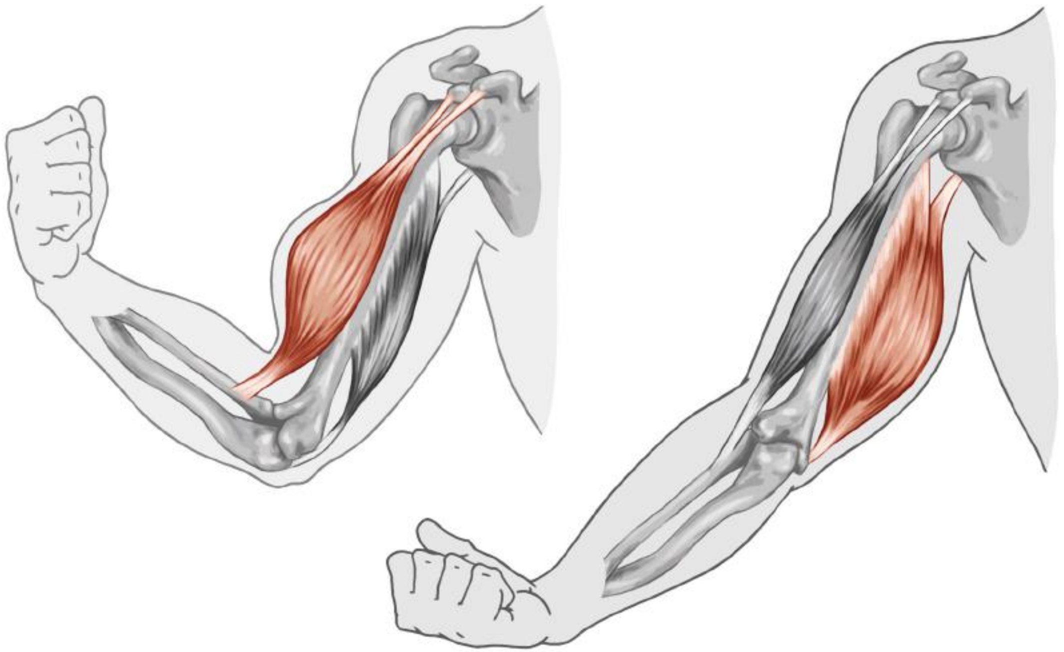
Flück, M., Li, R., Valdivieso, P., Linnehan, R. M., Castells, J., Tesch, P., & Gustafsson, T. (2014). Early changes in costameric and mitochondrial protein expression with unloading are muscle specific. BioMed research international, 2014. https://breathe-edu-downloads.s3.amazonaws.com/Fl%C3%BCck-2014.pdf

Li, R., Narici, M. V., Erskine, R. M., Seynnes, O. R., Rittweger, J., Pišot, R., . . . Flück, M. (2013). Costamere remodeling with muscle loading and unloading in healthy young men. Journal of anatomy, 223(5), 525-536. https://breathe-edu-downloads.s3.amazonaws.com/Li-2013.pdf



One fiber contracts, only pulls on on a few fibers of the tendon

Costameres lock fibers together so when one fiber contracts, the whole muscle shortens – pulling on more of the tendon fibers



4. Load-specific muscular coordination

- Increased drive to agonists (prime mover muscles)
- Decreased drive to antagonists (opposing muscles)

Balshaw, T. G., Massey, G. J., Maden-Wilkinson, T. M., Morales-Artacho, A. J., McKeown, A., Appleby, C. L., & Folland, J. P. (2017). Changes in agonist neural drive, hypertrophy and pre-training strength all contribute to the individual strength gains after resistance training. European journal of applied physiology, 117(4), 631-640. https://breathe-edu-downloads.s3.amazonaws.com/Balshaw-2017.pdf

Folland, J. P., & Williams, A. G. (2007). Morphological and neurological contributions to increased strength. Sports Medicine, 37(2), 145-168. https://breathe-edu-downloads.s3.amazonaws.com/Folland-2007.pdf

Kidgell, D. J., Stokes, M. A., Castricum, T. J., & Pearce, A. J. (2010). Neurophysiological responses after short-term strength training of the biceps brachii muscle. The Journal of Strength & Conditioning Research, 24(11), 3123-3132. https://breathe-edu-downloads.s3.amazonaws.com/Kidgell-2010.pdf

More activation of agonists, less activation of antagonists

Same muscles, same position, different activation levels

More activation of stabilizers & antagonists, less activation of agonists

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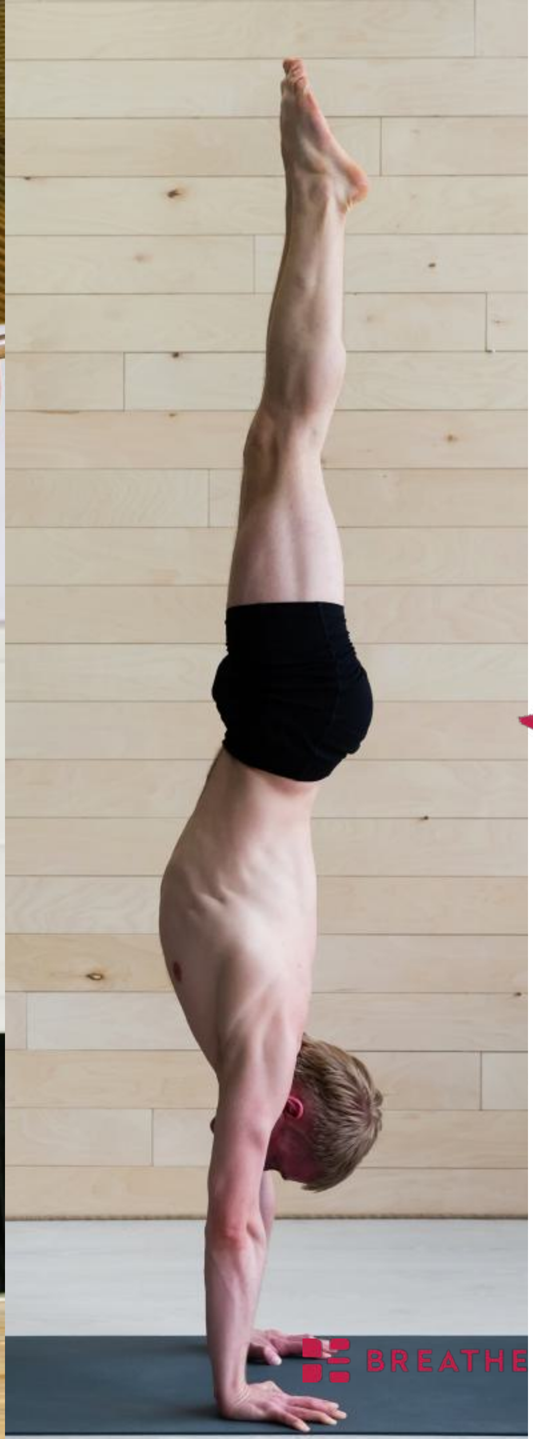


5. Load-specific motor skill

The skill of moving an object through space is specific to the weight, stability and size of the object

Same muscles, different motor skill

Balshaw, T. G., Massey, G. J., Maden-Wilkinson, T. M., Morales-Artacho, A. J., McKeown, A., Appleby, C. L., & Folland, J. P. (2017). Changes in agonist neural drive, hypertrophy and pre-training strength all contribute to the individual strength gains after resistance training. European journal of applied physiology, 117(4), 631-640. https://breathe-edu-downloads.s3.amazonaws.com/Balshaw-2017.pdf

Folland, J. P., & Williams, A. G. (2007). Morphological and neurological contributions to increased strength. Sports Medicine, 37(2), 145-168. https://breathe-edu-downloads.s3.amazonaws.com/Folland-2007.pdf

Same muscles,
different motor skill

Strength gains are a result of increased:

Results from high levels of tension on individual fibers → 1. Muscle fiber size

Results from high levels of tension on the whole muscle-tendon unit → 2. Lateral force transmission; 3. Tendon stiffness

Results from practice lifting heavy loads → 4. Load-specific muscle coordination; 5. Load-specific motor skill

Self Test

- What happens inside your muscle to make the muscle get **bigger**?
- What happens inside your body to make you get **stronger**?

Learning goals

- Why strength & hypertrophy are not the same thing
- **The primary stimulus for hypertrophy is high levels of mechanical tension on individual muscle fibers, the primary stimulus for strength is high levels of mechanical tension on the MTU**

The primary stimulus for hypertrophy is high levels of tension on individual muscle fibers

The primary stimulus for strength is high levels of tension on the whole muscle-tendon unit

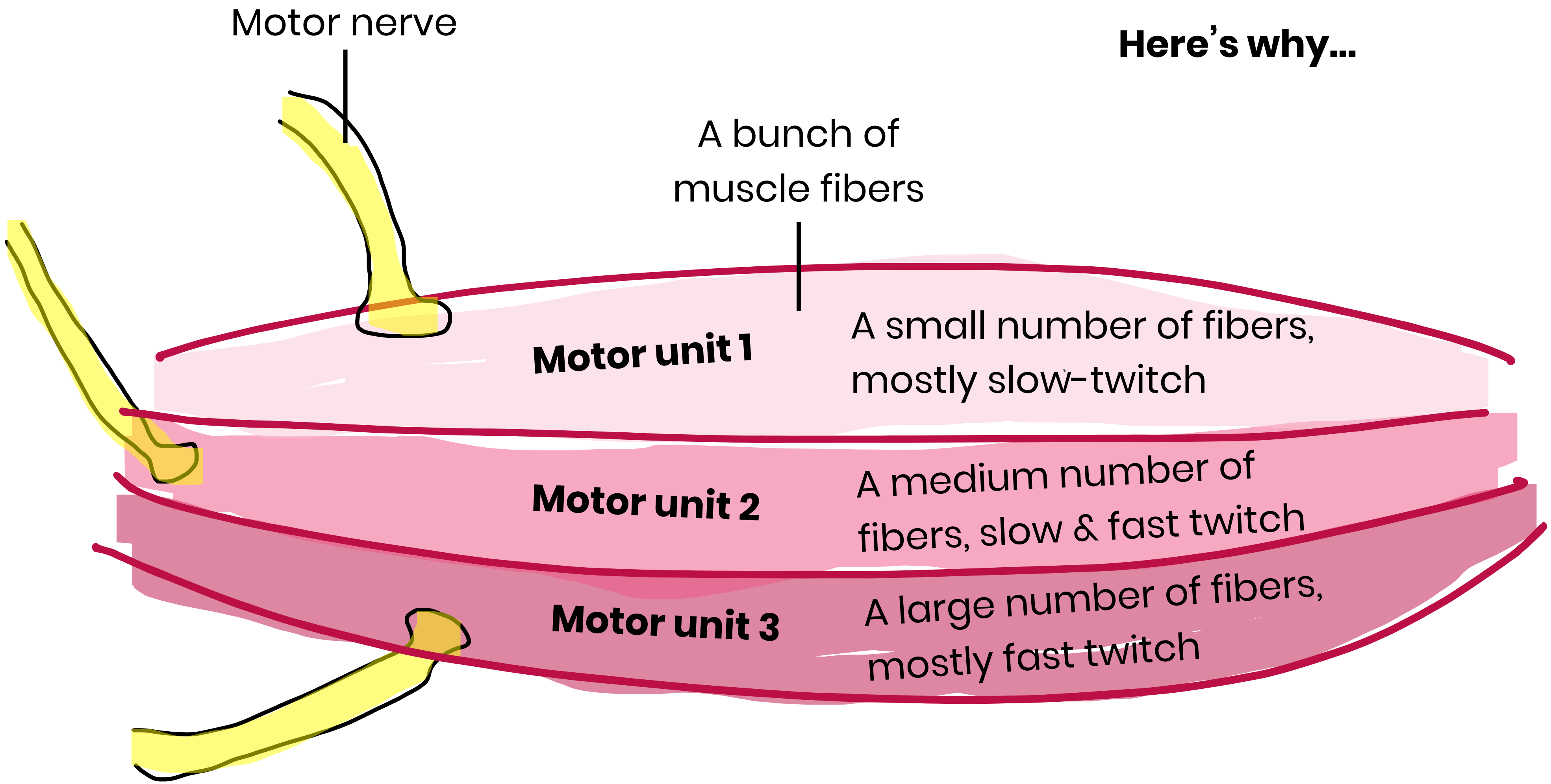
Tension, not activation is the stimulus for muscle growth.

Intense passive stretching...

Results in equal muscle growth to strength training

Wohlann, T., Warneke, K., Kalder, V., Behm, D. G., Schmidt, T., & Schiemann, S. (2024). Influence of 8-weeks of supervised static stretching or resistance training of pectoral major muscles on maximal strength, muscle thickness and range of motion. European journal of applied physiology, 1-9. https://breathe-edu-downloads.s3.amazonaws.com/Wohlann-2024.pdf

Here's why...



A **motor unit** is a group of muscle fibers, plus the motor nerve that innervates them

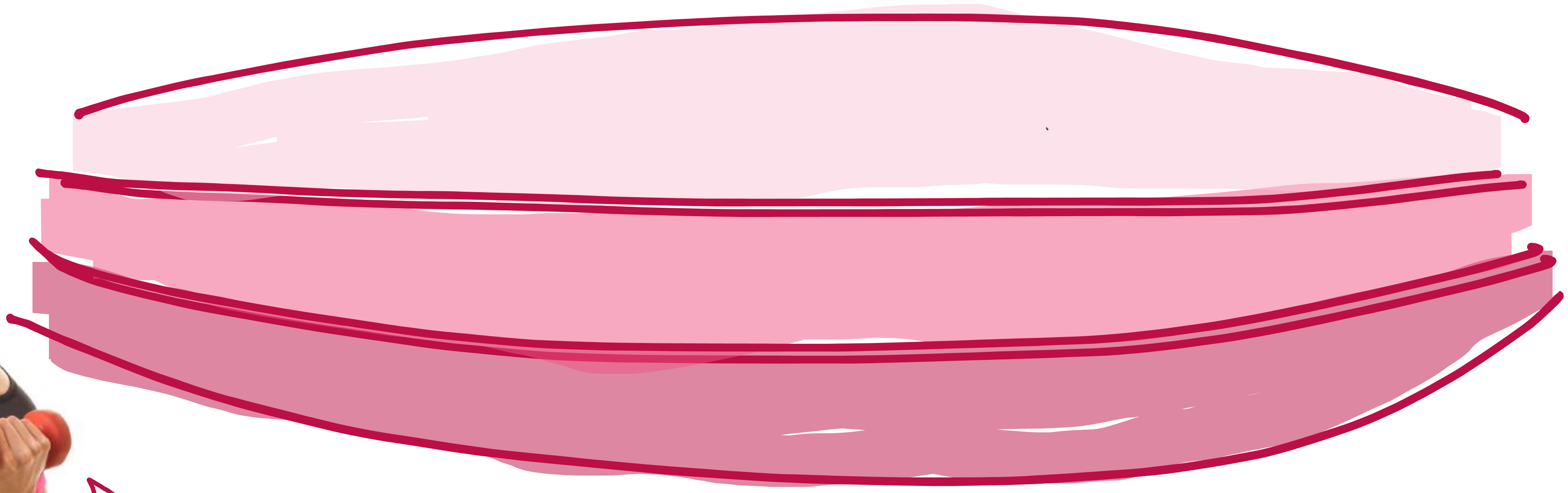
Motor units are recruited in size order

Small	**Motor unit 1**	**Always recruited first** for light loads
Medium	**Motor unit 2**	**Always recruited second** for moderate loads
Large	**Motor unit 3**	**Always recruited last** for heavy loads

Duchateau, J., & Enoka, R. M. (2011). Human motor unit recordings: origins and insight into the integrated motor system. Brain Research, 1409, 42-61. https://breathe-edu-downloads.s3.amazonaws.com/Duchateau-2011.pdf

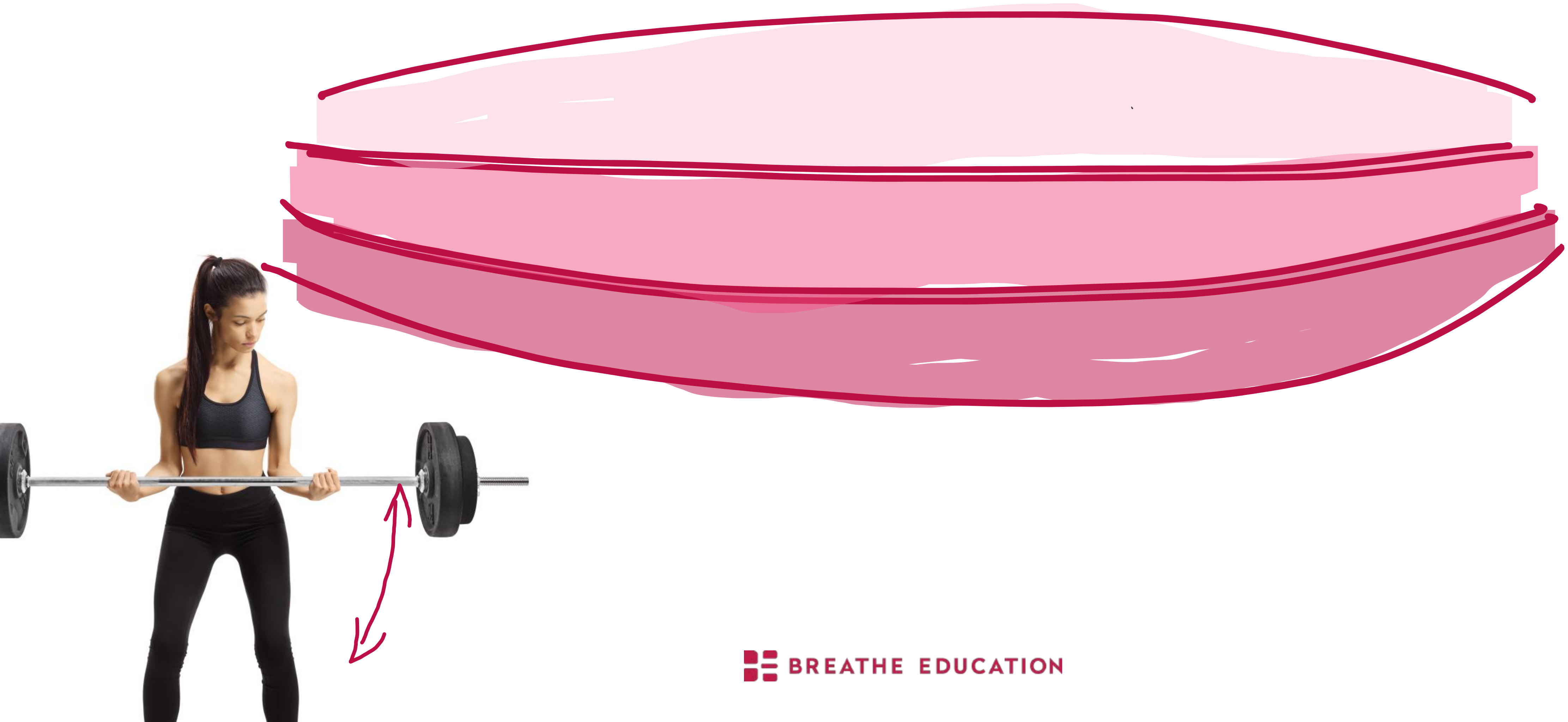
Adam, A., & De Luca, C. J. (2003). Recruitment order of motor units in human vastus lateralis muscle is maintained during fatiguing contractions. Journal of neurophysiology, 90(5), 2919-2927 https://breathe-edu-downloads.s3.amazonaws.com/Adam-2003.pdf

Your largest motor units are only subject to tension for the final ~10 reps before failure.



When you lift light loads, to maximally stimulate your largest motor units, and thus your entire muscle, you must work **very close to failure**

When you lift heavy loads › 85% of your max, all your motor units are recruited and subjected to high levels of tension from the first rep



1 set to failure with a light load you can do 30 reps

1 set to failure with a heavy load you can only do 6 reps

That's why if you take your sets near failure, sets from 6 reps – 30 reps result in identical muscle growth

Because either way, only the last ~10 reps recruit high threshold motor units and subject them to high levels of mechanical tension

Lopez, P., Radaelli, R., Taaffe, D. R., Newton, R. U., Galvão, D. A., Trajano, G. S., . . . Pinto, R. S. (2021). Resistance Training Load Effects on Muscle Hypertrophy and Strength Gain: Systematic Review and Network Meta-analysis. Med Sci Sports Exerc, 53(6), 1206-1216. doi:10.1249/mss.0000000000002585 https://breathe-edu-downloads.s3.amazonaws.com/Lopez-2021.pdf

Same muscle growth

=

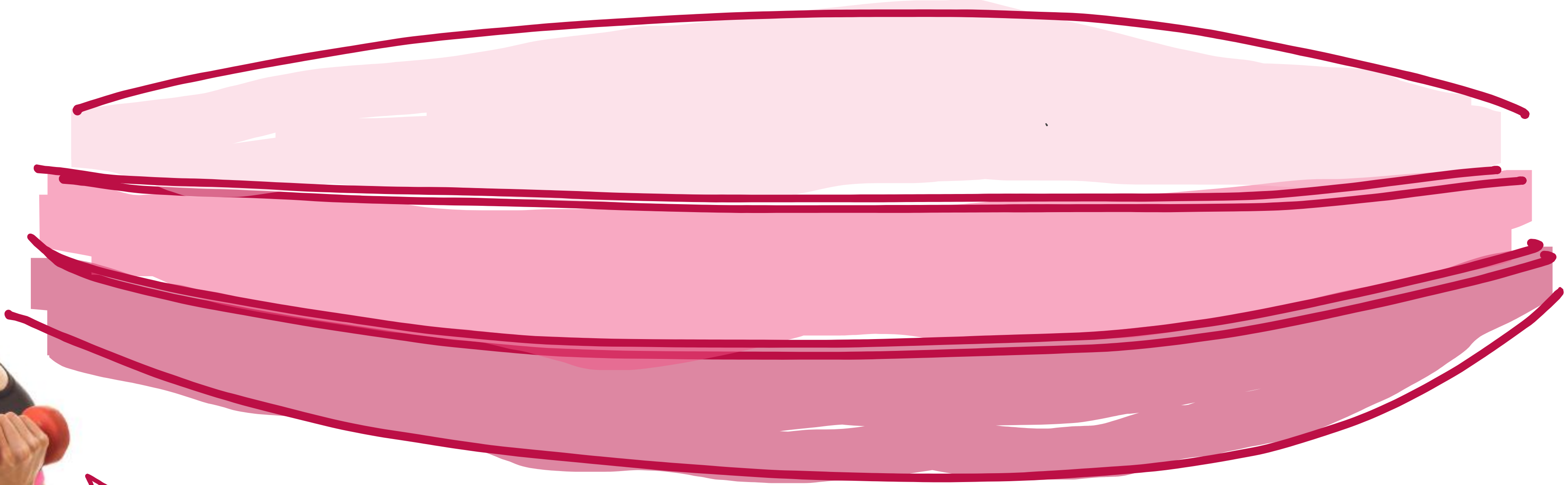
=

1 set of 30 reps to failure

1 set of 12 reps to failure

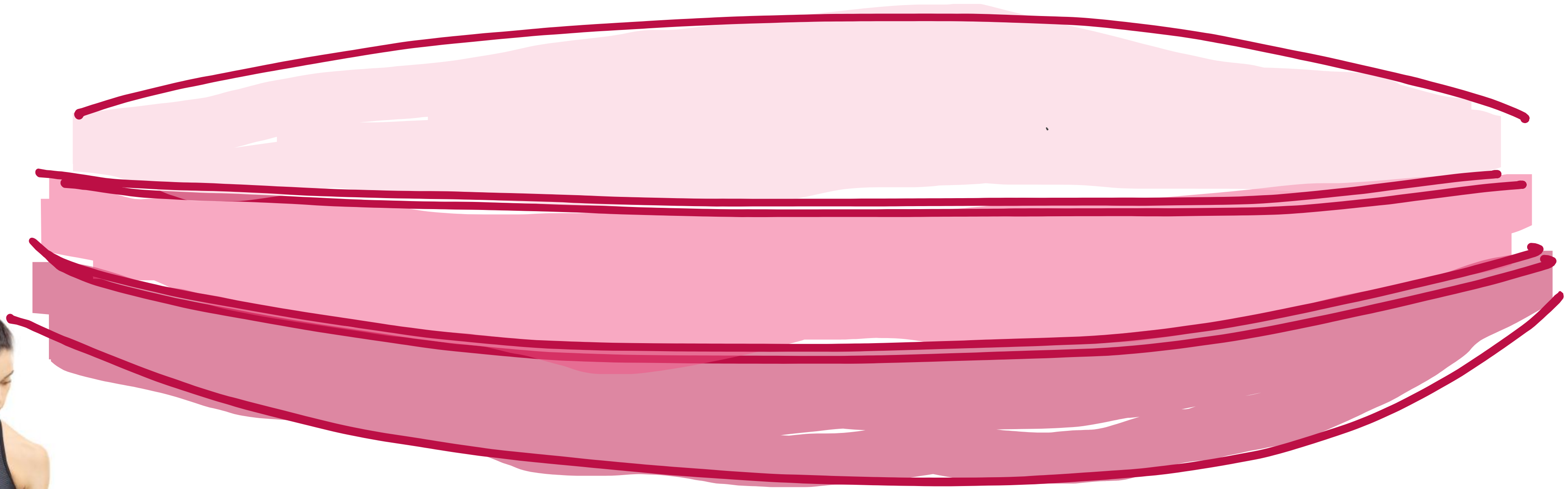
1 set of 6 reps to failure

When you lift light or moderate loads to failure, only a faction of your motor units are active at any one time



Thus subjecting individual motor units to high levels of tension, but never subjecting the whole muscle organ or its tendon to high levels of tension.

When you lift heavy loads >85% of your max you recruit all your motor units at the same time



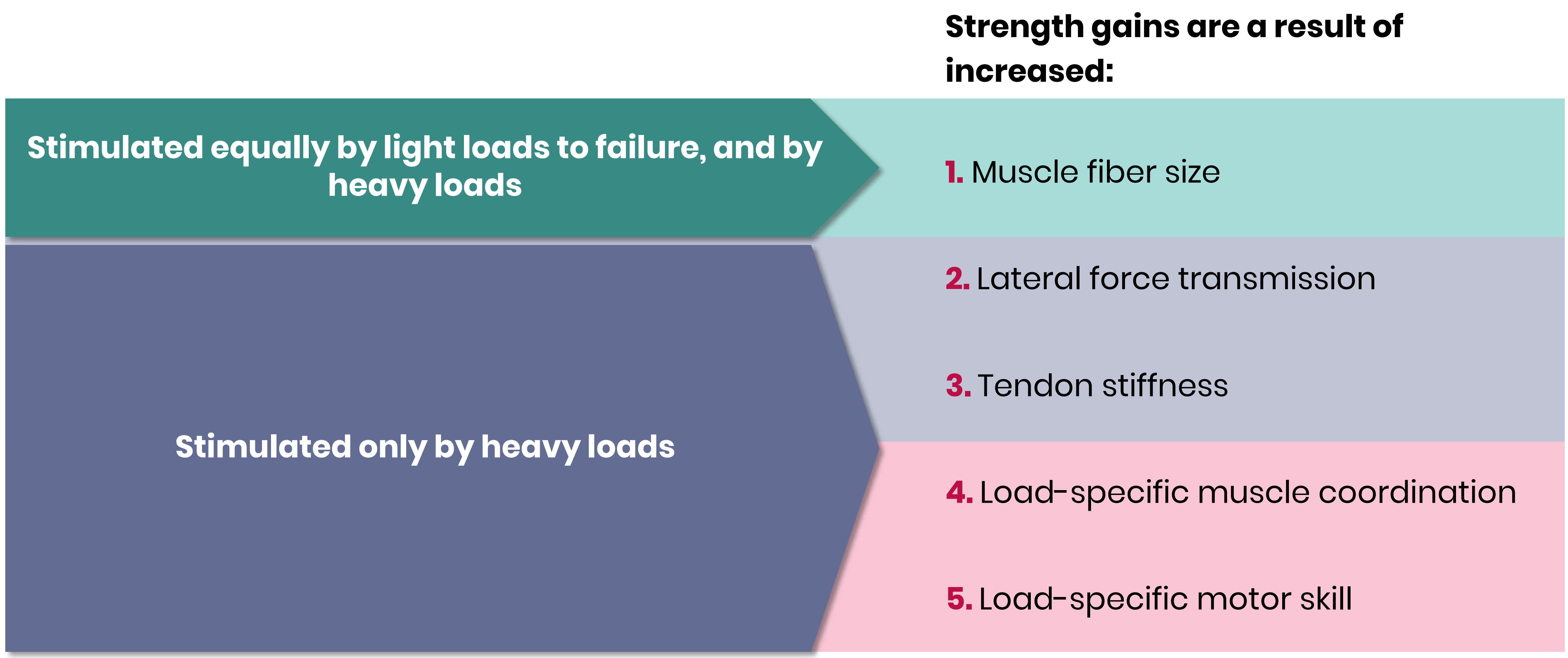
Stimulating costamere production, tendon collagen deposition, high load-specific muscle coordination & high load-specific motor skill

Strength gains are a result of increased:

Results from high levels of tension on individual fibers → 1. Muscle fiber size

Results from high levels of tension on the whole muscle-tendon unit → 2. Lateral force transmission; 3. Tendon stiffness

Results from practice lifting heavy loads → 4. Load-specific muscle coordination; 5. Load-specific motor skill



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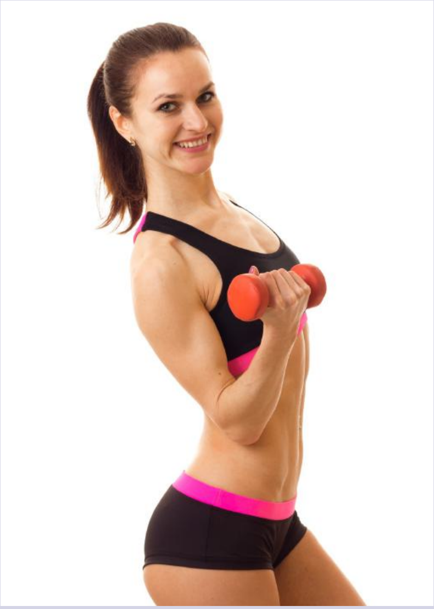
That's why **heavier loads build more strength**

Good



1 set of 30 reps to failure

Better

1 set of 12 reps to failure

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Best

1 set of 6 reps to failure

Lopez, P., Radaelli, R., Taaffe, D. R., Newton, R. U., Galvão, D. A., Trajano, G. S., . . . Pinto, R. S. (2021). Resistance Training Load Effects on Muscle Hypertrophy and Strength Gain: Systematic Review and Network Meta-analysis. Med Sci Sports Exerc, 53(6), 1206-1216. doi:10.1249/mss.0000000000002585 https://breathe-edu-downloads.s3.amazonaws.com/Lopez-2021.pdf

Most people self-select loads that are too light to produce results

- The median gym lifter selects a load where they can do ~20 reps, **for sets of 10 reps**
- This means most people stop ~10 reps before failure
- Stopping 10 reps from failure may stimulate **minimal or no** hypertrophy & strength

Steele, J., Malleron, T., Har-Nir, I., Androulakis-Korakakis, P., Wolf, M., Fisher, J. P., & Halperin, I. (2022). Are Trainees Lifting Heavy Enough? Self-Selected Loads in Resistance Exercise: A Scoping Review and Exploratory Meta-analysis. Sports Medicine, 52(12), 2909-2923. https://breathe-edu-downloads.s3.amazonaws.com/Steele-2022.pdf

Robinson, Z., Pelland, J., Remmert, J., Refalo, M., Jukic, I., Steele, J., & Zourdos, M. (2023). Exploring the Dose-Response Relationship Between Estimated Resistance Training Proximity to Failure, Strength Gain, and Muscle Hypertrophy: A Series of Meta-Regressions. https://breathe-edu-downloads.s3.amazonaws.com/Robinson-2023.pdf

Self Test

- When you lift a light load to failure what sequence are your motor units recruited in?
- How much load is needed to recruit all motor units together from the first rep?
- Why do lifting light loads to failure, and lifting heavy loads, both cause the same amount of muscle growth?
- Why does lifting heavy loads cause more strength gains than lifting light loads to failure?

Learning goals

- Why strength & hypertrophy are not the same thing
- The primary stimulus for hypertrophy is high levels of mechanical tension on individual muscle fibers, the primary stimulus for strength is high levels of mechanical tension on the MTU
- **1-20 RM builds strength, 6-30RM builds muscle**

1–20RM builds strength…

6–30RM builds muscle

Aka it's a continuum not a dichotomy

RM = repetition maximum

12RM is the maximum load you can lift for 12 reps

7RM is the maximum load you can lift for 7 reps

1RM is the maximum load you can lift once

“Maximum load you can lift for 12 reps” means

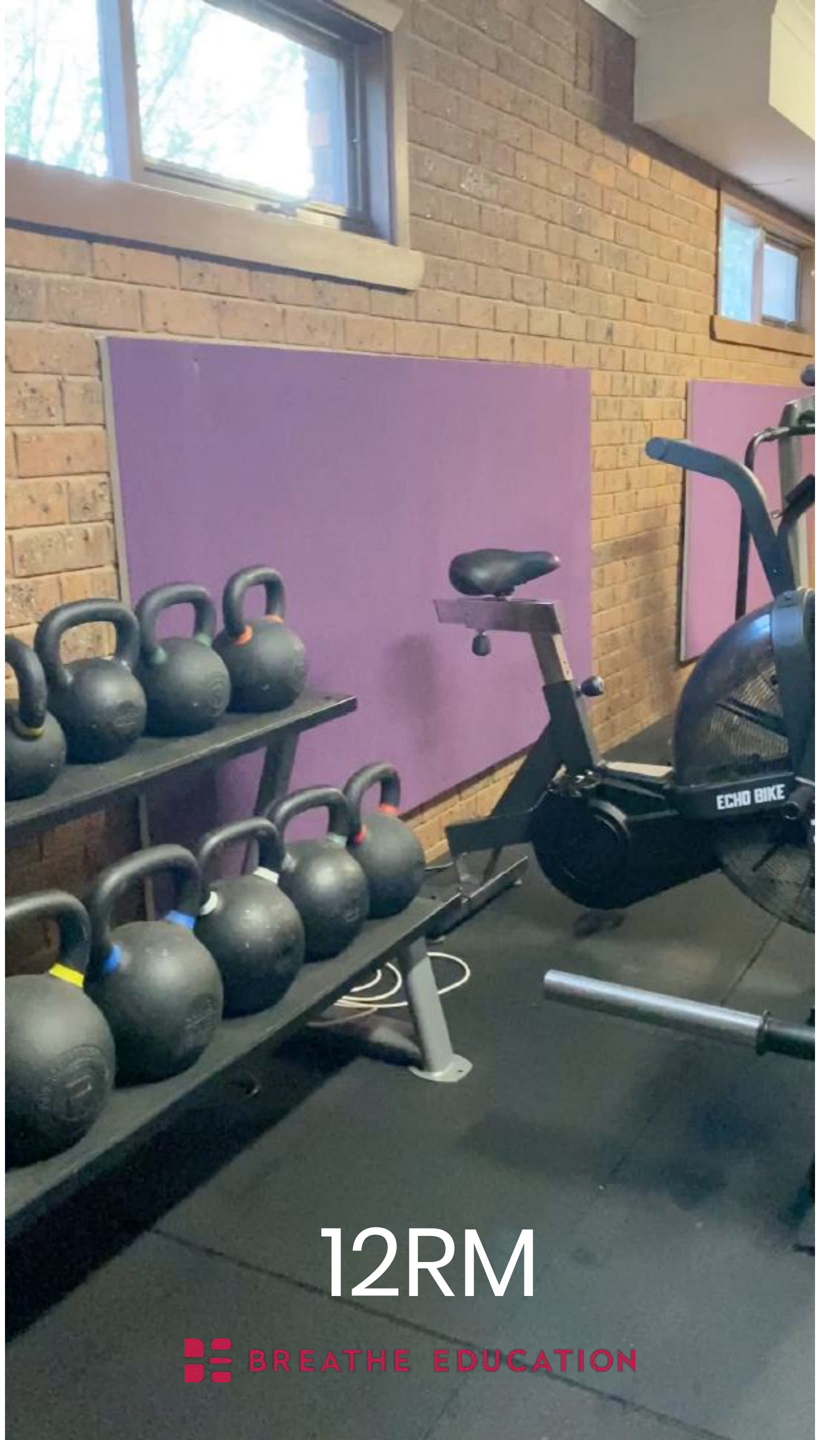
After 12 reps you **cannot continue**

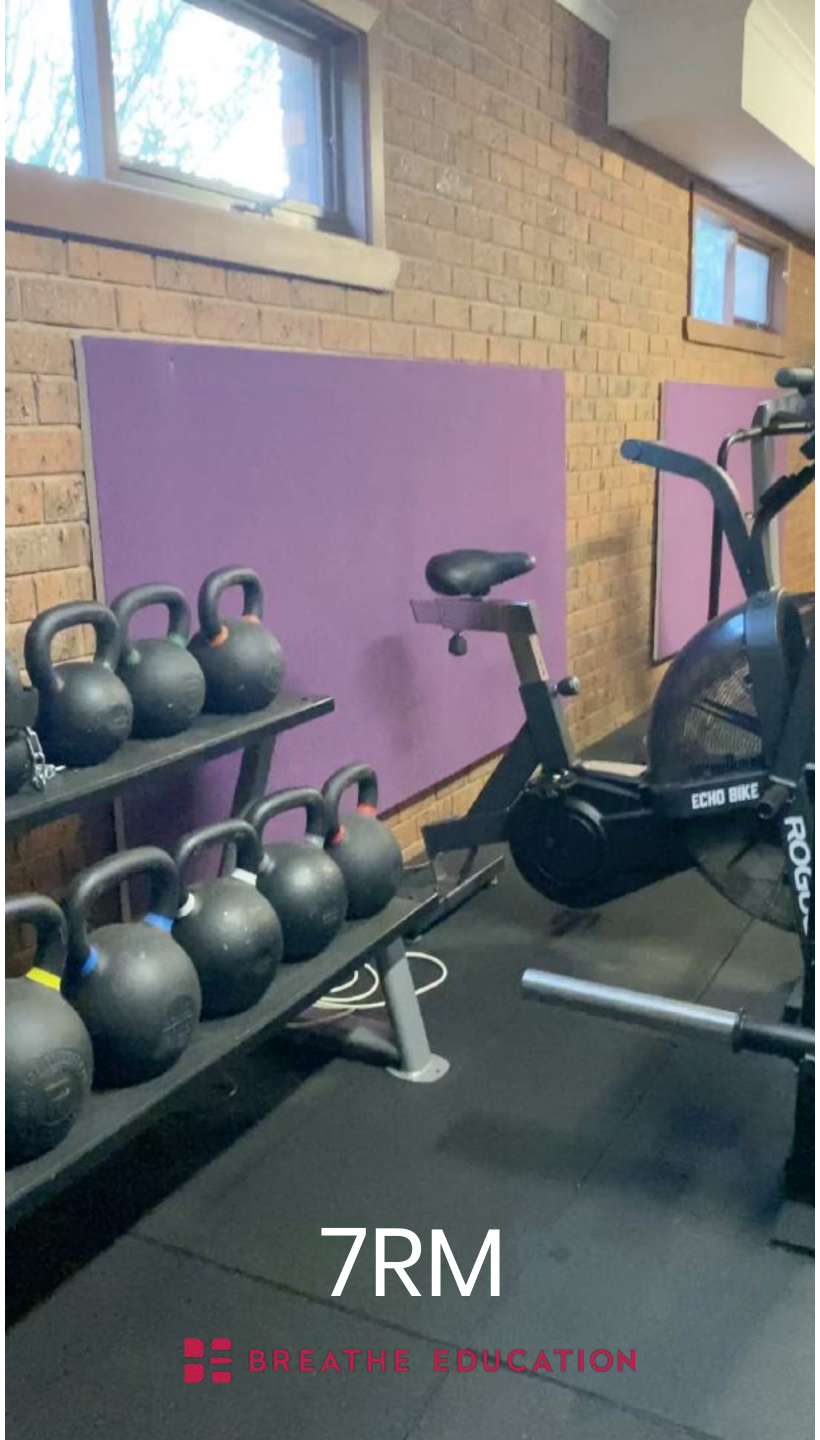
Or in other words, you hit **muscular failure**

Muscular failure

You cannot complete another rep in good form

What muscular failure looks like 👉


ECHO BIKE
12RM
BREATHE EDUCATION



7RM

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We express load as either

RM (repetition maximum) e.g. 7 RM = you can do 7 reps and fail on the 8^{th} rep

A percentage of your 1RM e.g. 85% of your 1RM

RM Max reps before failure	**% of your 1RM**	**Intensity**
51+	0-35%	Very light
21-50	40-55%	Light
11-20	60-75%	Moderate
1-10	80-100%	Heavy

Low intensity cardio

Hypertrophy zone 6-30+ reps **IF** you train near failure

Strength zone 1-20 RM, **maximized** at 1-10 RM

Nuzzo, J. L., Pinto, M. D., Nosaka, K., & Steele, J. (2023). Maximal Number of Repetitions at Percentages of the One Repetition Maximum: A Meta-Regression and Moderator Analysis of Sex, Age, Training Status, and Exercise. Sports Med. doi:10.1007/s40279-023-01937-7 https://breathe-edu-downloads.s3.amazonaws.com/Nuzzo-2023.pdf

Schoenfeld, B. J., Grgic, J., Ogborn, D., & Krieger, J. W. (2017). Strength and Lopez, P., Radaelli, R., Taaffe, D. R., Newton, R. U., Galvão, D. A., Trajano, G. S., . . . Pinto, R. S. (2021). Resistance Training Load Effects on Musce Hypertrophy and Strength Gain: Systematic Review and Network Meta-analysis. Med Sci Sports Exerc, 53(6), 12061216.doi:10.1249/mss.0000000000002585 https://breathe-edu-downloads.s3.amazonaws.com/Lopez-2021.pdf

Lacio, M., Vieira, J. G., Trybulski, R., Campos, Y., Santana, D., Filho, J. E., . . . Wilk, M. (2021). Effects of Resistance Training Performed with Different Loads in Untrained and Trained Male Adult Individuals on Maximal Strength and Muscle Hypertrophy: A Systematic Review. International journal of environmental resea 18(21), 11237. Retrieved from https://breathe-edu-downloads.s3.amazonaws.com/Lacio-2

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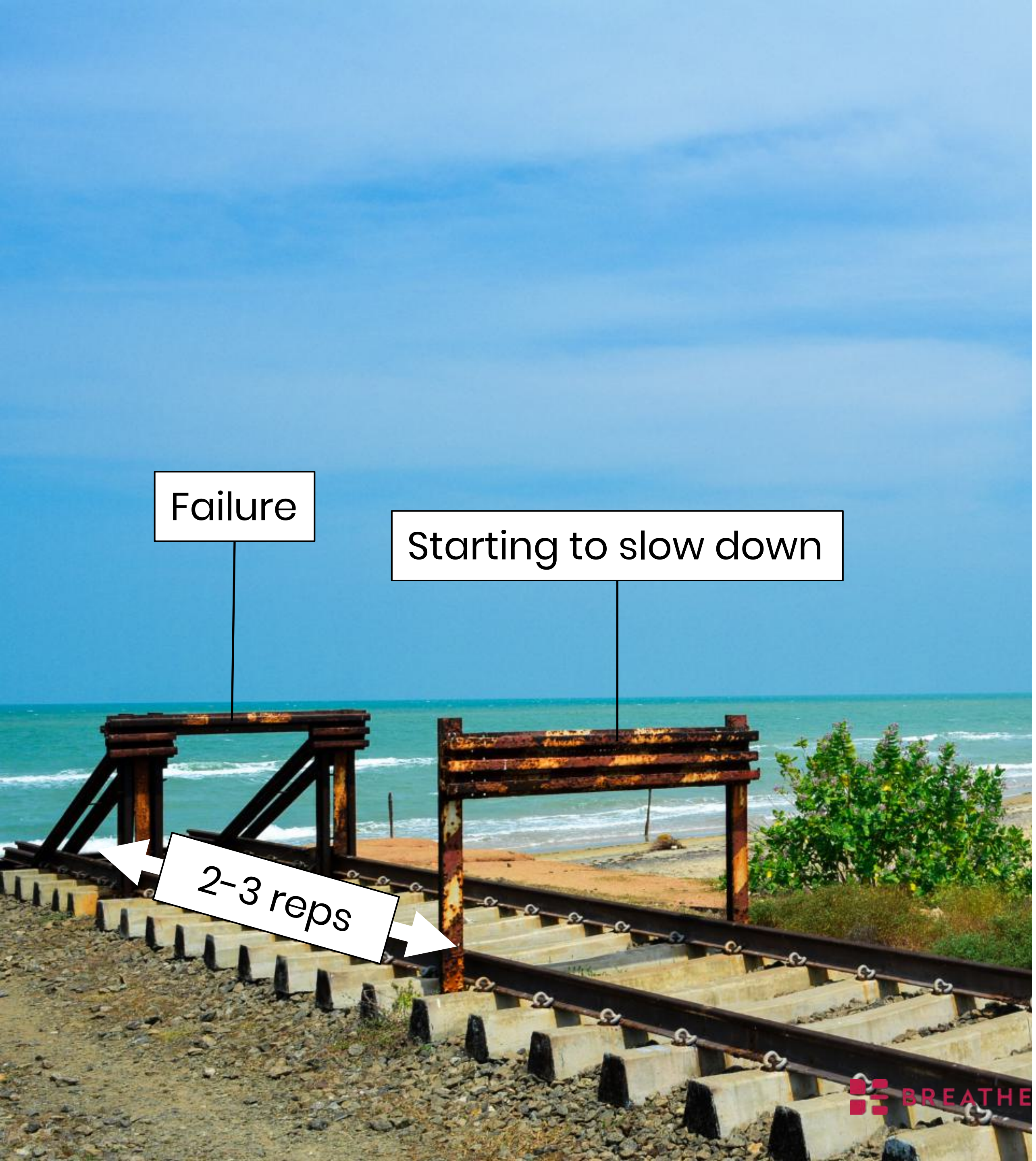
Self Test

- What does 10RM mean?
- How can you tell if you've reached muscular failure?
- What rep range will cause hypertrophy (aka muscle growth)?
- What rep range will increase strength?
- To maximize strength, you need to work at least ___RM or ___% of your maximum
- True/False: If you can do 51+ reps you're unlikely to build strength OR muscle

Learning goals

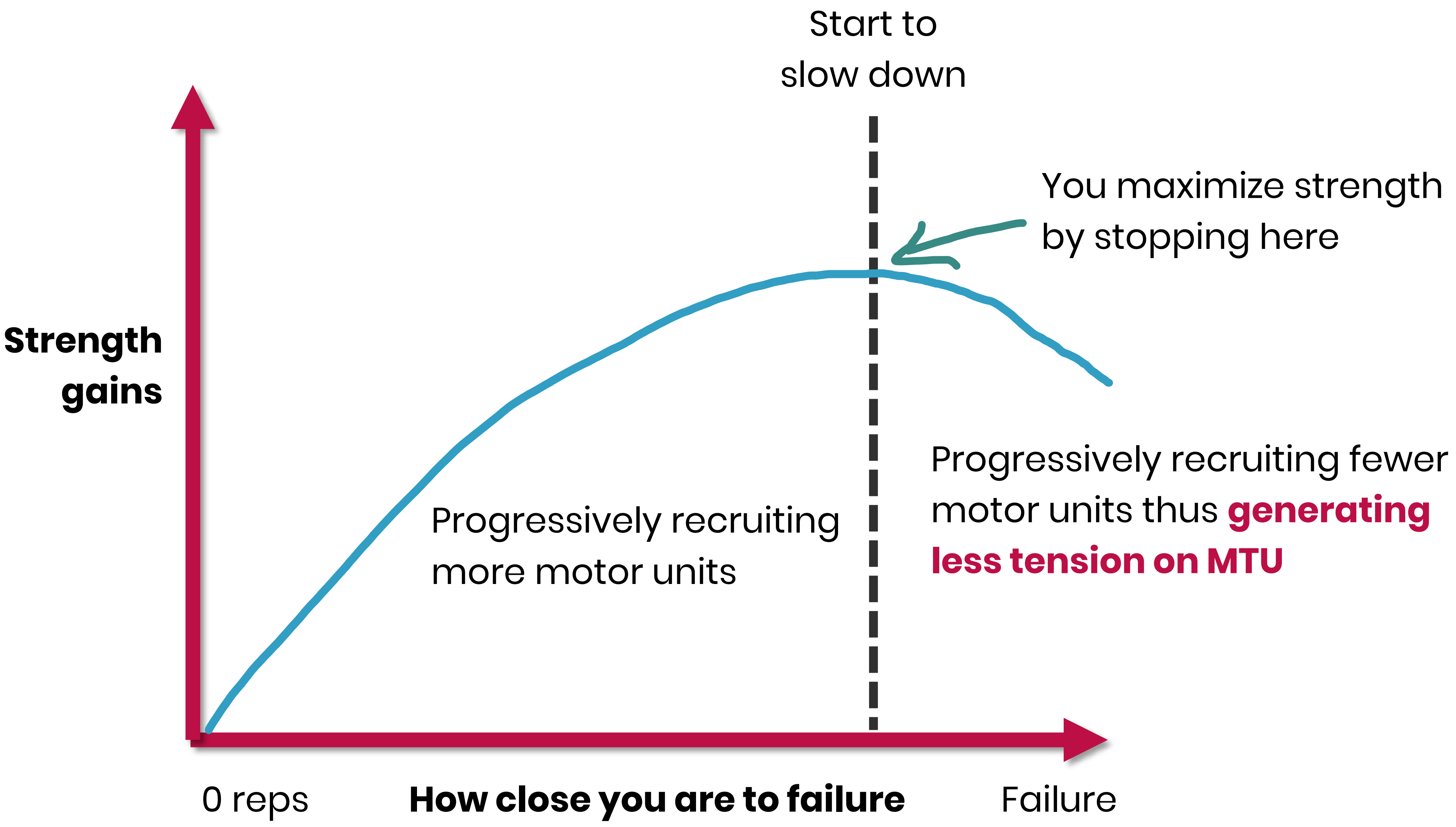
- Why strength & hypertrophy are not the same thing
- The primary stimulus for hypertrophy is high levels of mechanical tension on individual muscle fibers, the primary stimulus for strength is high levels of mechanical tension on the MTU
- 1-20 RM builds strength, 6-30RM builds muscle
- **To maximize strength, stop 2-3 reps before failure, to maximize hypertrophy go to failure**



To maximize strength, **stop each set when you start to slow down**

This is ~2-3 reps before failure

Grgic, J., Schoenfeld, B. J., Orazem, J., & Sabol, F. (2021). Effects of resistance training performed to repetition failure or non-failure on muscular strength and hypertrophy: a systematic review and meta-analysis. Journal of sport and health science. https://be-research-papers.s3.amazonaws.com/Diploma+lecture+research+papers/Lecture+8+Strength/Grgic-2021-Effects+of+resistance+training+perf.pdf



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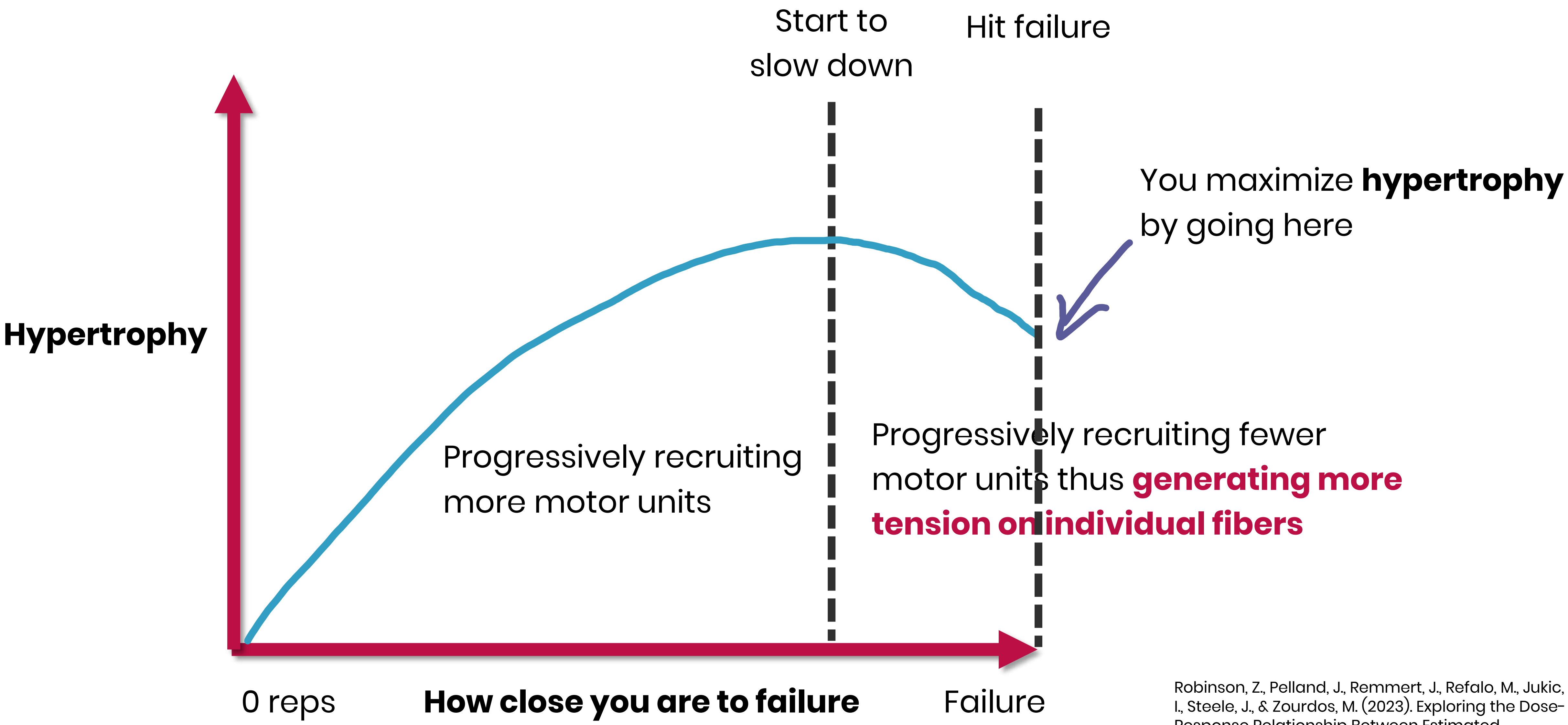
Jukic, I., Castilla, A. P., Ramos, A. G., Van Hooren, B., McGuigan, M. R., & Helms, E. R. (2023). The Acute and Chronic Effects of Implementing Velocity Loss Thresholds During Resistance Training: A Systematic Review, Meta-Analysis, and Critical Evaluation of the Literature. Sports Medicine, 53(1), 177-214. doi:10.1007/s40279-022-01754-4 https://breathe-edu-downloads.s3.amazonaws.com/Jukic-2023.pdf

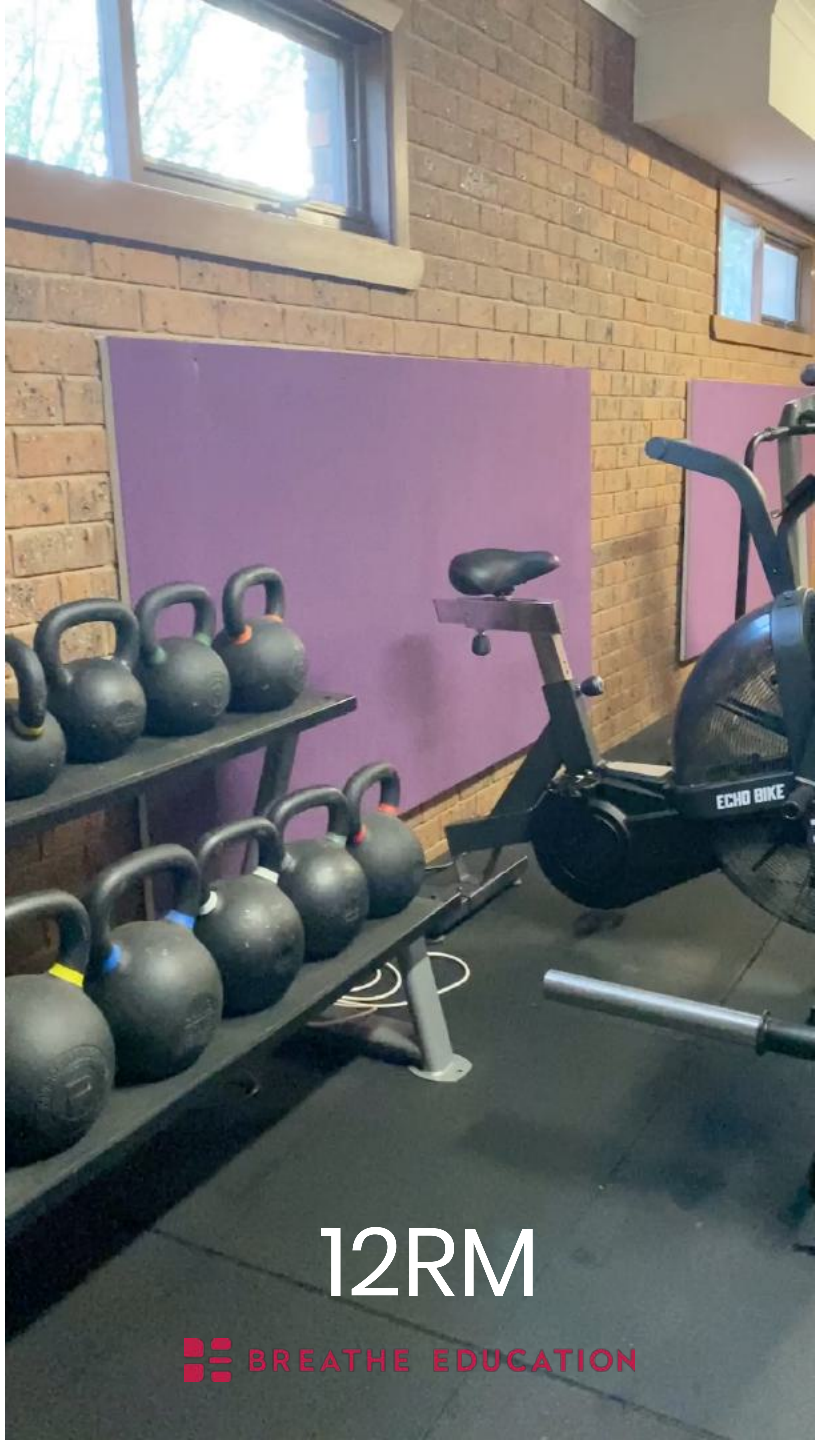
Piqueras-Sanchiz, F., Cornejo-Daza, P. J., Sánchez-Valdepeñas, J., Bachero-Mena, B., Sánchez-Moreno, M., Martín-Rodríguez, S., . . . Pareja-Blanco, F. (2022). Acute mechanical, neuromuscular, and metabolic responses to different set configurations in resistance training. Journal of Strength and Conditioning Research, 36(11), 2983-2991.

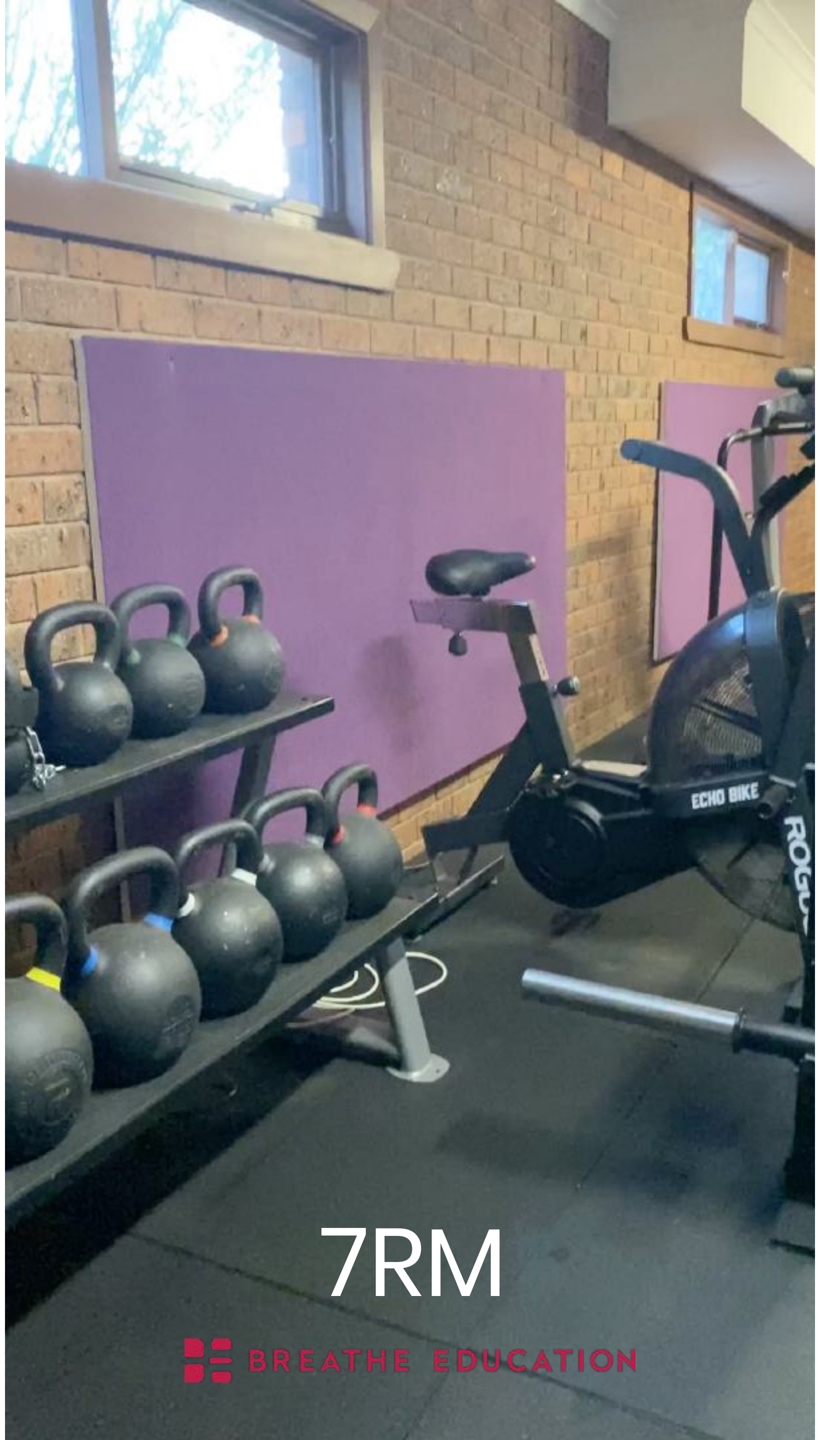


Robinson, Z., Pelland, J., Remmert, J., Refalo, M., Jukic, I., Steele, J., & Zourdos, M. (2023). Exploring the Dose-Response Relationship Between Estimated Resistance Training Proximity to Failure, Strength Gain, and Muscle Hypertrophy: A Series of Meta-Regressions. https://breathe-edu-downloads.s3.amazonaws.com/Robinson-2023.pdf

Can you spot when I start to slow down?

This is where I should stop the set, if I want to maximize strength


ECHO BIKE
12RM
BREATHE EDUCATION


ECHO BIKE
7RM
BREATHE EDUCATION

Self Test

- To maximize strength, stop when you ___, to maximize hypertrophy stop when you ____
- True/False: Muscular failure is where it starts to burn real bad
- How can you tell when you're at muscular failure?
- How can you tell when you are 2–3 reps short of failure?

Learning goals

- Why strength & hypertrophy are not the same thing
- The primary stimulus for hypertrophy is high levels of mechanical tension on individual muscle fibers, the primary stimulus for strength is high levels of mechanical tension on the MTU
- 1-20 RM builds strength,
  6-30RM builds muscle
- To maximize strength, stop 2-3 reps before failure, to maximize hypertrophy go to failure
- **Things NOT required for strengthening**

Things **not** required for strengthening…

1. **Cueing muscle activation**
2. **Muscle damage**
3. **Exercise variety & muscle confusion**
4. **Feeling the burn & DOMS**
5. **Instability**

Increased activation does not result in increased strengthening

Remember that the critical stimulus for strengthening is…

High levels of mechanical tension on individual muscle fibers?

Activating **more muscle fibers** with the same load...

Decreases the tension on each fiber

Therefore, decreasing the strengthening stimulus

To get stronger... **add more load**

J Appl Physiol 126: 30–43, 2019.
First published October 18, 2018; doi:10.1152/japplphysiol.00685.2018.

REVIEW | *Synthesis*

Stimuli and sensors that initiate skeletal muscle hypertrophy following resistance exercise

Henning Wackerhage,[1] Brad J. Schoenfeld,[2] D. Lee Hamilton,[3] Maarit Lehti,[4] and Juha J. Hulmi[5]
[1]Department of Sport and Exercise Sciences, Technical University of Munich, Munich, Germany; [2]CUNY Lehman College, Bronx, New York; [3]Faculty of Health, School of Exercise and Nutrition Sciences, Deakin University, Victoria, Australia; [4]LIKES Research Centre for Physical Activity and Health, Jyväskylä, Finland; and [5]Neuromuscular Research Center, Biology of Physical Activity, Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland

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Wackerhage H, Schoenfeld BJ, Hamilton DL, Lehti M, Hulmi JJ. Stimuli and sensors that initiate skeletal muscle hypertrophy following resistance exercise. *J Appl Physiol* 126: 30–43, 2019. First published October 18, 2018; doi:10.1152/japplphysiol.00685.2018.—One of the most striking adaptations to exercise is the skeletal muscle hypertrophy that occurs in response to resistance exercise. A large body of work shows that a mammalian target of rapamycin complex 1 (mTORC1)-mediated increase of muscle protein synthesis is the key, but not sole, mechanism by which resistance exercise causes muscle hypertrophy. While much of the hypertrophy signaling cascade has been identified, the initiating, resistance exercise-induced and hypertrophy-stimulating stimuli have remained elusive. For the purpose of this review, we define an initiating, resistance exercise-induced and hypertrophy-stimulating signal as "hypertrophy stimulus," and the sensor of such a signal as "hypertrophy sensor." In this review we discuss our current knowledge of specific mechanical stimuli, damage/injury-associated and metabolic stress-associated triggers, as potential hypertrophy stimuli. Mechanical signals are the prime hypertrophy stimuli candidates, and a filamin-C-BAG3-dependent regulation of mTORC1, Hippo, and autophagy signaling is a plausible albeit still incompletely characterized hypertrophy sensor. Other candidate mechanosensing mechanisms are nuclear deformation-initiated signaling or several mechanisms related to costameres, which are the functional equivalents of focal adhesions in other cells. While exercise-induced muscle damage is probably not essential for hypertrophy, it is still unclear whether and how such muscle damage could augment a hypertrophic response. Interventions that combine blood flow restriction and especially low load resistance exercise suggest that resistance exercise-regulated metabolites could be hypertrophy stimuli, but this is based on indirect evidence and metabolite candidates are poorly characterized.

hypertrophy; mechanotransduction; signal transduction; skeletal muscle

There is no direct evidence muscle damage has any role in stimulating strength gains

How exhausted and shattered you are after a workout does not influence muscle growth or strength.

Training to the point of exhaustion probably just reduces your force output, lengthens recovery times and increases injury risk

Wackerhage, H., Schoenfeld, B. J., Hamilton, D. L., Lehti, M., & Hulmi, J. J. (2019). Stimuli and sensors that initiate skeletal muscle hypertrophy following resistance exercise. Journal of Applied Physiology. https://breathe-edu-downloads.s3.amazonaws.com/Wackerhage-2019.pdf

Brief Review

The Journal of Strength and Conditioning Research

Does Varying Resistance Exercises Promote Superior Muscle Hypertrophy and Strength Gains? A Systematic Review

Witalo Kassiano,[1] João Pedro Nunes,[1] Bruna Costa,[1] Alex S. Ribeiro,[1,2] Brad J. Schoenfeld,[3] and Edilson S. Cyrino[1]

[1]*Metabolism, Nutrition and Exercise Laboratory, Physical Education and Sport Center, State University of Londrina, Londrina, Brazil;* [2]*Center for Research in Health Sciences, University of Northern of Paranà, Londrina, Brazil; and* [3]*Health Sciences Department, CUNY Lehman College, Bronx, New York*

Abstract

Kassiano, W, Nunes, JP, Costa, B, Ribeiro, AS, Schoenfeld, BJ, and Cyrino, ES. Does varying resistance exercises promote superior muscle hypertrophy and strength gains? A systematic review. *J Strength Cond Res* 36(6): 1753–1762, 2022—Fitness professionals routinely employ a variety of resistance training exercises in program design as a strategy to enhance muscular adaptations. However, it remains uncertain whether such an approach offers advantages over a fixed-exercise selection. The objective of this review was to review the effects of exercise variation on muscle hypertrophy and strength. A search of the literature was conducted using PubMed/MEDLINE, Scopus, and Web of Science databases. Eight studies were identified as meeting inclusion criteria. The combined total sample of the studies was $N = 241$, comprising all young men. The methodological quality of included studies was considered "good" and "excellent" based on the Physiotherapy Evidence Database Scale. The available studies indicate that varying exercise selection can influence muscle hypertrophy and strength gains. Some degree of systematic variation seems to enhance regional hypertrophic adaptations and maximize dynamic strength, whereas excessive, random variation may compromise muscular gains. We conclude that exercise variation should be approached systematically with a focus on applied anatomical and biomechanical constructs; on the contrary, employing different exercises that provide a redundant stimulus, as well as excessive rotation of different exercises (i.e., high frequency of change), may actually hinder muscular adaptations.

Key Words: strength training, exercise variation, muscle size, programming

"Excessive, random variation (in exercises) may compromise muscular gains."

Variety is not what stimulates strength or hypertrophy

The key stimulus for both strength and hypertrophy is high levels of mechanical tension

LOAD, not variety is key for results

Kassiano, W., Nunes, J. P., Costa, B., Ribeiro, A. S., Schoenfeld, B. J., & Cyrino, E. S. (2022). Does Varying Resistance Exercises Promote Superior Muscle Hypertrophy and Strength Gains? A Systematic Review. The Journal of Strength & Conditioning Research, 36(6), 1753-1762. doi:10.1519/jsc.0000000000004258 https://breathe-edu-downloads.s3.amazonaws.com/Kassiano-2022.pdf

Exercise variety is not necessary for strengthening

- The key stimulus for strengthening is high levels of mechanical tension on individual muscle fibers.
- Changing exercises reduces tension on some muscles and increases tension on other muscles
- To strengthen a muscle, it needs high levels of mechanical tension applied consistently over time
- Therefore, **doing the same exercises consistently over time with progressive overload** is the most effective strategy to build strength

The key stimulus for strength gains is **mechanical tension**

Not

- Fatigue
- Activation
- Muscle confusion / exercise variety

Schoenfeld, B. J. (2012). Does exercise-induced muscle damage play a role in skeletal muscle hypertrophy? The Journal of Strength & Conditioning Research, 26(5), 1441-1453. https://breathe-edu-downloads.s3.amazonaws.com/Schoenfeld-2012.pdf

Ashida, Y., Himori, K., Tatebayashi, D., Yamada, R., Ogasawara, R., & Yamada, T. (2018). Effects of contraction mode and stimulation frequency on electrical stimulation-induced skeletal muscle hypertrophy. Journal of Applied Physiology, 124(2), 341-348. https://breathe-edu-downloads.s3.amazonaws.com/Ashida-2018.pdf

Burkholder, T. J. (2007). Mechanotransduction in skeletal muscle. Frontiers in bioscience: a journal and virtual library, 12, 174 https://breathe-edu-downloads.s3.amazonaws.com/Burkholder-2007.pdf

Rindom, E., Kristensen, A. M., Overgaard, K., Vissing, K., & de Paoli, F. V. (2019). Activation of mTORC1 signalling in rat skeletal muscle is independent of the EC-coupling sequence but dependent on tension per se in a dose-response relationship. Acta physiologica, 227(3), e13336. https://breathe-edu-downloads.s3.amazonaws.com/Rindom-2019.pdf

Why feeling the burn does **not** mean you're getting stronger

- The feeling of burning is caused by lactate & free hydrogen ion accumulation in the muscle as a result of anaerobic glycolysis
- Getting stronger is a result of high levels of mechanical tension
- Lactate & hydrogen ion accumulation ≠ high levels of mechanical tension

Pollak, K. A., Swenson, J. D., Vanhaitsma, T. A., Hughen, R. W., Jo, D., Light, K. C., . . . Light, A. R. (2014). Exogenously applied muscle metabolites synergistically evoke sensations of muscle fatigue and pain in human subjects. Experimental physiology, 99(2), 368-380. https://breathe-edu-downloads.s3.amazonaws.com/Pollak-2014.pdf

BREATHE EDUCATION

DOMS is **not** a good indicator you're building strength

- DOMS = delayed onset muscle soreness
- DOMS may be related to muscle damage and/or calcium ion accumulation in the muscle cell
- Strengthening is triggered by high levels of mechanical tension
- Muscle damage & calcium ion accumulation ≠ high levels of mechanical tension

Schoenfeld, B. J., & Contreras, B. (2013). Is postexercise muscle soreness a valid indicator of muscular adaptations? Strength & Conditioning Journal, 35(5), 16-21. https://dip2022.s3.amazonaws.com/Lecture%207/Schoenfeld-2013-Is%20postexercise%20muscle%20sorenes.pdf

Effect of Repetition Duration–Total and in Different Muscle Actions–On the Development of Strength, Power, and Muscle Hypertrophy: A Systematic Review

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Lifting **fast**...

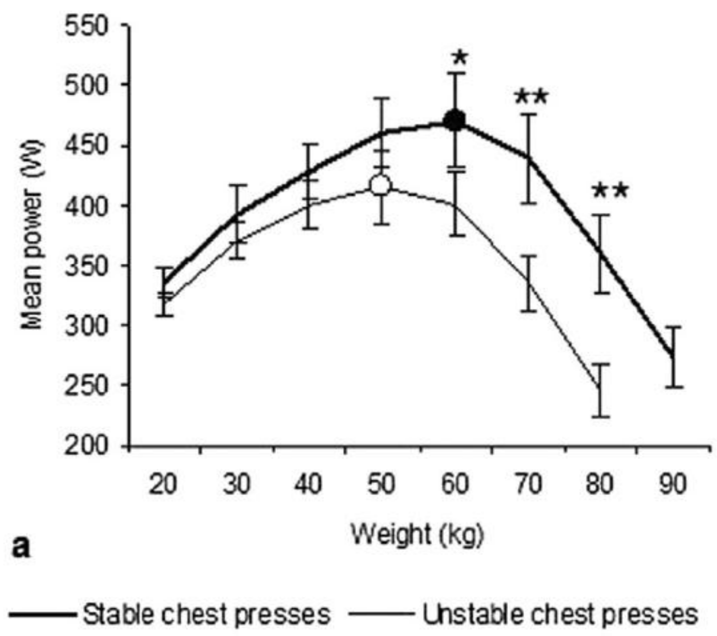
And lowering at half speed works best

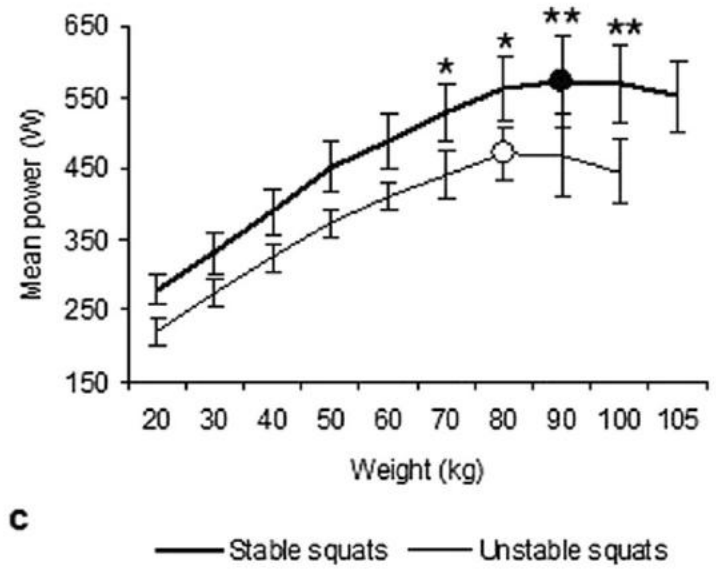
- 1 second or less concentric (lifting)
- 2-4 seconds eccentric (lowering)

Moreno-Villanueva, A., Pino-Ortega, J., & Rico-González, M. (2022). Effect of repetition duration—total and in different muscle actions—on the development of strength, power, and muscle hypertrophy: a systematic review. Strength and Conditioning Journal, 44(5), 39-56. https://breathe-edu-downloads.s3.amazonaws.com/Moreno-Villanueva-2022.pdf

González-Badillo, J. J., Rodríguez-Rosell, D., Sánchez-Medina, L., Gorostiaga, E. M., & Pareja-Blanco, F. (2014). Maximal intended velocity training induces greater gains in bench press performance than deliberately slower half-velocity training. European journal of sport science, 14(8), 772-781. https://breathe-edu-downloads.s3.amazonaws.com/Gonz%C3%A1lez-Badillo-2014.pdf

Tøien, T., Malmo, T., Espedal, L., & Wang, E. (2022). Maximal intended velocity enhances strength training-induced neuromuscular stimulation in older adults. European journal of applied physiology, 122(12), 2627-2636. https://breathe-edu-downloads.s3.amazonaws.com/T%C3%B8ien-2022.pdf



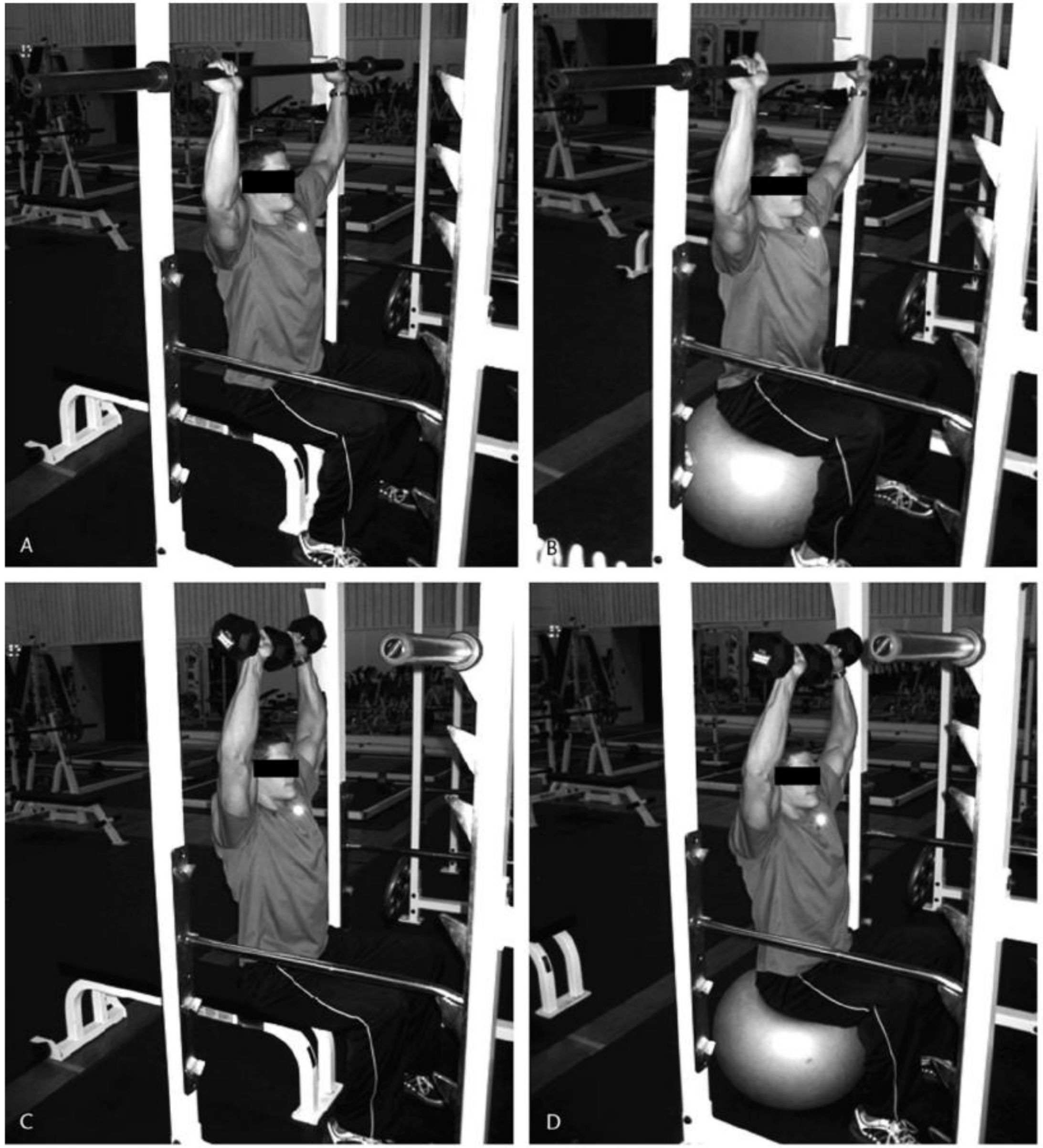


Training on unstable surfaces reduces force production

This reduces mechanical tension

Probably because of increased co-activation of opposing muscles, and decreased activation of prime movers

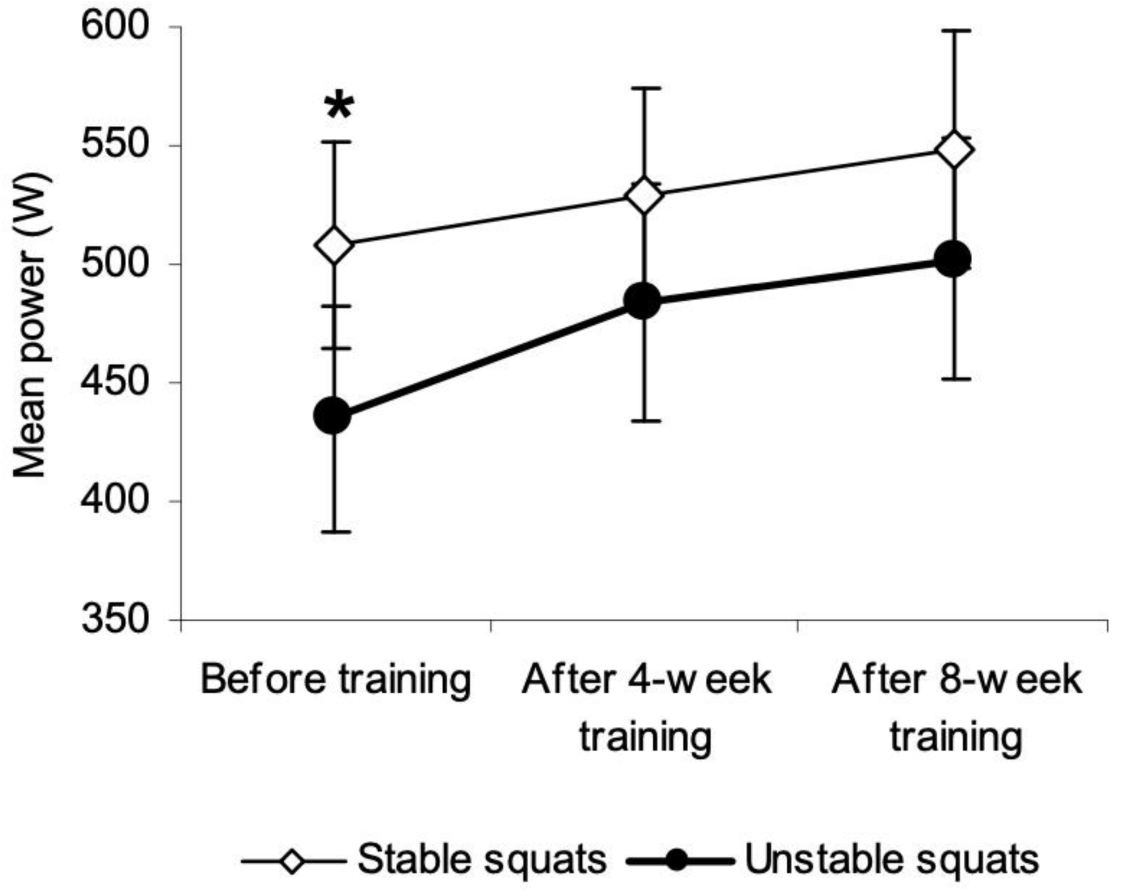
Zemková, E. (2021). Stable to unstable differences in force-velocity-power profiling during chest presses and squats. J Biomech, 122, 110463. doi:10.1016/j.jbiomech.2021.110463 https://breathe-edu-downloads.s3.amazonaws.com/Zemkov%C3%A1-2021.pdf



Overhead shoulder press conditions. A) Stable load/stable surface, (B) stable load/unstable surface, (C) unstable load/stable surface, and (D) unstable load/unstable surface.

As instability goes up, external load goes down

Kohler, J. M., Flanagan, S. P., & Whiting, W. C. (2010). Muscle Activation Patterns While Lifting Stable and Unstable Loads on Stable and Unstable Surfaces. The Journal of Strength & Conditioning Research, 24(2), 313-321. doi:10.1519/JSC.0b013e3181c8655a https://breathe-edu-downloads.s3.amazonaws.com/Kohler-2010.pdf



In line with the principle of specificity, training on unstable surfaces doesn't transfer to stable surfaces

Training on unstable surfaces makes you better at...

Training on unstable surfaces

Zemková, E., Jeleň, M., Cepková, A., & Uvaček, M. (2021). There Is No Cross Effect of Unstable Resistance Training on Power Produced during Stable Conditions. Applied Sciences, 11(8), 3401. https://breathe-edu-downloads.s3.amazonaws.com/Zemkov%C3%A1-2021-b.pdf

Granacher et al. BMC Sports Science, Medicine, and Rehabilitation 2014, 6:40
http://www.biomedcentral.com/2052-1847/6/40

BMC
Sports Science, Medicine & Rehabilitation

RESEARCH ARTICLE Open Access

Effects of core strength training using stable versus unstable surfaces on physical fitness in adolescents: a randomized controlled trial

Urs Granacher[1*], Jörg Schellbach[2], Katja Klein[2], Olaf Prieske[1], Jean-Pierre Baeyens[2,3] and Thomas Muehlbauer[1]

Abstract

Background: It has been demonstrated that core strength training is an effective means to enhance trunk muscle strength (TMS) and proxies of physical fitness in youth. Of note, cross-sectional studies revealed that the inclusion of unstable elements in core strengthening exercises produced increases in trunk muscle activity and thus provide potential extra training stimuli for performance enhancement. Thus, utilizing unstable surfaces during core strength training may even produce larger performance gains. However, the effects of core strength training using unstable surfaces are unresolved in youth. This randomized controlled study specifically investigated the effects of core strength training performed on stable surfaces (CSTS) compared to unstable surfaces (CSTU) on physical fitness in school-aged children.

Methods: Twenty-seven (14 girls, 13 boys) healthy subjects (mean age: 14 ± 1 years, age range: 13–15 years) were randomly assigned to a CSTS (n = 13) or a CSTU (n = 14) group. Both training programs lasted 6 weeks (2 sessions/week) and included frontal, dorsal, and lateral core exercises. During CSTU, these exercises were conducted on unstable surfaces (e.g., TOGU© DYNAIR CUSSIONS, THERA-BAND© STABILITY TRAINER).

Results: Significant main effects of Time (pre vs. post) were observed for the TMS tests (8-22%, $f = 0.47$-0.76), the jumping sideways test (4-5%, $f = 1.07$), and the Y balance test (2-3%, $f = 0.46$-0.49). Trends towards significance were found for the standing long jump test (1-3%, $f = 0.39$) and the stand-and-reach test (0-2%, $f = 0.39$). We could not detect any significant main effects of Group. Significant Time x Group interactions were detected for the stand-and-reach test in favour of the CSTU group (2%, $f = 0.54$).

Conclusions: Core strength training resulted in significant increases in proxies of physical fitness in adolescents. However, CSTU as compared to CSTS had only limited additional effects (i.e., stand-and-reach test). Consequently, if the goal of training is to enhance physical fitness, then CSTU has limited advantages over CSTS.

Trial registration: ClinicalTrials.gov Identifier: NCT02290457 Registered 13 November 2014.

Keywords: Resistance training, Trunk muscle strength, Physical fitness

Core training on unstable surfaces is not more effective than on stable surfaces

Granacher, U., Schellbach, J., Klein, K., Prieske, O., Baeyens, J.-P., & Muehlbauer, T. (2014). Effects of core strength training using stable versus unstable surfaces on physical fitness in adolescents: a randomized controlled trial. BMC sports science, medicine and rehabilitation, 6(1), 40. doi:10.1186/2052-1847-6-40 https://breathe-edu-downloads.s3.amazonaws.com/Granacher-2014.pdf

Sports Med (2015) 45:1645–1669
DOI 10.1007/s40279-015-0384-x

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SYSTEMATIC REVIEW

Effects of Strength Training Using Unstable Surfaces on Strength, Power and Balance Performance Across the Lifespan: A Systematic Review and Meta-analysis

David G. Behm[1] · Thomas Muehlbauer[2] · Armin Kibele[3] · Urs Granacher[2]

Published online: 10 September 2015

Abstract
Background The effectiveness of strength training on unstable surfaces (STU) versus stable surfaces (STS) or a control condition (CON; i.e. no training or regular training only) for strength, power and balance performance across the lifespan has not yet been investigated in a systematic review and meta-analysis.
Objective The aims of this systematic review and meta-analysis were to determine the general effects of STU versus STS or CON on muscle strength, power and balance in healthy individuals across the lifespan and to investigate whether performance changes following STU are age endurance, muscle power, or static/dynamic balance. In total, 22 studies met the inclusion criteria.
Study Appraisal and Synthesis Methods The included studies were coded for the following criteria: age, sex, training status, training modality, exercise and test modality. Effect size measures included within-subject standardized mean differences (SMD_w) and weighted between-subject standardized mean differences (SMD_b). Heterogeneity between studies was assessed using I^2 and χ^2 statistics. The methodological quality of each study was assessed using the Physiotherapy Evidence Database (PEDro) Scale.

No clear evidence unstable training improves strength, power or endurance

Compared to stable surface training

Behm, D. G., Muehlbauer, T., Kibele, A., & Granacher, U. (2015). Effects of Strength Training Using Unstable Surfaces on Strength, Power and Balance Performance Across the Lifespan: A Systematic Review and Meta-analysis. Sports Med, 45(12), 1645-1669. doi:10.1007/s40279-015-0384-x https://breathe-edu-downloads.s3.amazonaws.com/Behm-2015.pdf

More instability does not lead to more strength

- The key stimulus for strengthening is high levels of mechanical tension
- Working with unstable loads, or on unstable surfaces requires you to co-contract multiple muscles around each joint, reducing your total force production
- Which means you have to use lighter loads
- Which results in less tension on the prime mover muscles
- Which results in less strengthening and less hypertrophy
- BUT more skill working on unstable surfaces or with unstable loads

Self Test

- Why does cueing more muscle activation not result in more strengthening of that muscle?
- Why is muscle damage not necessary for strengthening?
- Why is variety not necessary for strengthening?
- Why is feeling the burn not necessary for strengthening?
- Why is DOMS not necessary for strengthening?
- Why does adding instability not result in more strengthening?

Learning goals

- Why strength & hypertrophy are not the same thing
- The primary stimulus for hypertrophy is high levels of mechanical tension on individual muscle fibers, the primary stimulus for strength is high levels of mechanical tension on the MTU
- 1-20 RM builds strength, 6-30RM builds muscle
- To maximize strength, stop 2-3 reps before failure, to maximize hypertrophy go to failure
- Things NOT required for strengthening

Questions?