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Muscle hypertrophy: theory, application and periodization

Something about me

- Jan Cacek, PhD
  - my sports career:
    runner 800 a 1500 m, soccer player, ice hockey player
    3 children (17 – 14 – 11 years old)
  - Vice dean for research and science FSpS MU
  - Chairman of the National Association of Strength and Conditioning Trainers of the C Republic
  - Head of division of Track and Field FSpS MU
  - Study program guarantor „Personal and Strength and Conditioning Trainer“
  - Chief editor of the Journal Studia Sportiva
  - Member of the Methodological Committee of the Czech Athletic Federation and Rowing federation
  - Track and Field and Strength and Conditioning trainer
    Coach of many elite athletes from different sports disciplines

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Determinants of strength and power

- total amount and composition of muscle fibers
- muscular architecture
- hormonal profile
- polymorphism
- neuromuscular factors

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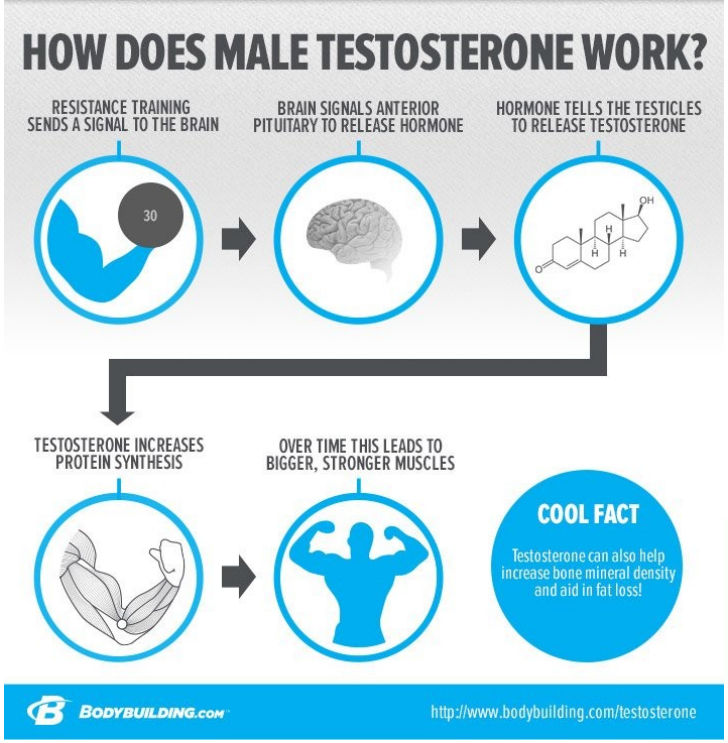


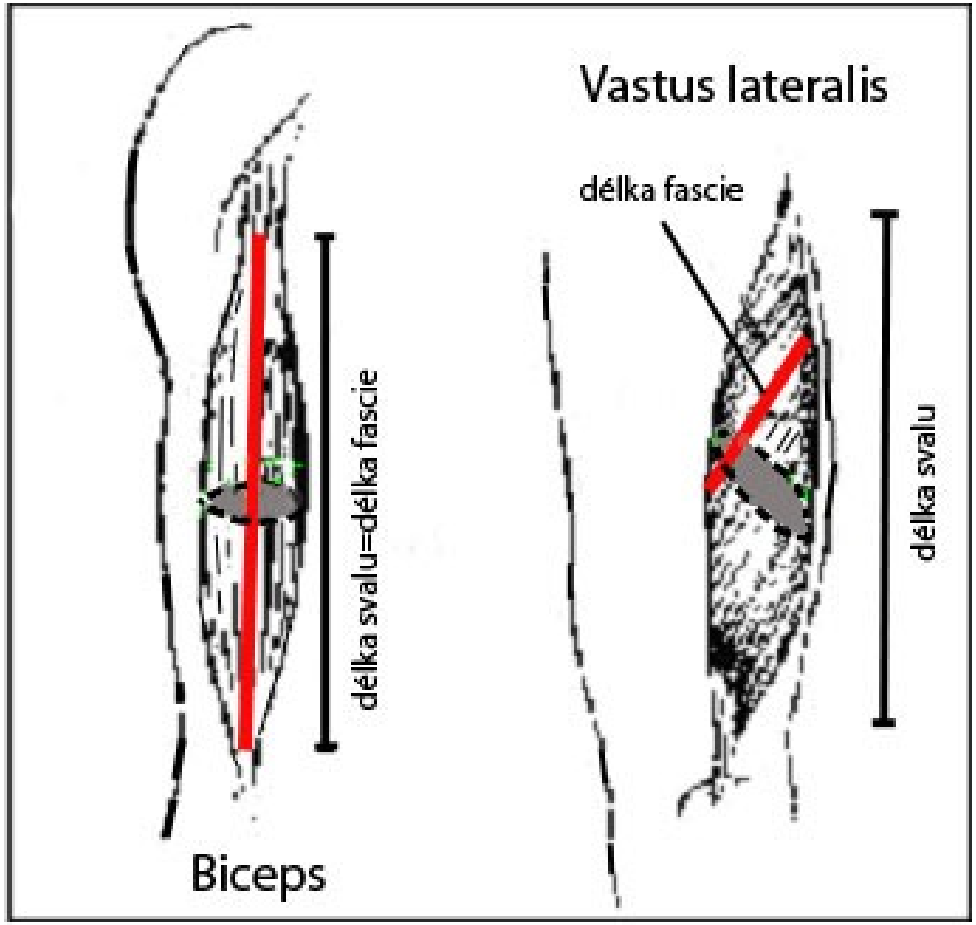
- stimulates GH secretion and increases the presence of neurotransmitters on muscle fibers
- helps activate muscle tissue growth

https://www.precisionnutrition.com/anabolic-hormones-and-muscle

- leads to protein synthesis

https://trmorrisnd.com/2013/11/11/a-recent-va-study-published-in-jama-indi/

Muscle architecture



Fusiform muscle (biceps)
X
Penniform muscles (*vastus lateralis*)

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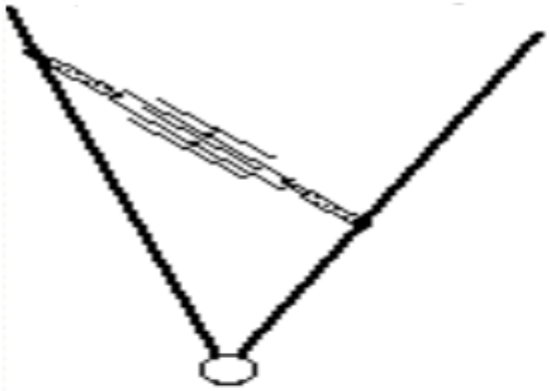

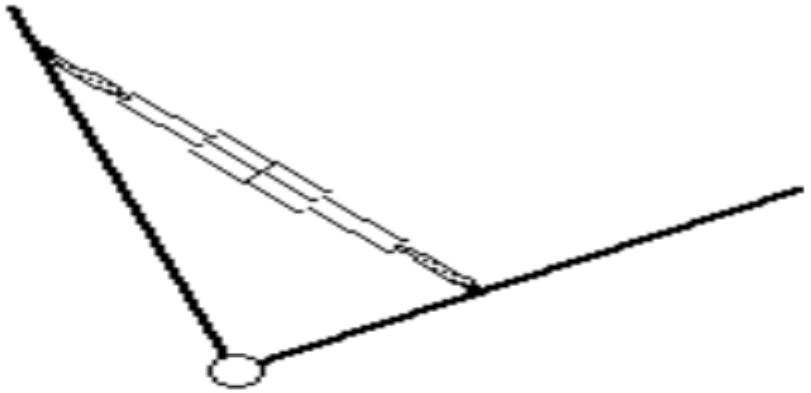

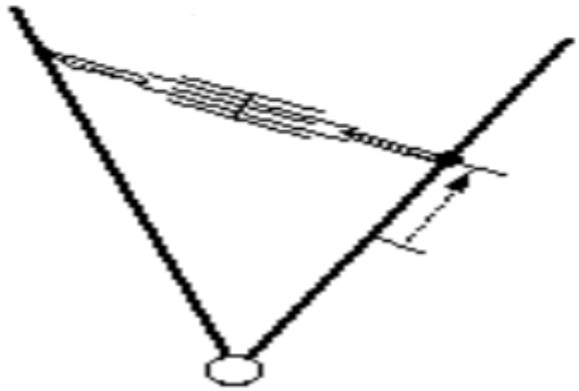

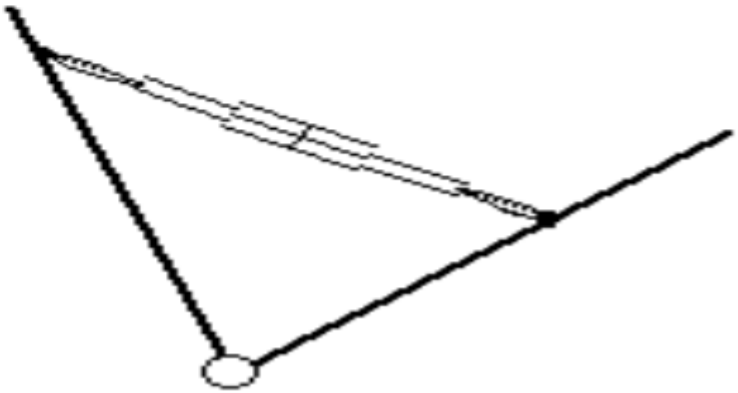

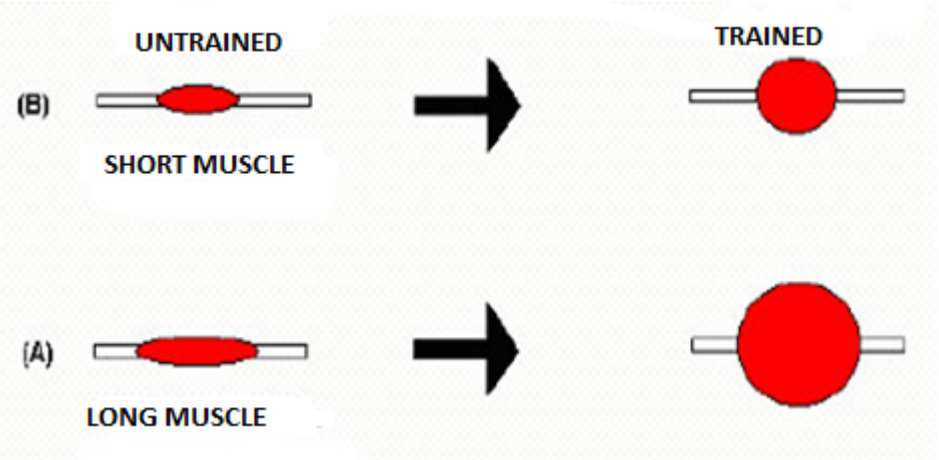

potential for muscle hypertrophy - limited by muscle length

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Polymorphism

- Interleukin 6 (IL-6) gene -174 G / C
  - studies demonstrate a pivotal role in post-exercise hypertrophy processes (Ruiz, 2010)
  - power athletes had a higher incidence of G.
- Gene for hypoxia-induced factor 1α (HIF1A) - Pro582Ser
  - detection of HIF1A variant - Pro582Ser in Russian power athletes (weightlifters, wrestlers) at regional and national level vs control group
- Gene for creatine kinase muscle isoform (CKM) - rs8111989 A / G
  - Alea G is associated with power output. Significant incidence was found in power-oriented athletes (Chen, 2017).
- Angiotensinogen Gene (AGT) - Met235Thr
  - The AG2 polymorphism of the Met235Thr gene can be considered a genetic determinant of strength, as evidenced in several investigations, for example, in jumpers, sprinters, or weightlifters, where more significant Met235Thr was observed (Zarębska et al., 2016).
- Nitric oxide synthase gene (NOS3) -786 T / C
  - T allele is associated with power output (Drozdovska, 2013). Drozdovska (2013)
  - significantly higher T allele frequencies in 53 Spanish elite power athletes (jumpers, sprinters)

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Neuromuscular factors determining muscle strength (FRY a kol.1994)

1. *Recruiting motor units*
2. *Rate coding*
3. *Intramuscular activation*
4. *Inter-muscle activation*
5. *Use elastic energy and reflexes*
6. *Neural inhibition*
7. *Type of motor units*
8. *Biomechanical and anthropometric factors*
9. *Hypertrophy*

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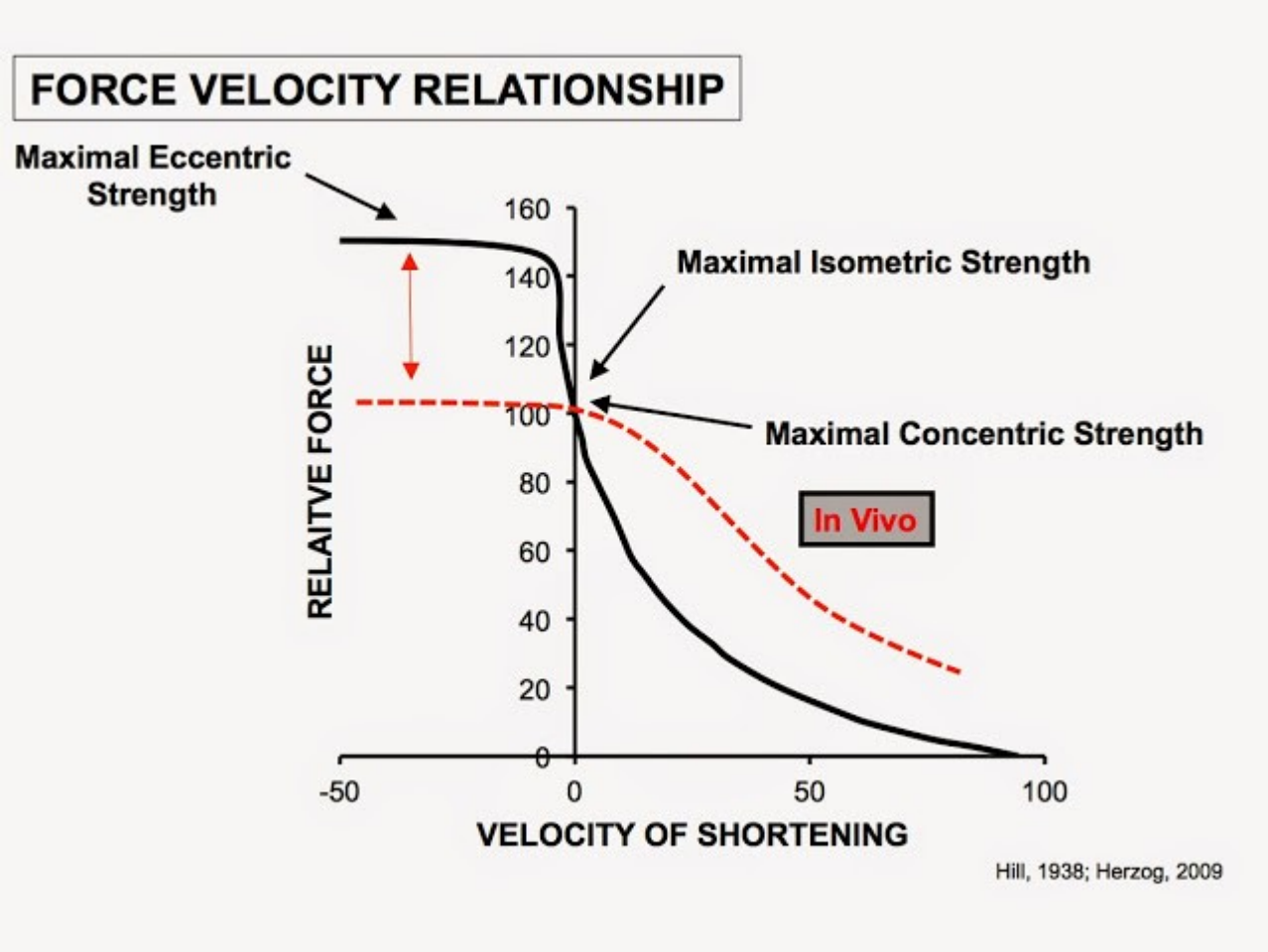
The relationship of force and velocity shortening



http://www.mcmillanspeed.com/2015/05/a-coaches-guide-to-strength-development.html

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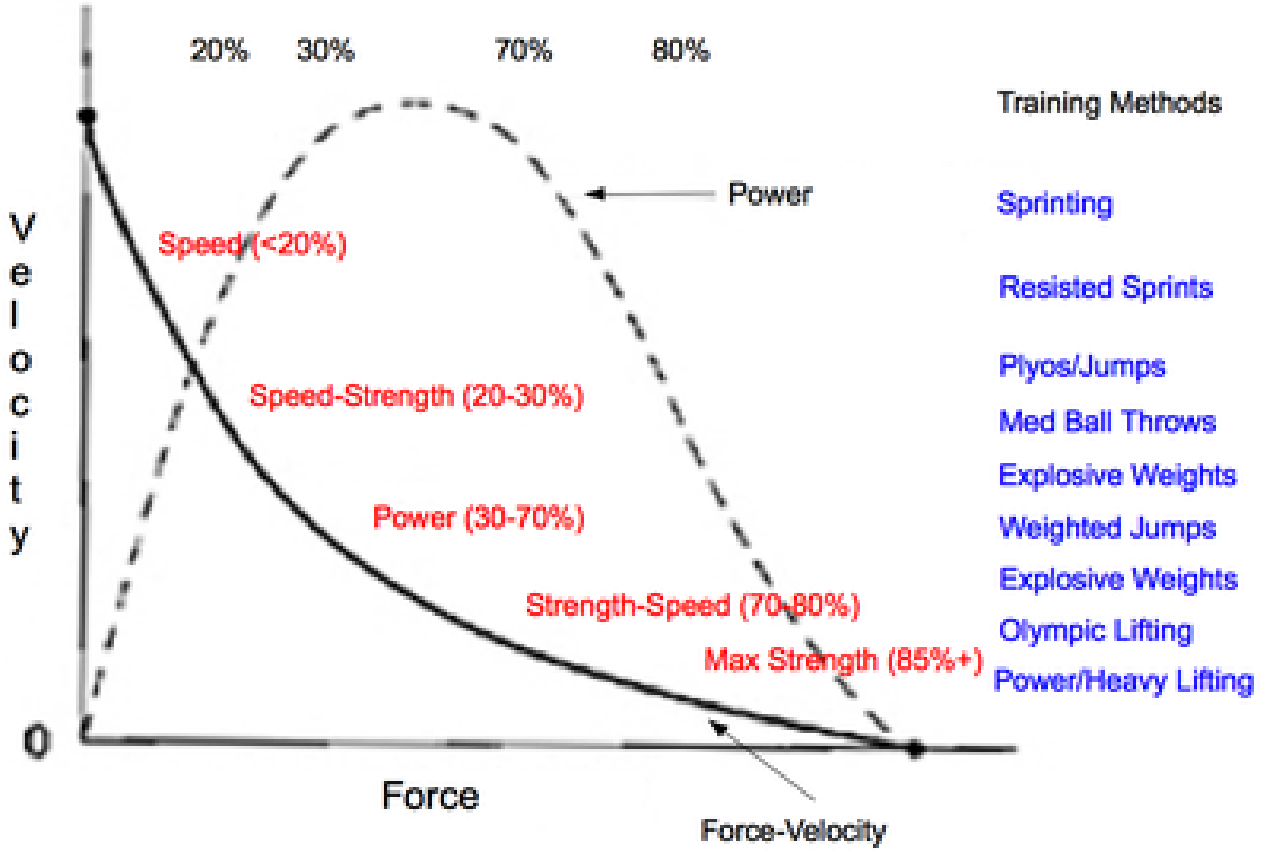
20%
30%
70%
80%
Training Methods
Power
Sprinting
Speed (<20%)
Resisted Sprints
Plyos/Jumps
Speed-Strength (20-30%)
Med Ball Throws
Explosive Weights
Power (30-70%)
Weighted Jumps
Explosive Weights
Strength-Speed (70-80%)
Olympic Lifting
Max Strength (85%+)
Power/Heavy Lifting
Velocity
0
Force
Force-Velocity

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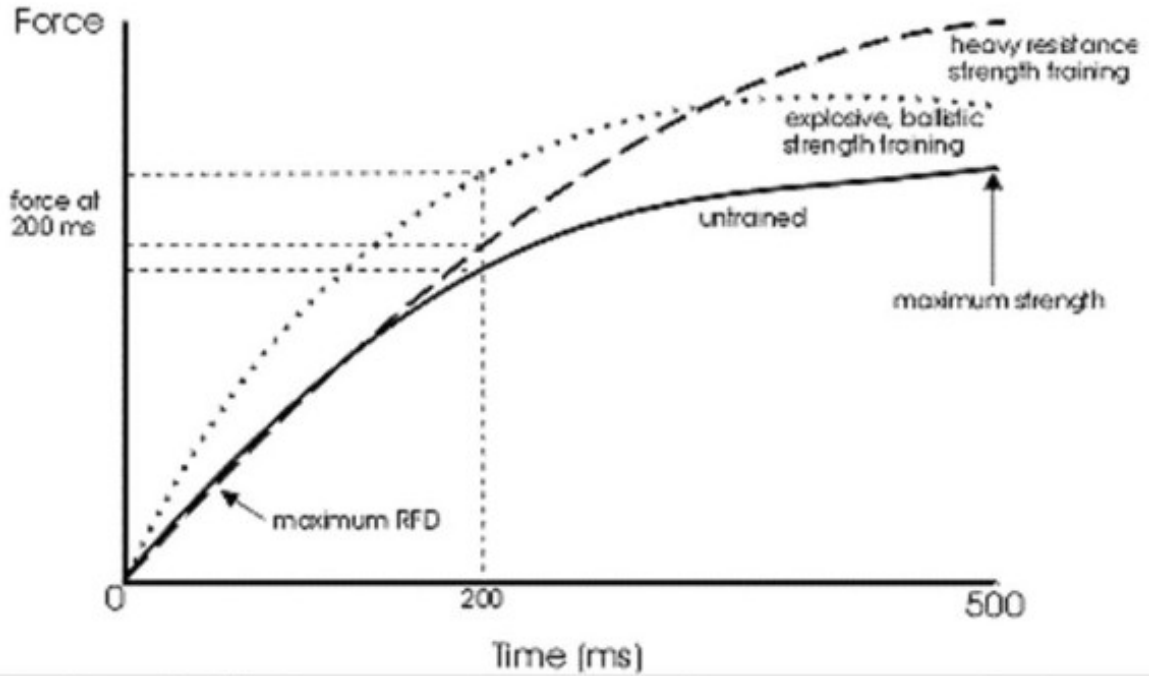
Neuromuscular activation training



Explosive, ballistic strength training increases maximal strength but especially develops a quicker force development. Heavy resistance strength training develops especially a higher, maximal force (Häkkinen & Komi 1985; RFD rate of force development).

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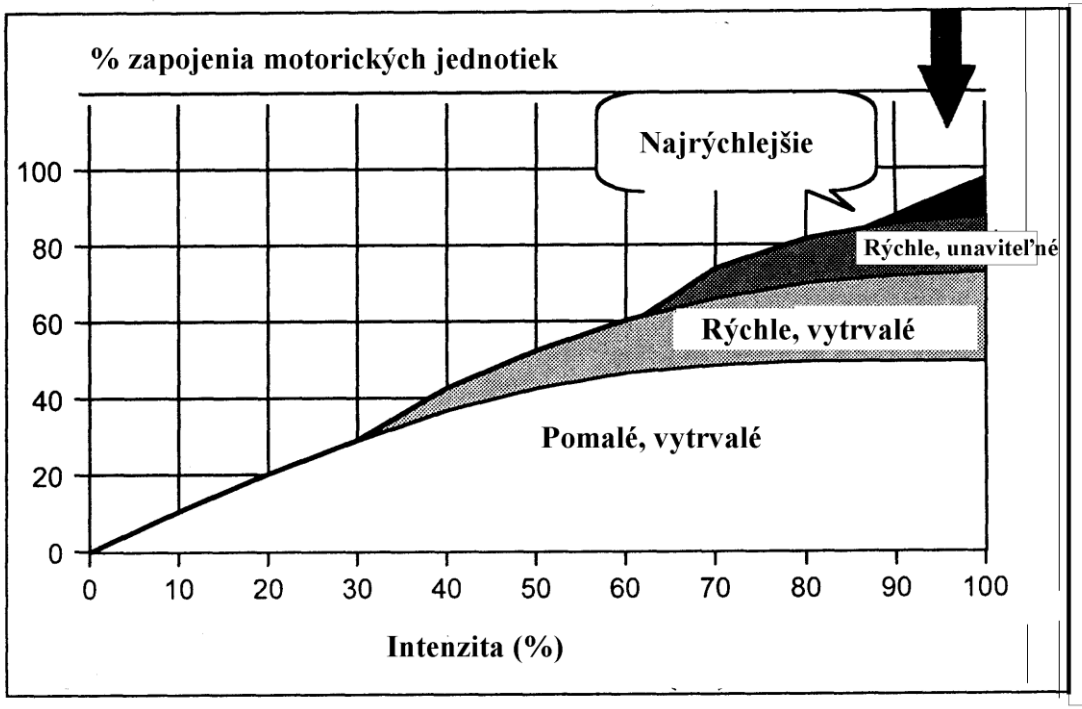
Henneman's principle of size



Poradie zapojenia motorických jednotiek v závislosti na intenzite

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Hypertrophy

- Definition - increasing the cross-section of muscle fibers
- Sarcoplasmic and Myofibrillary
- Zatsiorsky (5 - 60s)
- https://andersnedergaard.dk/en/kropblog/sarcoplasmic-hypertrophy/

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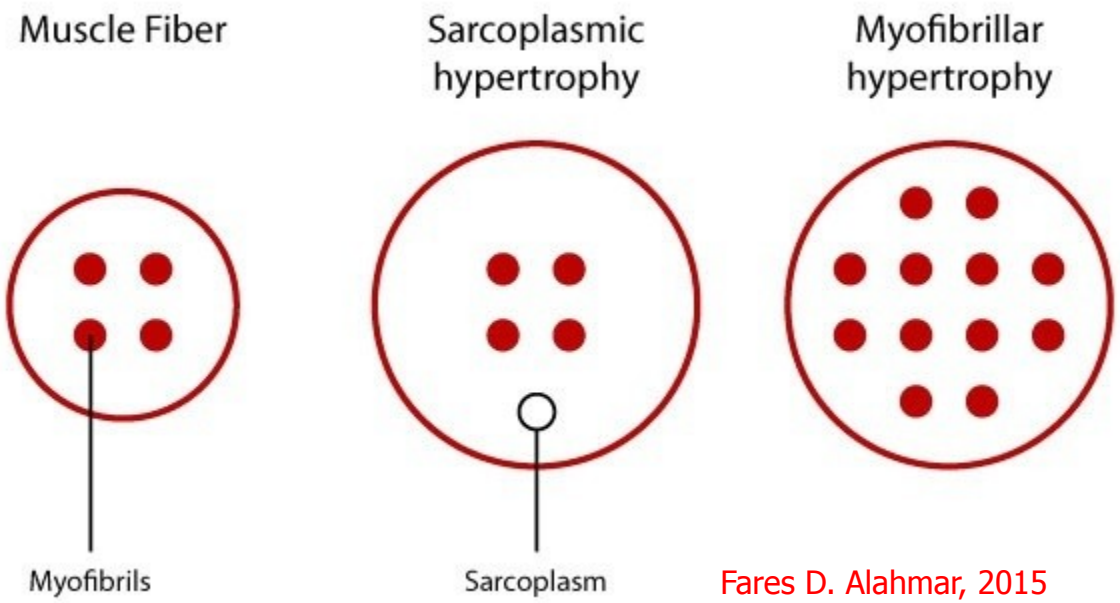


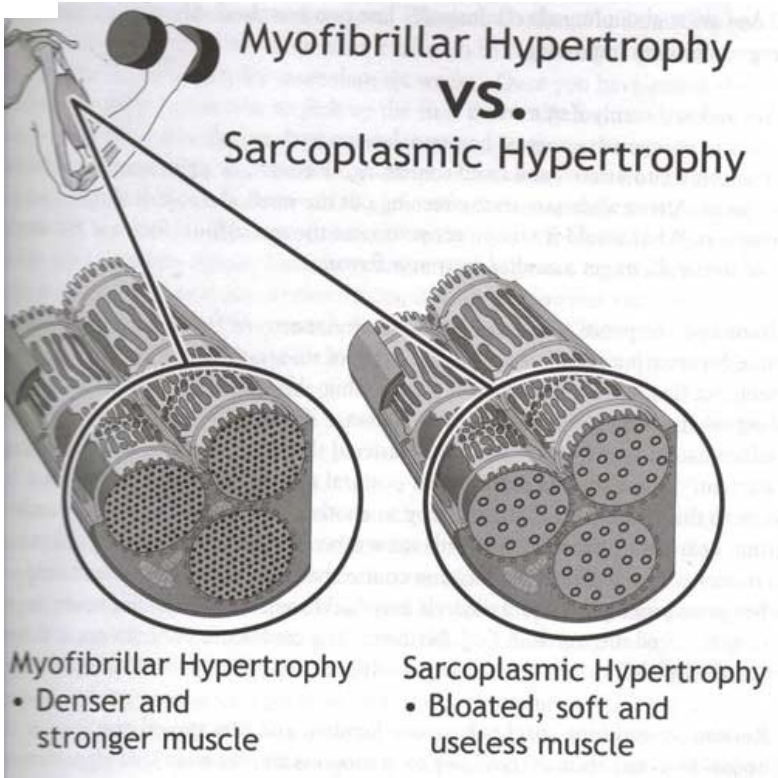
Fares D. Alahmar, 2015

?????

- hypertrophic progress over 100 %

muscle fibers composed of:

myofibrils - 85-90%
residue
extracellular connective tissue
blood vessels
mitochondria,
glycogen 5-10% 15-20%
membrane invagination - serves for propagation of electrical signals
Sarkoplasma 0.5-2%
(Macdougall et al., 1982)



Sarkoplas. hypertrophy?

Research shows TBW increase of about 3 l / 12 weeks (beginners)
Intracelular = about 1 kg (in sarkoplasma) muscles increase only 4% in 12 weeks
But in the body up to 3 liters of fluid outside the extra muscles - **where are they?**

Ribeiro et al. 2014

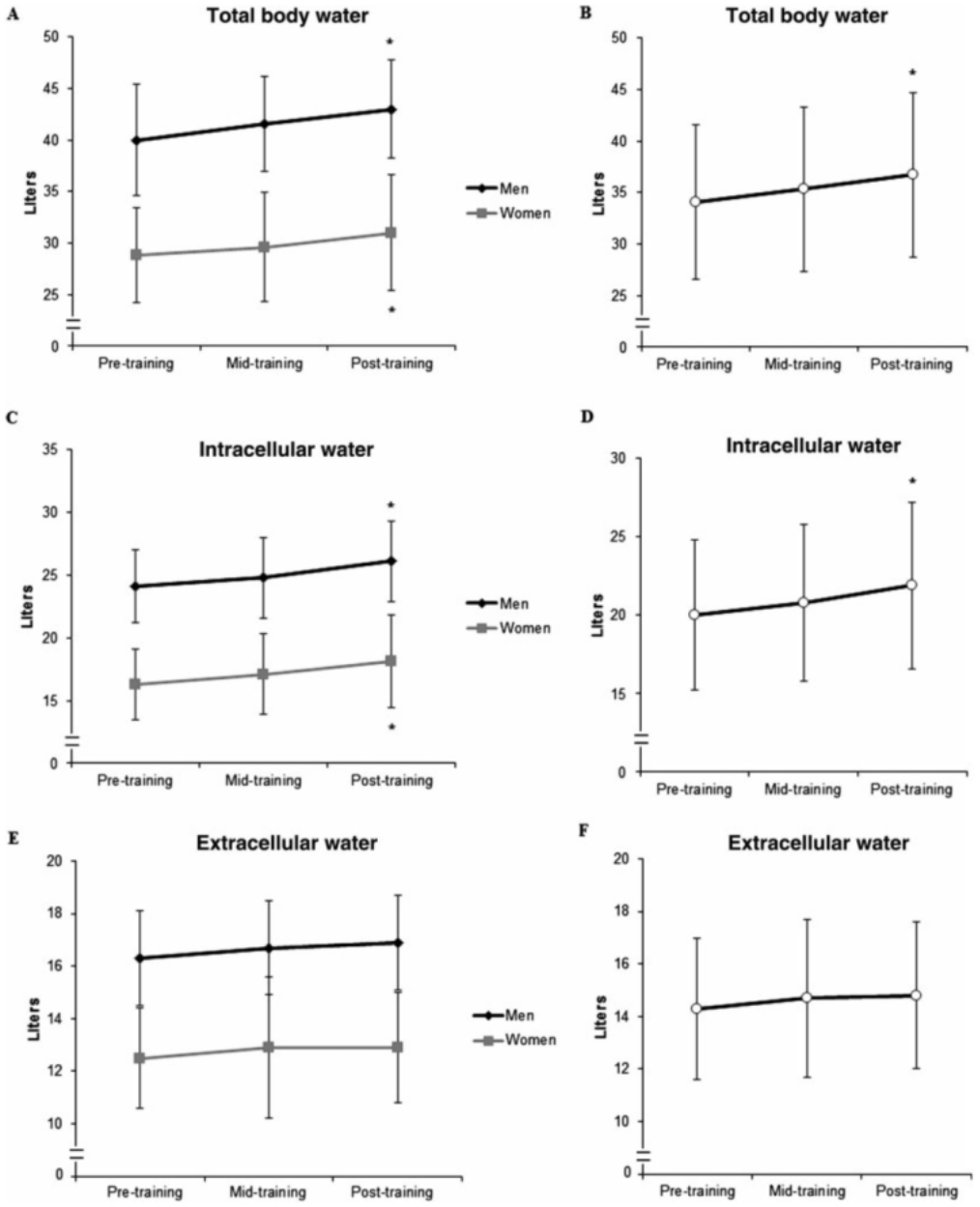


Figure 1. Total body water, intracellular and extracellular water in men and women (Panels A, C and E), and whole sample (Panels B, D and F) at different moments of the study. *$P < 0.05$ vs. Pre-training. There was no significant sex by time interaction ($P > 0.05$). Data are expressed as mean ± standard deviation.

Heavy loads: greater ↑ in strength and RFD than moderate loads?

https://www.strengthandconditioningresearch.com/perspectives/strength-training-sprinting/

Hypertrophy or maximum strength

3RM vs 10RM

STUDY OBJECTIVE

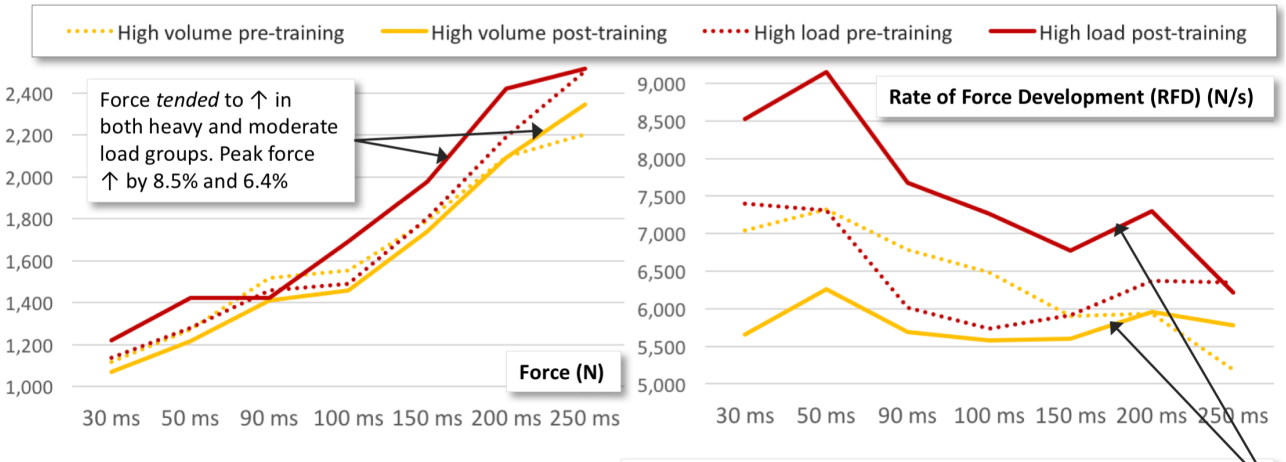
To compare the effects of long-term strength training with the same number of sets of either heavy (3 – 5RM) or moderate loads (10 – 12RM) on changes in force and rate of force development (RFD), in strength-trained males

How was this measured?

MEASUREMENTS

- Peak force and RFD in the isometric mid-thigh pull (IMTP) with a force plate; bar speed in pre-training 1RM squat and 1RM bench press, with a linear position transducer

Training: 4 workouts per week for 8 weeks. Each workout involved 4 sets of 6 exercises. Heavy group did 3 – 5 reps per set with 90% of 1RM, with a 3-minute rest between sets. Moderate group did 10 – 12 reps per set with 70 % of 1RM, with a 1-minute rest between sets.



WHAT DOES THIS MEAN?

Training with heavy loads *tended* to cause greater ↑ in maximum strength and RFD compared to moderate loads; the difference was most marked for RFD. Bar speed ↑ similarly in both groups.

Mangine, G. T., Hoffman, J. R., Wang, R., Gonzalez, A. M., Townsend, J. R., Wells, A. J., & LaMonica, M. B. (2016). Resistance training intensity and volume affect changes in rate of force development in resistance-trained men. *European Journal of Applied Physiology*, 1-8.

Strength & Conditioning Research

Effect of different forms of strength training on Fmax and RDF

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HYPERTROFICAL TRAINING

Manipulable Variables - Influence on Hypertrophic Processes

- the weight of resistence - the load
- number of repetitions
- number of sets
- rest time between sets
- exercise velocity
- type of rest

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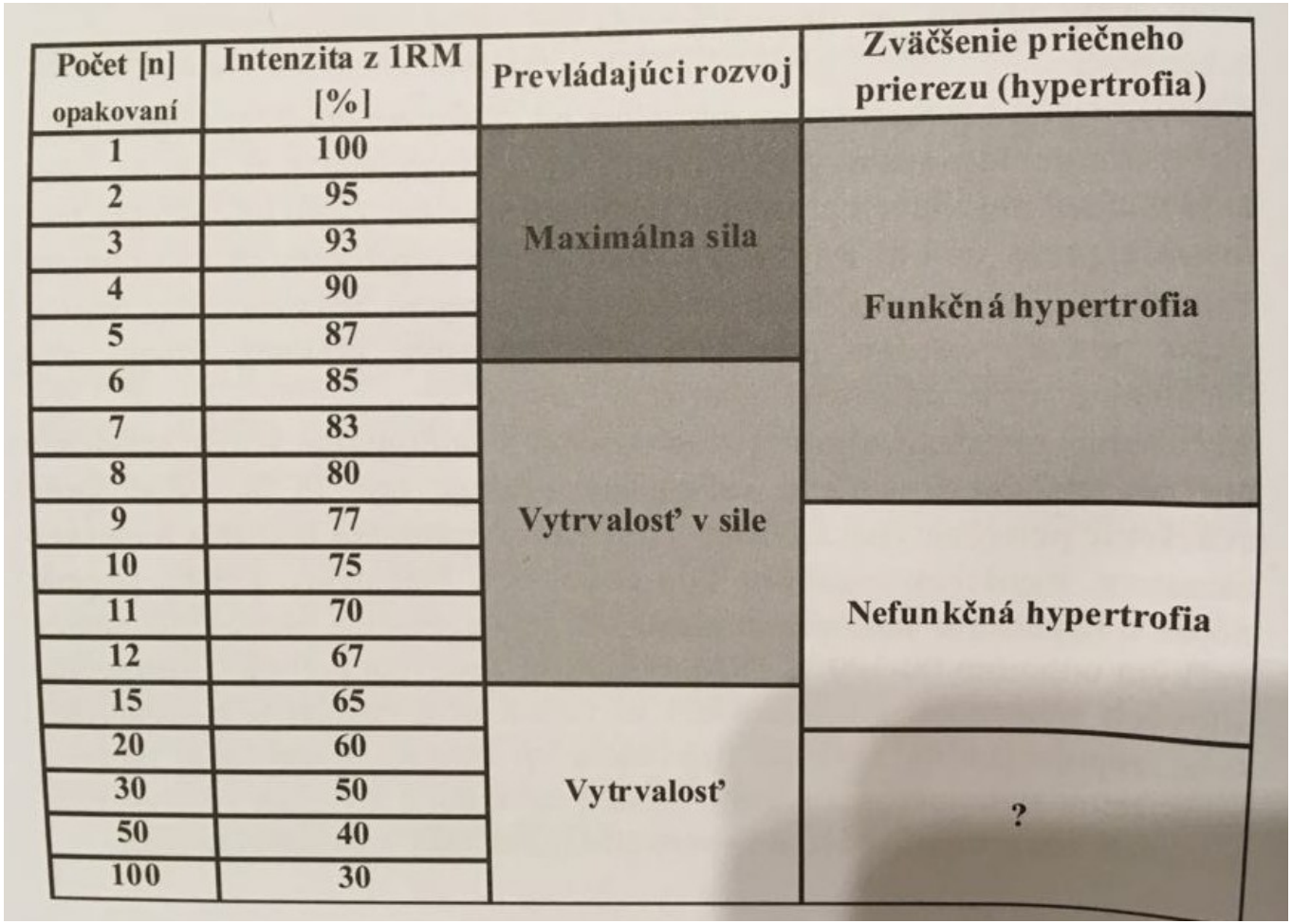
Functional hypertrophy

Vanderka (2016)



Počet [n] opakovaní	Intenzita z 1RM [%]	Prevládajúci rozvoj	Zväčšenie priečneho prierezu (hypertrofia)
1	100	Maximálna sila	Funkčná hypertrofia
2	95		
3	93		
4	90		
5	87		
6	85	Vytrvalosť v sile	
7	83		
8	80		
9	77		Nefunkčná hypertrofia
10	75		
11	70		
12	67		
15	65	Vytrvalosť	?
20	60		
30	50		
50	40		
100	30		

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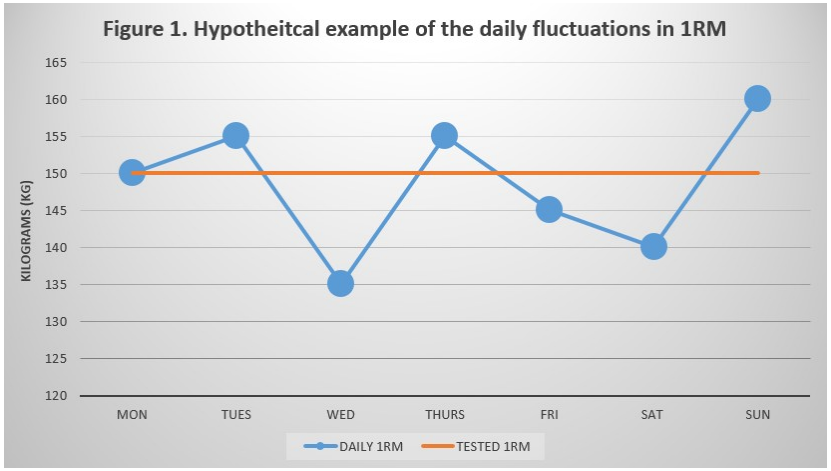
Assessment of exercise intensity

by calculating the training volume

calculating training intensity

Intensity vs Effort
Background 1 RM



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Intensity and velocity when exercise to failure

Decrease in intensity

decrease in repetition rate in series
reducing the amount of resistance between sets at the same number of times
reducing the number of repetitions between sets with the same resistance

Table 4. Average concentric velocity (m/s) for the repetitions in reserve during the back squat.

Reps left in the tank	60%	65%	70%	75%	Average (m/s)	SD	CV
9	0.54	0.51	0.50	0.49	0.51	0.02	4%
8	0.52	0.51	0.47	0.49	0.49	0.02	4%
7	0.50	0.50	0.48	0.47	0.49	0.02	4%
6	0.48	0.48	0.46	0.45	0.47	0.01	3%
5	0.49	0.47	0.46	0.44	0.46	0.02	5%
4	0.47	0.46	0.45	0.42	0.45	0.02	5%
3	0.47	0.43	0.43	0.41	0.43	0.02	5%
2	0.44	0.44	0.43	0.39	0.42	0.02	6%
1	0.39	0.40	0.44	0.38	0.40	0.02	6%
0	0.34	0.32	0.33	0.31	0.32	0.01	3%

This table is adapted from [24] and [5].

https://www.scienceforsport.com/velocity-based-training/?fbclid=IwAR2sIYHLNdDEQ4F2dqXS64BaMtN4Zbz1pU6RnONzBlkKt72xL0O76l8XjlU

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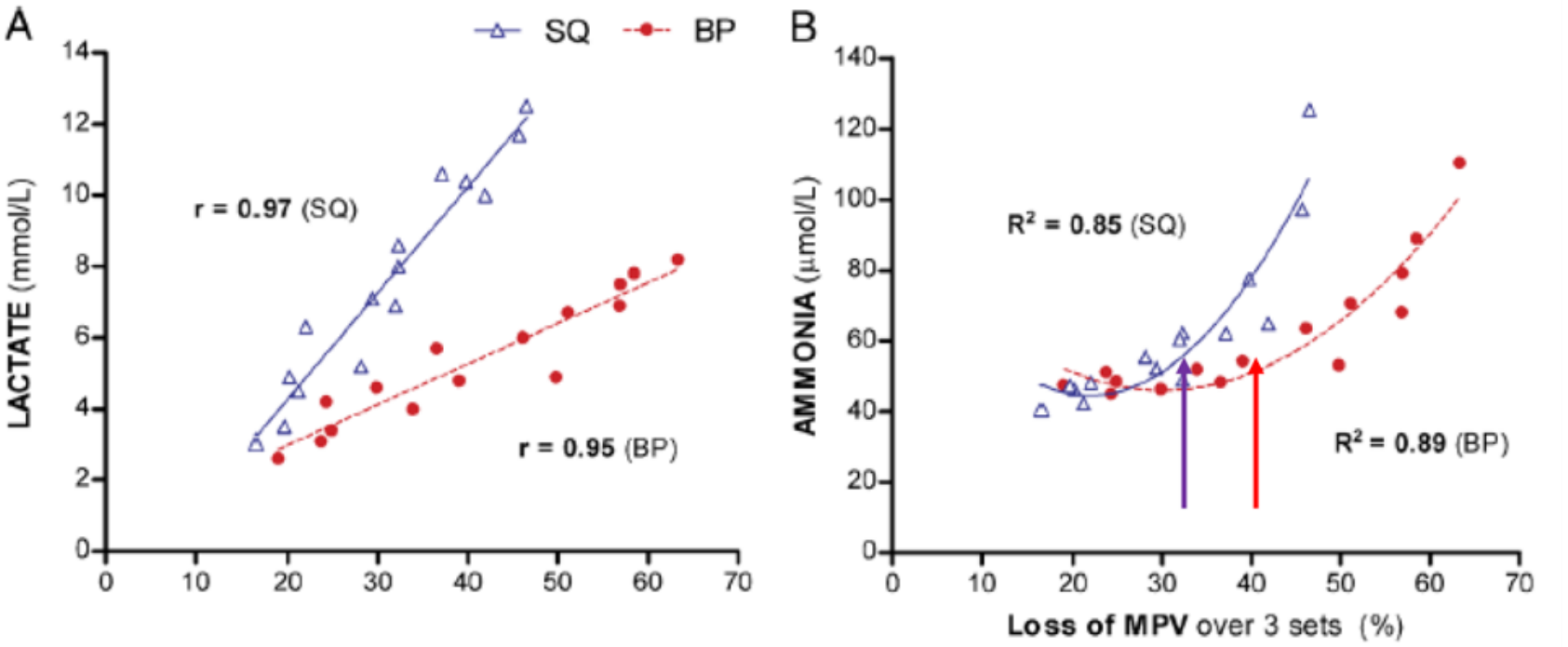
Metabolic Fatigue (LA - increases linearly)
Neuromuscular fatigue (increases in the shape of a curve)

To **increase muscle mass** (not necessarily related to body fluid)
it is not necessary to practice to failure, on the contrary,
it is necessary to exercise in large volume.
??? Is this also true for bodybuilders ???? = "Sarcoplasmic hypertrophy"

https://www.scienceforsport.com/velocity-based-training/?fbclid=IwAR2sIYHLNdDEQ4F2dqXS64BaMtN4Zbz1pU6RnONzBlkKt72xL0O76l8XjlU

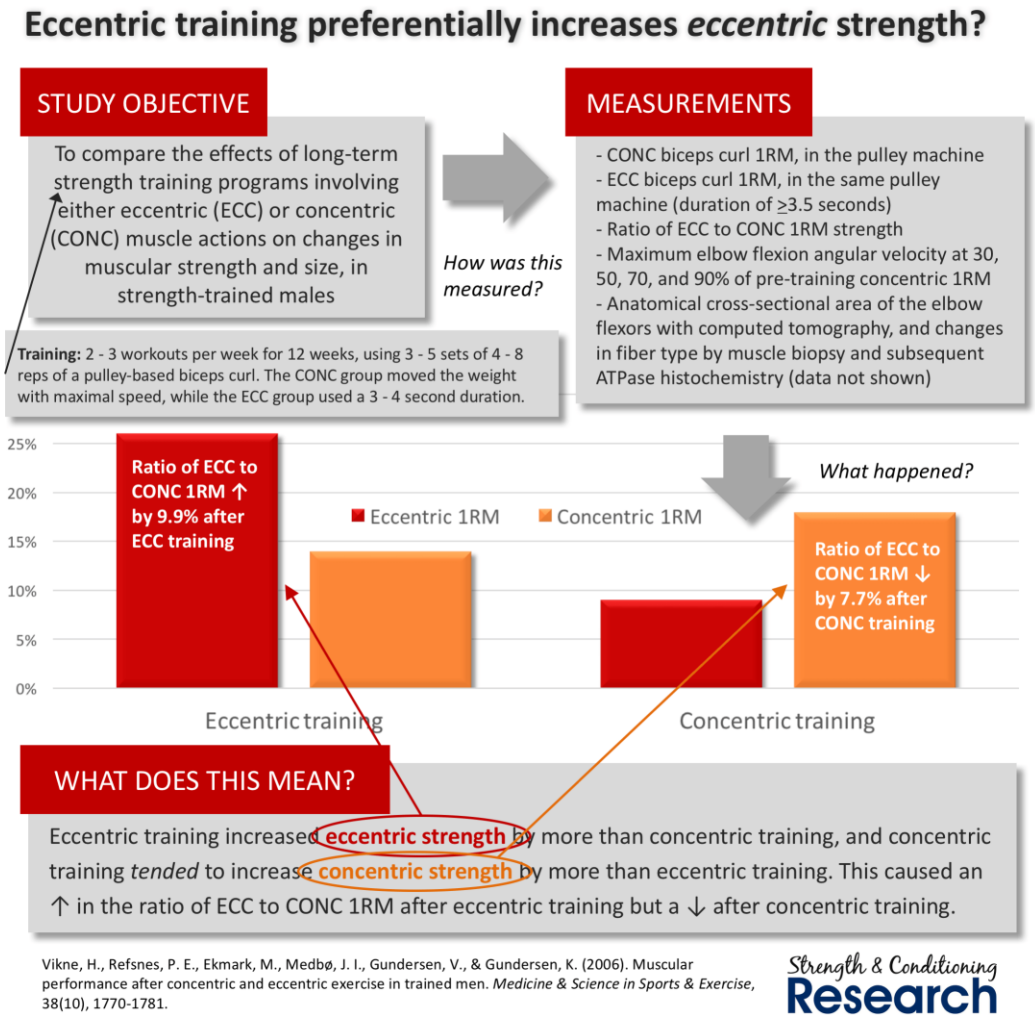


Concentric and eccentric strengt
Do we develop both components?
Do we know how to develop this types of strength?

Absence of research!

Concentric versus eccentric training

https://www.strengthandconditioningresearch.com/perspectives/strength-training-sprinting/



Structural adaptation

Eccentric training increases the amount of muscle mass

causes an increase in the cross-section of muscle fibers - associated with the growth of the number and cross-section of myofibrils - the role of satellite cells

It is not yet known what volume of work, exercise intensity and rest intervals are optimal for hypertrophy

Wernbom et al., In. Brady 2012

Phases Completed	Hypertrophy per Day
Concentric	0.06%
Eccentric	0.03%
Concentric & Eccentric (Quality Reps)	**0.12%**

Baroni, B. M. et al (2014)

Eccentric, isometric and concentric strength gains of knee extensor muscles in eccentric training studies

	Strength Δ% (pre- to post-training)			Strength Δ% (per training session)		
	ECC	ISO	CON	ECC	ISO	CON
Baroni et al. [107]	↑ 29%	↑ 24%	↑ 15%	↑ 1.38%	↑ 1.14%	↑ 0.71%
Baroni et al. [108]	–	–	–	–	–	–
Ben-Sira et al. [109] – A group	–	–	↑ 16%	–	–	↑ 1.00%
– B group			↑ 23%	–	–	↑ 1.44%
Blazevich et al. [100]	↑ 39%	–	↑ 16%	↑ 1.30%	–	↑ 0.53%
Blazevich et al. [102]	–	↑ 10%	–	–	↑ 0.33%	–
Franchi et al. [119]	↑ 44%	↑ 11%	–	↑ 1.47%	↑ 0.37%	–
Guilhem et al. [120] – A group	↑ 15–47%^{VD}	↑ 16%	ns-↑ 18%^{VD}	↑ 2.35%	↑ 0.80%	↑ 0.90%
– B group	ns-↑ 23%^{VD}	↑ 14%	ns-↑8%^{VD}	↑ 1.15%	↑ 0.70%	↑ 0.40%
Higbie et al. [93]	↑ 36%	–	↑ 7%	↑ 1.20%	–	↑ 0.23%
Hortobagyi et al. [94]	↑ 116%	↑ 45%	ns	↑ 3.22%	↑ 1.25%	**
Hortobagyi et al. [95]	↑ 42%	↑ 30%	ns	↑ 1.83%	↑ 1.30%	**
Housh et al. [113]	↑ 29%	–	–	↑ 1.61%	–	–
Mayhew et al. [92]	–	↑ 8%	–	–	↑ 0.67%	–
Melo et al. [103]	↑ 20%	–	–	↑ 0.83%	–	–
Miller et al. [99]	↑ 27%	–	↑ 25%	↑ 0.45%	–	↑ 0.42%
Nickols-Richardson et al. [101]	↑ 29%	–	↑ 15%	↑ 0.48%	–	↑ 0.25%
Poletto et al. [108]	↑ 38–41%	–	–	↑ 3.42%	–	–
Raj et al. [118]	–	↑ 7%	↑ 5–11%^{VD}	–	↑ 0.22%	↑ 0.34%
Raue et al. [116]	–	–	ns	–	–	**
Reeves et al. [117]	↑ 9–17%^{VD}	ns	ns-↑ 33%	↑ 1.41%	**	**
Rocha et al. [106]	ns-↑ 59%^{VD}	↑ 24%	ns	↑ 1.69%	↑ 0.69%	**
Santos et al. [105]	↑ 17–27%^{VD}	↑ 16%	–	↑ 2.25%	↑ 1.33%	–
Schroeder et al. [115] – A group	–	–	↑ 19%	–	–	↑ 0.59%
– B group	–	–	↑ 24%	–	–	↑ 0.75%
Seger and Thorstensson [97]	ns-↑ 43%^{VD}	–	ns	↑ 1.43%	–	**
Seger et al. [96]	ns-↑ 34%^{VD}	ns	ns-↑ 8%^{VD}	↑ 1.13%	**	↑ 0.27%
Smith and Rutherford [110]	–	ns-↑ 31%^{AD}	ns-↑ 21%^{VD}	–	↑ 0.52%	↑ 0.35%
Sorichter et al. [112] – A group	–	ns	–	–	**	–
– B group	–	↑ 9%	–	–	↑ 0.08%	–
Spurway et al. [114]	↑ 18–34%^{VD}	ns	ns-↑ 20%^{VD}	↑ 1.90%	**	↑ 1.10%
Symons et al. [98]	↑ 26%	↑ 25%	↑ 10%	↑ 0.72%	↑ 0.69%	↑ 0.28%
Tomberlin et al. [91]	↑ 53%	–	ns	↑ 2.94%	–	**
Weir et al. [111]	↑ 29%	ns-↑ 15%^{AD}	–	↑ 1.21%	↑ 0.63%	–

ECC = eccentric tests; ISO = isometric tests; CON = concentric tests; ns = not significant; ^{VD}velocity-dependence; ^{AD}angle-dependence; M = male; F = female; ** not significant values or not informed values of strength increments in pre- to post-training were not considered for analysis in per training session changes; obs.: when more than one velocity was tested, the higher strength increments were used to calculate the strength increment per training

Perodization of strength development

Planning an annual training plan - basic principles

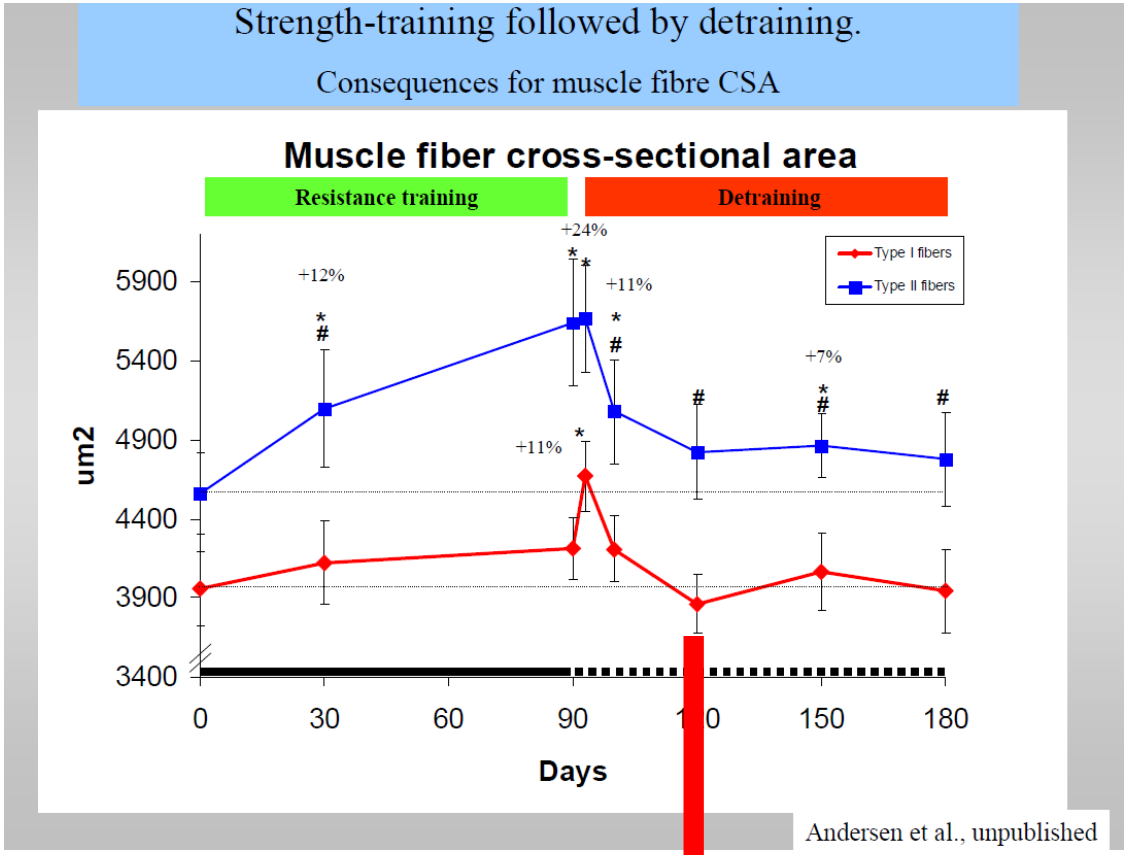
continuity

sequence

adequacy

individualization

specificity



(Andersen, přednáška)

- ZVÝŠENÉ RIZIKO PORANĚNÍ
- SNÍŽENÝ VÝKONNOSTNÍ POTENCIÁL

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Specificity

Structure of strength performance
Velocity
Type of contraction
Force vector
Muscle group
Power peak in relation to range of motion (angle) and speed
Stability (groud)
Range of motion
Metabolic coverage
One vs multi-joint exercise

https://www.strengthandconditioningresearch.com/perspectives/strength-training-sprinting/

Fmax and speed

Maximal concentric force vs. 100 m time

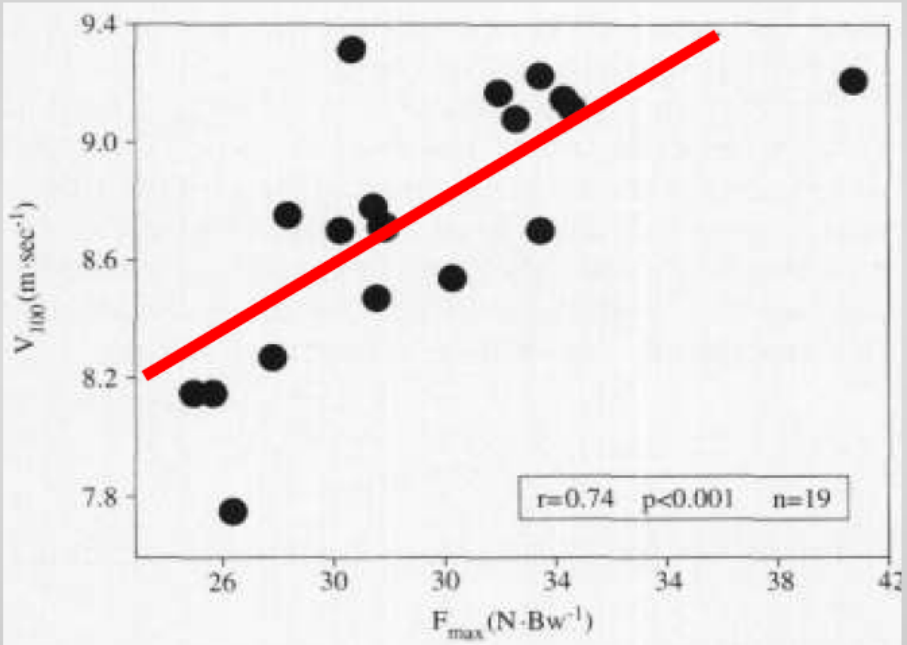
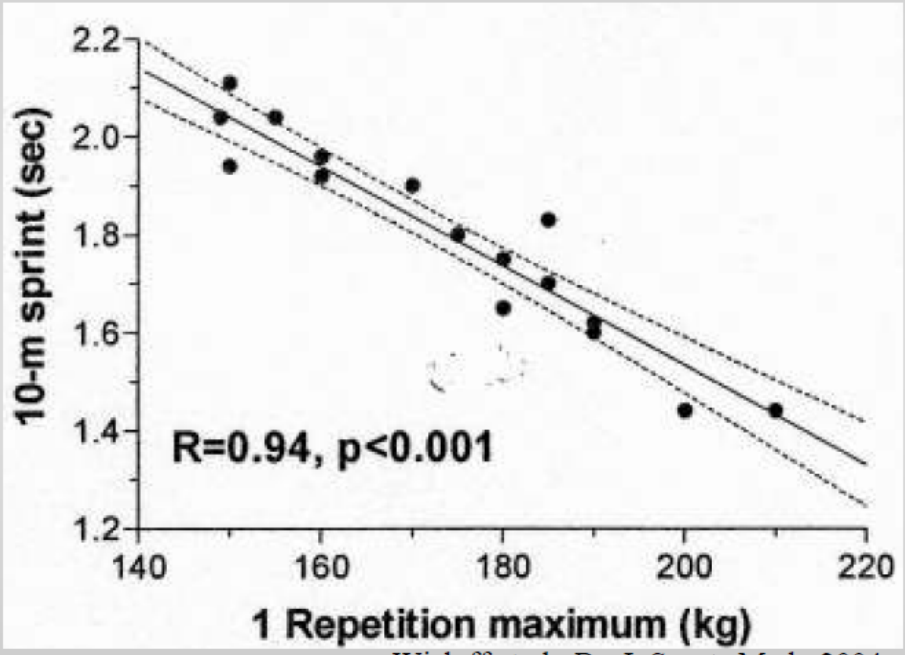


Fig. 2.—Relationship between the maximal force (F_{max}) and the mean velocity reached during a 100 m sprint (V_{100}).

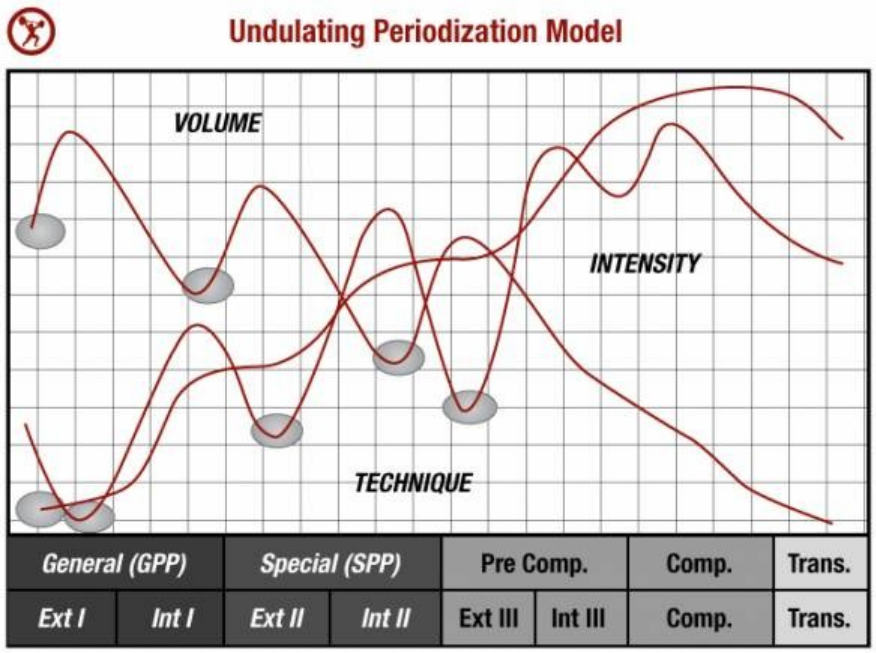
Bret et al, 2002

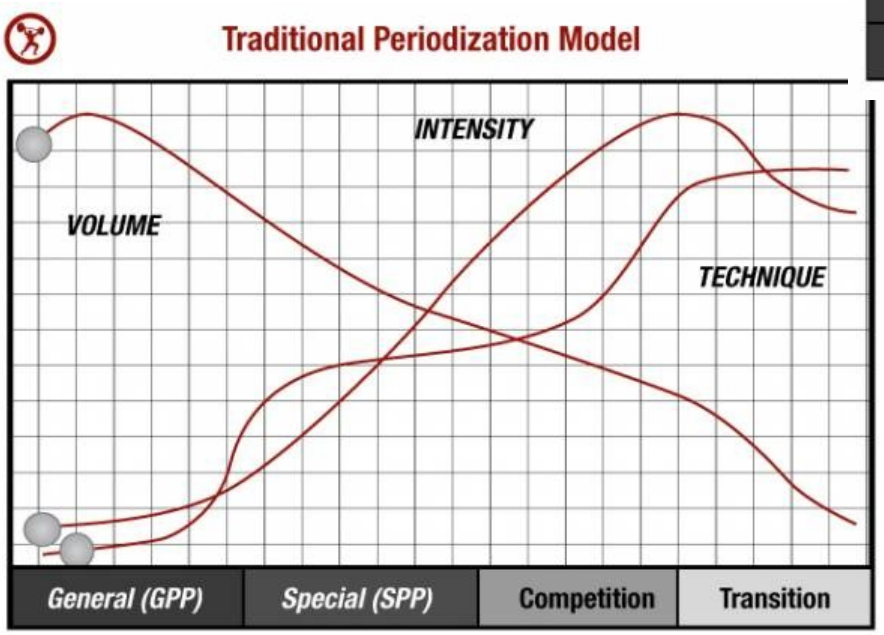
Short sprint vs. Maximal strength



Wisløff et al., Br. J. Sports Med., 2004

Type of periodization





https://breakingmuscle.com/fitness/a-simple-guide-to-periodization-for-strength-training

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Thank you for your attention