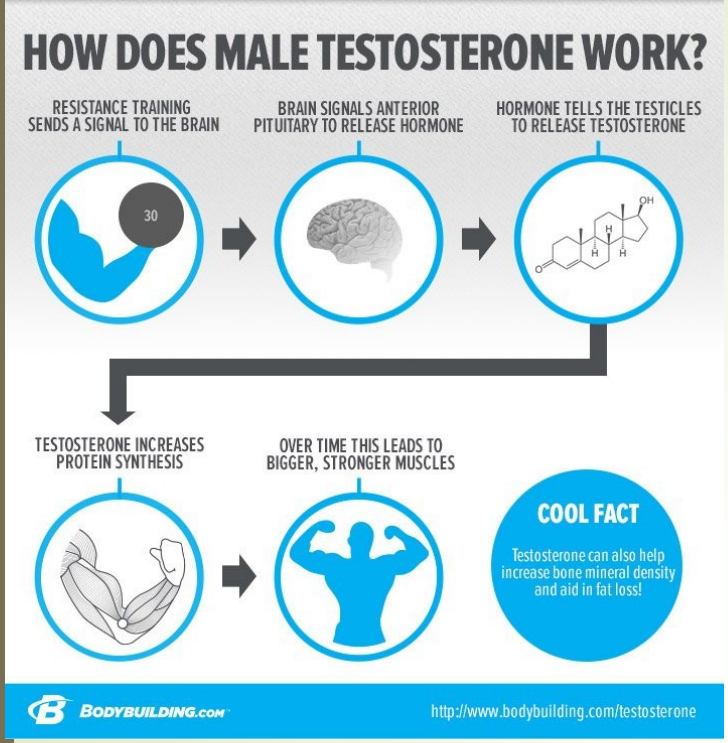
Muscle hypertrophy: theory, application and periodization

Something about me

- Jan Cacek
  - 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 Czech 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

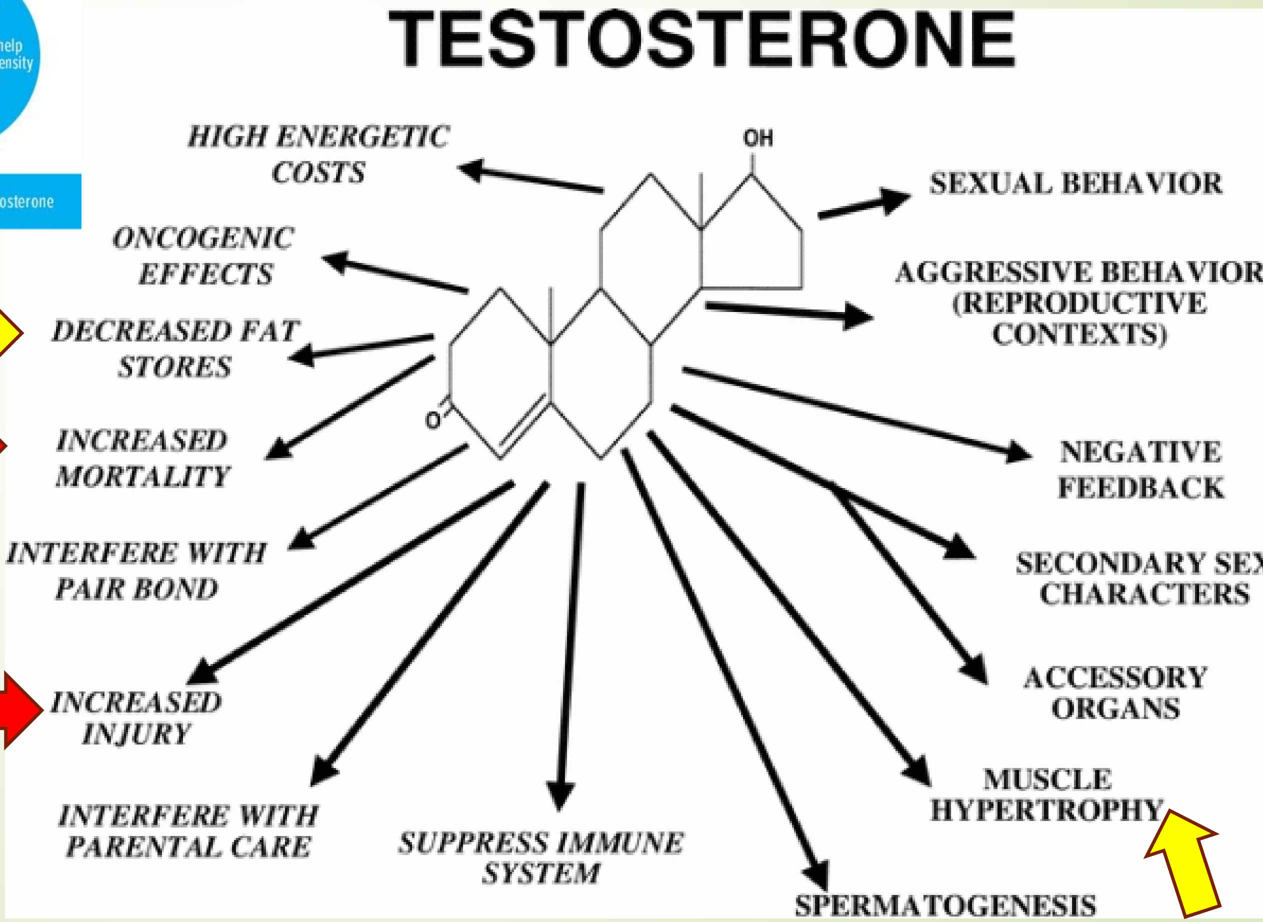
Determinants of strength and power

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



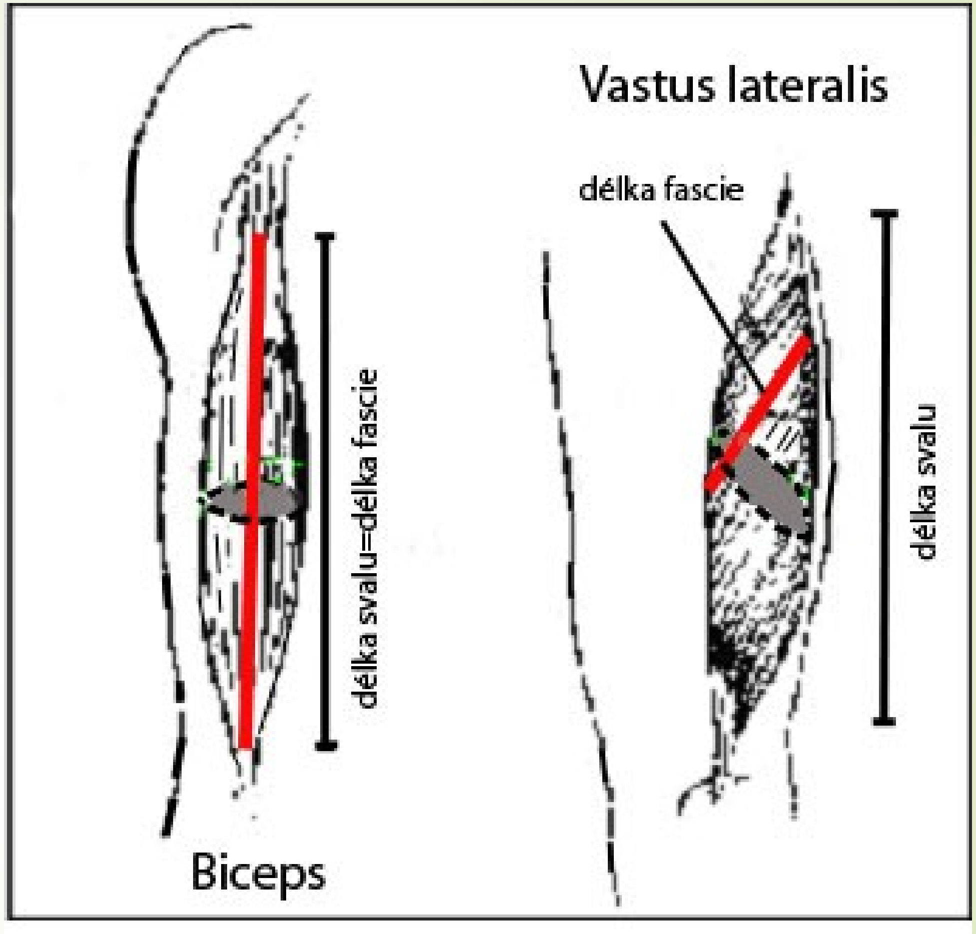
- stimulates GH secretion and increases the presence of neurotransmitters on muscle fibers
- helps activate muscle tissue growth
- leads to protein synthesis.

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



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

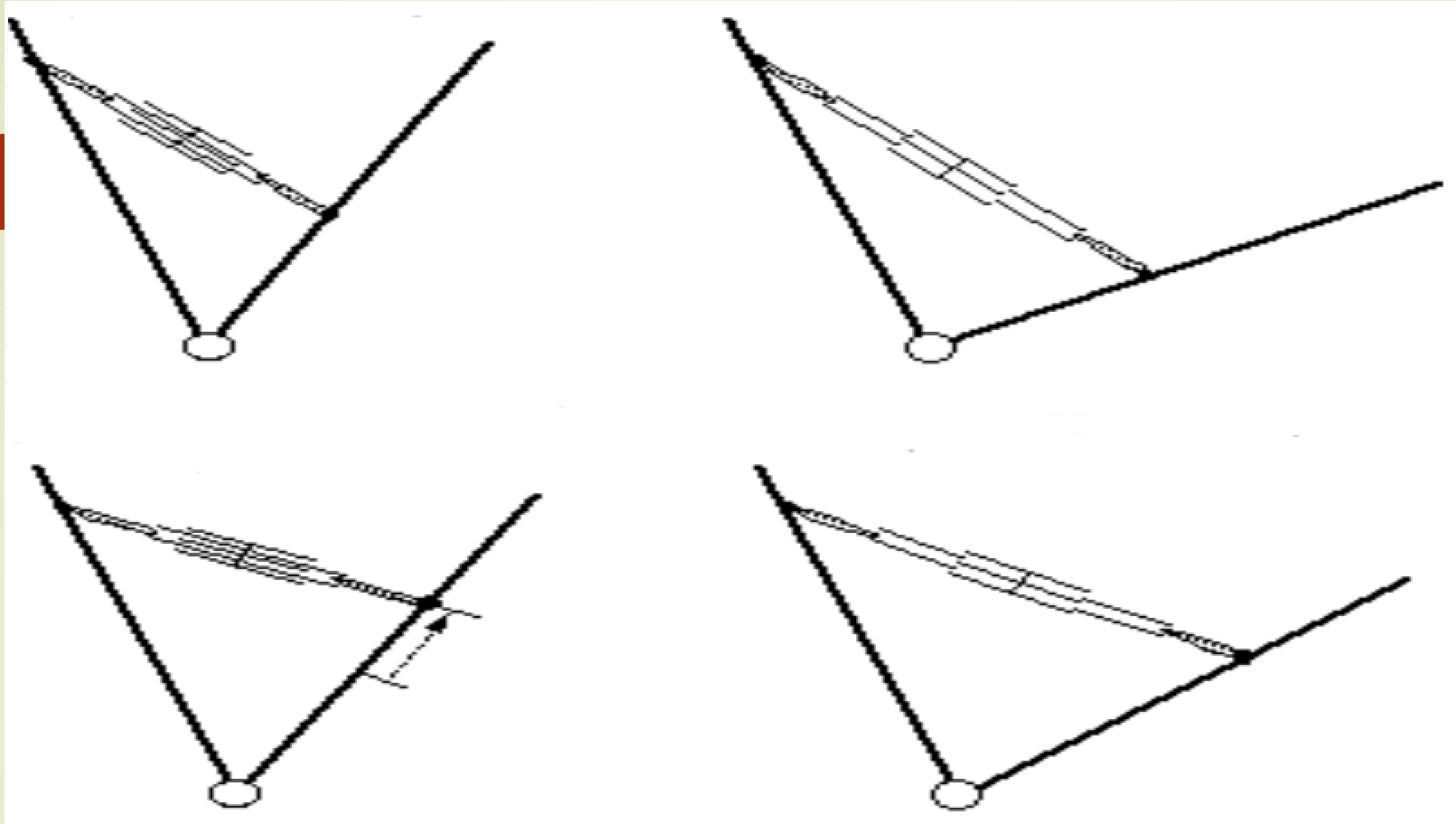
Muscle architecture

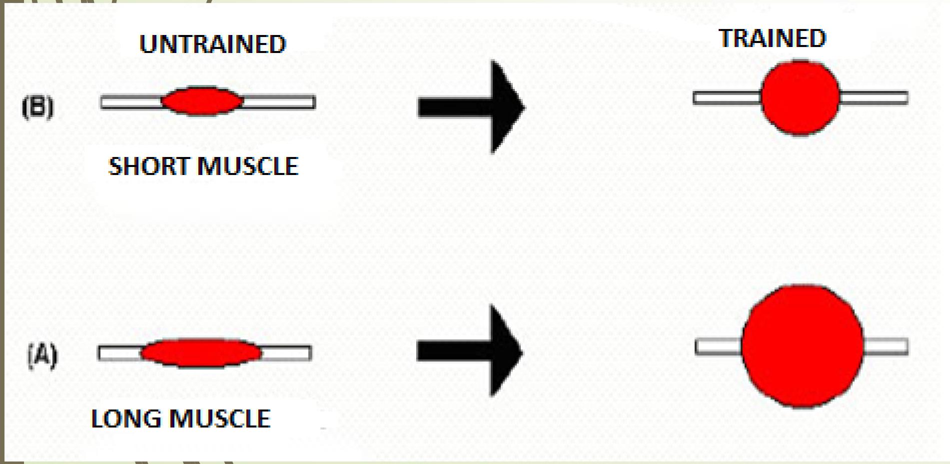


Fusiform muscle (biceps)

X

Penniform muscles (*vastus lateralis*)





potential for muscle hypertrophy - limited by muscle length

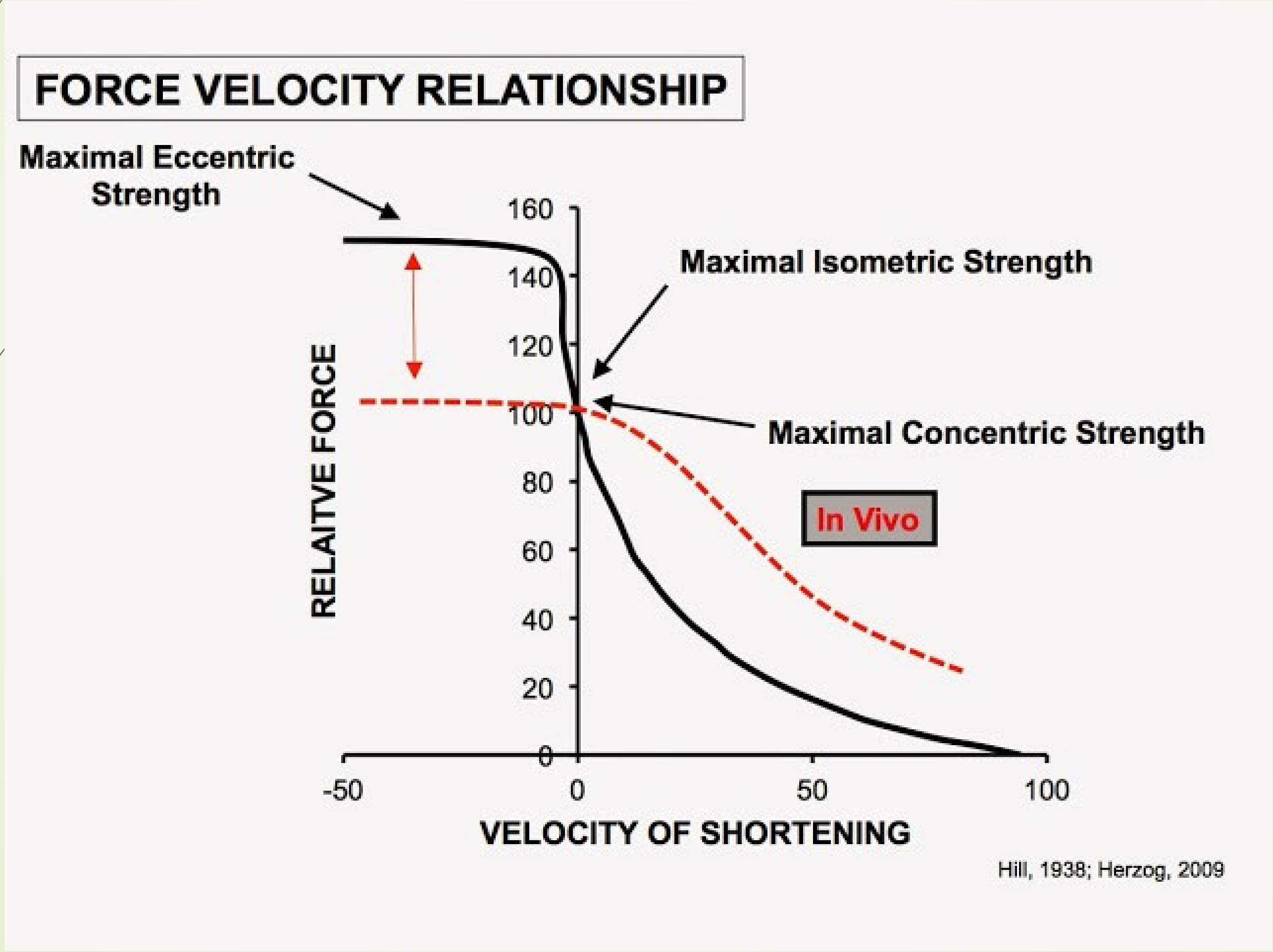
Polymorphism

- 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 1a (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)

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

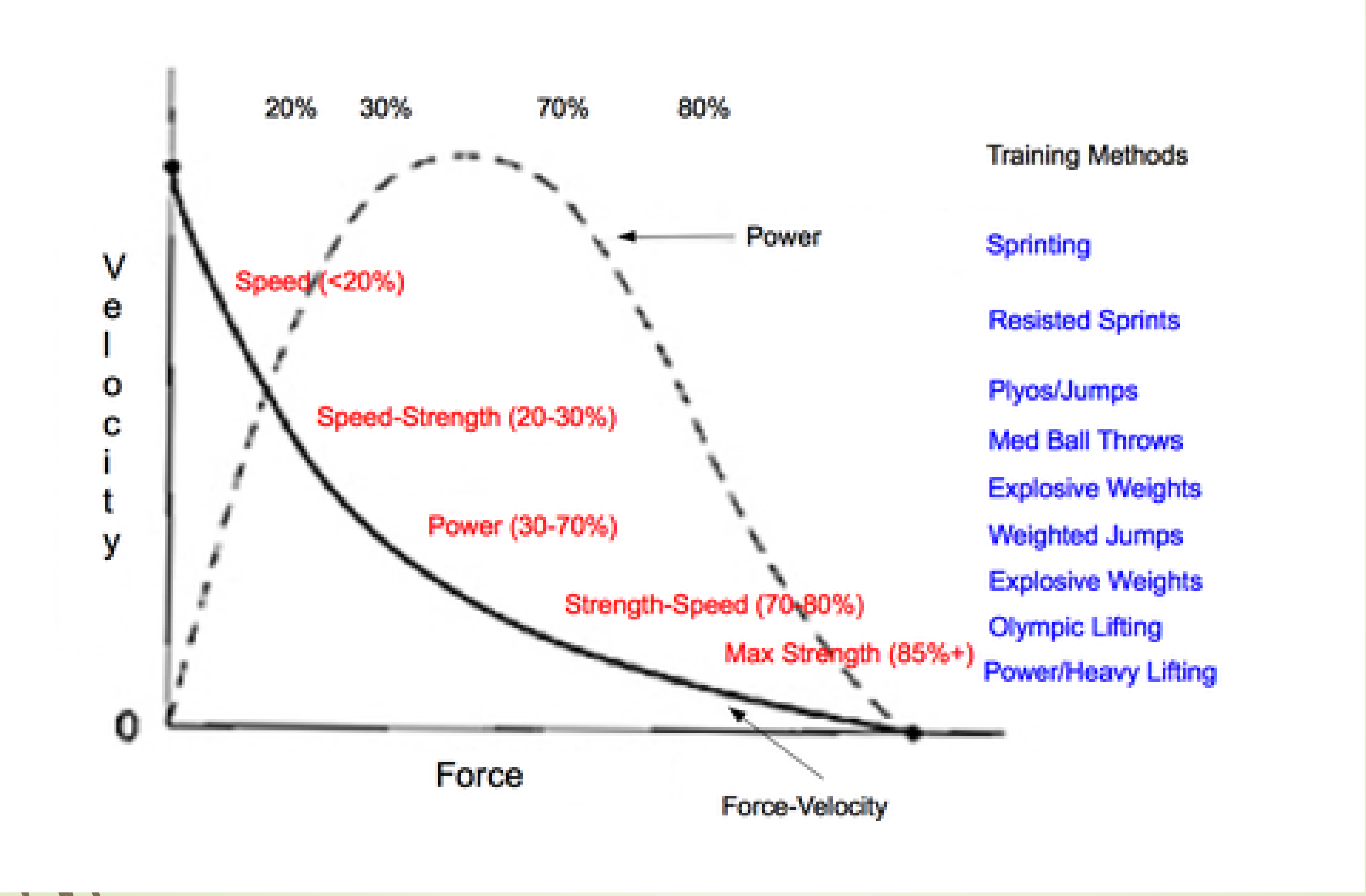
1. *Recruiting motor units*
2. *Rate coding*
3. *Intramuscular activation*
4. *Inter-muscle activation*
5. *Use elastic energy and reflexes*
6. *Neural inhibition*
7. *Type of motor units*
8. *Biomechanical and anthropometric factors*
9. *Hypertrophy*

The relationship of force and velocity shortening

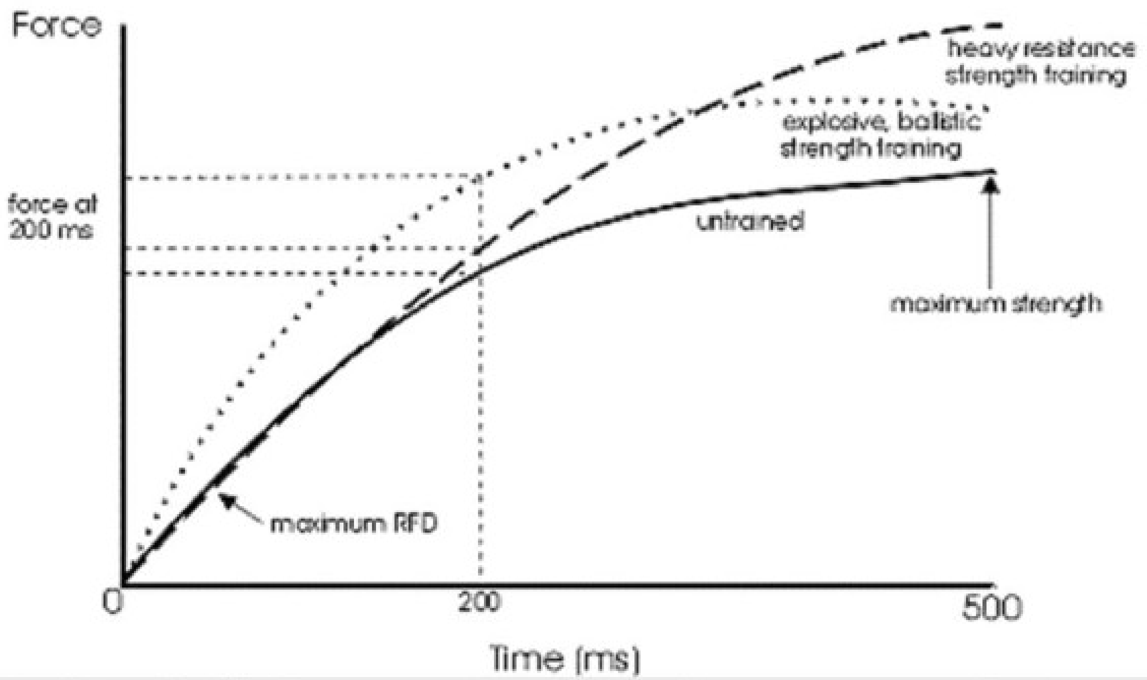


http://www.mcmillanspeed.com/2015/05/a-coaches-guide-to-strength-development.html

- Cooper, 2018 (https://www.12amlabs.com/blogs/news/shock-method-plyometric-training-for-elite-athleticism)

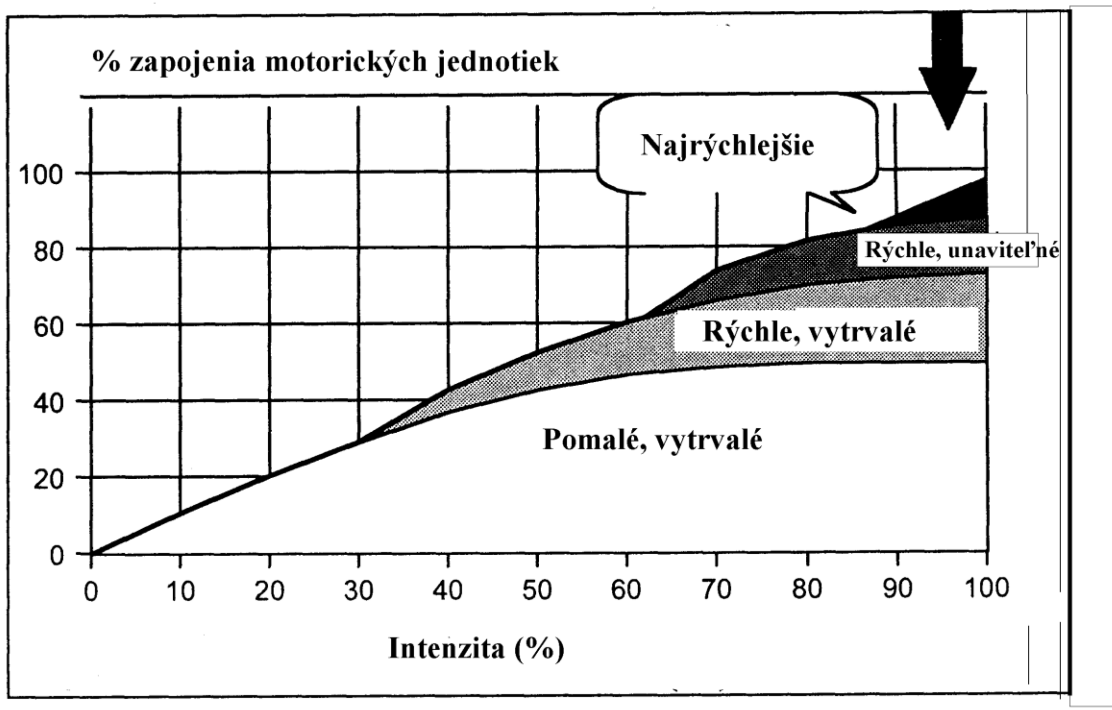


Neuromuscular activation training



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).

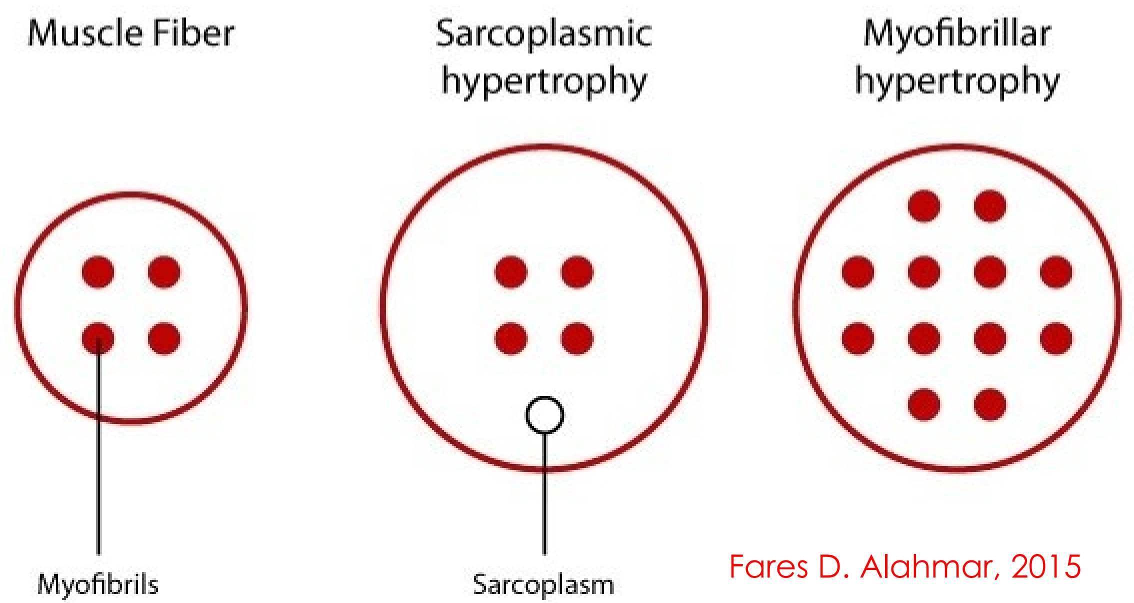
Henneman's principle of size



Poradie zapojenia motorických jednotiek v závislosti na intenzite

Hypertrophy

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



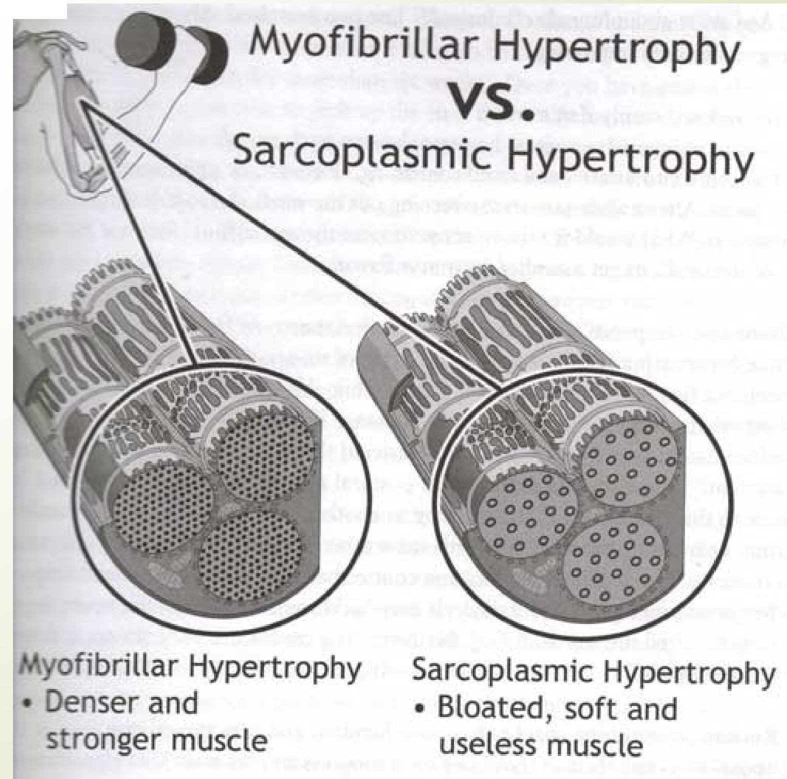
Fares D. Alahmar, 2015

?????

- 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

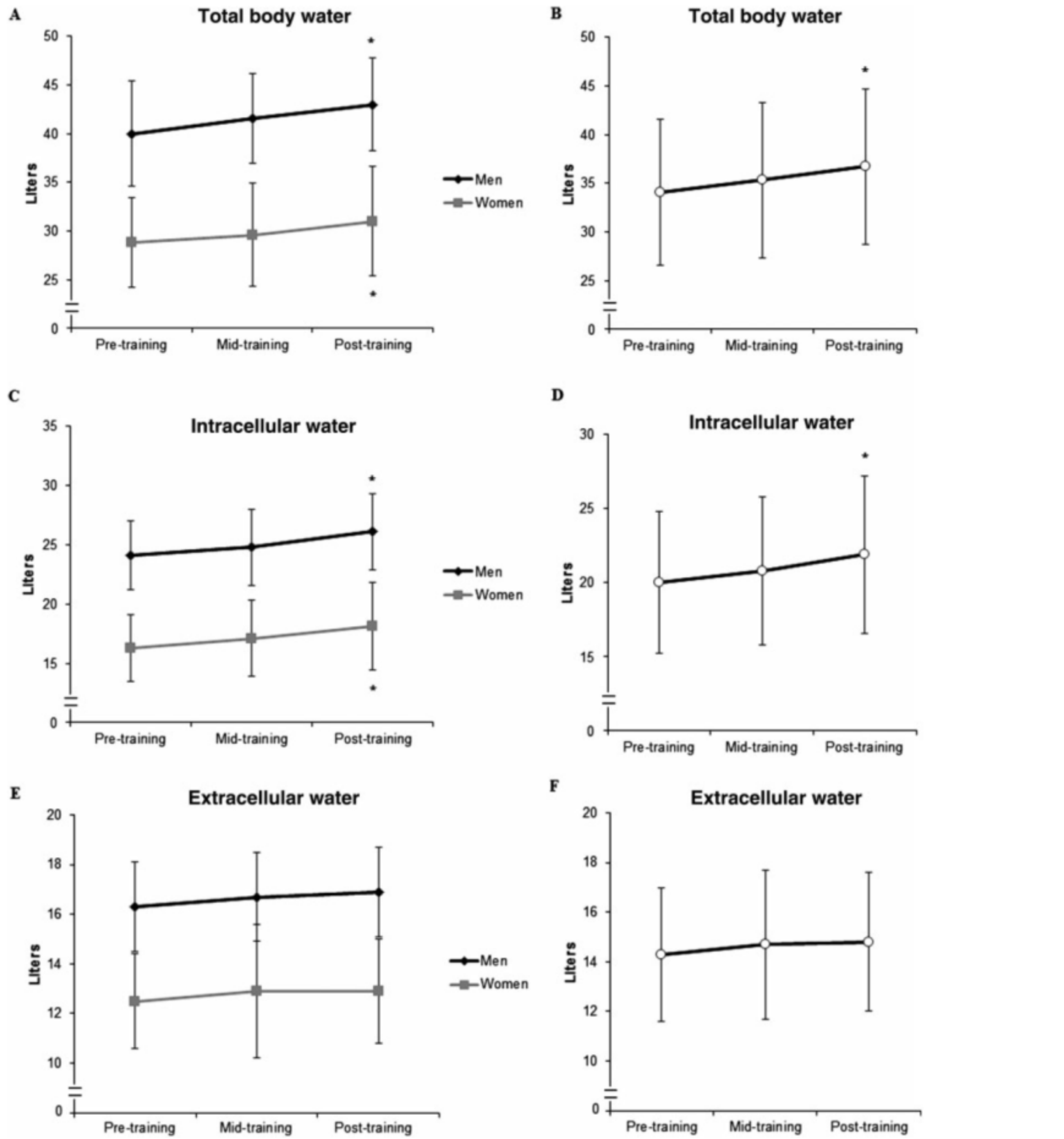


Figure 1. Total body water, intracellular and extracellular water in men and women (Panels A, C and E), and whole sample (Panels B, D and F) at different moments of the study. *$P < 0.05$ vs. Pre-training. There was no significant sex by time interaction ($P > 0.05$). Data are expressed as mean ± standard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

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

- Hypertrophy or maximum strength
- 3RM vs 10RM

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

STUDY OBJECTIVE

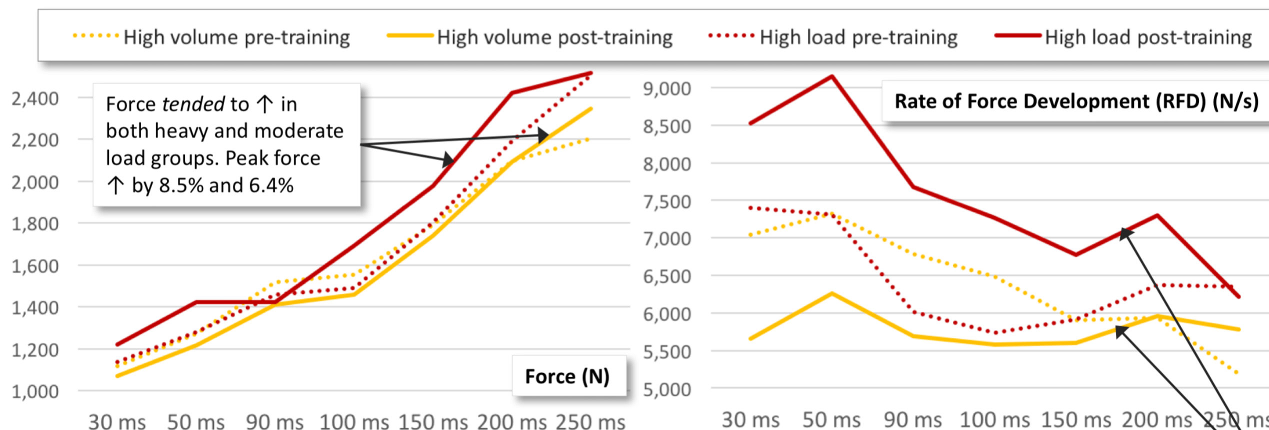
To compare the effects of long-term strength training with the same number of sets of either heavy (3 – 5RM) or moderate loads (10 – 12RM) on changes in force and rate of force development (RFD), in strength-trained males

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.



RFD *tended* to ↑ in the heavy load group (peak RFD ↑ by 16%) but it *tended* to ↓ in the moderate load group (peak RFD ↓ by 7%)

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

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

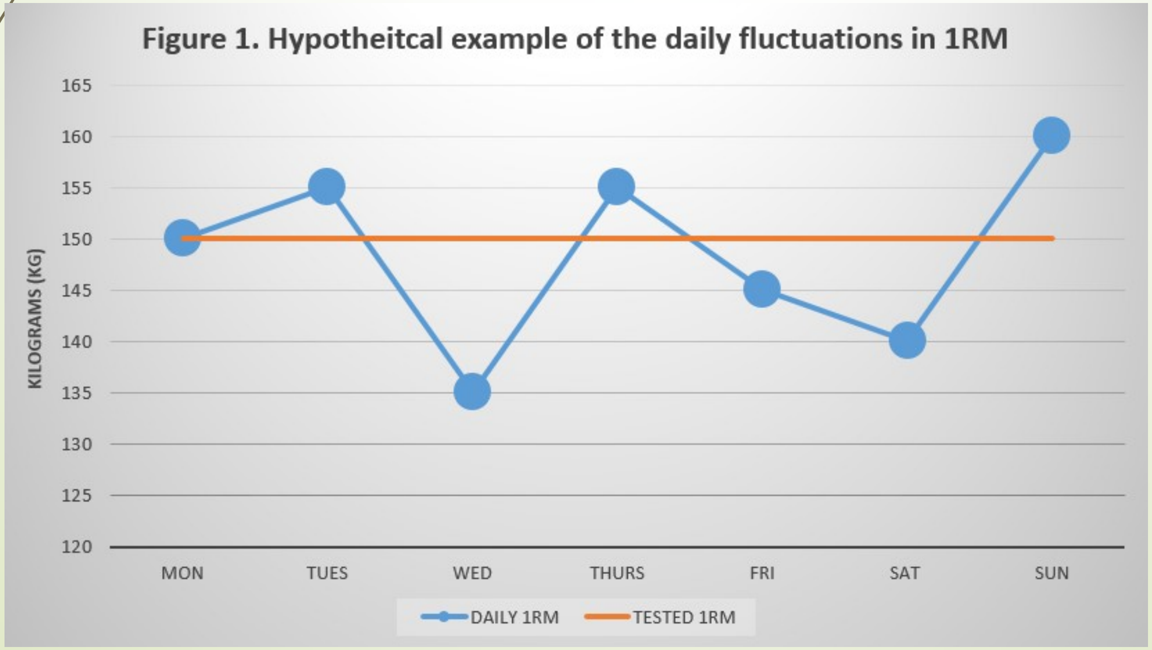
Functional hypertrophy

- Vanderka (2016)

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

Assessment of exercise intensity

- by calculating the training volume
- calculating training intensity
  - Intensity vs Effort
  - Background 1 RM



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%

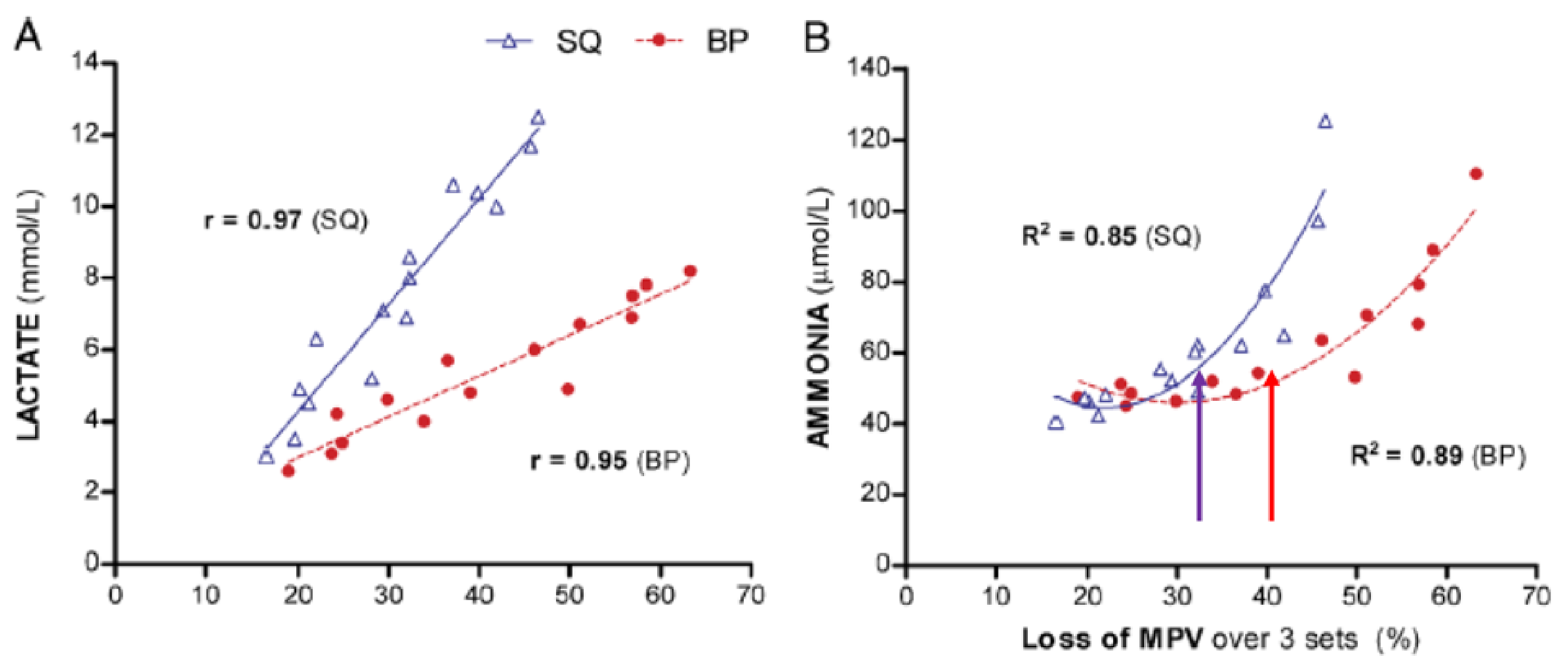
This table is adapted from [24] and [5].

https://www.scienceforsport.com/velocity-based-training/?fbclid=IwAR2sIYHLNdDEQ4F2dqXS64BaMtN4Zbz1pU6RnONzBlkKt72xL0O76I8XjlU

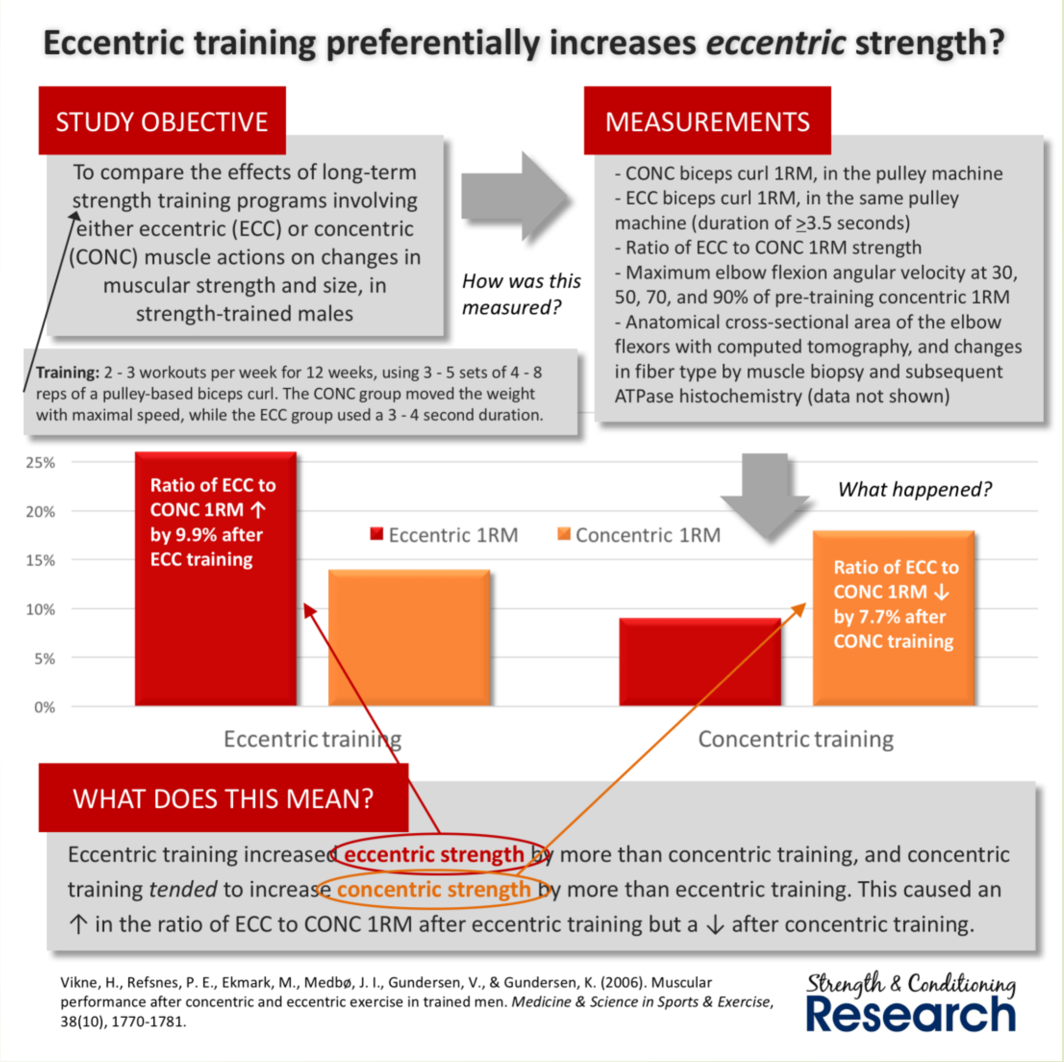
- Metabolic Fatigue (LA - increases linearly)
- Neuromuscular fatigue (increases in the shape of a curve)

- 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 strength
- 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)

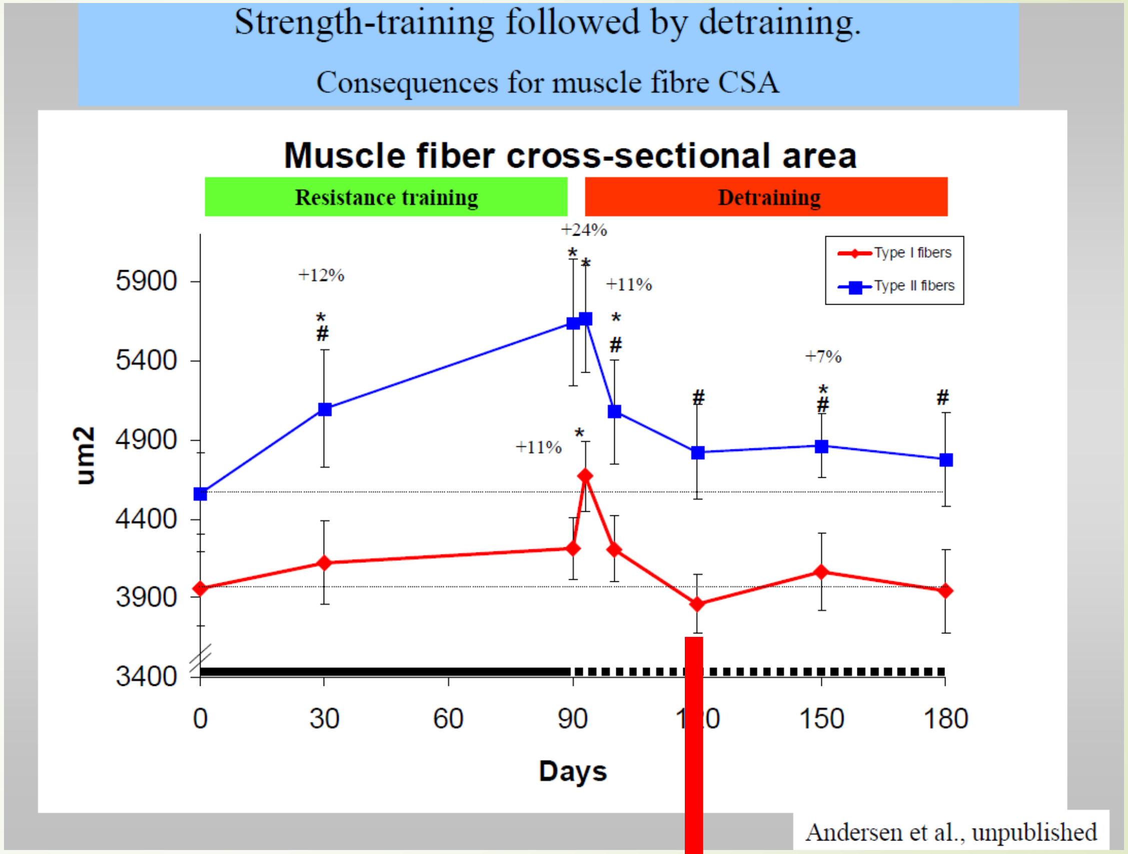
Eccentric, isometric and concentric strength gains of knee extensor muscles in eccentric training studies

	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

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

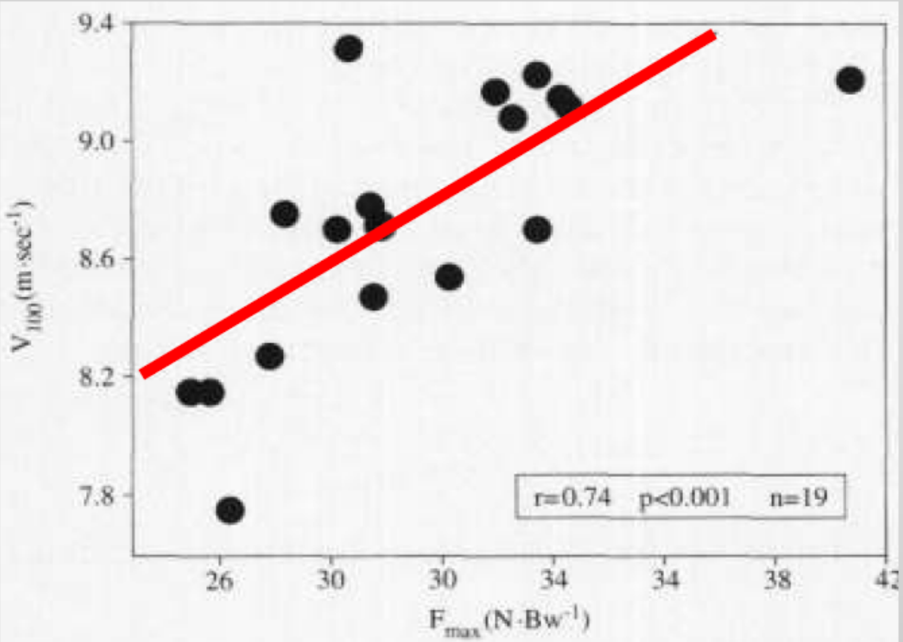
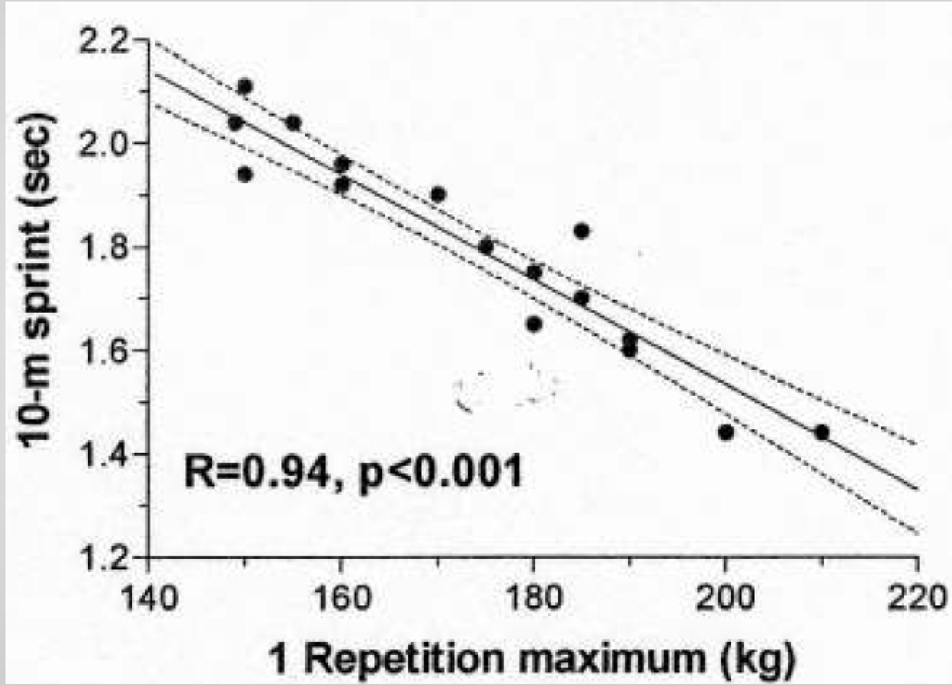


Fig. 2.—Relationship between the maximal force (F_{max}) and the mean velocity reached during a 100 m sprint (V_{100}).

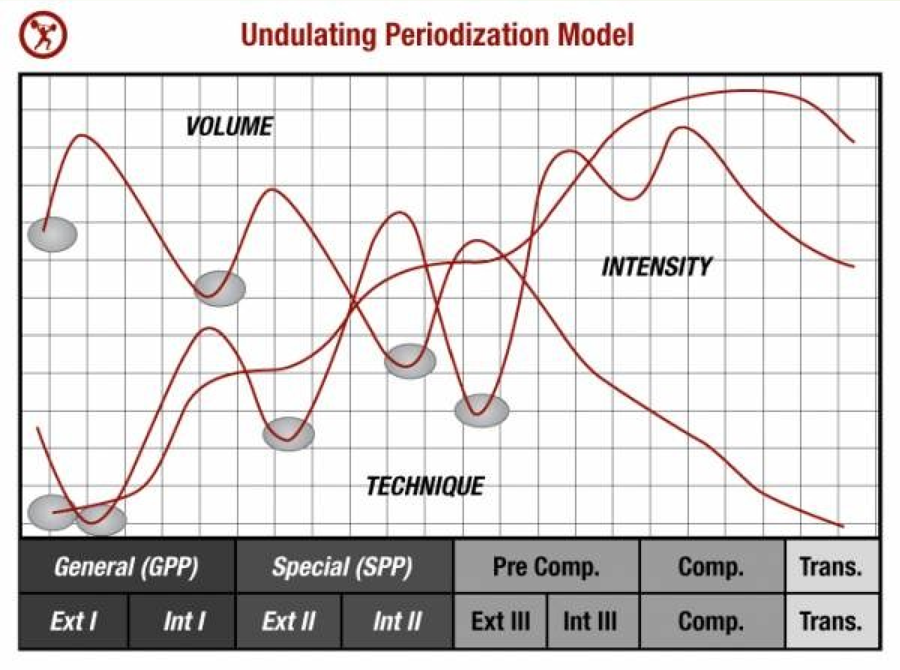
Bret et al, 2002

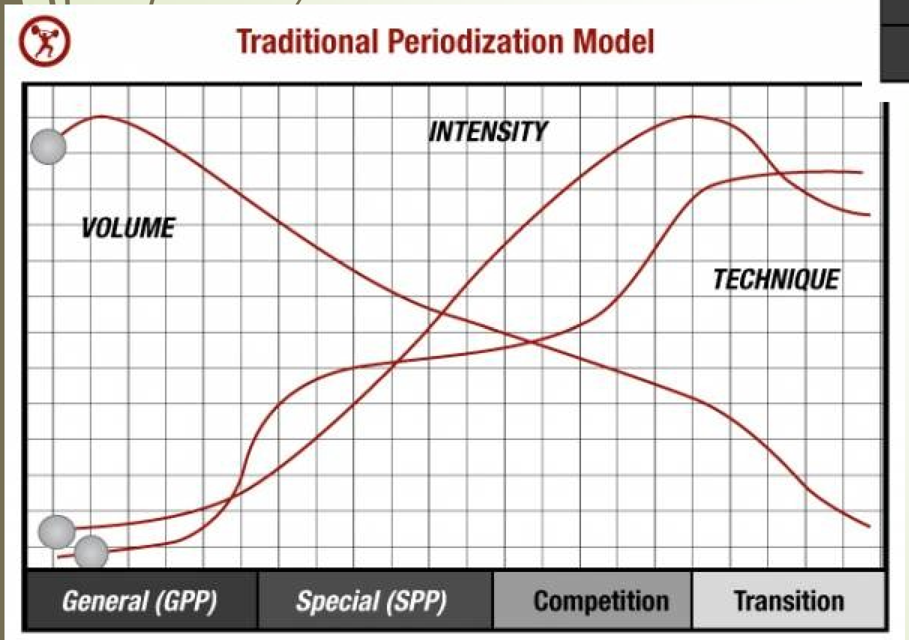
Short sprint vs. Maximal strength



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

Type of periodization





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

Thank you for your attention