Eccentric training: theory, application and periodization

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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)

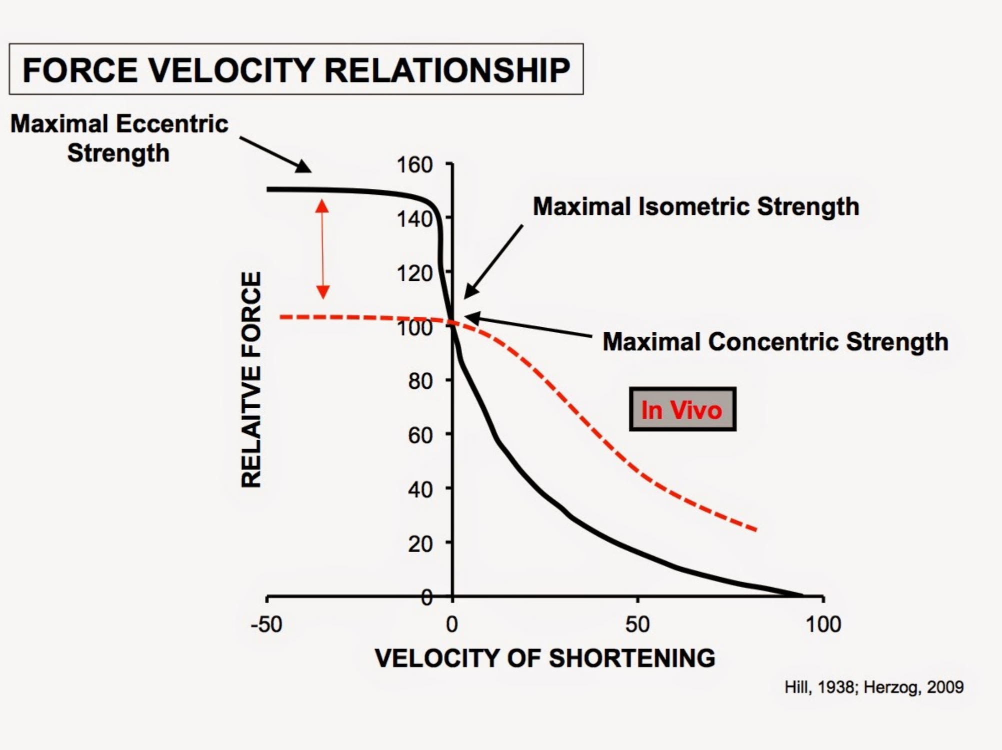
  - Vice dean for research and science FSpS MU
  - Chairman of the National Association of Strength and Conditioning Trainers of the Czech Republic
  - Head of division of Track and Field FSpS MU
  - Study program guarantor „Personal and Strength and Conditioning Trainer“
  - Chief editor of the Journal 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

Lecture structure

- Theory:
  - History of eccentric training
  - Possibilities of using eccentric training
  - Benefits of eccentric training
  - Risks of eccentric training in preparation

History of eccentric training

- **1882** - **Fick** found that the eccentric contraction muscle could **produce more strength than concentric** muscle contraction.
- **A.V. Hill** - The body has a **lower energy consumption in eccentric muscle activity** compared to concentric muscle work
- **1953 - Asmussen** introduced the concept of eccentric exercise
- The **term "eccentric"**, with "ex" meaning „away from“ and "centric" = exercise away from the center of the muscle
- **Lindstedt et al.** - In eccentric contraction, we talk about negative work.
  - function is creating braking force
- Mechanical Work in Muscle Activity $E = F(-\Delta L)$
- F = force
- ΔL = change in muscle length
- **Concentric work** - the muscle shortens - ΔL is therefore negative and the final work is positive
- **Eccentric activity** - muscle extends, ΔL is positive and resultant work negative (negative)



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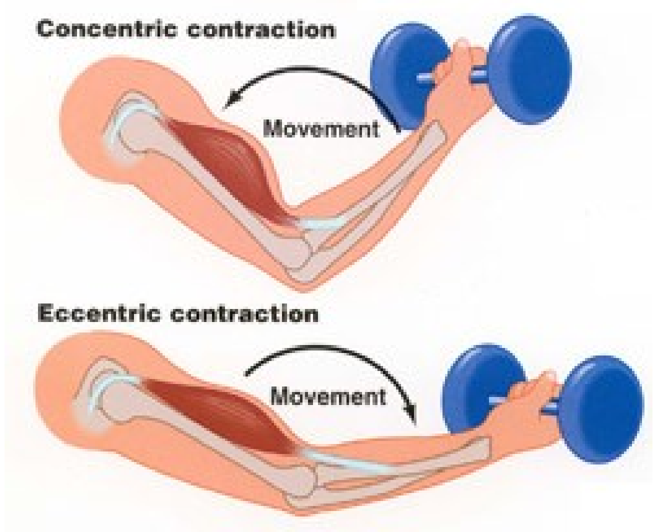
Eccentric contraction



Brady, D., 2012)

- **Muscle is prolonged when the muscle load is greater than the force produced** (Hamill, Knutzen, 2006).
- The reason for the load may be:
  - gravitation,
  - supramaximal loads with values exceeding 1RM
  - antagonist activity
- Eccentric contraction load moves downward (in the direction of gravity)
- Muscles brake and control movement down, not initiating movement (deceleration)
- The eccentric load requires only **about 1/6 - 1/7 of the amount of O2 than in concentric** mode with **the same load** (Bigland-Ritchie & Woods in Lastayo et al, 1999)
- Eccentric exercise requires a lower level of control

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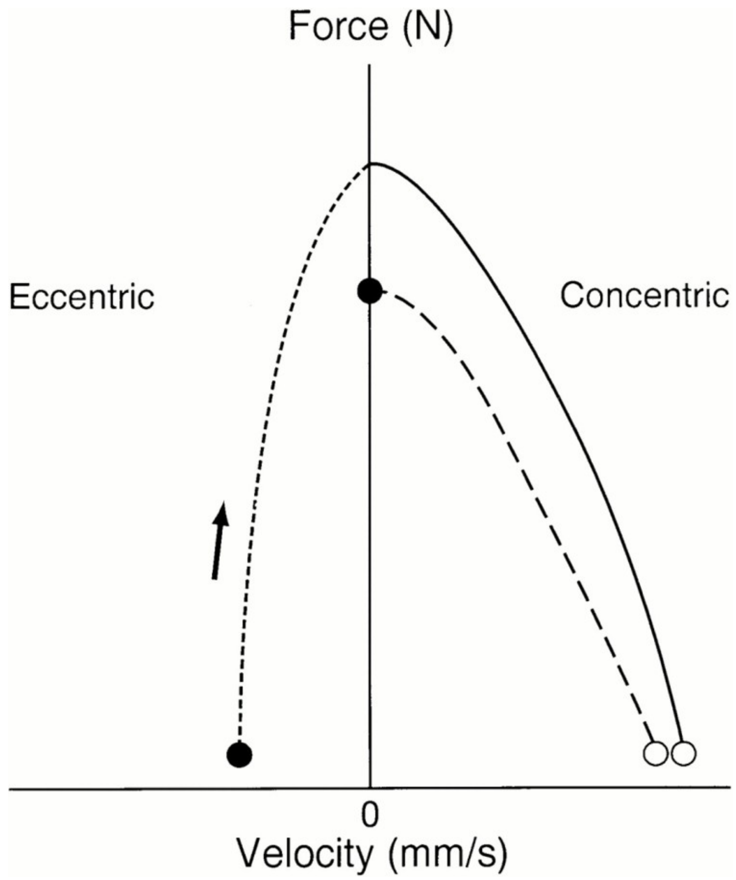
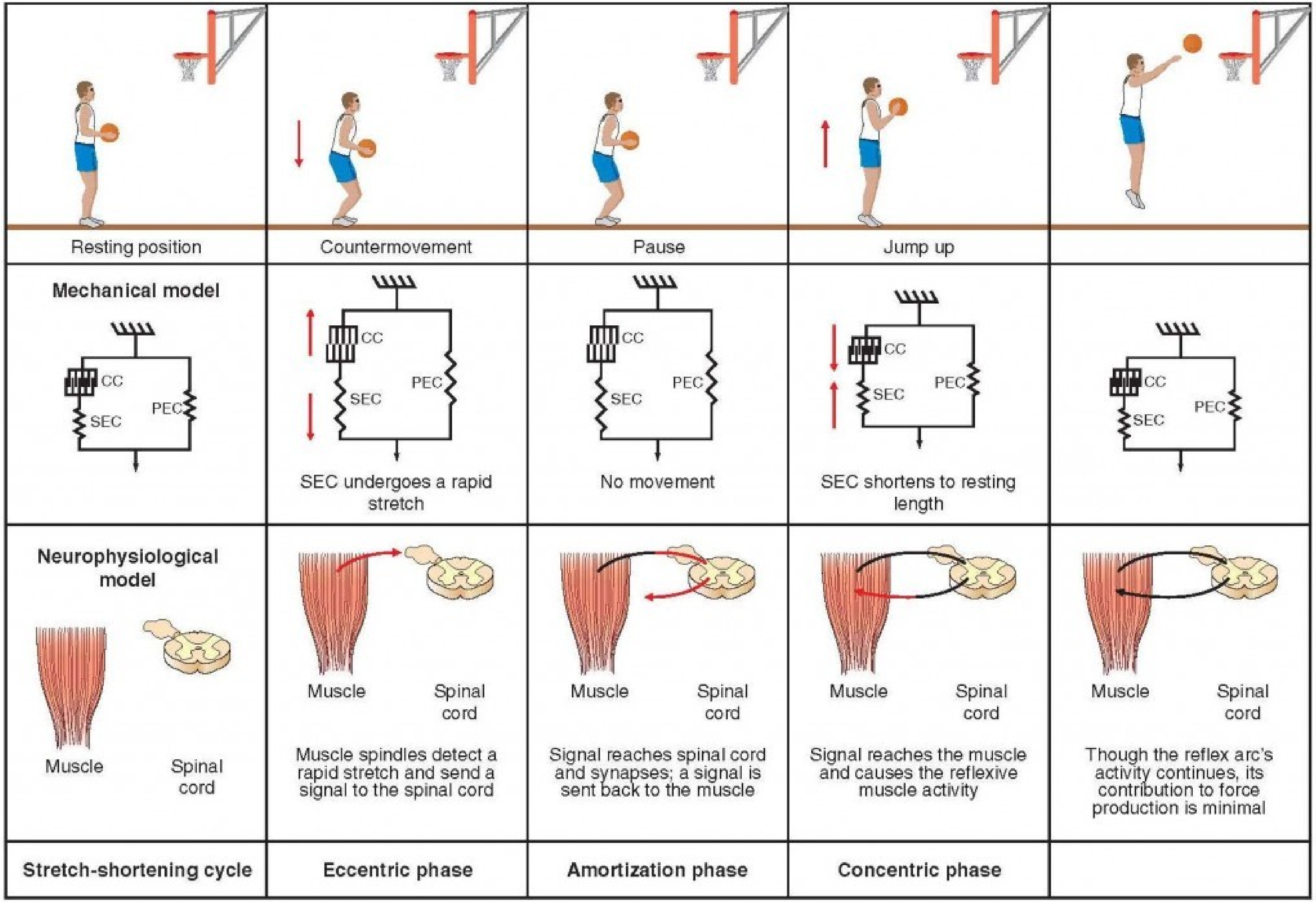
Eccentric contraction

Enoka, 1996

- prolonged muscle absorbs mechanical energy which:
  - it can be dispensed in the form of heat
  - it is temporarily stored as a back energy potential of the so-called deformation (elastic) energy and subsequently used
- strech-shortening cycle improves muscle work economy by up to 50% (Hamill, Knutzen, 1995, p. 87-89)





http://davidpotach.com/stretch-shortening-cycle/

Only concentric movement

SS
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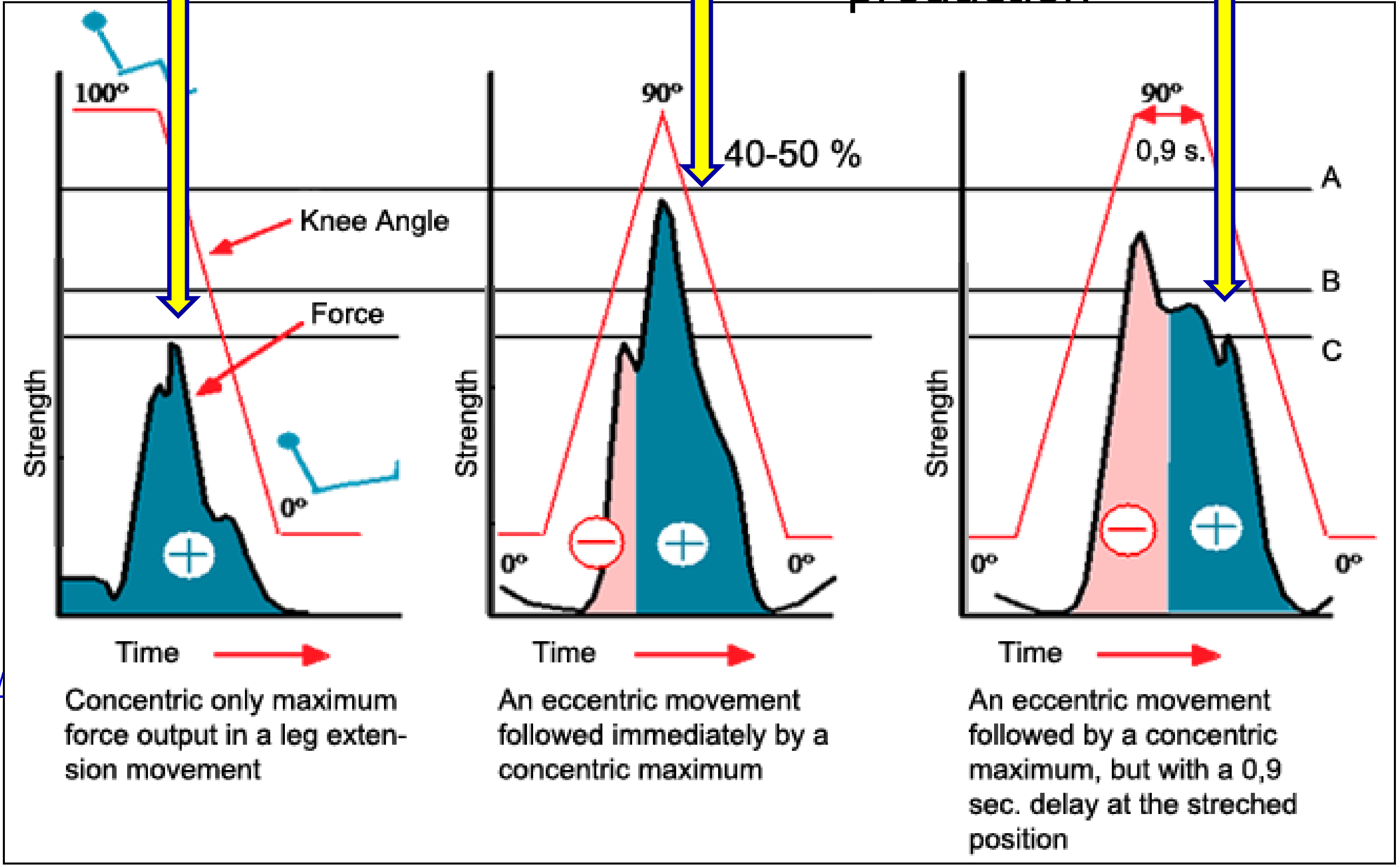
Stretching phase longer than 0.9s - concentric phase = lower power production

Electromyography: Characteristics of Produced Strength of Lower Leg Extensors in Elite Weightlifters During Isometric, Concentric and Variable SSC Cycle

Häkkinen K; Komi P V; Kauhanen H., 1989. International journal of sports medicine 1986;7(3):144-51 In: https://www.david.fi/technology/design/effectiveness/



Mechanisms associated with force increase in eccentric contraction

- Exist three theories but they are not explored enough.

- Proprioceptive afferentation (transfer of information to the Brain) the threshold of alpha motoneuron irritation decreases and therefore eccentric contraction is sometimes referred to as the contraction with the most powerful recruitment of motor units

- irritation of both **Muscle spindles** (muscle lengthens) and **Golgi muscle tendon** (muscle develops tension and therefore increases tension at the transition of muscle and tendon)

  Concentration contraction does not maintain increased afferentation from both receptor types

- motor unit recruitment is in reverse order to concentric contraction - **clearly not proven**

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Acute Effect of Eccentric Exercise = Structural Damage to Muscle and Reduction of Functionality

- At functional level the effect results in:
  - Reducing muscle strength
  - change the optimal muscle length
  - increase in passive muscle tension

  - delayed onset of muscular serenses (DOMS)
  - increasing serum muscle protein,
  - muscle edema
- chronology of muscle damage - different, may take several days = reduces performance and increases the risk of movement injury

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Benefits of eccentric training for athletes

- Increase in muscle strength
- Injury prevention - hamstrings
- Positive effect on tendons and bone tissue
- Minimizing symptoms of delayed onset of muscle pain (DOMS)

Increase in muscle strength Baroni, B. M. et al (2014)

- Eccentric Training - Progress of Eccentric Strength 10-60% (0.5% to 3.5% / Training Unit)
- Significant better than by concentric training (only half-intervention studies)
- **The increase in strength depended on:**
  - Intervention design
  - Frequency - there is no difference between 4 training session / week and 2 - 3 session / week
  - duration of intervention program (4-8 weeks = 2.16% / TS; 9-12 weeks = 1.49% / TS; greater than 12 weeks = 0.78% / TS).
  - volume, intensity - 3 - 5 series, 6 - 10 reps, 2 - 4 times a week
  - The angular velocity
  - Exercise type - isotonic exercise showing higher progression of strength than isokinetic
  - Mobility of joints
  - Muscle groups
  - Entry level of strength
  - Gender (men more than women)
  - Ages (young men higher than older men)

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Neuromuscular adaptation

- increased ability to activation agonist muscles
- improving inter-muscle coordination
- reduction of antagonist muscle activation - inconsistent conclusions (Stability Of Joints versus Peak torque)
- higher capacity for activation of motor units in eccentric contraction (NO for concentric) = specificity for type of contraction

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Structural adaptation

- First theory
- the muscle adapts by changing its resting length
- the number of sarcomers increases in series and the muscle is more prolonged (Brockett et al., 2001).

- Second theory:
- after the first intensive stage of eccentric exercise, the weak fibers are reduced
- stronger and more resilient fibers remain and have a protective effect (Armstrong et al. In. LaStayo et al., 2003).
- Chronic eccentric load causes more muscle fiber strength. This strength is important in stretching the muscle, where it protects the muscle from excessive damage

- Exc. training increases the amount of muscle mass - leads to an increase in muscle fiber cross-section - associated with the growth of both 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

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

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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.

Baroni, B. M. et al (2014)

Eccentric resistance training programs of the knee extensor muscles

	N	Gender	Age	Period	Frequency	Volume	Intensity	Exercise	Velocity
Baroni et al. [107]	20	M	24	12	2	3–5 × 10	maximal	ID	60°/s
Baroni et al. [108]	20	M	24	12	2	3–5 × 10	maximal	ID	60°/s
Ben-Sira et al. [109] – A group	10	F	21	8	2	3 × 10	65% 1-RM	KEM	3–4 s
– B group	8	F	21	8	2	3 × 5	130% 1-RM	KEM	3–4 s
Blazevich et al. [100]	11	M-F	23	10	3	4–6 × 6	maximal	ID	30°/s
Blazevich et al. [102]	11	M-F	23	10	3	4–6 × 6	maximal	ID	30°/s
Franchi et al. [119]	6	M	25	10	3	4 × 8-10	80% 1-RM$_{ecc}$	LPM	3s
Guilhem et al. [120] – A group	11	M	21	9	2–3	3–5 × 8	100–120% 1-RM	ID*	10–30°/s
– B group	10	M	20	9	2–3	3–5 × &	maximal	ID	10–30°/s
Higbie et al. [93]	19	F	20	10	3	3 × 10	maximal	ID	60°/s
Hortobagyi et al. [94]	7	M	20	12	3	4–6 × 8–12	maximal	ID	60°/s
Hortobagyi et al. [95]	14	F	21	6	4	4 × 6-10	submaximal	ID	60°/s
Housh et al. [113]	9	M	24	8	3	3–5 × 6	80% 1-RM$_{ecc}$	KEM	1–2 s
Mayhew et al. [92]	10	M-F	24	4	3	5 × 10	submaximal	ID	60°/s
Melo et al. [103]	9	M	62	12	2	2–4 × 8–12	submaximal	ID	60°/s
Miller et al. [99]	17	F	20	20	3	1–5 × 6	maximal	ID	60°/s
Nickols-Richardson et al. [101]	33	F	20	20	3	1–5 × 6	maximal	ID	60°/s
Poletto et al. [108]	18	M	22	6	2	3 × 10	maximal	ID	30°/s
Raj et al. [118]	13	M-F	68	16	2	3 × 5	50% 1-RM	LPM	ni
Raue et al. [116]	6	M	24	4	3	4 × 8	75–100% 1-RM	KEM	ni
Reeves et al. [117]	10	M-F	67	14	3	4 × 10	80% 5-RM$_{ecc}$	KEM/LPM	3 s
Rocha et al. [106]	10	M	26	12	3	2–5 × 7–9	maximal	ID	60°/s
Santos et al. [105]	20	M	22	6	2	3 × 10	maximal	ID	30°/s
Schroeder et al. [115] – A group	14	F	24	16	2	3 × 10	75% 1-RM	KEM	4 s
– B group	14	F	24	16	2	3 × 6	125% 1-RM	KEM	4 s
Seger and Thorstensson [97]	5	M	25	10	3	4 × 10	maximal	ID	90°/s
Seger et al. [96]	5	M	25	10	3	4 × 10	maximal	ID	90°/s
Smith and Rutherford [110]	10	M-F	20	20	3	4 × 10	RMs	LPM	3 s
Sorichter et al. [112] – A group	10	M	23	5	1	7 × 10	150% MIF	KEM	1–2 s
– B group	10	M	23	5	2–3	7 × 10	150% MIF	KEM	1–2 s
Spurway et al. [114]	20	M-F	24	6	3	3 × 6	RMs	KEM	ni
Symons et al. [98]	9	M-F	70	12	3	3 × 10	maximal	ID	90°/s
Tomberlin et al. [91]	21	M-F	27	6	3	3 × 10	maximal	ID	100°/s
Weir et al. [111]	9	F	24	8	3	3–5 × 6	80% 1-RM$_{ecc}$	KEM	1–2 s

N = number of subjects; Age = mean age of subjects; Period = number of training weeks; Freq. = frequency of training sessions per week; Volume = sets × repetitions; Exercise: type of exercise performed in eccentric training; Velocity = angular velocity or execution time of eccentric contractions; M = male; F = female; & = number of repetitions normalized by the work performed in the isokinetic group; 1-RM = 1-repetition maximum test; 1-RM$_{ecc}$ = 1-repetition maximum eccentric test; 3-RM = 3-repetition maximum test; 5-RM$_{ecc}$ = 5-repetition maximum eccentric test; RM = maximal eccentric repetitions method; MIF = maximal isometric force; ID = isokinetic dynamometer; ID* = modified isokinetic dynamometer; KEM = knee extensor machine; LPM = leg-press machine; ni = not informed.

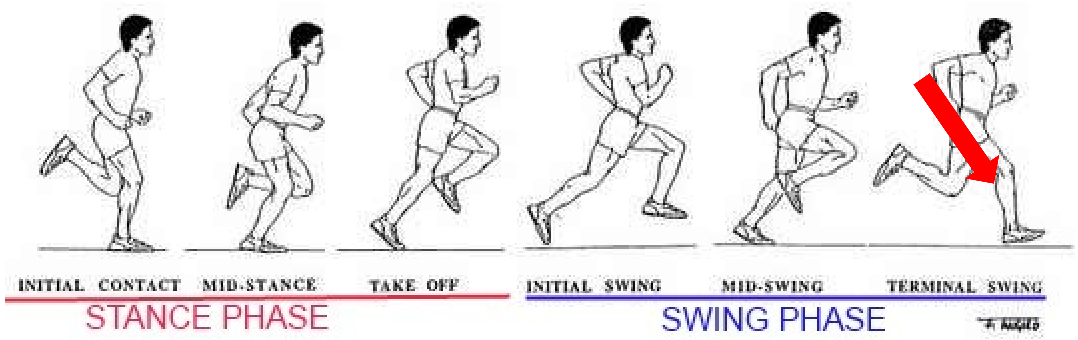
- Baroni, B. M. et al (2014)

Effect of eccentric training on speed and explosive power

- Cook et al. 2013: Comparison of 4 training programs, (3 weeks, 20 rugby, squats, bench): eccentric, concentric, eccentric + overspeed, concentric + overspeed
  - the biggest effect on speed and explosive power = Exc. + overspeed
  - Only the eccentric training improved onlythe maximum power
  - CONCLUSION: a combination of resistive eccentric training with training in which there are incentives for explosive strength and speed is recommended
- Wirth et al. (2015) examined the effects of eccentric training on maximum and explosive strength in untrained (6 weeks, unilateral legpress in eccentric phase)
  - 31.1% maximum strength improvement
  - the improvement in explosive power (jump with counter-motion) was nonsignificant
- The Wirth study supports Cook's results
  - eccentric training with resistances alone will not cause positive changes in speed and explosive force indicators
  - Exc. training with specific exercises in terms of mechanics (speed, angles…)

Injury prevention and performance - hamstrings

- The most frequent injuries of hamstrings arise at the initial contact with ground (Guex et al, 2016)
- The ratio of flexors to knee extensors
  - Problem = mostly hamstrings
  - especially for sprinters
  - Lysholma and Wiklander (1987) report injured hamstrings = 11% of running injuries
  - except for muscle injuries, the tendon hamstring is also overloaded



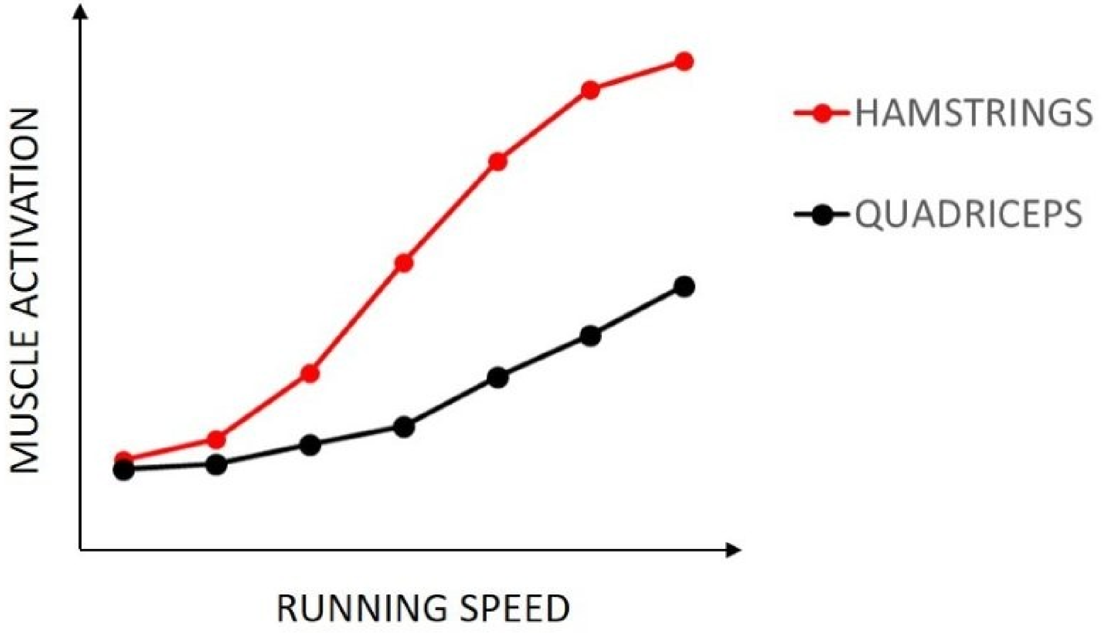
https://www.google.cz/search?q=terminal+swing+phase&client=firefox-b-ab&biw=1540&bih=822&source=lnms&tbm=isch&sa=X&ved=0ahUKEwizh7mLsMLQAhUHBsAKHaxMAEwQ_AUIBigB#imgrc=scF5srkGLW1dGM%3A

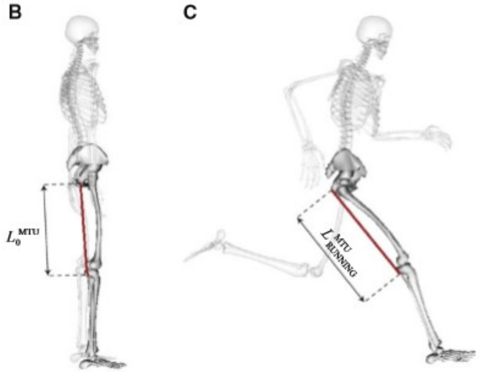
Hamstrings and Performance

Schache et al, 2013

-

  288/5000
- As the speed increases, the importance of the ratio between hamstrings and quadriceps increases
- H/Q ratio is associated with a good/bad running economy (Sundby and Gorelick, 2014)
- it is therefore recommended, in particular for sprinters, to include eccentric hamstring exercises to improve their H/Q ratio





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Hamstring injury and eccentric training

- Askling, Karlsson and Thorstensson (2002) investigate the effect of an eccentric strength program on the incidence and severity of hamstring injury (n = 30)
  - The experimental group realized eccentric hamstring training (1-2 times per week, 10 weeks) using a special devices
- Diagnosed
  - isokinetic strength of hamstrings before and after the intervention program
  - all hamstring injuries 10 months after the end of the intervention.
- Results:
  - the incidence of hamstring injury was clearly lower in the training group (3/15) vs. the control group (10/15)
  - there was a significant increase in strength and speed in the training group

Positive effect on tendons

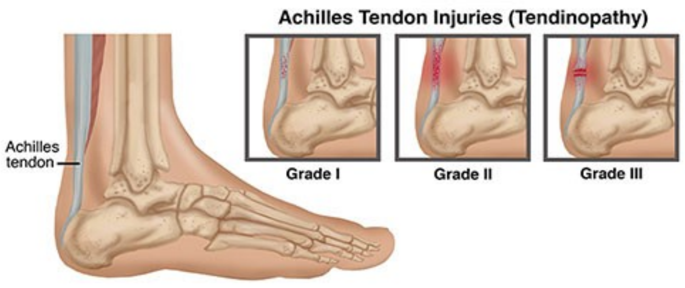
- Eccentric exercise = there is action of large forces on muscle-tendon transition
- When the acting force is greater than the muscle itself can create, there is a risk of damage to muscle, tendon, insertion
- Eccentric training has a positive effect on muscle and tendon status = treatment of tendopathies
- Adaptation to eccentric training
  - stimulation by eccentric exercise leads to collagen formation and increased fibroblastic activity - tendon hypertrophy (better muscle-tendon transfer)
  - tendon becomes stronger in tension - normalization of glycosaminoglycan levels
  - increasing the energy absorbing capacity of the muscle - reducing the risk of excessive stretching

Chronic tendinopathy of Achilles tendon

- **Painful tendon thickening**

- Especially for runners due to tendon overload = degenerative process

- Symptoms:
- increased level of glycosaminoglycans,
- irregular structure and arrangement of fibers, no inflammation
- morning stiffness
- pain limiting movement - the greatest after exercise
- new formation of blood vessels



- **Recommendation:**
- **Alfredson's exercise protocol**
- **12 weeks, 3 x 15 reps, 2 times a day**
- **with straight and bent knee**
- **exercise is slow,**
- **we increase intensity when exercise is pain free (Habets et al, 2015)**

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- Langsberg et al. - 12 soccer players (6 healthy controls, 6 with Achilles tendon, 12 weeks eccentric exercise)
  - confirmed the effectiveness of this type of treatment - eccentric exercise stimulates the synthesis of type I collagen in the area of the damaged tendon.
  - as a result of the improvement of the tendon structure, pain increase and tendon adaptation to the load also occur

- Fahlström et al. (2003) combination of eccentric exercise and stretching - application of 12 weeks to patients with pain:
  - middle part of the Achilles tendon (78 patients, 101 affected tendons)
  - with tendon pain of this tendon (30 patients, 31 affected tendons)
  - in the group of middle tendon pain, 89% of them experienced pain relief after treatment, and returned to an earlier stage of activity
  - the remaining 11% = women, higher BMI
  - In patients with tendon tendon pain - 32% tendons improved

  - the difference in the results of this group may be due to the different source of pain (bursa, bone) and not the tendon (Fahlström et al., 2003).

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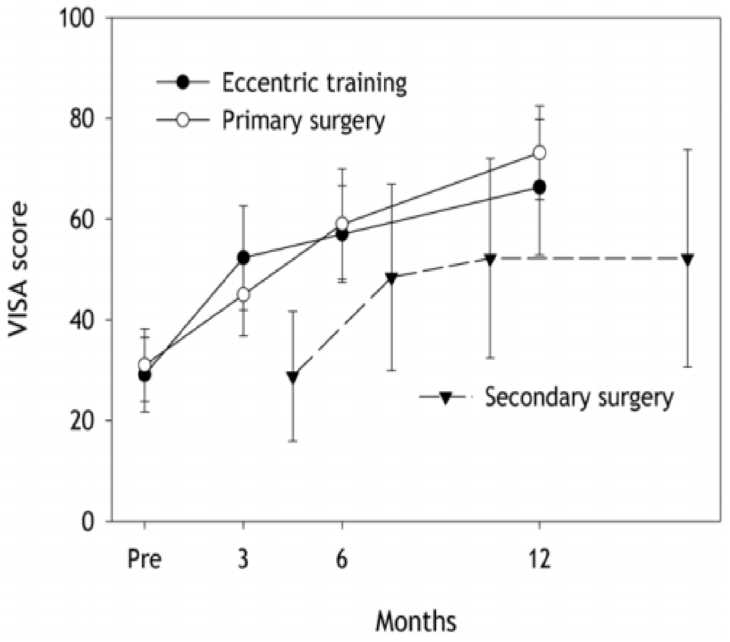
- Bahr, et al. (2006) compared the effects of surgical treatment with eccentric training of patellar tendinopathy
  - 35 patients, divided into two groups
  - 1. gr. surgical treatment with subsequent rehabilitation
  - 2. gr. eccentric strength training - squats on 25 ° inclined plate (3x15 - 2x daily, 12 weeks)
- The Victorian Institute of Sport Assessment (VISA) - (range 0 - 100), based on questionnaire responses
- specially developed for patellar tendinopathy. three, six and twelve months of follow-up
- both improvement groups (p <0.001)
- the mean VISA score for both groups increased from 30 to 49 (95% CI, 42 to 55) at three months, 58 (95% CI, 51 to 65) at six months, and 70 (95% CI, 62-78) for twelve months
- there was no superior efficacy of surgical treatment compared to eccentric strength training



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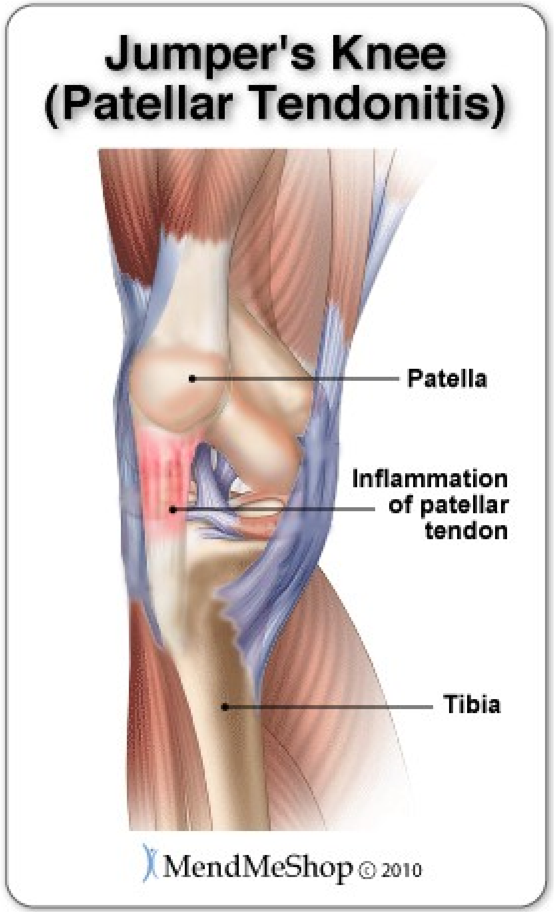
Jumpers knee - Patellar tendinopathy

- Typical of jumpers and sprinters - high demands on knee extensors
  - Occurrence can be up to 50%
- Symptoms
  - pain under the paw - especially after exercise (walking up stairs, jumps, squats)
  - In the advanced stage of pain, the workload is disabled
  - changes in tendon structure and vessel formation,
  - inflammatory origin not proven
- Cause
  - excessive tendon stress (high intensity exercise)
- Jonsson and Alfredson (2005) looked at the different efficacy of eccentric and concentric training in 15 patients with long-term ligamentum patelae involvement. Training unit twice a day for 12 weeks)
  - Eccentric and concentric training, one exercise, three series, 15 reps
  - after 6 weeks the work of the concentric group was interrupted - without positive results
  - eccentric training -l relieving pain and allowing a return to previous (pre-trauma) training activity in 90% of patients.
  - long-term effect after less than 3 years



http://www.aidmyachilles.com/tendon-muscle-injuries-in-the-leg/tendinitis-of-the-patellar-tendon.php

Minimizing symptoms of Delayed onset muscle soreness (DOMS)

- Appears when the **intensity or volume of an eccentric exercise suddenly increases**, or an **unusual high intensity movement is performed** (Nosaka, Newton, 2002)
  - In athletics typically - downhill running, overspeed, endurance runs in the field
  - Plyometric training
  - Eccentric training for beginners
- **Cause**
  - disrupting the sarcomere structure and damaging the excitation-contraction coupling mechanism (Warren et al. in Proske, Morgan, 2001, p. 333)
- **Typical symptoms**
  - decreased muscle strength
  - increase in serum creatine kinase,
  - damage to the muscle fiber structure,
  - Inflammation,
  - increasing the activity of proteolytic enzymes and pains (Stupka et al., 2001).
- **minimization = eccentric exercise** performed according to the principles of adequacy and sequence (low intensity at the start of stimulation)
- symptoms of pain = result of poorly controlled training

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RISKS OF ECCENTRIC TRAINING

- Acute injury
  - Exercise technique = 2/1, jumps
  - If the muscle produces the same torque at both concentric and eccentric contractions, fewer motor units are involved in eccentric contraction.
  - greater risk of muscle and other connective tissue damage - fewer muscle units produce a given strength, overload and easier injury to muscle (McHugh, 2003).
  - More frequent damage = fast muscle fibers (Fridén et al. In McHugh, 2003).
- Chronic injuries
  - Spine
  - Joints
- Overload
  - DOMS,
  - Non-respect of training principles
- Overtraining

Trends and possibilities of using eccentric training

- Types of eccentric training according to Mike, Kerksick a Kravitz In: Horák, (2016)
- The recovery time between training sessions should be at least 24-48 hours (Nosaka, Newton, 2002).

Excentrický trénink – technika				
Technika	provedení	Doba trvání	Série/opakování	Příklady cvičení
technika 2/1	Zvedání závaží v koncentrické fázi pomocí 2 končetin, spouštění pouze 1 končetinou	5s	70 – 80% 1RM Vybraného cviku 60s – interval odpočinku	Předkopávání, zakopávání, dřepy, bicepsový zdvih atd.
Kombinovaná technika dvou cviků	Složený pohyb z koncentrického multikloubního cviku a izolovaného excentrického cviku	5s	4 – 5 sérií x 5 opakování 90 – 110% 1RM 60s – interval odpočinku	Vzpěračský nadhoz
Pomalu/rychle	Super pomalá excentrická fáze zatímco koncentrická je explozivní	Různorodost vlivem zátěže Nižší % 1RM umožňuje delší excentrickou kontrakci (60% 10 – 12s)	60 – 85 % 1RM 60s- interval odpočinku	Tricepsové stahování kladky, dřepy s činkou, bench press atd.
Negativní (spramax.)	Brzdící technika vyžadující dopomoc 1 – 2 lidí	Závislá na zatížení	Jedno opakování 4 – 6 sérií 110 – 130% 1RM	Dřep, bench press atd.

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- The Most Effective Eccentric Exercise For Progress For Athletes

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  - Isotonic,
  - Less Effective Isokinetic,
  - Least Effective Isometric

- Bridgeman et al. recommends using SSC exercises for athletes whose performance has SSC character - drop jump
  - the length of contact with the pad should correspond optimally with the length of contact in the competition conditions during the exercises

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Conclusion

- significant physiological adaptations due to eccentric loading are manifested in both concentric and eccentric muscle activities
- for sprinters to combine with training speed or supramaximal speed
- Specific performance requires specific adaptation and that specific stimulus = mechanics, energy, coordination
- Eccentric training increases tendon strength and positively stimulates skeletal minerals
- Ecc. training acts as a prevention of hamstring injury, reduction of DOMS manifestations, therapeutic effects on patellar tendinopathy and tendonopathy of Achilles tendon.
- Eccentric Exercises are recommended to include - the prerequisite for the application of eccentric training is excellent strength preparation (concentric 1RM training), technical level and part of the RTC

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