The effect of eccentric training and tendon length on force enhancement

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Introduction

Force enhancement
When a muscle is stretched while activated and held at a certain length long enough for the force transients to cease, the steady force achieved is always higher than the steady force that develops when the muscle is activated while already held isometrically at the same final length (Figure 1)

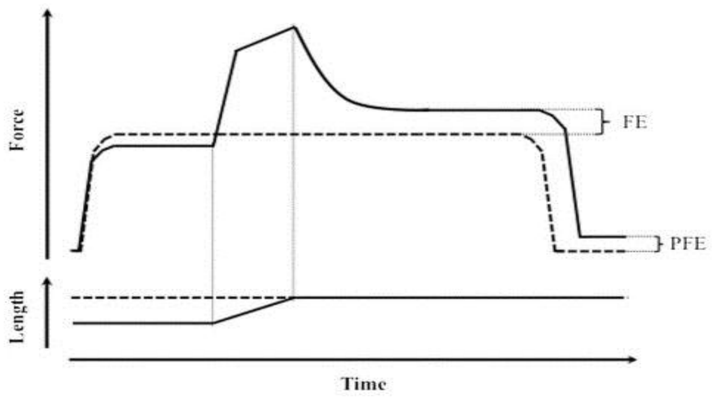

Figure 1: schematic representation force enhancement and passive force enhancement

Influence eccentric training
- Increasing eccentric force
- Membrane damage → more calcium → increasing stiffness titin

Influence tendons
- Less change in muscle length → greater muscle force
- Fast lengthening → more power transfer

Influence eccentric training on tendons
- Decrease tendon stiffness → larger energy capacity

Research question

1) Influence 4-weeks eccentric training on force enhancement

2) Influence tendons on force enhancement
- M. quadriceps femoris (QF) tendon length/ fiber length ratio: 3.9
- M. triceps surae (TS) tendon length/ fiber length ratio: 10.1

Methods

test protocol (Pre and Post) on isokinetic dynamometer:
- Same protocol for TS and QF in sitting position
  - TS: knee extended 0°, ankle plantar flexion 35°→0°
  - QF: knee flexion 30°→ 90°

Warming up + stretch	Isometric contraction (ISO 1)	Eccentric-isometric contraction	Isometric contraction (ISO 2)	Cooling down + stretch
60% HR max 15 min, treadmill QF + TS stretch	3x8s contractions 30s rest between each contraction	3x8s : - 30°/s contraction - 60°/s contraction 30s rest between each contraction	3x8s contractions 30s rest between each contraction	60% HR max 15 min Treadmill QF + TS stretch

✖ : 3 minutes rest

Table 1: test protocol

4 weeks eccentric training program:
- 2x/week: home based exercises
  - Lunge, Single leg squat, Single leg heel drop
  - 3x10 repetitions, +5 each following week
- 1x/week: supervised session: home based exercises + weight training
  - Single leg press eccentric, single leg heel drop leg press, single knee extension eccentric
  - 90% 1RM, 3x10 repetitions, +10% 1RM each following week

Results

No fatigue
- ISO 1 = ISO 2

Effect eccentric training
- Table 2

Training effect			
Muscle + speed	Isometric	Eccentric-isometric	Force enhancement
QF 30°/s	↗	↗	none
QF 60°/s	↗	=	none
TS 30°/s	=	=	=
TS 60°/s	=	↗	↗

Table 2: influence four-weeks eccentric training

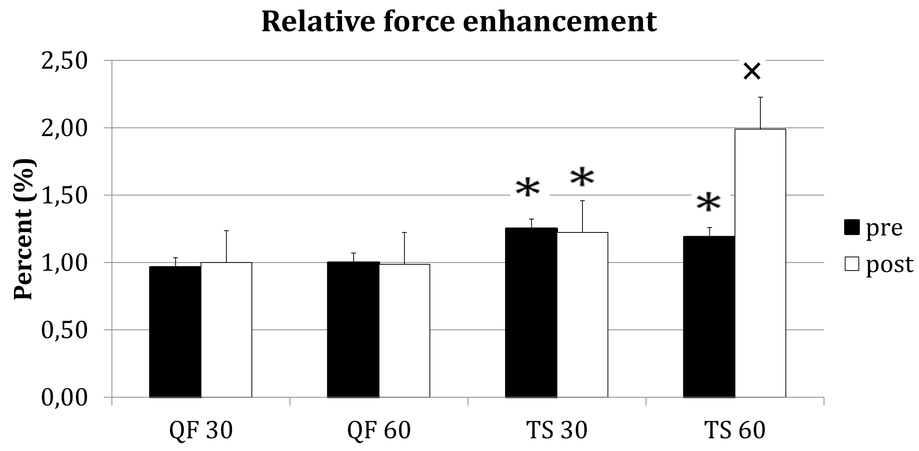

Figure 2: relative force enhancement (eccentric-isometric/isometric
* Significantly different from 1 with P<0.05,
x significantly different from TS 30 pre, TS 30 post and TS 60 pre with P<0.05

- There was no difference between the eccentric-isometric and isometric contraction of the QF at the two speeds, before or after training.
- TS, with a 2.6 larger average tendon/fiber length ratio than the QF, shows 19 to 99% more FE than QF.
- TS demonstrates a significant increase of 80% at a speed of 60°/s.
- There was no significant training effect of FE for TS 30.

Discussion & Conclusion

Difference of force enhancement between QF and TS and the role of tendons
- Absent force enhancement at QF
  - Larger stretch amplitude of 60°
    → protective neural inhibition of the muscle
  - Co-contraction
- Force enhancement at TS
  - 2.6 larger average tendon/fiber length ratio
  - Advantage tendons
    - Avoiding excessive lengthening resulting in absent protective neurological inhibition or co-contraction
    - Pennate muscle
      - Beneficial for generating force
- TS relatively more in stretch position than m. rectus femoris as a part of QF.

Training effect of force enhancement
- TS 60°/s:
  - Isometric force unchanged after training,
  - Eccentric-isometric force increased after training
- Decreasing tendon stiffness after eccentric training
  →Larger energy capacity
- Increase stiffness titin as result of calcium inflow after eccentric training.

Implications natural human movement and sport performances
- More stable landing of a gymnast due to stronger isometric contraction after an eccentric phase.

Conclusion
TS shows 19-99% more force enhancement than QF
It can be explained by a suppressed inhibition and co-contraction due to beneficial effect of tendon, beneficial muscle architecture and stretch position.
TS can withstand a higher amount of force after an active stretch of 60°/s as a result of four-weeks eccentric training program.
Possibly because of the decreasing tendon stiffness and increase stiffness of titin after eccentric training.

References

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