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How different types of strength training affect ankle muscles and tendons

Submission date
29/10/2025

Recruitment status
No longer recruiting

Registration date
13/11/2025

Overall study status
Completed

Last Edited
26/01/2026

Condition category
Other

[_] Prospectively registered
[_] Protocol
[_] Statistical analysis plan
[_] Results
[_] Individual participant data
[X] Record updated in last year

Plain English summary of protocol

Background and study aims
This study aims to explore how different strength training methods affect the muscles and tendons in the lower leg. We are comparing eccentric quasi-isometric (EQI) training — a method that combines slow and static muscle actions — with traditional eccentric training, which involves controlled lowering movements. Understanding how these methods influence muscle and tendon properties may help improve exercise and rehabilitation programs.

Who can participate?
Healthy men and women aged 18 to 30 years who regularly participate in resistance training (at least two to three sessions per week) can take part. Participants must have no lower-limb injuries in the past year and no other health conditions that limit physical activity.

What does the study involve?
After initial testing, participants will be randomly assigned to one of three groups: EQI training, traditional eccentric training, or a control group. The training groups will complete two supervised sessions per week for six weeks. Measurements of muscle and tendon properties, strength, and ankle flexibility will be taken before and after the training period.

What are the possible benefits and risks of participating?
The exercises may help improve muscle strength and tendon resilience. Risks are minimal and limited to temporary muscle soreness similar to that experienced after intense exercise.

Where is the study run from?
The study is coordinated by the University of Primorska, Faculty of Health Sciences, in Izola, Slovenia.

When is the study starting and how long is it expected to run for?
Recruitment begins in October 2025, and the intervention phase will last six weeks. The study is expected to finish in January 2026.

Who is funding the study?
The study is funded by the Slovenian Research and Innovation Agency (ARIS), within the postdoctoral research project EQI-TRAIN (Z5-50181).

Who is the main contact?
Dr Žiga Kozinc, ziga.kozinc@fvz.upr.si

Contact information

Type(s)
Public, Scientific, Principal investigator

Contact name
Dr Žiga Kozinc

ORCID ID
https://orcid.org/0000-0003-3555-8680

Contact details
Bernetičeva 8
Koper
Slovenia
6000
+38640161503
ziga.kozinc@fvz.upr.si

Additional identifiers

Protocol serial number
EQI_Train3 (internal protocol ID, University of Primorska)

Study information

Scientific Title
Effects of eccentric quasi-isometric and eccentric training on mechanical and architectural properties of the ankle plantar flexors: a randomized controlled trial

Acronym
EKI-TRAIN3

Study objectives
The primary objective of this study is to compare the effects of eccentric quasi-isometric (EQI) training and traditional eccentric resistance training on the mechanical and architectural properties of the ankle plantar flexor muscles and the Achilles tendon in healthy adults.

Secondary objectives are to evaluate changes in:
1. Isometric, concentric, and eccentric strength of the plantar flexors,
2. Ankle range of motion
3. Perceived muscle soreness and session difficulty following both training interventions.

The findings will provide insight into how distinct eccentric loading strategies influence muscle–tendon adaptation and may contribute to optimizing training and rehabilitation protocols targeting the ankle plantar flexor complex.

Ethics approval required
Ethics approval required

Ethics approval(s)
Approved 15/09/2025, Komisija Republike Slovenije za medicinsko etiko (Republic of Slovenia's National Medical Ethics Committee) (Štefanova ulica 5, Ljubljana, 1000, Slovenia; +386 1 478 60 00; kme.mz@gov.si), ref: 0120-489/2024-2711-5

Primary study design
Interventional

Study design
Randomized controlled interventional study with three parallel groups

Study type(s)
Prevention

Health condition(s) or problem(s) studied
This study focuses on muscle–tendon adaptation and function in healthy adults. It does not involve patients with pathological conditions. The research investigates how different eccentric loading strategies affect the mechanical and architectural properties of the ankle plantar flexor muscles and Achilles tendon.

Interventions
Participants will be randomly assigned to one of three groups:

Eccentric quasi-isometric (EQI) training:
Participants will complete a 6-week EQI training program targeting the right ankle plantar flexors, performed twice weekly. Each session includes a standardized warm-up and repeated quasi-isometric contractions under load, alternating with eccentric muscle actions until fatigue. The load corresponds to 100% of one-repetition maximum (1RM), re-evaluated at weeks 1, 3, and 5.

Traditional eccentric training:
Participants will perform a 6-week unilateral eccentric heel-drop program using an Olympic barbell load equal to 100% of 1RM (reassessed at weeks 1, 3, and 5). The program progresses from 2 × 15 repetitions in week 1 to 4 × 15 from week 4 onward, with a 3-second eccentric phase and 2-minute rest between sets.

Control group:
Participants will maintain their normal physical activity routines but will refrain from any targeted strengthening or proprioceptive training involving the ankle plantar flexors.

Participants will be randomly assigned to one of the three groups (1:1:1 ratio) using sealed opaque envelopes. The envelopes will contain pre-prepared group assignments and will be shuffled prior to the start of the study. Each participant will draw one envelope after completing baseline testing to determine group allocation. The envelope method ensures allocation

concealment, as neither participants nor assessors will know the assignment until the envelope is opened.

Intervention Type
Behavioural

Primary outcome(s)
1. Muscle fascicle length is measured using panoramic B-mode ultrasound imaging of the medial and lateral gastrocnemius at baseline and 1 week after completion of the 6-week intervention
2. Muscle pennation angle is measured using panoramic B-mode ultrasound imaging of the medial and lateral gastrocnemius at baseline and 1 week after completion of the 6-week intervention
3. Muscle thickness is measured using panoramic B-mode ultrasound imaging of the medial and lateral gastrocnemius at baseline and 1 week after completion of the 6-week intervention

Key secondary outcome(s)
1. Isometric peak torque of the ankle plantar flexors is measured using an isokinetic dynamometer (HumacNorm, USA) under isometric conditions at baseline and 1 week after completion of the 6-week intervention
2. Concentric peak torque of the ankle plantar flexors is measured using an isokinetic dynamometer (HumacNorm, USA) at 60°/s at baseline and 1 week after completion of the 6-week intervention
3. Eccentric peak torque of the ankle plantar flexors is measured using an isokinetic dynamometer (HumacNorm, USA) at 60°/s at baseline and 1 week after completion of the 6-week intervention
4. Ankle dorsiflexion range of motion is measured using a goniometer in open- and closed-kinetic-chain positions at baseline and 1 week after completion of the 6-week intervention
5. Perceived muscle soreness is measured using a 10-point numerical rating scale before and after each training session during the 6-week intervention
6. Perceived session difficulty is measured using a 10-point numerical rating scale before and after each training session during the 6-week intervention

Completion date
16/01/2026

Eligibility

Key inclusion criteria
1. Healthy adults (male and female) aged 18–30 years.
2. No musculoskeletal injuries in the past 3 months.
3. No ankle injuries in the past 12 months.
4. Regular participation in resistance training (≥2–3 sessions per week during the past 6 months).
5. Ability and willingness to participate in all testing and training sessions.
6. Agreement to maintain usual daily physical activity and to refrain from any additional resistance or proprioceptive training targeting the ankle plantar flexors during the study period.

Participant type(s)
Healthy volunteer

Healthy volunteers allowed
No

Age group
Adult

Lower age limit
18 Years

Upper age limit
30 Years

Sex
All

Total final enrolment
48

Key exclusion criteria
1. Presence of chronic infectious or metabolic disease.
2. Cardiovascular or respiratory disorder that limits physical activity.
3. Diagnosed neurological condition (e.g., multiple sclerosis, Parkinson’s disease).
4. Current or recent musculoskeletal injury not meeting inclusion criteria.
5. Use of medications that may influence physical performance or neuromuscular function.
6. Pregnancy.

Date of first enrolment
06/11/2025

Date of final enrolment
15/11/2025

Locations

Countries of recruitment
Slovenia

Study participating centre
University of Primorska, Faculty of Health Sciences
Polje 42
Izola
Slovenia
6310

Sponsor information

Organisation

University of Primorska, Faculty of Health Sciences

Funder(s)

Funder type
Government

Funder Name
Slovenian Research and Innovation Agency (ARIS)

Results and Publications

Individual participant data (IPD) sharing plan

IPD sharing plan summary
Not expected to be made available

Study outputs

Output type	Details	Date created	Date added	Peer reviewed?	Patient-facing?
Participant information sheet			30/10/2025	No	Yes