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Effects of 8 weeks of free-weight and machine-based resistance training on knee muscle function

Submission date
08/07/2025

Recruitment status
Recruiting

Registration date
17/07/2025

Overall study status
Ongoing

Last Edited
17/07/2025

Condition category
Musculoskeletal Diseases

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

Plain English summary of protocol

Background and study aims
Previous studies have explored the differences in strength, power, and muscle hypertrophy between long-term free weight training and machine-based training. However, there has been limited investigation into the effects of free weight and machine training on muscle activation. Therefore, the primary aim of this study is to investigate the effects of free weight versus machine-based training on muscle activity and function in the lower limbs.

Who can participate?
Healthy volunteer adults aged between 18 and 35 years old

What does the study involve?
Participants will be randomly assigned to either a barbell squat group or a leg press group. After the assignment, participants will schedule an appointment with the researcher for their first baseline data collection session, which will take approximately 2 hours. During this session, participants will complete a series of questionnaires. Researchers will then measure mid-thigh circumference and assess the muscle thickness of the vastus medialis, vastus lateralis, and rectus femoris using ultrasound imaging. Surface electromyography measures and countermovement jump tests will follow. High-density surface EMG and maximum voluntary contraction assessments will also be conducted. Finally, a one-repetition maximum test will be performed to determine maximum strength.

In the first part of the session, surface electromyography sensors will be attached to the skin over multiple muscles of the lower extremities. Before placing these sensors, local shaving may be required using a disposable razor. Under the guidance of the researcher, participants will then stand on a platform and perform a series of jumps, including a countermovement jump and a squat jump.

In the second part of the session, additional sensors will be attached to the muscles of the dominant leg. Participants will sit on a machine that records muscle force and perform a series of seated knee muscle contractions, including maximum isometric, concentric, eccentric, and

explosive isometric contractions. After completing the knee extension tests, participants will also perform several maximum and submaximal isometric mid-thigh pull tests.

Under the guidance of an experienced strength and conditioning coach, participants will complete a one-repetition maximum test for either the barbell squat or leg press to determine the initial weight for the intervention.

Following baseline data collection, participants will engage in intervention training conducted twice a week with 48–72 hours between sessions. Each training session will include a standard warm-up followed by a 5x5 training session at a 3-1-X tempo (concentric-isometric-eccentric), starting at 70% of the baseline one-repetition maximum. Training weight will progressively increase under supervision. A deload week will follow every three weeks of overload training to manage fatigue. Experimental data will be recollected in the second, fourth, and eighth weeks using the same tests as the initial assessment. Throughout the study, participants will complete 19 sessions: 12 conventional training sessions, 2 deload sessions, 1 familiarisation session, and 4 data collection sessions.

What are the possible benefits and risks of participating?
Potential benefits of participating include improvements in lower-limb muscle strength, muscle mass, and physical performance. Resistance training is also strongly associated with better functional capacity, reduced risk of injury in daily life, and enhanced overall quality of life, especially when targeting lower-body strength.

Resistance training is generally considered safe for healthy adults, but like any form of physical activity, it carries some inherent risks. Based on previous research, the estimated injury rate is approximately 2–4 injuries per 1,000 training hours, typically involving minor issues such as muscle strains or joint sprains. To minimise these risks, all sessions in this study will be closely supervised by Rongda Zhang, an experienced strength and conditioning coach.

Where is the study run from?
The experiment will take place in laboratories at the School of Sport, Exercise and Rehabilitation Sciences, University of Birmingham, UK.

When is the study starting and how long is it expected to run for?
November 2024 to December 2026

Who is funding the study?
The bench fees of PhD student Rongda Zhang at the University of Birmingham cover the costs of this study.

Who is the main contact?
Professor Deborah Falla, d.falla@bham.ac.uk

Contact information

Type(s)
Public, Scientific, Principal Investigator

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Additional identifiers

EudraCT/CTIS number
Nil known

IRAS number

ClinicalTrials.gov number
Nil known

Secondary identifying numbers
Nil known

Study information

Scientific Title
Effects of 8 weeks of free-weight and machine-based resistance training on neuromuscular function

Study objectives
The primary objective of the study is to compare the effects of free weight training (barbell squats) and machine training (leg press) on neuromuscular function and motor unit behaviour of lower limb muscles over an 8-week period.

Ethics approval required
Ethics approval required

Ethics approval(s)
Approved 13/01/2025, Science, Technology, Engineering and Mathematics Committee (University of Birmingham, Birmingham, B152TT, United Kingdom; -; ethics-queries@contacts.bham.ac.uk), ref: ERN_3214-Jan2025

Study design
Single-centre randomized controlled trial

Primary study design
Interventional

Secondary study design
Randomised controlled trial

Study setting(s)

University/medical school/dental school

Study type(s)
Other

Participant information sheet
See study outputs table

Health condition(s) or problem(s) studied
Training of lower limb strength in healthy individuals

Interventions
Free weight training (barbell squats) or machine training (leg press) was performed over 8 weeks.

1. Randomization will be performed in advance, using a computer-generated random number sequence to assign participants 1 to 54 to two equal groups. After enrollment, participants will be assigned to the corresponding group according to the pre-randomly assigned participant number.
2. The intervention consists of either barbell back squat training or machine-based leg press training, carried out over 8 weeks. Participants will train twice per week with at least 48 hours between sessions. Each training session will involve 5 sets of 5 repetitions, performed at a minimum of 70% of the participant's most recently assessed one-repetition maximum (1RM). Load will be adjusted in real time based on individual readiness to ensure adherence to the principle of progressive overload. Each repetition will follow a 3-1-X tempo (3 seconds eccentric, 1 second isometric, and an explosive concentric phase).
To facilitate recovery and manage accumulated neuromuscular fatigue, a deload session using approximately 50% 1RM will be incorporated every fourth week (i.e., after three consecutive weeks of overload training).
Each session will last a minimum of 30 minutes and will include a structured warm-up, the main training exercise (either squat or leg press), and a cool-down phase. No additional resistance exercises will be included beyond the assigned intervention.
3. All intervention sessions will be supervised and delivered solely by Rongda Zhang, the doctoral researcher conducting the study. Rongda has over 10 years of experience in fitness and strength and conditioning instruction, with several thousand hours of hands-on coaching. He previously served as a strength and conditioning coach for the Chinese national teams in freestyle wrestling, cross-country skiing, and kickboxing.
He earned a Master's degree in Sports Training from Beijing Sport University in 2023, with a specialization in strength and conditioning. In addition, Rongda holds multiple professional certifications, including NSCA Certified Strength and Conditioning Specialist (CSCS), NASM Performance Enhancement Specialist (PES), and EXOS Performance Specialist (XPS).
4. The interventions will be delivered in one-on-one or small group formats, depending on the participant's availability. All sessions will be supervised by Ronda, who will provide real-time coaching and guidance to ensure each repetition is completed with correct technique. Loads will be adjusted based on the speed and tempo of movement observed during each lift to allow for personalized progression while maintaining technical quality.
5. The intervention will take place in the Strength Laboratory within the School of Sport, Exercise and Rehabilitation Sciences at the University of Birmingham. The training equipment includes a standard Olympic men's barbell (20 kg, Strength UK), a power rack (Strength UK), a leg press machine (Cybex, USA), and calibrated weight plates ranging from 1.25 kg to 20 kg.

Intervention Type

Behavioural

Primary outcome measure
The following primary outcome measures will be assessed at baseline and after the 3rd, 4th, and 7th training sessions (within the 8-week intervention period):
1. Knee extensor muscle strength will be measured using an isokinetic dynamometer (Biodex System 3, USA) during maximal voluntary isometric, concentric, and eccentric contractions
2. Maximal isometric force will be measured using an isometric belt squat test with a force sensor (RS, UK)

Secondary outcome measures
The following secondary outcome measures will be assessed at baseline and after the 3rd, 4th, and 7th training sessions (within the 8-week intervention period):
1. Vertical jump performance, including countermovement jump (CMJ) and squat jump (SJ), will be measured using a force platform system (BTS Bioengineering, Italy). Jump height is calculated using the flight time method.
2. Intermuscular coordination will be measured using wireless surface electromyography (sEMG) systems (BTS Bioengineering, Italy). sEMG signals will be synchronously recorded from eight lower-limb muscles: vastus medialis, vastus lateralis, rectus femoris, tibialis anterior, gluteus maximus, biceps femoris (long head), semitendinosus, and medial gastrocnemius during the performance of countermovement jumps (CMJ) and squat jumps (SJ). Non-negative matrix factorization (NMF) will be applied to the multichannel EMG data to evaluate changes in muscle coordination patterns over time.
3. Vasti muscle activity will be measured using high-density surface electromyography (HDsEMG) with 64-channel (13×5) electrode grids (OT Bioelettronica, Italy) placed over the vastus medialis, vastus lateralis, and rectus femoris muscles. HDsEMG signals will be recorded during multiple contraction tasks including: (1) isometric knee extensions on a Biodex System 3 dynamometer (USA) at MVC, trapezoidal contractions at 10%, 30%, 50%, and 70% MVC, and explosive contractions at 75% MVC for RTD assessment; (2) concentric and eccentric contractions at MVC and submaximal efforts (10% and 50% MVC) using visual template matching; and (3) isometric belt squat tests using a force sensor (RS, UK), followed by 10% and 50% MVC trapezoidal contractions. All submaximal tasks will be performed with real-time visual feedback on an external screen to ensure force tracking accuracy.
EMG signals will be analysed using custom MATLAB scripts to extract RMS values, entropy, and spatial activation maps. Motor unit decomposition is conducted using Swarm Contrastive Decomposition (SCD) to determine recruitment thresholds and discharge rates.

Overall study start date
01/11/2024

Completion date
31/12/2026

Eligibility

Key inclusion criteria
1. Healthy adult males aged between 18 and 35 years
2. No history of major sports injuries to the spine or lower limb joints, such as severe sprains, fractures, or tendon ruptures
3. No history of lower limb or spine surgery, and no current or recent chronic pain or functional limitations

4. A BMI ranging from 18.5 to 29.9, covering the normal to slightly overweight categories
5. No chronic diseases that could affect study outcomes, such as diabetes, cardiovascular diseases, respiratory conditions, or other systemic illnesses
6. Not taking any medications that could influence the study results, including but not limited to steroids, antihypertensive drugs, or glucocorticoids

Participant type(s)
Healthy volunteer

Age group
Adult

Lower age limit
18 Years

Upper age limit
35 Years

Sex
Both

Target number of participants
54

Key exclusion criteria
1. History of major lower extremity injury or surgery (e.g., fracture, ligament tear, tendon rupture, etc.)
2. Existing leg pain, swelling, or functional limitation which may affect the safety and effectiveness of resistance training
3. Diagnosis of severe osteoarthritis or osteoporosis
4. Any bone or joint disorders known to limit the movement of the lower extremities
5. History of cardiovascular disease, such as coronary heart disease, heart failure, uncontrolled hypertension, or recent cardiac surgery
6. History of neurological conditions such as stroke, multiple sclerosis, or spinal cord injury
7. Any neurological disorder that may affect muscle control or coordination
8. Severe chronic medical conditions, such as diabetes, kidney disease, or uncontrolled thyroid dysfunction

Date of first enrolment
08/07/2025

Date of final enrolment
31/07/2026

Locations

Countries of recruitment
England

United Kingdom

Study participating centre
University of Birmingham
Edgbaston Park Road
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Sponsor information

Organisation
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Sponsor details
Edgbaston Park Road
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Sponsor type
University/education

Website
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ROR
https://ror.org/03angcq70

Funder(s)

Funder type
University/education

Funder Name
University of Birmingham

Alternative Name(s)

Funding Body Type
Private sector organisation

Funding Body Subtype

Universities (academic only)

Location
United Kingdom

Results and Publications

Publication and dissemination plan
The findings from this study will be presented in the form of presentations and scientific papers as appropriate.

Intention to publish date
01/12/2026

Individual participant data (IPD) sharing plan
The datasets generated during and/or analysed during the current study will be available upon request from Professor Deborah Falla, d.falla@bham.ac.uk

IPD sharing plan summary
Available on request

Study outputs

Output type	Details	Date created	Date added	Peer reviewed?	Patient-facing?
Participant information sheet	Consent form		17/07/2025	No	Yes
Protocol file			17/07/2025	No	No