

Effects of foot positioning and biofeedback on strength and power during squat exercise in elite female handball players

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Registration date 12/06/2026	Overall study status Completed	<input type="checkbox"/> Statistical analysis plan <input type="checkbox"/> Results
Last Edited 12/06/2026	Condition category Other	<input type="checkbox"/> Individual participant data <input checked="" type="checkbox"/> Record updated in last year

Plain English summary of protocol

Background and study aims

Success in handball depends on the ability to generate high levels of force and power during activities such as jumping, sprinting and changing direction. The foot plays an important role in transferring force from the muscles of the lower limb to the ground. Previous research suggests that changing the position of the toes may improve the mechanical efficiency of the foot and potentially enhance athletic performance. However, little is known about whether these changes can immediately improve strength and power in elite athletes, particularly when combined with real-time performance feedback.

Who can participate?

Elite female handball players aged 18 years or older who are free from injury and have experience in resistance training.

What does the study involve?

Participants attend several testing sessions over about 4 weeks. After an initial assessment and familiarisation period, each participant performs loaded squat exercises under six different experimental conditions. These conditions combine three different foot positions (0°, 10° and 30° forefoot wedges) and two feedback conditions (with and without real-time visual feedback). The order of the conditions is randomised, and all participants complete every condition. During each session, participants perform three sets of three squats at 65% of their individual maximum squat strength. Force platforms are used to measure force production, power output and movement speed during the exercise.

What are the possible benefits and risks of participating?

Participants may benefit from receiving information about their physical performance and strength characteristics. The study may also help identify simple strategies to improve athletic performance in elite sport and improve understanding of foot biomechanics during strength training.

The risks are minimal and are similar to those associated with normal strength training. Muscle fatigue, temporary muscle soreness or mild discomfort during testing may occur. All testing is supervised by experienced researchers and qualified strength and conditioning professionals.

Where is the study run from?

The study is conducted by researchers from the University of Málaga and is carried out at the Exercise Physiology and Sports Medicine Laboratory of the University of Málaga and the Eshmún Sport Clinic, Málaga, Spain.

When is the study starting and how long is it expected to run for?

August 2022 to August 2022

Who is funding the study?

University of Málaga (Spain)

Who is the main contact?

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Contact information

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Principal investigator

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Study information

Scientific Title

Effects of windlass mechanism activation using 10° and 30° forefoot wedges with and without real-time biofeedback versus no wedge and no biofeedback on concentric force, power output and movement velocity during loaded squats in elite female handball players: a randomized repeated-measures crossover trial

Study objectives

Study hypothesis and objectives:

The windlass mechanism plays a fundamental role in foot stiffness, force transmission and lower-limb propulsion during athletic performance. However, the acute effects of externally activating the windlass mechanism through forefoot wedges, either alone or combined with real-time biofeedback, have not been adequately investigated in elite athletes.

Primary objective:

To determine the acute effects of windlass mechanism activation using forefoot wedges of different inclinations (0°, 10° and 30°) on concentric force production, power output and movement velocity during loaded squat exercise in elite female handball players.

Secondary objectives:

1. To evaluate whether increasing forefoot wedge inclination produces a dose-response effect on force, power and velocity outcomes.
2. To determine the acute effects of real-time visual biofeedback on force production, power output and movement velocity during loaded squat performance.
3. To investigate whether combining windlass mechanism activation and real-time biofeedback

produces greater performance improvements than either intervention alone.
4. To identify the experimental condition associated with the highest neuromuscular performance outputs in elite female handball players.

Study hypothesis:

It is hypothesised that activation of the windlass mechanism through a 30° forefoot wedge will significantly increase force production, power output and movement velocity compared with the control condition and that the addition of real-time biofeedback will further enhance these performance outcomes.

Ethics approval required

Ethics approval required

Ethics approval(s)

approved 15/07/2019, Research Ethics Committee of the University of Málaga (Edificio del Rectorado (Principal Address) Avenida de Cervantes, 2, Málaga, 29071, Spain; +34 (0)951 952 743 /+34 (0)951 952 745; cie@uma.es / coacie@uma.es), ref: 38-2019-H

Primary study design

Interventional

Allocation

Randomized controlled trial

Masking

Open (masking not used)

Control

Active

Assignment

Crossover

Purpose

Performance enhancement, biomechanics and exercise physiology

Study type(s)

Health condition(s) or problem(s) studied

Neuromuscular performance and force production

Interventions

This study uses a randomised, open-label, crossover repeated-measures design. Following eligibility assessment, informed consent, anthropometric measurements and one-repetition maximum (1RM) squat testing, participants complete six experimental conditions combining three forefoot wedge inclinations (0°, 10° and 30°) and two biofeedback conditions (with and without real-time visual biofeedback).

The six conditions are performed in a randomised order, and all participants receive all interventions, acting as their own controls. The control condition consists of squats performed without a forefoot wedge (0°) and without biofeedback. A minimum washout period of 48 hours is maintained between testing sessions.

During each condition, participants perform three sets of three back squat repetitions at 65% of their individual 1RM using a Smith machine. Squat depth is standardised at 90° knee flexion. Custom-made forefoot wedges are positioned beneath the first metatarsophalangeal joint to induce dorsiflexion and activate the windlass mechanism. In the biofeedback conditions, participants receive real-time visual feedback from the force platform system during exercise performance.

Outcome measures are obtained using a dual-force platform system sampling at 1000 Hz. Primary measurements include concentric force production, power output and movement velocity during the squat exercise. The total duration of participation is approximately 4 weeks, including familiarisation, strength assessment and completion of all testing conditions.

Intervention Type

Other

Primary outcome(s)

1. Peak concentric vertical force measured using a dual force platform system (ForceDecks, VALD Performance, Australia) during the concentric phase of the back squat under each experimental condition, at each testing session immediately following completion of the squat protocol
2. Peak concentric power output measured using a dual force platform system (ForceDecks, VALD Performance, Australia) during the concentric phase of the back squat under each experimental condition, at each testing session immediately following completion of the squat protocol
3. Peak concentric velocity measured using a dual force platform system (ForceDecks, VALD Performance, Australia) during the concentric phase of the back squat under each experimental condition, at each testing session immediately following completion of the squat protocol

Key secondary outcome(s)

1. Mean concentric vertical force measured using a dual force platform system (ForceDecks, VALD Performance, Australia) during the concentric phase of the back squat under each experimental condition, at each testing session immediately following completion of the squat protocol
2. Mean concentric power output measured using a dual force platform system (ForceDecks, VALD Performance, Australia) during the concentric phase of the back squat under each experimental condition, at each testing session immediately following completion of the squat protocol
3. Relative peak power output measured using force platform data and normalised to body mass under each experimental condition, at each testing session immediately following completion of the squat protocol

4. Relative mean power output measured using force platform data and normalised to body mass under each experimental condition, at each testing session immediately following completion of the squat protocol

5. Mean concentric velocity measured using a dual force platform system (ForceDecks, VALD Performance, Australia) during the concentric phase of the back squat under each experimental condition, at each testing session immediately following completion of the squat protocol

Completion date

30/08/2022

Eligibility

Key inclusion criteria

1. Female handball players competing at an elite or professional level
2. Age between 18 and 40 years
3. Extensive previous experience in resistance training
4. Ability to correctly perform the back squat exercise as verified by certified strength and conditioning coaches
5. Negative Jack's test at the first metatarsophalangeal joint (absence of functional hallux limitus)
6. Willingness to participate and provision of written informed consent

Healthy volunteers allowed

Yes

Age group

Adult

Lower age limit

18 years

Upper age limit

40 years

Sex

Female

Total final enrolment

17

Key exclusion criteria

1. Acute musculoskeletal injury at the time of testing
 2. Serious musculoskeletal injury within the previous 6 months that could affect force production, power output or squat performance
 3. Presence of functional hallux limitus (positive Jack's test)
 4. Any neurological, musculoskeletal or medical condition that could interfere with study participation or performance testing
- Inability to complete all experimental testing sessions

Date of first enrolment

01/08/2022

Date of final enrolment

15/08/2022

Locations

Countries of recruitment

Spain

Study participating centre

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Sponsor information

Organisation

Universidad de Málaga

ROR

<https://ror.org/036b2ww28>

Funder(s)

Funder type**Funder Name**

Universidad de Málaga

Alternative Name(s)

University of Málaga, Málaga University, University of Malaga, Universitas Malacitana, UMA

Funding Body Type

Government organisation

Funding Body Subtype

Universities (academic only)

Location

Spain

Results and Publications

Individual participant data (IPD) sharing plan

IPD sharing plan summary

Not expected to be made available