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Effect of caffeine and citrulline malate on resistance exercise and jumping performance: a randomized double-blind placebo-controlled crossover study

Submission date
02/11/2022

Recruitment status
No longer recruiting

Registration date
10/02/2023

Overall study status
Completed

Last Edited
17/07/2023

Condition category
Nutritional, Metabolic, Endocrine

[_] Prospectively registered
[_] Protocol
[_] Statistical analysis plan
[X] Results
[_] Individual participant data

Plain English summary of protocol

Background and study aims
The mechanisms underlying the ergogenic (enhanced physical performance) effects of caffeine and citrulline malate (CitMal) and the potential interactions between them remain to be elucidated, but co-ingestion could potentially both attenuate and hamper the performance-enhancing effects of either supplement ingested in isolation. Therefore, this study aimed to explore the isolated and combined effects of caffeine and CitMal on jumping performance, muscular strength, endurance, and pain perception.

Who can participate?
Healthy volunteers aged between 18 and 45 years old

What does the study involve?
Performing a strength test with countermovement jump, and dynamic exercises for maximal strength. Along with this, supplements were used to see the effect on performance and pain perception.

What are the possible benefits and risks of participating?
Potential benefits are feedback on their own training technique and testing in safe environments with experienced and contribution to science. Potential risks are injuries that can occur under maximal effort strength training.

Where is the study run from?
Nord University (Norway)

When is the study starting and how long is it expected to run for?
November 2021 to June 2022

Who is funding the study?
1. Investigator initiated and funded (Norway)
2. Nord University lab (Norway)

Who is the main contact?
Markus Haugen, haugen.research@gmail.com

Contact information

Type(s)
Scientific

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Additional identifiers

Clinical Trials Information System (CTIS)
Nil known

ClinicalTrials.gov (NCT)
Nil known

Protocol serial number
Nil known

Study information

Scientific Title
Effect of isolated and combined ingestion of caffeine and citrulline malate on resistance exercise and jumping performance: a randomized double-blind placebo-controlled crossover study

Study objectives
We hypothesized that both caffeine and citrulline malate (CitMal) would be ergogenic and that their combined ingestion would produce additive effects on exercise performance

Ethics approval required

Old ethics approval format

Ethics approval(s)
Approved 03/12/2021, Ethics Committee for the Norwegian Center for Research Data (Harald Hårfagres gate 29, N-5007, Bergen, Norway; +47 53 21 15 00; postmottak@sikt.no), ref: 445723

Study design
Randomized double-blind placebo-controlled crossover trial

Primary study design
Interventional

Study type(s)
Other

Health condition(s) or problem(s) studied
Sports-related outcomes

Interventions
Study design
A randomized, double-blind, placebo-controlled, crossover trial is being used to investigate the isolated and combined effects of caffeine and CitMal on countermovement jump (CMJ) performance, maximal strength, muscular endurance, and pain perception. In the first session, the participants are being familiarized with the testing protocol, which will then be repeated for all the experimental sessions. The experimental sessions involve four testing trials where the participants will receive either placebo (zero-calorie drink), 5 mg/kg caffeine, 12 g of CitMal, or the respective dosages of caffeine and CitMal combined, mixed in 500 mL non-caloric cordial. In all four conditions, supplementation is provided 60 minutes before the start of the testing protocol. All testing trials are separated by a minimum of 72 hours and a maximum of seven days to ensure treatment washout and sufficient recovery. The participants are instructed to refrain from caffeine, alcohol, and training 24 hours prior to every testing session. All participants are recording a 24-hour diet log the day prior to testing and a weekly caffeine log. The participants are instructed to replicate the food log before every trial to reduce variation in energy intake and hydration level. The order of the trials is counterbalanced and randomized using Microsoft Excel (Version 2205, 64-bit).

Participants
A total of 40 healthy resistance-trained males (n=20) and females (n=20) with no known medical condition, injuries, or any other health limitation are being recruited. The study is being performed in accordance with the Helsinki Declaration and approved by the Norwegian Center for Research Data (NSD) (project nr: 445723) and by the local ethics committee at the University of Agder (Kristiansand, Norway). All participants are signing a written consent.

Supplementation
All supplement conditions will have a similar color and taste as they are mixed in 500 mL of Fun Light zero-calorie sweetened water (200 ml water and 300 ml non-caloric Fun light sweetener; Fun Light©, Stabburet, Nordre Follo, Norway), and consist of:
1. 5 mg/kg of caffeine as an anhydrous powder (Caffeine, ReagentPlus, Sigma-Aldrich)
2. 12 g of CitMal powder with a ratio between L-citrulline and malate of 2:1 (Citrulline Malate,

Trade Ingredients)
3. The same dosages of caffeine (5 mg/kg) and CitMal (12 g) combined
4. Placebo (water and Fun Light sweetener)

Participants are provided with the drink in bottles 60 minutes prior to testing and are required to complete the whole drink within one minute to ensure that they reached peak or close to peak plasma levels of caffeine and CitMal when the tests are initiated. Bottles with supplements are shaken between every sip. An independent researcher who will not participate in other measurements or analyses will randomize the treatment order, mix, and administer the treatments. This researcher will unblind the conditions only after the data collection for all participants is completed. After every testing session, participants will be asked which supplement they thought they have received. A standard question is given to all participants at the end of the testing sessions: “Which supplement do you think you received?” Answers included: placebo; only caffeine; both caffeine and CitMal; only CitMal.

Measurements
Countermovement jump
Each testing session starts with the CMJ test on a force plate (Muscle lab, Ergotest Technology AS, Porsgrunn, Norway), which is used to evaluate jump height (cm), maximal power (W), rate of force development (kN/s), and peak force (N/kg). The CMJ is performed with feet shoulder-width apart and hands on the hips during the whole jump. From a standing position, participants are required to squat to a self-selected depth and then perform a maximal vertical jump. The feet have to be straight during the flight time. Jump height is calculated with impulse (Muscle lab, Ergotest Technology AS, Porsgrunn, Norway). As a warm-up, the participants perform three submaximal CMJ trials with approximately 50%, 75%, and 90% intensity (45 seconds of rest between attempts). Following the warm-up, three CMJ attempts are performed, and the participants rest 15 seconds between each attempt. Highest values for each of the analyzed variables are used for statistical analysis.

1RM squat and bench press
Participants are completing a 1RM test for both the squat and the bench press. In both exercises, a five sets warm-up protocol is utilized. In the first set, the participants complete several repetitions only with the barbell. Then, they complete 8, 6, 3, and 2 repetitions with loads amounting to 40%, 60%, 70%, and 80% of their estimated 1RM, respectively. 1RM attempts start following the completion of the warm-up sets. After every successful 1RM attempt, the weight is increased by 0.25 kg to 5 kg (subjectively evaluated) until a final 1RM is reached. Four minutes of rest are provided between 1RM attempts. Equipment used for the testing includes: a half rack (half rack easy 2.0, Group AS, Asker, Norway), a calibrated (± 10 g) 20 kg barbell (Powerbar stainless steel 29mm, Group AS, Asker, Norway), and calibrated (± 10 g) plates from 0.25 kg to 50 kg (Powerlifting Steel Plate, Group AS, Asker, Norway). For the squat, the participants are required to reach the depth requirement set by the International Powerlifting Federation, which requires that the top surface at the hip joint should be below the knees. A test leader visually inspects the depth together with a rubber band that the participants can use as external feedback. Safety pins and two experienced spotters are used in the 1RM attempts to ensure safety. In the bench press, the elbows have to be fully extended at the completion of the lift for a 1RM to be approved. A pause on the chest at the bottom of the lift is not mandatory (self-selected by the participants and standardized for all testing sessions). However, the shoes have to be in touch with the floor and the gluteal region and upper back in touch with the bench throughout the lift. Stance width in the squat and grip width in the bench press is recorded in the familiarization session, and the same width is used in all experimental sessions. Equipment such as lifting belts, shoes, wrist wraps, knee sleeves and chalk are allowed, but participants have to use the self-selected equipment at all trials to ensure standardization.

Repetitions to failure and pain perception
Muscular endurance is being evaluated by having the participants complete one set of repetitions to muscular failure in the squat and bench press using 60% of 1RM (from 1RM measured at each trial). During the set, the number of completed repetitions is counted out loud by the test leader. No breaks are allowed between repetitions. Technical requirements are the same as in the 1RM tests. Muscular failure is defined as not being able to complete a full repetition without assistance or failing to keep up the standardized tempo set by the test leader on two consecutive repetitions. Specifically, if a participant includes too long of a pause (>1 sec) between muscle actions, a warning from the test leader is provided; if the same occurs in the next repetition, this is deemed as muscular failure, thus denoting the end of the test. Within 15 seconds of completion of the test, the participants are required to rate their perceived pain on an 11-point numerical rating scale, with the instruction that 0 points are equivalent to “no pain” and 10 points are their “worst imaginable pain”.

Intervention Type
Supplement

Primary outcome(s)
1. Jump height (cm) measured using a force plate at every trial before the strength test and after warmup
2. Maximal power (W) measured using a force plate at every trial before the strength test and after warmup
3. Rate of force development (kN/s) measured using a force plate at every trial before the strength test and after warmup
4. Peak force (N/kg) measured using a force plate at every trial before the strength test and after warmup
5. Maximal strength measured using a barbell and plates for loading at every trial after the jump test
6. Number of repetitions to failure with barbell and plates for loading on every trial after the jump test

Key secondary outcome(s))
Pain perception measured using a numerical rating scale straight after the number of repetitions to failure test for both bench press and back squat

Completion date
01/06/2022

Eligibility

Key inclusion criteria
1. Aged between 18 and 45 years old
2. A minimum of 12 months of resistance training experience
3. Currently performing resistance training at least two times per week
4. Able to perform the barbell back squat and bench press with 120% and 100% of body mass for males and 100% and 70% of body mass for females

Participant type(s)
Healthy volunteer

Healthy volunteers allowed
No

Age group
Adult

Lower age limit
18 years

Sex
All

Total final enrolment
40

Key exclusion criteria
1. Smoking
2. Pregnancy or lactating

Date of first enrolment
01/09/2021

Date of final enrolment
01/12/2021

Locations

Countries of recruitment
Norway

Study participating centre
Nord university
Høgskolevegen 27
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Norway
7600

Sponsor information

Organisation
Nord University

ROR
https://ror.org/030mwrt98

Funder(s)

Funder type
Other

Funder Name
Investigator initiated and funded

Funder Name
Nord universitet

Alternative Name(s)
Nord University, Noerhte universitete, Nuortta universitiehtta

Funding Body Type
Government organisation

Funding Body Subtype
Universities (academic only)

Location
Norway

Results and Publications

Individual participant data (IPD) sharing plan
The dataset analysed during the current study will be available upon request from Markus Haugen (haugen.research@gmail.com; +4746823821).
Anonymous data will be shared from every test as well as dietary intake and supplement history. Consent from participants was required and obtained. All data are anonymized according to Norwegian ethics committee standards.

IPD sharing plan summary
Available on request

Study outputs

Output type	Details	Date created	Date added	Peer reviewed?	Patient-facing?
Results article		14/07/2023	17/07/2023	Yes	No
Participant information sheet	Participant information sheet	11/11/2025	11/11/2025	No	Yes