Influence of acute caffeine consumption on performance and biomechanical outcomes of vertical jumping: a randomized crossover trial

Influencia del consumo agudo de cafeína en el rendimiento y variables biomecánicas del salto vertical: un ensayo aleatorizado cruzado

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Abstract

Introduction: Although the ergogenic effects of caffeine (CAFF) are well documented, its impact on exercise technique requires more comprehensive investigation.
Objective: To evaluate the influence of 6mg/kg of CAFF on jumping technique and performance.
Methodology: This randomized, double-blind, crossover study included fourteen trained naïve-low consumers of CAFF. Participants performed six countermovement jumps without (PRE) and with (POST) fatigue during a control (CON), a placebo (PLA), and a CAFF session, with a 7-day wash-out between sessions. Performance and biomechanical variables were considered the primary outcomes.
Results: The fourteen athletes were included in the analyses. CAFF did not significantly affect the analyzed variables. Compared to CON, PLA increased knee valgus at the initial contact of the landing of the left leg (d=0.82) and the duration of the propulsive phase (d=0.76). Compared to CON PRE, propulsive duration was also greater in PLA PRE, PLA POST, and CAFF POST (d=1.19-1.45). Fatigue decreased knee valgus at the deepest landing position (d=0.48-0.50) and increased knee varus range of motion (d=0.52-0.68) in both legs, increased braking phase duration (d=0.65), reduced relative peak power (d=0.73), and decreased jump height (d=0.26).
Discussion: The lack of an effect of CAFF on performance contrasts with previous evidence, whereas the impact of PLA could reflect a nocebo effect.
Conclusions: CAFF was not ergogenic for countermovement jump height and did not appear to affect its biomechanics. However, compared to CON, PLA adversely influenced some outcomes. Fatigue also affected some of these variables in a complex manner.
This trial was prospectively registered at ClinicalTrials (NCT06039358).

Keywords

Countermovement jump; ergogenic aids; fatigue; injuries; technique.

Resumen

Introducción: Aunque los efectos ergogénicos de la cafeína (CAFF) están bien documentados, su impacto en la técnica durante el ejercicio físico requiere una investigación más exhaustiva.
Objetivo: Evaluar la influencia de 6mg/kg de CAFF en la técnica y el rendimiento del salto.
Metodología: Este estudio con diseño aleatorizado, cruzado y doble ciego incluyó catorce sujetos entrenados con consumo naïve-bajo de CAFF. Los participantes realizaron seis saltos con contramovimiento sin (PRE) y con (POST) fatiga durante una sesión control (CON), una sesión con placebo (PLA) y una sesión con CAFF, con un periodo de lavado de siete días entre sesiones. El rendimiento y los aspectos biomecánicos fueron considerados las variables principales.
Resultados: Los catorce participantes fueron incluidos en los análisis. CAFF no afectó significativamente a las variables analizadas. En comparación con CON, PLA incrementó el valgo de rodilla en el contacto inicial del aterrizaje de la pierna izquierda (d=0.82) y la duración de la fase propulsiva (d=0.76). En comparación con CON PRE, la duración de la fase propulsiva también aumentó en PLA PRE, PLA POST y CAFF POST (d=1.19-1.45). La fatiga disminuyó el valgo de rodilla en la posición más profunda del aterrizaje (d=0.48-0.50) e incrementó el rango de movimiento del varo de rodilla (d=0.52-0.68) en ambas piernas, aumentó la duración de la fase de frenado (d=0.65), redujo el pico de potencia relativo (d=0.73) y disminuyó la altura del salto (d=0.26).
Discusión: La falta de efecto de CAFF sobre el rendimiento contrasta con la evidencia previa, mientras que el impacto de PLA podría reflejar un efecto nocebo.
Conclusiones: CAFF no fue ergogénica para la altura del salto con contramovimiento, ni pareció afectar su biomecánica. No obstante, en comparación con CON, PLA afectó negativamente algunos resultados. La fatiga también afectó algunas variables de forma compleja.
Este estudio se registró prospectivamente en ClinicalTrials (NCT06039358).

Palabras clave

Ayudas ergogénicas; fatiga; lesiones; salto con contramovimiento; técnica.

Introduction

Among the vast market of purported ergogenic aids, caffeine (CAFF) is considered to have strong evidence regarding its safety and efficacy (Maughan et al., 2018). Its impact on the central nervous system is considered the main cause of its performance-enhancing effects, together with other potential mechanisms (Guest et al., 2021). In addition, CAFF can be ergogenic for performance-related movements, such as jumping (Grgic et al., 2020; Guest et al., 2021). Specifically, it could augment single and repeated jump height (Guest et al., 2021).

In this regard, jumping ability is crucial in sports where the capability to achieve horizontal or vertical displacement is essential for performance (Wang et al., 2025). Moreover, greater jump height may be favorably associated with other sport-relevant qualities, such as change-of-direction ability (Mejía Mejía et al., 2024). Furthermore, jumping is a weight-bearing, high-impact activity that may be related to health benefits, such as improved bone mineral density (Florence et al., 2023). However, lower-extremity injuries account for a significant proportion of time-loss injuries among physically active individuals, and certain kinematic and kinetic variables of the vertical jump may be related to future injuries (De Bleecker et al., 2020; Pedley et al., 2020). Additionally, neuromuscular fatigue has been linked to kinematic modifications during jumps that could increase the risk of specific injuries (Nardon et al., 2024).

Some studies have thoroughly assessed the effect of CAFF on jump biomechanics (e.g., squat jump (Bloms et al., 2016; Donahue et al., 2022), countermovement jump (Bloms et al., 2016; Donahue et al., 2022; Gallo-Salazar et al., 2024; González-García et al., 2023; Grgic, 2022; Lago-Rodríguez et al., 2021; Merino Fernández et al., 2021; Santos-Mariano et al., 2022; Tallis et al., 2024; Tamilio et al., 2022; Zbinden-Foncea et al., 2018), and drop jump (Tallis et al., 2024)), altering them on most occasions. To have a physiological explanation for the modifications generated by CAFF, these articles proposed some processes, including its capacity to increase motor unit recruitment (Bloms et al., 2016; Grgic, 2022; Lago-Rodríguez et al., 2021; Zbinden-Foncea et al., 2018) and the calcium sensitivity of myofibrils (Santos-Mariano et al., 2022), which may enable muscles to generate a greater force (Santos-Mariano et al., 2022; Zbinden-Foncea et al., 2018). Therefore, CAFF may be able to impact jump technique throughout its various phases. However, on most occasions, these previous investigations focused on force plate data and did not consider the landing phase of the jump. This may be relevant, since the landing phase of jump-landing assessments might provide the greatest insights into injury risk (Pedley et al., 2020). Moreover, some of the performance benefits attributed to CAFF include a reduction of the perceived effort during exercise and increased vigilance and alertness (Guest et al., 2021; Maughan et al., 2018). Assessing if these effects allow better technique development in fatigued circumstances may also be appropriate.

For these reasons, there are conceivable harmful consequences of measuring the impact of CAFF by only considering performance, disregarding other potential effects on technique or injury risk. As such, the goal of this study is to evaluate the CAFF effect on naïve-low CAFF consumers' performance and technique in the jumping and landing phases of countermovement jumps, before and after a fatiguing protocol, compared to placebo (PLA) and control (CON) sessions. The hypothesis we propose is that CAFF generates alterations in the technical execution of jumping in fatigued and unfatigued circumstances due to its physiological effects, which could be advantageous to performance and injury prevention.

Method

Participants

Eligible participants for this study were not pregnant, did not have relevant medical conditions, did not smoke, did not usually consume >25mg/day-0.99mg/kg/day of CAFF (naïve-low consumers (Filip et al., 2020)), did not consume supplements or medications either regularly or during the study, and were not <18 or >30 years old. These exclusion criteria were selected because they could influence the effect of CAFF (Pickering & Kiely, 2018). The inclusion criteria were: 1) Uninterrupted training time of ≥1 year in a regular physical activity modality; 2) Good exercise technique. These criteria ensured that participants had an advanced training level, based on previous research (Santos Junior et al., 2021). Posters hung at the University of Vic - Central University of Catalonia and at different sports facilities of the city were used during the recruitment process, which took place from October to November 2023. The initial characteristics of the fourteen subjects who completed this study are defined in Table 1. Data are shown for the whole sample, as well as according to the two possible experimental sequences followed by the participants: the "Control-Placebo-Caffeine order", in which they performed the CON session first, the PLA session second, and the CAFF session third; and the "Control-Caffeine-Placebo order", in which they performed the CON session first, the CAFF session second, and the PLA session third. This study considered any severe side effect episode as the sole early stopping criterion, and interim analyses were neither performed nor planned.

Table 1. Participants' baseline characteristics, by sequence and for the entire sample.

	Experimental Group (n=14)		
Characteristic	Control-Placebo-Caffeine order	Control-Caffeine-Placebo order	Full sample
Height (meters)	1.69 ± 0.07	1.76 ± 0.06	1.73 ± 0.07
Body mass (kilograms)	62.31 ± 6.33	75.53 ± 8.06	68.92 ± 9.77
Body fat (%)	22.26 ± 8.88	19.59 ± 4.34	20.92 ± 6.86
Age (years)	22.14 ± 3.08	22.00 ± 3.32	22.07 ± 3.08
Habitual consumption of caffeine as an ergogenic aid (milligrams/kilogram/day)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Habitual consumption of caffeine from foodstuffs (milligrams/kilogram/day)	0.25 ± 0.31	0.20 ± 0.35	0.22 ± 0.32
Sex (Male / Female)	4 (57.14%) / 3 (42.86%)	7 (100%) / 0 (0%)	11 (78.57%) / 3 (21.43%)

All the variables are reported as mean ± standard deviation, except for sex, which is described as frequency and percentage.

Procedure

Methodological approach

This article describes the jumping data from a project evaluating the effect of CAFF on jumping, running, and squatting, following the CONSORT guidelines (Dwan et al., 2019; Hopewell et al., 2025) (Online Resource 1). The project and its protocol were prospectively registered at ClinicalTrials (Identifier: NCT06039358 (https://clinicaltrials.gov/study/NCT06039358); registered September 15, 2023), and no major modifications were made to the pre-specified procedures. No public or participant involvement happened in the design, conduct, and reporting of the trial. The study protocol was approved by the University of Vic - Central University of Catalonia Research Ethics Committee (238/2022). The trial adhered to the principles of the Declaration of Helsinki and its later amendments, and respected the rights of the participants. All subjects gave their written informed consent before their inclusion in the study.

A randomized, controlled, double-blind, crossover design was employed to minimize the required sample size (Dwan et al., 2019). The participants had to complete five sessions throughout the study at the university facilities (Vic, Spain). These began with an enrollment session, which included the verification of the eligibility criteria of the subjects and the informed consent process. Next, their baseline data were collected, including sex, age, height measured utilizing a stadiometer (GIMA, Gessate, Italy), body mass and body fat measured utilizing a scale (Omron, Kyoto, Japan), habitual CAFF consumption from foodstuffs measured with a questionnaire (Bühler et al., 2014), and habitual CAFF ingestion as an ergogenic aid for physical activity.

The remaining sessions were scheduled for the following days and included familiarization, CON (e.g., no substance), CAFF, and PLA sessions. Each of them lasted approximately three hours and was separated by at least seven days to allow sufficient wash-out to prevent carry-over effects (Magkos & Kavouras, 2005). Their environmental characteristics were controlled (mean temperature: 21.50ºC ± 2.17ºC, mean humidity: 48.40% ± 10.15%), and the subjects could ingest water at will during them. Additionally, each participant performed the sessions at the same time of the day, and the follow-up period ended the morning after them. Forty-eight hours before the session, they had to avoid CAFF ingestion and fatiguing physical activities, and twenty-four hours before the visit, they could not consume alcohol and had a diet as standardized as possible. To achieve this goal, the ASA24 Dietary Assessment Tool (v. 2022, National Cancer Institute, Maryland, United States of America) was used to record their dietary intake. Moreover, participants were required to eat their usual pre-exercise meal two to four hours prior to the sessions.

The familiarization session was initiated with the subjects completing the ASA24 and the forty-eight-hour CAFF ingestion evaluations, the records of which had to be reproduced in the following sessions. Then, the participants were informed about the ergogenicity of CAFF to achieve a consistent PLA effect among the subjects. Afterward, they standardized the size of some elastic bandages and practiced the warm-up protocol to be used in subsequent sessions. They also individualized the intensity and execution of the squat movement performed in this project. The session concluded with an explanation of the exercises performed in the rest of the sessions, and participants then reproduced them until they executed a correct technique. The CAFF and PLA sessions were performed in a randomized and double-blinded order, and their data, together with the CON one, were used for the analyses of the study.

The structure of the CAFF, PLA, and CON sessions was consistent. Participants arrived at the facilities sixty minutes before the beginning of the assessed exercises. At this moment, they ingested the CAFF or PLA capsules and passively waited for forty-five minutes. In the CON session, they did not ingest any capsules but had the same waiting time. Afterwards, they did a standardized warm-up routine fifteen minutes before the beginning of the assessments: jogging at 10km/h on a treadmill for five minutes, executing general dynamic stretches for five minutes, and completing specific exercises for the assessed movements for five minutes. Then, the evaluation of the assessed movements was done, followed by a neuromuscular fatiguing protocol, and a second assessment of the movements. The evaluated exercises had a consistent randomized order for each participant (https://www.random.org).

To induce the neuromuscular fatigue, a Yo-Yo squat protocol, based on previous investigations (Lesinski et al., 2016), was employed. The subjects had to perform thirty-five Yo-Yo squats per minute at a constant velocity, achieving 90º of knee flexion in each repetition. When they could not maintain the cadence, they had one minute of passive rest and repeated this procedure until 60% of the repetitions of the first set could not be done. Besides, participants used a 6-20 Borg scale after each set to rate their perceived effort, confirming an elevated exertion. There was no resting time between the assessed movements or the fatigue protocol.

Additionally, in the CAFF and PLA sessions, the participants also answered an online questionnaire to indicate which substance they believed they had consumed. As reported in earlier studies (Saunders et al., 2017), just before and after the assessed exercises, they were asked to choose between the options "caffeine", "placebo", or "I don't know", explaining their reasoning. Moreover, the subjects were required to complete another online questionnaire the morning after the CAFF and PLA sessions, in which they reported any side effects of CAFF consumption that they experienced during the following hours. The form consisted of eight questions with dichotomous responses as previously suggested (Muñoz et al., 2020). Both questionnaires were used to compare the answers between the two sessions and were measured as secondary outcomes. The results of these questionnaires have already been reported (Baena-Riera et al., 2026) and, therefore, will not be presented in this article.

Jumping assessment

The effect of CAFF on various performance and technique parameters was the primary outcome of this study, comparing it to PLA and CON, both in fatigued and unfatigued circumstances. Participants performed six countermovement jumps, with a one-minute rest between repetitions. The analyses were performed considering their mean results, and the same researcher assessed all the outcomes. The subjects were instructed to jump as high as possible using a standardized technique, defined as four seconds of quiet standing with the legs fully extended, followed by a controlled 90º knee flexion and a coordinated explosive knee extension. During the flight phase, the knees had to remain extended, and lateral movements had to be avoided. The landing had to begin with the toes. Throughout the entire jump, participants were required to hold their hands in front of their lower back to facilitate the movement analysis. Using a pilot study, the assessed variables were considered feasible.

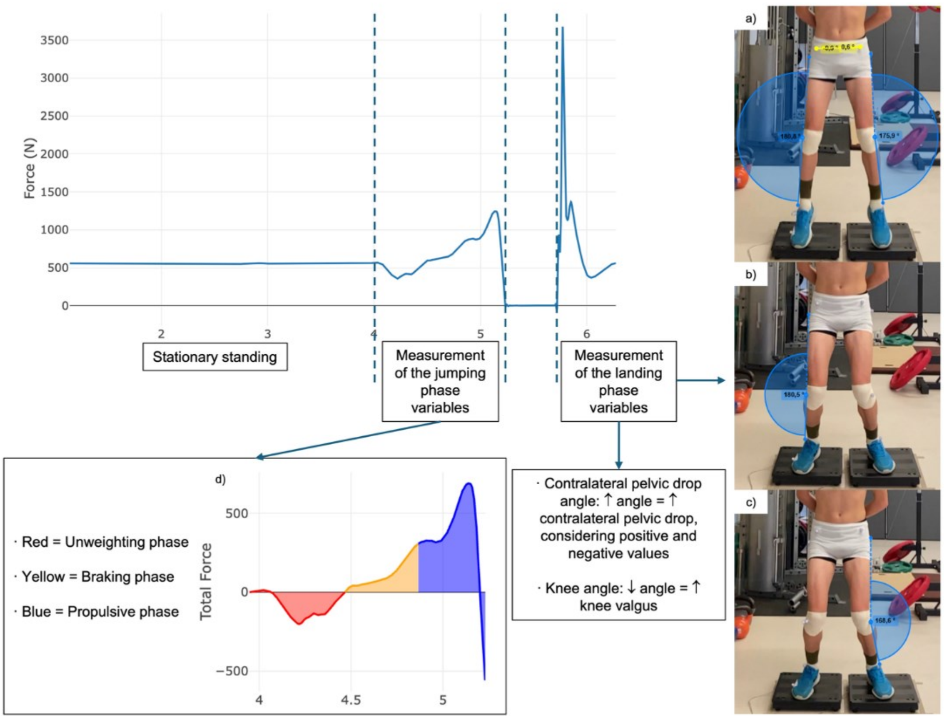
For the analysis, two portable force plates (Pasco scientific, Roseville, United States) were used. These types of instruments have shown their validity and reliability for the one-dimensional analysis of the countermovement jump (Sands et al., 2020). Data acquisition was done at 1000Hz, which was then analyzed using a 4th-order, low-pass Butterworth filter, with a 50Hz cut-off, in an R Shiny app (Sams, 2020). The analyzed variables were: 1) Unweighting phase duration; 2) Braking phase duration; 3)

Propulsive phase duration; 4) Relative peak power output (RPP); 5) Height of the jump. The definition of each variable is described in Online Resource 2.

Besides, 2D kinematic analyses were performed on both legs for the contralateral pelvic drop angle (angle formed by a horizontal line from the anterior superior iliac spine (ASIS) of the analyzed leg and a line that connects both ASIS) and the knee angle (angle formed by the greater trochanter (GT) - lateral femoral epicondyle (LFE) line, and the LFE - lateral malleolus (LM) line). Both angles were measured at the initial contact of the landing, and the knee angle was also determined during the deepest landing position. Each leg had these moments identified separately. Besides, the knee angle range of motion (ROM) (difference between the initial contact and the deepest landing position angles) was also measured.

The jumps were filmed at 240fps perpendicularly from the frontal plane (iPhone 11 Pro Max, Apple, Cupertino, USA), using a tripod at a height of 1.16m and a distance of 2.68m from the force plates. The 2D data were processed using Kinovea (v. 0.9.5), which has been shown to be valid and reliable (Puig-Diví et al., 2019). Reflective markers were placed by the same researcher on participants' anatomical landmarks: 1) ASIS; 2) GT; 3) LFE; 4) LM. These were localized with the subjects standing (ASIS, GT, and LM) or sitting with 90º-flexed knees (LFE). The placement of the markers and the angle definitions used for the lower-limb assessment were based on previous kinematic analysis protocols (Dingenen et al., 2014, 2018; Holden et al., 2015). Some of the analyzed jump variables are shown in Figure 1.

Figure 1. Jump movement force-time curve, highlighting the analyzed angles (images a), b), and c)) and time-periods measurements (image d)), with their interpretation. Image a) depicts the angles measured at the initial contact of the landing. In this case, both legs had the same initial contact frame. Images b) and c) depict the angle measurements at the deepest landing position. In this case, each leg had a different deepest landing position frame.



Caffeine supplementation

Both CAFF and PLA ingestion protocols were identical in presentation and format. They were swallowed in the form of three opaque capsules with 200ml of water. The substances were manually deposited in the capsules (Guinama, Valencia, Spain), and their ingestion was supervised by one of the researchers. The subjects consumed 6mg of anhydrous CAFF powder/kg (Harrison Sport Nutrition, Granada, Spain) (Maughan et al., 2018). On the other hand, cellulose (Guinama, Valencia, Spain) was used as PLA.

Participants and investigators blinding

This trial included fixed simple randomization without restrictions. A researcher who took part in the assessment sessions enrolled the participants in the trial. This researcher codified and wrote the subjects' names according to their enrollment order. This list was then sent to an external researcher, who randomized its order (https://www.random.org). Previously, this external researcher created a random allocation sequence using a list of computer-generated random numbers (http://www.randomizer.org). The implementation process involved him linking this sequence to the randomized list of subjects (e.g., the first codified name and the first number), assigning them to the appropriate intervention order (e.g., odd numbers - PLA-CAFF sequence; even numbers - CAFF-PLA sequence). Seven participants were allocated to each sequence (1:1 ratio). An allocation list copy was saved in a location that could not be accessed by the other investigators. Afterwards, the external researcher placed the CAFF and PLA capsules in envelopes. On the outside, he wrote the session in which the capsules should be consumed and by whom. Once the data analyses and outcome adjudication were completed, the participants and all the investigators were unblinded.

Statistical analysis

Sample size was calculated using G*Power (v. 3.1.9.6, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). The a priori power analysis determined a minimum sample size of eleven subjects (considering: a within repeated measures ANOVA; an effect size (ES) on the vertical jump height of 0.15 (f) (Grgic, 2022); a 1- β of 0.80; an α of 0.05; one group; six measurements; a 0.90 correlation among repeated measures (Grgic, 2022)). Fifteen subjects were recruited, considering possible dropouts.

The reliability of the 2D analysis variables was calculated using the ICC(2,1). Its interpretation was based on the 95% confidence interval (CI), categorized as poor (<0.50), moderate (0.50-<0.75), good (0.75-0.90), or excellent (>0.90). The evaluation of the differences in the frequencies of side effects was performed using the McNemar test. ES and their CI were not computed because most side effects had low or null incidence. Blinding effectiveness was assessed with the Bang Blinding Index (BBI).

The technique and performance variables are described as their median and 25-75 centile range (IQR) or their mean and standard deviation, for non-normally and normally distributed variables, respectively. For each outcome, the normality of the non-standardized residuals was assessed both numerically using the Shapiro-Wilk test and visually with Q-Q plots. Outliers were also numerically detected. If normal distribution and no outliers were identified, a two-way repeated measures ANOVA was performed, confirming the sphericity of the data using Mauchly's test. Conversely, an Aligned Rank Transform (ART) ANOVA was performed (Wobbrock et al., 2011). In the analyses where the ANOVA or ART ANOVA found any significant differences, post-hoc pairwise comparisons were done using Bonferroni's correction. In these situations, the ART-C procedure was followed for the ART ANOVA (Elkin et al., 2021). The relative ES of the ANOVAs is expressed as their partial eta squared ($\eta p2$), which is interpreted with conventional thresholds: small (0.01), medium (0.06), and large (0.14). The adjusted simple ES (differences in means of the aligned ranks or in means, for the non-parametric or parametric strategies, respectively) and their 95% CI are provided when multiple pairwise comparisons were performed. Cohen's D ES is also reported for these comparisons, considered as trivial (<0.2), small (0.2–<0.6), moderate (0.6–<1.2), large (1.2–<2.0), very large (2.0-<4.0), and extremely large (≥4). Since the ES obtained from ART and ART-C analyses are calculated using the aligned rank-transformed data, they should be interpreted with caution. The significance threshold was set at $p < 0.05$. All the analyses and plots were done using R (v. 4.4.2, R Foundation for Statistical Computing, Vienna, Austria) and RStudio (v. 2023.06.0+421, Posit Software, Boston, United States of America), including different add-on packages ("ggplot2", "effectsize", "dplyr", "emmeans", "patchwork", "knitr", "psych", "ARTool", "ggdist", "car", "readxl", "BI", "rcompanion", "afex", and "rstatix").

Results

Technique and performance outcomes

As a result of an injury outside the study, one subject did not complete the protocol, withdrawing between the enrollment and the familiarization sessions (Online Resource 2). All statistical analyses were based on data collected at the outcome time point and included the 14 participants who finalized the study, in accordance with their original randomization.

All the performance and biomechanical outcomes were analyzed with non-parametric procedures, except for the knee angle of the right leg at the initial contact and the jump height. The complete data of the analyses can be found in Online Resource 2. A summary of the significant results found on these analyses is displayed in Table 2, and some of them are also described in Figures 2, 3, and 4. There were no significant results for the rest of the comparisons and variables.

Table 2. Overview of statistically significant effects and pairwise analyses.

Measured variable	ANOVA / ART ANOVA (p-value)	Pairwise tests (p-value)	Meaning of the difference
Knee angle at the initial contact of the left leg	Treatment (p = 0.0122)	PLA - CON (p = 0.0093)	↓ knee angle (e.g., ↑ knee valgus) in PLA
Knee angle at the deepest landing position of the right leg	Fatigue (p = 0.0299)	PRE - POST (p = 0.0299)	↑ knee angle (e.g., ↓ knee valgus) in POST
Knee angle at the deepest landing position of the left leg	Fatigue (p = 0.0266)	PRE - POST (p = 0.0266)	↑ knee angle (e.g., ↓ knee valgus) in POST
Knee angle ROM of the right leg	Fatigue (p = 0.0027)	PRE - POST (p = 0.0027)	↑ positive ROM (e.g., ↓ knee valgus from initial contact to deepest landing position) in POST
Knee angle ROM of the left leg	Fatigue (p = 0.0194)	PRE - POST (p = 0.0194)	↑ positive ROM (e.g., ↓ knee valgus from initial contact to deepest landing position) in POST
Braking phase duration	Fatigue (p = 0.0042)	PRE - POST (p = 0.0042)	↑ braking phase duration in POST
Propulsive phase duration	Treatment (p = 0.0152)	PLA - CON (p = 0.0173)	↑ propulsive phase duration in PLA
	Treatment*Fatigue (p = 0.0332)	· PLA PRE - CON PRE (p = 0.0045) · PLA POST - CON PRE (p = 0.0364) · CAFF POST - CON PRE (p = 0.0326)	· PLA PRE ↑ propulsive phase duration than CON PRE · PLA POST ↑ propulsive phase duration than CON PRE · CAFF POST ↑ propulsive phase duration than CON PRE
RPP	Fatigue (p = 0.0013)	PRE - POST (p = 0.0013)	↓ RPP in POST
Jump height	Fatigue (p = 0.0023)	PRE - POST (p = 0.0023)	↓ jump height in POST

Abbreviations: PLA = Placebo session. CON = Control session. CAFF = Caffeine session. PRE = Values before fatigue. POST = Values after fatigue. ROM = Range of motion. RPP = Relative peak power output. ↑ = More. ↓ = Less.

Figure 2. Differences in the jump height between the caffeine, control, and placebo sessions, before (top) and after (bottom) the fatiguing protocol. The linked dots illustrate within-subject changes across sessions.

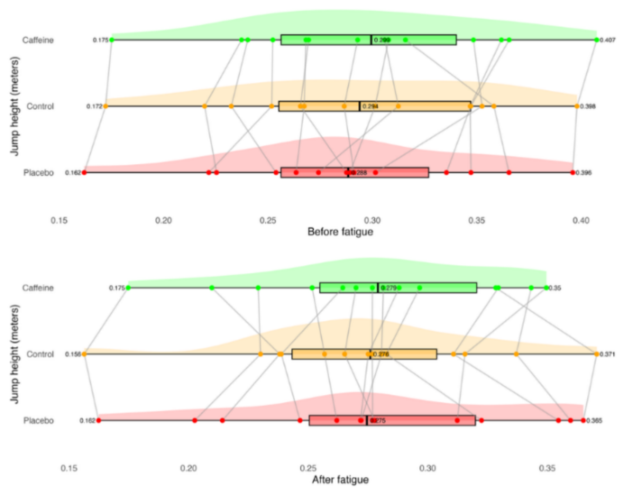


Figure 3. Differences in the propulsive phase duration between the caffeine, control, and placebo sessions, before (top) and after (bottom) the fatiguing protocol. The linked dots illustrate within-subject changes across sessions.

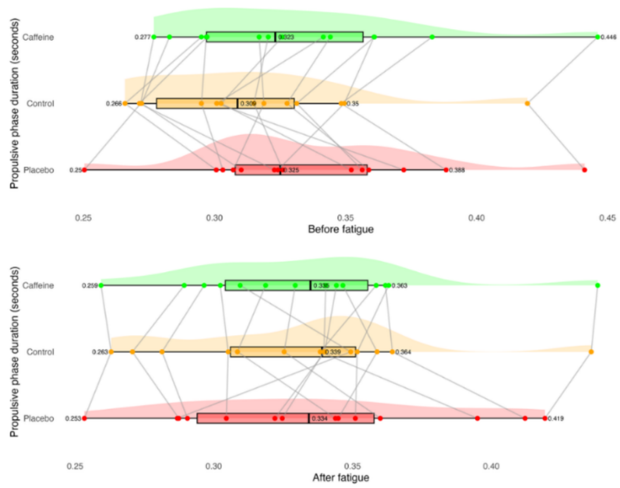
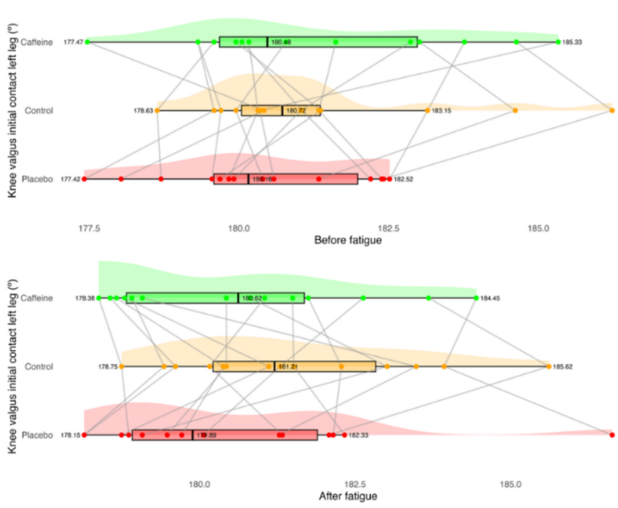


Figure 4. Differences in the knee valgus angle at the initial contact of the landing of the left leg between the caffeine, control, and placebo sessions, before (top) and after (bottom) the fatiguing protocol. The linked dots illustrate within-subject changes across sessions.



Measurement reliability, blinding assessment, and adverse effects

The full analyses of the blinding effectiveness and side effects can be found elsewhere (Baena-Riera et al., 2026). On the other hand, the complete results of the reliability of the measurements are presented in Online Resource 2. In brief, all the analyzed 2D variables had excellent intrarater reliability (ICC: 0.98-1.00).

Discussion

The core purpose of this research was to investigate the influence of CAFF on jumping performance and technique. Considering the findings, since CAFF could not significantly affect most biomechanical outcomes or performance, our hypothesis cannot be confirmed. The results denoted that CAFF, PLA, and fatigue affected the temporal execution of the jumping phase. Besides, PLA and fatigue affected the knee valgus landing kinematics, and fatigue affected RPP and jump height. The potential implications of these results will now be discussed. However, the relationship between the mechanical variables of the countermovement jump and injuries appears to be less studied compared to other types of jumps (De Bleecker et al., 2020; Pedley et al., 2020). Accordingly, some inferences will be drawn from other types of jump-landing movements, and, as such, the corresponding conclusions should be treated with caution.

First, although CAFF can be ergogenic for a broad spectrum of physical activities, including jump height (Grgic et al., 2020), we did not find this effect in our results, and only fatigue generated a lower jump height. Several factors may affect CAFF response (Guest et al., 2021; Pickering & Kiely, 2018), and although most of them were considered with the inclusion criteria of our study, some were not controlled due to practical reasons. Notwithstanding, CAFF non-responders may be infrequent and depend on the CAFF and the exercise protocols employed (Grgic, 2018). Therefore, a CAFF effect could be observed in the analyzed subjects if the dose, timing, or exercise assessed were modified, or even if the study was repeated. Besides, as shown in Figures 2-4, CAFF had different effects on the participants. Consequently, CAFF consumption protocols should be individualized through trial and error to optimize its beneficial effects (Guest et al., 2021; Maughan et al., 2018).

With respect to the RPP, fatigue reduced it. A smaller RPP during single-leg countermovement jumps may be associated with the risk of non-contact ankle injury (Pedley et al., 2020). Additionally, RPP has been studied in some of the previously mentioned studies that comprehensively assessed the effect of CAFF on countermovement jump, with a positive impact reported in most of them (Gallo-Salazar et al., 2024; Lago-Rodríguez et al., 2021; Santos-Mariano et al., 2022; Tamilio et al., 2022), although no effects were also observed in some cases (Merino Fernández et al., 2021). Therefore, our study aligns with the latter evidence.

Regarding the temporal execution of the jump, fatigue increased the duration of the braking phase, and there was a greater propulsive phase duration in PLA without fatigue (PRE), PLA with fatigue (POST), and CAFF POST than in CON PRE, as well as in PLA than in CON. Previous investigations analyzed the effect of CAFF on the duration of different temporal phases of countermovement jump execution, and while CAFF could reduce the braking phase (Gallo-Salazar et al., 2024), most times it was unable to affect them (González-García et al., 2023; Lago-Rodríguez et al., 2021; Merino Fernández et al., 2021; Tallis et al., 2024). However, generally, these studies used different phase definitions, which may preclude firm conclusions. Our results support the notion that CAFF alone may not affect the temporal execution of the countermovement jump, albeit it may have a detrimental impact under fatigued conditions.

It is noteworthy that PLA prolonged the propulsive phase relative to CON, since decreased movement speed can harm performance and increase injury risk (Zhang et al., 2024). The correct perception of having ingested PLA can lead to a worsened performance (Saunders et al., 2017), and when the assumed performance-enhancing effects of CAFF are not perceived, a reduction in performance may ensue (Ortiz-Sánchez et al., 2024). Therefore, the participants in our study may have experienced a nocebo effect in the propulsive phase duration due to not feeling the supposed improvement in performance with CAFF.

Notably, CAFF had a better and more regular blinding. Six subjects successfully identified PLA at the beginning of the sessions, which may have harmed their performance, as discussed. However, it is also important to mention that after the PLA session, this perception shifted, and the same number of participants thought they had consumed CAFF, making this assumption more intricate. As for adverse effects, although their frequency often differed between treatments, there were no significant differences in their incidence.

Finally, PLA also increased the knee valgus angle at the initial contact of the left leg compared to CON, while fatigue decreased the knee valgus at the deepest landing position and its ROM (e.g., more knee varus) in both legs. As mentioned, jump-landing tasks other than the bilateral countermovement jump are more commonly used to assess landing kinematics and injury risk. Accordingly, most available reference values for dynamic knee valgus are task-specific and not derived from bilateral countermovement jump assessments; therefore, they should be interpreted with caution when applied to other movements. For example, normative reference values for knee valgus at the lowest point of the landing phase during bilateral drop jumps have been proposed to be 7-13º in females and 3-8º in males, with symmetrical values between limbs (Herrington & Munro, 2010). It should also be noted that normative knee valgus displacement values during the countermovement jump have been reported (Holden et al., 2015), although these were based on data collected from early adolescents, which may limit their applicability to the present sample.

An increased knee abduction angle at the initial contact and at peak knee abduction of a drop jump might be a predictor of increased anterior cruciate ligament injury risk (Hewett et al., 2005). Moreover, greater valgus displacement and lower normalized knee separation distance at peak knee flexion during drop jumps may be associated with the risk of lower-extremity injuries (Pedley et al., 2020). Consequently, PLA may negatively impact landing technique in countermovement jumps, although the evidence in this regard is controversial (Cronström et al., 2020; De Bleecker et al., 2020; Pedley et al., 2020). In addition, the absolute differences between treatments in our study were smaller than those previously reported (Hewett et al., 2005). On the other hand, neuromuscular fatigue may increase knee valgus during the maximal knee flexion of the landings of a single-leg drop jump, but not during their initial contact (Nardon et al., 2024). These contrasting results compared to our study may be due to the bilateral nature of the countermovement jump.

Limitations

This study has limitations. First, because the 2D analyses and portable force plates used capture only a subset of biomechanical parameters, our interpretations are limited to those measurements. In addition, although it is recommended not to have multiple primary outcomes in randomized controlled trials (Hopewell et al., 2025), we assessed different variables as primary outcomes due to the thorough analysis proposed for the countermovement jump. Furthermore, the results of this study should be considered with caution when wanting to generalize and interpret them in other circumstances and supplementation protocols than those analyzed. Lastly, the differences between the CON session and the CAFF and PLA sessions could be biased, since although a familiarization session was performed and the CON session could be identified, it was always the first session assessed. However, similar circumstances have been previously described (Filip-Stachnik et al., 2022). Additionally, seven participants completed the PLA-CAFF and the CAFF-PLA sequences, respectively, which may help balance any bias between treatments, and substance carry-over effects were probably avoided by incorporating the wash-out period between sessions.

Conclusions

The results of this study indicate that CAFF is not ergogenic for countermovement jumps and cannot independently affect the temporal or kinetic characteristics of the jumping phase, nor the biomechanics of the landing. On the other hand, PLA could negatively influence some of these jumping and landing mechanics compared to CON, which suggests that its use in practical sport settings requires prudent application. In addition, in most cases, fatigue can also affect the analyzed variables in a complex way. Overall, it is relevant to highlight that this study presents biomechanics-oriented sports nutrition research, a novel approach that offers valuable insights into supplementation effects on mechanics, performance, and injury risk. Future research should investigate whether the impact of CAFF (or other sports supplements) and PLA is similar in circumstances closer to sports competitions, as well as with further methodological refinements.

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Competing Interests

The authors declare that they have no competing interests.

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Data availability

The anonymized participant-level datasets used for this article are available at CORA.RDR repository (https://doi.org/10.34810/data2510).

Online resources

Online resource 1 can be accessed at https://doi.org/10.6084/m9.figshare.31939956.

Online resource 2 can be accessed at https://doi.org/10.6084/m9.figshare.31939941.

CRediT authorship contribution statement

ABR: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Visualization, Supervision, Project administration, Funding acquisition. XBB: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Writing - Review & Editing, Visualization, Supervision. JP: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Writing - Review & Editing, Visualization, Supervision, Funding acquisition.

References

Baena-Riera, A., Borràs-Boix, X., & Peña, J. (2026). Effects of caffeine ingestion on performance and biomechanical parameters of running: A randomized crossover trial. Journal of Human Sport and Exercise, 21(2), 756–780. https://doi.org/10.55860/9dtvnv89

Bloms, L. P., Fitzgerald, J. S., Short, M. W., & Whitehead, J. R. (2016). The effects of caffeine on vertical jump height and execution in collegiate athletes. *Journal of Strength and Conditioning Research*, *30*(7), 1855–1861. https://doi.org/10.1519/JSC.0000000000001280

Bühler, E., Lachenmeier, D. W., Schlegel, K., & Winkler, G. (2014). Development of a tool to assess the caffeine intake among teenagers and young adults. *Ernahrungs Umschau*, *61*(4), 58–63.

https://doi.org/10.4455/eu.2014.011

Cronström, A., Creaby, M. W., & Ageberg, E. (2020). Do knee abduction kinematics and kinetics predict future anterior cruciate ligament injury risk? A systematic review and meta-analysis of prospective studies. *BMC Musculoskeletal Disorders*, *21*(1), 563. https://doi.org/10.1186/s12891-020-03552-3

De Bleecker, C., Vermeulen, S., De Blaiser, C., Willems, T., De Ridder, R., & Roosen, P. (2020). Relationship between jump-landing kinematics and lower extremity overuse injuries in physically active populations: A systematic review and meta-analysis. *Sports Medicine (Auckland, N.Z.)*, *50*(8), 1515–1532. https://doi.org/10.1007/s40279-020-01296-7

Dingenen, B., Barton, C., Janssen, T., Benoit, A., & Malliaras, P. (2018). Test-retest reliability of two-dimensional video analysis during running. Physical Therapy in Sport, 33, 40–47. https://doi.org/10.1016/j.ptsp.2018.06.009

Dingenen, B., Malfait, B., Vanrenterghem, J., Verschueren, S. M. P., & Staes, F. F. (2014). The reliability and validity of the measurement of lateral trunk motion in two-dimensional video analysis during unipodal functional screening tests in elite female athletes. Physical Therapy in Sport, 15(2), 117–123. https://doi.org/10.1016/j.ptsp.2013.05.001

Donahue, P. T., Wright, A., & Victory, J. (2022). Impact of Acute Caffeine Ingestion on Isometric Squat and Vertical Jump Performance. *The Journal of Sports Medicine and Physical Fitness*, *62*(10), 1306–1312. https://doi.org/10.23736/S0022-4707.21.12808-7

Dwan, K., Li, T., Altman, D. G., & Elbourne, D. (2019). CONSORT 2010 statement: Extension to randomised crossover trials. *BMJ (Clinical Research Ed.)*, *366*, l4378. https://doi.org/10.1136/bmj.l4378

Elkin, L. A., Kay, M., Higgins, J. J., & Wobbrock, J. O. (2021). An Aligned Rank Transform Procedure for Multifactor Contrast Tests. *The 34th Annual ACM Symposium on User Interface Software and Technology, USA*, 754–768. https://doi.org/10.1145/3472749.3474784

Filip-Stachnik, A., Krzysztofik, M., Del Coso, J., & Wilk, M. (2022). Acute effects of two caffeine doses on bar velocity during the bench press exercise among women habituated to caffeine: a randomized, crossover, double-blind study involving control and placebo conditions. *European Journal of Nutrition*, *61*(2), 947–955. https://doi.org/10.1007/s00394-021-02708-8

Filip, A., Wilk, M., Krzysztofik, M., & Del Coso, J. (2020). Inconsistency in the ergogenic effect of caffeine in athletes who regularly consume caffeine: Is it due to the disparity in the criteria that defines habitual caffeine intake? *Nutrients*, *12*(4), 1087. https://doi.org/10.3390/nu12041087

Florence, G. E., Oosthuyse, T., & Bosch, A. N. (2023). Skeletal site-specific effects of jump training on bone mineral density in adults: a systematic review and meta-analysis. *Journal of Sports Sciences*, *41*(23), 2063–2076. https://doi.org/10.1080/02640414.2024.2312052

Gallo-Salazar, C., Del Coso, J., Lara, B., Aguilar-Navarro, M., Giráldez-Costas, V., Areces, F., Revuelta, C., Gutiérrez-Hellín, J., & Salinero, J. J. (2024). Caffeine Enhances Some Aspects of Physical Performance in Well-Trained Hammer and Discus Throwers. *Nutrients*, *16*(22), 3908. https://doi.org/10.3390/nu16223908

González-García, J., Aguilar-Navarro, M., Giráldez-Costas, V., & Romero-Moraleda, B. (2023). Time course of jump recovery and performance after velocity-based priming and concurrent caffeine intake. *Research Quarterly For Exercise and Sport*, *94*(3), 655–667. https://doi.org/10.1080/02701367.2022.2041162

Grgic, J. (2018). Are There Non-Responders to the Ergogenic Effects of Caffeine Ingestion on Exercise Performance? *Nutrients, 10*(11), 1736. https://doi.org/10.3390/nu10111736

Grgic, J. (2022). A comprehensive assessment of caffeine's effects on components of countermovement jump performance. *Biology of Sport*, *39*(3), 515–520. https://doi.org/10.5114/biolsport.2022.107017

Grgic, J., Grgic, I., Pickering, C., Schoenfeld, B. J., Bishop, D. J., & Pedisic, Z. (2020). Wake up and smell the coffee: Caffeine supplementation and exercise performance-an umbrella review of 21 published meta-analyses. *British Journal of Sports Medicine*, *54*(11), 681–688. https://doi.org/10.1136/bjsports-2018-100278

Guest, N. S., VanDusseldorp, T. A., Nelson, M. T., Grgic, J., Schoenfeld, B. J., Jenkins, N. D. M., Arent, S. M., Antonio, J., Stout, J. R., Trexler, E. T., Smith-Ryan, A. E., Goldstein, E. R., Kalman, D. S., & Campbell, B. I. (2021). International Society of Sports Nutrition position stand: Caffeine and exercise performance. *Journal of the International Society of Sports Nutrition*, *18*(1), 1. https://doi.org/10.1186/s12970-020-00383-4

Herrington, L., & Munro, A. (2010). Drop jump landing knee valgus angle; normative data in a physically active population. Physical Therapy in Sport, 11(2), 56–59. https://doi.org/10.1016/j.ptsp.2009.11.004

Hewett, T. E., Myer, G. D., Ford, K. R., Heidt, R. S. J., Colosimo, A. J., McLean, S. G., van den Bogert, A. J., Paterno, M. V, & Succop, P. (2005). Biomechanical Measures of Neuromuscular Control and Valgus Loading of the Knee Predict Anterior Cruciate Ligament Injury Risk in Female Athletes: A Prospective Study. *The American Journal of Sports Medicine*, *33*(4), 492–501. https://doi.org/10.1177/0363546504269591

Holden, S., Boreham, C., Doherty, C., Wang, D., & Delahunt, E. (2015). Clinical assessment of countermovement jump landing kinematics in early adolescence: Sex differences and normative values. Clinical Biomechanics (Bristol, Avon), 30(5), 469–474. https://doi.org/10.1016/j.clinbiomech.2015.03.008

Hopewell, S., Chan, A.-W., Collins, G. S., Hróbjartsson, A., Moher, D., Schulz, K. F., Tunn, R., Aggarwal, R., Berkwits, M., Berlin, J. A., Bhandari, N., Butcher, N. J., Campbell, M. K., Chidebe, R. C. W., Elbourne, D., Farmer, A., Fergusson, D. A., Golub, R. M., Goodman, S. N., … Boutron, I. (2025). CONSORT 2025 explanation and elaboration: updated guideline for reporting randomised trials. *BMJ (Clinical Research Ed.)*, *389*, e081124. https://doi.org/10.1136/bmj-2024-081124

Lago-Rodríguez, Á., Jodra, P., Bailey, S., & Domínguez, R. (2021). Caffeine improves performance but not duration of the countermovement jump phases. *The Journal of Sports Medicine and Physical Fitness*, *61*(2), 199–204. https://doi.org/10.23736/S0022-4707.20.11099-5

Lesinski, M., Prieske, O., Demps, M., & Granacher, U. (2016). Effects of fatigue and surface instability on neuromuscular performance during jumping. *Scandinavian Journal of Medicine and Science in Sports*, *26*(10), 1140–1150. https://doi.org/10.1111/sms.12548

Magkos, F., & Kavouras, S. A. (2005). Caffeine use in sports, pharmacokinetics in man, and cellular mechanisms of action. *Critical Reviews in Food Science and Nutrition*, *45*(7–8), 535–562. https://doi.org/10.1080/1040-830491379245

Maughan, R. J., Burke, L. M., Dvorak, J., Larson-Meyer, D. E., Peeling, P., Phillips, S. M., Rawson, E. S., Walsh, N. P., Garthe, I., Geyer, H., Meeusen, R., Van Loon, L. J. C., Shirreffs, S. M., Spriet, L. L., Stuart, M., Vernec, A., Currell, K., Ali, V. M., Budgett, R. G., … Engebretsen, L. (2018). IOC consensus statement: Dietary supplements and the high-performance athlete. *British Journal of Sports Medicine*, *52*(7), 439–455. https://doi.org/10.1136/bjsports-2018-099027

Mejía Mejía, N. F., Randolfo Funez, C., Suazo Zelaya, A. M., Laínez Bonilla, J. E., Restrepo Marín, A., & Sánchez Alvarado, A. (2024). Asociación entre potencia y cambio de dirección en voleibol universitario masculino (Association between power and change of direction in men's college volleyball). *Retos*, *51*, 1070–1075. https://doi.org/10.47197/retos.v51.100560

Merino Fernández, M., Ruiz-Moreno, C., Giráldez-Costas, V., Gonzalez-Millán, C., Matos-Duarte, M., Gutiérrez-Hellín, J., & González-García, J. (2021). Caffeine doses of 3 mg/kg increase unilateral and bilateral vertical jump outcomes in elite traditional Jiu-Jitsu athletes. *Nutrients*, *13*(5), 1705. https://doi.org/10.3390/nu13051705

Muñoz, A., López-Samanes, Á., Aguilar-Navarro, M., Varillas-Delgado, D., Rivilla-García, J., Moreno-Pérez, V., & Del Coso, J. (2020). Effects of CYP1A2 and ADORA2A genotypes on the ergogenic response to caffeine in professional handball players. *Genes (Basel)*, *11*(8), 933. https://doi.org/10.3390/genes11080933

Nardon, M., Ferri, U., Caffi, G., Bartesaghi, M., Perin, C., Zaza, A., & Alessandro, C. (2024). Kinematics but not kinetics alterations to single-leg drop jump movements following a subject-tailored fatiguing protocol suggest an increased risk of ACL injury. *Frontiers in Sports and Active Living*, *6*, 1418598. https://doi.org/10.3389/fspor.2024.1418598

Ortiz-Sánchez, D., Bravo-Sánchez, A., Ramírez-delaCruz, M., Abián, P., & Abián-Vicén, J. (2024). Placebo Effect of Caffeine on Physiological Parameters and Physical Performance. *Nutrients*, *16*(10), 1405. https://doi.org/10.3390/nu16101405

Pedley, J. S., Lloyd, R. S., Read, P. J., Moore, I. S., De Ste Croix, M., Myer, G. D., & Oliver, J. L. (2020). Utility of kinetic and kinematic jumping and landing variables as predictors of injury risk: A systematic review. *Journal of Science in Sport and Exercise*, *2*(4), 287–304. https://doi.org/10.1007/s42978-020-00090-1

Pickering, C., & Kiely, J. (2018). Are the current guidelines on caffeine use in sport optimal for everyone? Inter-individual variation in caffeine ergogenicity, and a move towards personalised sports nutrition. *Sports Medicine (Auckland, N.Z.)*, *48*(1), 7–16. https://doi.org/10.1007/s40279-017-0776-1

Puig-Diví, A., Escalona-Marfil, C., Padullés-Riu, J. M., Busquets, A., Padullés-Chando, X., & Marcos-Ruiz, D. (2019). Validity and reliability of the Kinovea program in obtaining angles and distances using coordinates in 4 perspectives. *PLoS One*, *14*(6), e0216448. https://doi.org/10.1371/journal.pone.0216448

Sams, M. (2020, August 17). *Shiny Vertical Jump Analysis*. Github. https://github.com/mattsams89/shiny-vertical-jump

Sands, W. A., Bogdanis, G. C., Penitente, G., Donti, O., McNeal, J. R., Butterfield, C. C., Poehling, R. A., & Barker, L. A. (2020). Reliability and validity of a low-cost portable force platform. *Isokinetics and Exercise Science*, *28*(3), 247–253. https://doi.org/10.3233/IES-202106

Santos-Mariano, A. C., Cristina-Souza, G., Santos, P. S., Domingos, P. R., De-Oliveira, P., Bertuzzi, R., Rodacki, C., & Lima-Silva, A. E. (2022). Caffeine intake increases countermovement jump performance in well-trained high jumpers. *PharmaNutrition*, *21*, 100305. https://doi.org/10.1016/j.phanu.2022.100305

Santos Junior, E. R. T., de Salles, B. F., Dias, I., Ribeiro, A. S., Simão, R., & Willardson, J. M. (2021). Classification and determination model of resistance training status. *Strength and Conditioning Journal*, *43*(5), 77–86. https://doi.org/10.1519/ssc.0000000000000627

Saunders, B., de Oliveira, L. F., da Silva, R. P., de Salles Painelli, V., Gonçalves, L. S., Yamaguchi, G., Mutti, T., Maciel, E., Roschel, H., Artioli, G. G., & Gualano, B. (2017). Placebo in sports nutrition: A proof-of-principle study involving caffeine supplementation. *Scandinavian Journal of Medicine and Science in Sports*, *27*(11), 1240–1247. https://doi.org/10.1111/sms.12793

Tallis, J., Duncan, M. J., Clarke, N. D., Morris, R. O., & Tamilio, R. A. (2024). Are caffeine effects equivalent between different modes of administration: the acute effects of 3 mg.kg(-1) caffeine on the muscular strength and power of male university Rugby Union players. *Journal of the International Society of Sports Nutrition*, *21*(1), 2419385. https://doi.org/10.1080/15502783.2024.2419385

Tamilio, R. A., Clarke, N. D., Duncan, M. J., Morris, R. O., & Tallis, J. (2022). How Repeatable Is the Ergogenic Effect of Caffeine? Limited Reproducibility of Acute Caffeine (3 mg.kg(-1)) Ingestion on Muscular Strength, Power, and Muscular Endurance. *Nutrients*, *14*(20), 4416. https://doi.org/10.3390/nu14204416

Wang, X., Soh, K. G., Samsudin, S., Li, L., Liu, C., Sun, M., & Ma, S. (2025). Effects of high-intensity training on jumping performance among athletes: a systematic review with meta-analysis. *Scientific Reports*, *15*(1), 1763. https://doi.org/10.1038/s41598-024-83161-5

Wobbrock, J. O., Findlater, L., Gergle, D., & Higgins, J. J. (2011). The Aligned Rank Transform for Nonparametric Factorial Analyses Using Only ANOVA Procedures. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, USA*, 143–146. https://doi.org/10.1145/1978942.1978963

Zbinden-Foncea, H., Rada, I., Gomez, J., Kokaly, M., Stellingwerff, T., Deldicque, L., & Peñailillo, L. (2018). Effects of caffeine on countermovement-jump performance variables in elite male volleyball players. *International Journal of Sports Physiology and Performance*, *13*(2), 145–150. https://doi.org/10.1123/ijspp.2016-0705

Zhang, Y., Zhuang, Y., Zhang, L., & Sun, M. (2024). The impact of eccentric training on athlete movement speed: a systematic review. *Frontiers in Physiology*, *15*, 1492023. https://doi.org/10.3389/fphys.2024.1492023

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