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**AKUTNI UČINAK KOFEINA IZ RAZLIČITIH
IZVORA NA MIŠIĆNU JAKOST I SNAGU**

DOKTORSKI RAD

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**THE ACUTE EFFECTS OF CAFFEINE FROM
VARIOUS SOURCES ON MUSCLE STRENGTH
AND POWER**

DOCTORAL THESIS

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AKUTNI UČINAK KOFEINA IZ RAZLIČITIH IZVORA NA MIŠIĆNU JAKOST I SNAGU

Sažetak

Cilj: Primarni cilj ovog randomiziranog, dvostruko slijepog, placebo kontroliranog istraživanja bio je ispitivanje akutnih učinaka kofeina iz različitih izvora (guma za žvakanje, gel, kapsule) na mišićnu jakost i snagu u osoba iskusnih u treningu s otporom. Sekundarni cilj bila je izravna usporedba veličine učinka kofeina (u istoj apsolutnoj dozi) iz različitih izvora na mišićnu jakost i snagu. Tercijarni cilj odnosi se na ispitivanje učinka kofeina na mišićnu jakost i snagu i uspoređivanje tih učinaka s učinkom placeba s jedne, i s kontrolnim mjerenjem (mjerenjem bez suplementacije) s druge strane.

Metode: Izvedba skoka procijenjena je putem testa bilateralnog vertikalnog skoka s pripremom na platformi za mjerenje sile. Jakost i snaga mišića donjeg dijela tijela procijenjena je na izokinetičkom uređaju. Snaga mišića gornjih ekstremiteta procijenjena je putem vježbe potiska s ravne klupe pri 50%, 75% i 90% 1RM uz pomoć PowerLift iOS aplikacije, dok se za procjenu snage mišića cijelog tijela koristio test na veslačkom ergometru. Testovi su provedeni kroz sedam dolazaka u laboratorij tijekom kojih su sudionici prije testiranja konzumirali: (a) gumu za žvakanje s kofeinom (300 mg) odnosno placebo gumu za žvakanje; (b) kapsulu s kofeinom (6 mg/kg) odnosno placebo kapsulu; i (c) gel s kofeinom (300 mg) odnosno placebo gel. U segmentu istraživanja učinaka kofeina iz kapsula, jedan dolazak u laboratorij sastojao se u testiranju bez ikakve prethodne konzumacije (tzv. kontrolno mjerenje). Uzorak sudionika varirao je od n=16 (dob (AS ± SD): 22.9 ± 2 god) u segmentu istraživanja učinaka kofeina iz gelova do n=26 (dob (AS ± SD): 24.2 ± 5 god) u segmentu istraživanja učinaka kofeina iz kapsula.

Rezultati: U usporedbi s placebo gumom za žvakanje, kofein iz guma za žvakanje akutno je poboljšao (za 3-9%) izvedbu skoka s pripremom, jakost i snagu mišića donjeg dijela tijela, snagu mišića gornjeg dijela tijela te snagu cijelog tijela. Konzumacija kofeina iz gelova akutno je poboljšala (za 3-12%) sve prethodno navedene dimenzije jakost i snage u odnosu na konzumaciju placebo gela. Nije bilo razlike u veličini učinka kofeina iz gelova i guma za žvakanje na mišićnu jakost i snagu. Kofein iz kapsula je, u odnosu na placebo kapsulu i u odnosu na kontrolno mjerenje, značajno poboljšao (za 3-8%) visinu vertikalnog skoka, jakost

i snagu mišića donjeg dijela tijela te snagu mišića gornjeg dijela tijela. Kofein iz kapsula akutno je poboljšao (za 4%) snagu mišića cijelog tijela u usporedbi s placebo, ali ne i u usporedbi s kontrolnim mjerenjem. Iako placebo uglavnom nije imao ergogeni učinak u odnosu na kontrolno mjerenje kod većine testova, ipak je u dva testa (vertikalni skok s pripremom, potisak s ravne klupe) taj učinak uočen.

Zaključak: Konzumacija kofeina iz alternativnih izvora (gelovi, gume za žvakanje) može akutno poboljšati visinu skoka, jakost i snagu mišića donjih ekstremiteta, snagu mišića gornjih ekstremiteta te snagu mišića cijelog tijela u osoba iskusnih u treningu s otporom. Nema razlika u veličini akutnog učinka kofeina na jakost i snagu kad se promatra kofein u istoj apsolutnoj dozi konzumiran iz različitih izvora. Stoga, odabir izvora kofeina u vježbača zainteresiranih za suplementaciju kofeinom stvar je, čini se, osobnih preferencija. Konačno, u pojedinim testovima mišićne jakost i snage konzumacija placebo je bila ergogena u odnosu na kontrolno mjerenje, što ukazuje na postojanje placebo učinka kojeg treba uzeti u obzir kako u znanstvenim istraživanjima kofeina kao ergogenog sredstva, tako i u praksi tjelesnog vježbanja i sportskog treninga.

Ključne riječi: ergogena sredstva, suplementacija, trening s otporom

THE ACUTE EFFECTS OF CAFFEINE FROM VARIOUS SOURCES ON MUSCLE STRENGTH AND POWER

Summary

Purpose: The primary objective of this randomized, double-blind, placebo-controlled study was to investigate the acute effects of caffeine from various sources (gel, chewing gum, capsule) on muscular strength and power in resistance-trained individuals. The secondary objective was to directly compare the magnitude of caffeine's effects (at the same absolute dose) from different sources on muscular strength and power. The tertiary objective was to examine the impact of caffeine on muscular strength and power and compare these effects with the placebo effect on one hand, and with the control measurement (measurement without supplementation) on the other.

Methods: Jump performance was assessed through a bilateral countermovement jump test on a force measurement platform. Lower body strength and power were assessed on an isokinetic device. Upper body power was assessed using the bench press exercise at 50%, 75%, and 90% 1RM with the assistance of the PowerLift iOS application, while whole-body power was assessed using a rowing ergometer test. The tests were conducted over seven laboratory visits during which participants, before testing, consumed: (a) caffeinated chewing gum (300 mg) or placebo chewing gum; (b) caffeinated gel (300 mg) or placebo gel; and (c) caffeine capsules (6 mg/kg) or placebo capsules. In the segment investigating the effects of caffeine from capsules, one laboratory visit consisted of testing without any prior consumption (referred to as the "control measurement"). The participant sample size varied across different study segments, ranging from n=16 (age (mean \pm SD): 22.9 \pm 2 years) in the segment investigating the effects of caffeine from gels to n=26 (age (mean \pm SD): 24.2 \pm 5 years) in the segment investigating the effects of caffeine from capsules.

Results: Compared to placebo chewing gum, caffeine from chewing gum acutely improved (by 3-9%) countermovement jump performance, lower body strength and power, upper body power, and whole-body power. Consumption of caffeine from gel acutely improved (by 3-12%) all the previously mentioned strength and power dimensions in comparison to placebo gel consumption. There was no difference in the magnitude of caffeine's effects between gel and chewing gum sources on muscular strength and power.

Caffeine from capsules significantly improved (by 3-8%) vertical jump height, lower body strength and power and upper body power compared to the placebo capsule and the control measurement. Caffeine from capsules acutely enhanced (by 4%) whole-body power compared to the placebo, but not compared to the control measurement. Although the placebo generally did not exhibit an ergogenic effect compared to the control measurement in most tests, such an effect was observed in two tests (countermovement jump, bench press exercise).

Conclusion: The consumption of caffeine from alternative sources (gels, chewing gums) can acutely enhance jump height, lower body strength and power, upper body power and whole-body power in resistance-trained individuals. There are no differences in the magnitude of acute effects of caffeine on strength and power when considering caffeine at the same absolute dose consumed from different sources. Therefore, the choice of caffeine source for individuals interested in caffeine supplementation appears to be a matter of personal preference. Finally, in certain tests of muscular strength and power, placebo consumption was ergogenic compared to the control measurement, indicating the presence of a placebo effect that should be considered both in scientific research on caffeine as an ergogenic aid and in the practice of physical exercise and sports training.

Keywords: ergogenic aids, supplementation, resistance training