**Effects of different dosages of caffeine administration on wrestling performance during a simulated tournament**

**Submission type:** Original Investigation

Raoof Negaresh1, Juan Del Coso2, Motahare Mokhtarzade1, Adriano Eduardo Lima-Silva3, Julien S. Baker4, Mark E. T. Willems5, Sina Talebvand6, Mostafa Khodadoost7, Farid Farhani8

1Department of Physical Education & Sport Sciences, Faculty of Humanities, Tarbiat Modares University, Tehran, Iran. 2Exercise Physiology Laboratory, Camilo José Cela University, Madrid, Spain. 3Human Performance Research Group, Technological Federal University of Parana, Parana, Brazil. 4 Applied Physiology Research Laboratory, School of Health and Life Sciences, University of the West of Scotland, Lanarkshire Campus, Scotland, UK. 5Institute of Sport, University of Chichester, College Lane, Chichester, United Kingdom. 6Department of Sports Physiology, Shahid Chamran University of Ahvaz, Ahvaz, Iran. 7Department of physical education, Abadan branch, Islamic Azad University, Abadan, Iran. 8 Department of Exercise Physiology, Faculty of Physical Education and Sport Sciences, Kharazmi University, Tehran, Iran.

Corresponding author:

Raoof Negaresh

Department of Exercise Physiology, Tarbiat Modares University, Tehran, Iran

Phone: +989164262029; Fax: +986153360839, E-mail: Raoof.negaresh@modares.ac.ir

**Acknowledgements**

We are most thankful all indi­viduals who participated in the study. This study was supported by the Shahid Chamran University and Abadan branch of Islamic Azad University.

**Effects of different dosages of caffeine administration on wrestling performance during a simulated tournament**

**Abstract**

The aim of the present study was to investigate the effects of different forms of caffeine administration on physical performance during a simulated wrestling tournament. In a double-blind and randomized experiment, twelve male freestyle wrestlers competed in a simulated wrestling tournament (5 wrestling matches consisting of 2×3-min wrestling rounds) following the ingestion of: a placebo, a high-dose of caffeine (10 mg/kg), a moderate-dose caffeine (4 mg/kg), a repeated-dose caffeine (2 mg/kg before each match to a total of 10 mg/kg) or a selective caffeine administration based on performance decrement previously measured (6.16±1.58 mg/kg). The Pittsburgh Wrestling Performance Test (PWPT) was measured before each match to assess physical performance. In comparison to the placebo, the high dose of caffeine only reduced PWPT time before the first match (56.8±2.0 vs. 52.9±1.8 s; p < 0.05). The moderate dose of caffeine did not affect PWPT performance during the tournament. Both, the repeated dose and the selective administration of caffeine reduced PWPT time with respect to the placebo in the third (66.7±1.8 vs. ~63.1±1.4 s; p < 0.05) and fourth matches (72.3±2.4 vs. ~65.9±1.3 s; p < 0.05). However, only the selective dose of caffeine reduced PWPT time before the fifth match (62.7±3.0 vs. 56.3±2.0; p < 0.05). The dosage and administration of caffeine affect the ergogenic effects obtained following the ingestion of this substance. An individualized protocol to provide caffeine when physical performance is expected to be reduced might improve wrestling performance during the latter stages of a tournament.

**Keywords**: *Competition, Performance, Coaching, Recovery.*

**Introduction**

Wrestling is a combat sport that was practiced in the Ancient Greek Olympics Games and is also one of the most important combat sports in which two people that has inclusion in the Modern Olympic Games ([Barbas et al., 2011](#_ENREF_5); [Demirkan, Koz, Kutlu, & Favre, 2015](#_ENREF_11)). Wrestling compromises a physical fight between two opponents of similar body mass with the purpose of gaining and maintaining a superior position over the rival. The fight includes grappling-type techniques such as clinch fighting, throws, takedowns, joint locks, pins and other grappling positions with the final aim of throwing and pinning the rival to the matted area ([Chaabene et al., 2017](#_ENREF_6)). Greco-Roman style wrestlers are only allowed to use their upper-body during the fight -thus, holds below the waist are forbidden. However, freestyle wrestlers are permitted to use their whole body during competition ([Chaabene et al., 2017](#_ENREF_6)). A wrestling match consists of two 3-min rounds which include short periods of high-intensity efforts interspersed with brief periods of rest or moderate-intensity work to allow recovery for the next bout ([Barbas et al., 2011](#_ENREF_5)). All these characteristics indicate the necessity of possessing highly developed capacities of maximal strength, power, endurance and anaerobic capabilities in elite wrestlers. Specifically, the short bursts of maximal intensity observed during the fight are mainly maintained by anaerobic metabolic pathways which include anaerobic glycolysis. The primary role of the aerobic system is to aid in the recovery process within and between successive matches ([Rezasoltani, Ahmadi, Nehzate-Khoshroh, Forohideh, & Ylinen, 2005](#_ENREF_23); [Terbizan & Seljevold, 1996](#_ENREF_28)).

Wrestling tournaments are one-day or two-day events, with three to five matches per day, depending on the success of a wrestler throughout the progressive rounds. For instance, the winner of the 2017 World Wrestling Championships had to fight five matches in a single day ([United World Wrestling, 2017](#_ENREF_30)). However, what makes wrestling more physiologically demanding and challenging is the short recovery (from 30 min to 3 hours) allowed between the matches ([Barbas et al., 2011](#_ENREF_5); [Chaabene et al., 2017](#_ENREF_6)). A few previous studies investigating the physiological profiles in wrestling tournaments have shown that the succession of matches during the tournament induces significant increases in the ratings of fatigue and decreases in muscular power and strength ([Barbas et al., 2011](#_ENREF_5); [Kafkas et al., 2016](#_ENREF_19); [Kraemer et al., 2001](#_ENREF_20)). This suggests an incomplete recovery between matches that produces a progressive decline in physical performance ability for the remaining tournament duration.

An interesting question is how wrestlers can achieve a faster physiological recovery to return to the required level of fitness prior to the next match. Legal ergogenic aids with properties to increase performance and/or to accelerate recovery between matches may be of benefit to improve the athletes’ recovery profile. The ergogenic effect observed may also enhance the athlete’s chance of overall tournament success. Caffeine seems a promising substance to provide benefits during multi-match events such as a wrestling tournament. Caffeine has been previously reported as being beneficial in other sports comprising various competitions in the same day ([Del Coso et al., 2013](#_ENREF_10); [Diaz-Lara, Del Coso, Portillo, et al., 2016](#_ENREF_13); [Santos et al., 2014](#_ENREF_25)). Specifically, caffeine administration seems to improve several physiological parameters that are specifically related to wrestling performance. These include, muscle power, strength, agility, vigilance, attention and reaction time ([Aedma, Timpmann, & Oopik, 2013](#_ENREF_1); [Astorino & Roberson, 2010](#_ENREF_4); [Spriet, 2014](#_ENREF_27)). Although, the scientific literature is scarce, previous work on combat sport demonstrated that caffeine ingestion might improve reaction time and delay fatigue during successive taekwondo combats (5 mg/kg)([Santos et al., 2014](#_ENREF_25)) or the time spent in offensive actions during a Brazilian jiu-jitsu competition (3 mg/kg) ([Diaz-Lara, Del Coso, Portillo, et al., 2016](#_ENREF_13)). Two other studies conducted by Lopes-Silva et al. and Saldanha ([João Paulo Lopes-Silva et al., 2015](#_ENREF_21))et al. showed that although the estimated glycolytic contribution after caffeine ingestion increased but no performance improvement has been achieved in during simulated taekwondo combat (3 rounds of 2 min separated by 1 min passive recovery) and simulated judo matches (three 5 minute matches with 15 minute intervals), respectively ([João Paulo Lopes-Silva et al., 2015](#_ENREF_21); [Saldanha, Kons, & Detanico, 2018](#_ENREF_24)). However, a unique study trying to mimic wrestling matches found that acute caffeine ingestion (5 mg/kg) had a partially detrimental effect on upper body intermittent sprint performance in trained wrestlers ([Aedma et al., 2013](#_ENREF_1)).

It should be noted here that the simulated competition consisted of four 6-min upper body intermittent sprint performance tests with 30-min recovery periods, which may not entirely represent a real wrestling tournament.

In an attempt to advance the knowledge regarding the efficacy of caffeine ingestion to increase wrestling performance, we designed a research protocol to determine which form of caffeine administration is more beneficial to maintain physical performance during a simulated one-day wrestling tournament. Moreover, because caffeine ingestion may be associated with dehydration and gastrointestinal complaints([Spriet, 2014](#_ENREF_27)), we also investigated which methodological approach(s) resulted in lower prevalence of side effects while maximizing performance.

**Material and methods**

*Participants*

From an initial sample of 41 volunteers, 12 wrestlers were recruited (age: 24±3 years, body mass: 75.8±4.0 kg, and body mass index: 24.1±1.8 kg/m2). The inclusion criteria consisted of the following: wrestlers to be professional male freestyle, wrestling experience of at least 10 years, age between 20 to 28 years, non-smoker, and no current musculoskeletal problems. All wrestlers were screened by a physician prior to participating in the study. All participants indicated that they consumed less than 3 cups of coffee per day, and as a result were considered as low-to-moderate caffeine consumers. Wrestlers were familiarized with testing devices and procedures prior to experimental data collection. All subjects were meticulously informed about the benefits and risks of the study prior to providing their written informed consent. The study was approved by the University Institutional Review Board.

*Study Design*

The study was performed 2 weeks after completing the in-season wrestling period. This ensured that the athletes were fully recovered from the effects of prior competitions and that they all reported for testing with maximal levels of physical fitness restored. During these two post-season weeks, routine exercise sessions mainly consisted of technical and tactical tasks. Body mass and height (287, Seca, Germany) were taken two days before the first experimental session to allow individualized caffeine dosages. The day before each experimental trial, participants refrained from strenuous exercise and adopted a similar diet and fluid intake regimen, replicating their pre-competition routines. Participants were encouraged to keep nutrition and exercise diaries, routine lifestyle and sleep habits during study, especially before each experimental visit. Moreover, participants were encouraged to withdraw from all dietary sources of caffeine (coffee, chocolate, cola drinks, etc.) and alcohol for 48 hours before testing. Before each session, the participants were asked about the implementation of the recommendation; all participants reported that they had executed the recommendations.

All participants undertook 5 experimental trials with 5 days between each trial to facilitate washout and recovery. In a randomized order (using envelopes and cards) and in a double-blinded manner, participants ingested: a placebo, a high-dose of caffeine (10 mg/kg), a moderate-dose of caffeine (4 mg/kg), a repeated-dose caffeine (5 × 2 mg/kg), and selective caffeine consumption protocol based on the expected physical performance decrement previously measured (6.16±1.58 mg/kg; see below).

In each experimental trial, participants competed in a simulated wrestling tournament following the rules of the International Federation of Associated Wrestling Styles (FILA). This was used to improve the ecological validity of the outcome measures. Participants performed five matches; each match consisted of 2×3-min rounds of competitive wrestling with 30 s of passive rest between the rounds. As in a real wrestling tournament, the second, third, and fourth wrestling matches were performed 45 min after the previous match, while the last match was performed after 3 h after of recovery (Figure 1). To standardize all procedures, all the trials included the 5 times of ingestion, one 45 min before the first match (that included the full dose of caffeine for 10 and 4 mg/kg trials) and the remaining four capsules (that included caffeine or placebo) ~30 min before the following matches. Caffeine (Oriola OY, Finland) was always co-ingested with a drink containing Sprite® and cherry syrup to mask the taste of caffeine.

Of note, the selective caffeine supplementation was innovative because it was designed to individually provide caffeine when physical performance decreases. For this protocol, one week before the first experimental trial, participants performed 10 Pittsburgh Wrestling Performance Test (PWPT) with 30-min rest between bouts. For each participant, the mean and the standard deviation (SD) of PWPTs were calculated and performance declination was defined as having an increase in PWPT time longer than 1 SD. Thus, during the experimental trial with the selective caffeine supplementation, caffeine (2 mg/kg for each time) was provided when PWPT time increased 1 SD from baseline. In this experimental trial, no athlete was provided with caffeine before the first match, but 7/12 athletes were provided with 2 mg/kg before the second match, 9/12 athletes received caffeine before the third match, 12/12 athletes received caffeine before the fourth match and 9/12 athletes before the final match. The average caffeine intake in this trial was 6.16±1.58 mg/kg with one wrestler consuming caffeine twice in the protocol (4 mg/kg) and another wrestler receiving a maximal dose of 8 mg/kg.

*Physical performance measurements*

The PWPT was performed 6 times in each experimental trial: in the baseline measurement (20 min before the first intake of caffeine/placebo; Figure 1) and 5 min before each match, as part of the athlete's warm-up protocol. The PWPT was always performed as described previously ([Utter, 2001](#_ENREF_31)). For this measurement, wrestlers were paired with an opponent of the same weight category who did not participate in the study. The test consisted of a series of 5 special wrestling moves with 5 repetitions including double-leg and single-leg takedown, stomach-to-back lift, fireman’s carry and hip toss ([Utter, 2001](#_ENREF_31)). The partner was completely inactive during the test and did not move any opposition or consent. After each move, the inactive wrestler came back to the standing position until the active wrestler completed the 5-repetition set. During the test, the participant was asked to perform the test with the same intensity, speed and technique as during a real match. Wrestling performance was evaluated based on the PWPT time to the nearest 1.0 s using two stopwatches (Delta E200, Switzerland). Maximal hip/back strength and jump height were measured during baseline measurement and immediately before and after each match. Hip/back strength was measured using a dynamometer (Takei Digital Dynamometer, UK) as previously described ([Barbas et al., 2011](#_ENREF_5); [Kraemer et al., 2001](#_ENREF_20)) while the maximal vertical jump height was measured using an infrared beam system (Just Jump System, Probotics, USA). The best score in three attempts for each of these two tests was used for statistical analysis.

*Heart rate, fatigue and blood lactate concentration*

Heart rate, perceived fatigue ratings and blood lactate concentration were measured during baseline measurement and immediately before and after each match. Heart rate was monitored in a seated position by a standard Monark belt (Vansbro, Dalarna, Sweden) for 1 min. Fatigue rating was obtained using 0-10 a Likert scale, as previously described ([Barbas et al., 2011](#_ENREF_5); [Kraemer et al., 2001](#_ENREF_20)). Wrestlers reported feeling of fatigue, with zero score being “no fatigue” and 10 “severe fatigue”. Blood lactate concentrations were measured from fingertip blood samples using a portable analyzer (Lactate Pro, Arkray KDK, Japan). The order of measurements before and after each match were standardized that first, heart rate, then blood lactate and fatigue and following these measures, hip/back strength and vertical jump were evaluated.

*Hydration Status and gastrointestinal complaints*

A urine sample was obtained from each participant during baseline measurement and post final wrestling match, to indirectly assess hydration status in each experimental trial. Urine volume was determined by a graduated cylinder, urine specific gravity was measured using a refractometer (RHB-90ATC, Brix, Hongkong) while urine osmolality was calculated by an advanced osmometer (A20, Hettich Benelux, Netherlands). Dehydration index was determined based on four dehydration scores including urine color, osmolality, specific gravity and creatinine excretion ([Armstrong et al., 2010](#_ENREF_2); [Hahn & Waldreus, 2013](#_ENREF_18)). In addition, gastrointestinal complaints were determined by a questionnaire at the end of the experimental trials ([Felippe, Lopes-Silva, Bertuzzi, McGinley, & Lima-Silva, 2016](#_ENREF_15)). The gastrointestinal complaints questionnaire consisted of 11 items which each item having a score between 1 and 10, where 1 shows “no problem”, and 10 is “the worst case”.

*Statistical Analysis*

SPSS21 software (IBM, USA) was used for statistical analysis. The effect of the different forms of caffeine administration on variables measured in each experimental trial was assessed using a two-way repeated-measures analysis of variance (condition × time). The effect of the different caffeine forms of administration on urine osmolality and urine specific gravity was assessed using analysis of covariance. Furthermore, the effects of the different caffeine forms of administration on gastrointestinal complaints, urine volume and dehydration index was measured using a one-way analysis of variance. Partial Eta squared (ηp2) was used as effect size in repeated-measures analysis of variance tests and analysis of covariance. Eta squared (η2) was used as effect size in one-way analysis of variance. The assumptions for statistical tests applied in the current study were reviewed and approved. Bonferroni post hoc test was applied when necessary. Statistical significance was set at p < 0.05. Values are expressed as mean ± SD for the study sample.

**Results**

*Physical performance measurements*

The times employed to complete the PWPT in each experimental trial are presented in Figure 2. From similar baseline values, PWPT time progressively increased until the fourth match (p < 0.05) and then declined before the final match (p < 0.05) in all experimental trials (ηp2 for time effect: 0.86). Before the first match, PWPT time was lower with the ingestion of the high-dose of caffeine in comparison to all the other trials (p < 0.05, ηp2: 0.1 to 0.13), although this effect disappeared in the following matches (ηp2: 0.04 to 0.6). Both, the repeated dose of caffeine and the selective administration of caffeine reduced PWPT times before the third and fourth matches when compared to all the other trials (p < 0.05, ηp2: 0.01 to 0.26 and ηp2: 0.01 to 0.49, respectively). However, only the selective dose of caffeine reduced PWPT time before the fifth match (p < 0.05, ηp2: 0.26 to 0.39). Although there was a significant time effect for hip/back strength and vertical jump height (p < 0.05; supplemental data, ηp2: 0.13 and 0.09, respectively), there were no any significant effect on these variables with any of the administration protocols of caffeine.

*Heart rate, fatigue and blood lactate concentration*

Heart rate increased in all matches in all conditions, but pre-match values in second match was higher with the high dose of caffeine compared to the remaining trials (p < 0.05; Table 1). After the third match, heart rate was higher with the medium dose of caffeine and the repeated administration in comparison to all other conditions (p < 0.05), while after the fifth match, heart rate was significantly lower with the selective administration of caffeine (p < 0.05). Fatigue rating increased until the fourth match and then decreased in the fifth match relative to the previous match. Wrestlers indicated that they were less fatigued before the fourth match with the repeated and selective administration of caffeine (p < 0.05) while participants reported higher levels of fatigue with the placebo before the third and final matches (p < 0.05). Regarding blood lactate concentration, this variable presented higher values after the third match with the repeated and selective administration of caffeine (p < 0.05). Before the fourth match, blood lactate concentration was lower with the selective administration of caffeine and higher with the repeated administration (p < 0.05) in comparison to the remaining trials. Interestingly, blood lactate concentration was higher with the selective administration of caffeine after the fourth and fifth matches (p < 0.05).

*Hydration Status and gastrointestinal complaints*

Urine osmolality and urine specific gravity did not differ among experimental trials and remained unchanged across the tournament (Table 2). However, the urine volume and dehydration index were higher with the administration of the high dose of caffeine when compared to all other conditions (p < 0.05, η2: 0.06 and 0.12, respectively). The administration of the placebo and the selective dose of caffeine condition showed lower dehydration index after the tournament when compared to all the other conditions (p < 0.05). The scores of gastrointestinal complaints and gastrointestinal discomfort were significantly higher with the high dose of caffeine and the repeated dose of caffeine compared to all the experimental trials (p < 0.05, η2: 0.19).

**Discussion**

To our knowledge, this is the first study investigating the effect of several forms of caffeine administration on physical performance, hydration status, and gastrointestinal discomfort during a simulated one-day wrestling tournament. For this purpose, 4 protocols of caffeine administration, which combined varied doses (from 4 to 10 mg of caffeine per kg of body mass) and timing of ingestion (pre-competition, repeated doses and expected performance decline) were compared to the ingestion of a placebo in professional wrestlers competing in 5 simulated matches. Briefly, wrestling performance measured by means of PWPT was weakened until fourth match; regard to the fact that the rest time between the fourth and fifth matches was more extensive, the performance improved, but was still weaker than the first match. In comparison, PWPT improved before the third and fourth matches with the repeated administration of caffeine before each combat (5 × 2 mg/kg) and with the selective administration of caffeine, which was individually provided when the wrestler’ physical performance diminished before the combat (6.16 ± 1.58 mg/kg). In addition, these two protocols of progressive delivery of caffeine also reduced pre-match ratings of fatigue before the fourth match. Interestingly, only the selective administration of caffeine, was capable of improving PWPT before the final match (Figure 2). On the other hand, the administration of a high dose of caffeine (i.e. 10 mg/kg) before the onset of the competition improved PWPT performance before the first match but also produced the largest gastrointestinal and hydration disturbances during the tournament. Together, these results suggest that individual supplementation of caffeine based on expected performance decrements during the competition might be an effective strategy for those wrestlers seeking to maintain physical performance in the final matches of a wrestling competition. Moreover, results indicate that the fourth match is facing the most performance loss, which emphasizes the vitality of this match.

There is an ample body of evidence demonstrating that caffeine might positively affect physical performance in various disciplines ([Astorino & Roberson, 2010](#_ENREF_4); [Dolan, Witherbee, Peterson, & Kerksick, 2017](#_ENREF_14); [Shearer & Graham, 2014](#_ENREF_26); [Spriet, 2014](#_ENREF_27); [Trexler, Smith-Ryan, Roelofs, Hirsch, & Mock, 2016](#_ENREF_29)) and accordingly, this substance is widely used in most sports ([Del Coso, Munoz, & Munoz-Guerra, 2011](#_ENREF_9)); however, some studies have not been reported positive effects of caffeine on the performance of athletes ([João Paulo Lopes-Silva et al., 2015](#_ENREF_21); [Saldanha et al., 2018](#_ENREF_24)). Collectively, the information about the ergogenic effects of caffeine in combat sport is scarce and even contradictory. Astley et al. found that 4 mg/kg of caffeine ingestion improved performance in judo-specific testing along with a significant reduction in perceived exertion ([Astley, Souza, & Polito, 2017](#_ENREF_3)) but Lopez-Silva et al. determined that 6 mg/kg of caffeine were ineffective to increase physical performance in judokas undergoing rapid weight loss ([J. P. Lopes-Silva, Felippe, Silva-Cavalcante, Bertuzzi, & Lima-Silva, 2014](#_ENREF_22)). Diaz-Lara et al. demonstrated that 3 mg/kg of caffeine improved physical performance before and during a simulated competition of Brazilian jiu-jitsu ([Diaz-Lara, Del Coso, Garcia, et al., 2016](#_ENREF_12); [Diaz-Lara, Del Coso, Portillo, et al., 2016](#_ENREF_13)) while Santos et al. showed that caffeine ingestion (5 mg/kg) delayed fatigue during successive taekwondo combats ([Santos et al., 2014](#_ENREF_25)). Saldanha et al. used a similar design with current study on judo athletes; they asked their participants to applied three 5 minute matches with 15 minute intervals 1 hour after the caffeine (5 mg/kg). They reported that caffeine intake increased the estimated glycolytic contribution, but the countermovement jump, judogi grip strength test and number of attacks did not improve over the matches ([Saldanha et al., 2018](#_ENREF_24)). However, the only investigation carried out with caffeine in wrestling indicated that 5 mg/kg of this substance was ineffective in increasing performance ([Aedma et al., 2013](#_ENREF_1)). In the current investigation, the use of a moderate dose of caffeine (4 mg/kg) was investigated along with other forms of acute and repeated caffeine administration. Confirming the investigation of Aedma et al. the moderate dose of caffeine was not enough to increase any of the variables used in this investigation to assess performance ([Aedma et al., 2013](#_ENREF_1)) (Table 1 and Figure 2). Yet, the acute ingestion of 10 mg/kg was effective to significantly improve PWPT performance before the first match. This suggests that higher doses of caffeine are necessary to produce ergogenic effects in wrestlers. This high-dosing of caffeine before the competition did not produce further benefits during the tournament. Also, the participants reported a higher frequency of gastrointestinal complaints in conjunction with a diminished hydration status (Table 2).

Caffeine is rapidly absorbed within the stomach and small intestine and appears in the blood within 5–15 min of ingestion. However, it takes about ~40 minutes to reach peak values in the plasma ([Spriet, 2014](#_ENREF_27)). This fast absorption rate of caffeine can produce elevated serum caffeine concentrations when the dose is high and acute, and thus, increase the likelihood of positive performance but also negative gastrointestinal effects. Due to the possible side-effects derived from the acute ingestion of a 10 mg/kg of caffeine, we also investigated the effectiveness of the same absolute dose but divided into 5 timed periods of ingestion (one before each match; i.e., 5 × 2 mg/kg). According to a previous investigation ([Conway, Orr, & Stannard, 2003](#_ENREF_7)), the division of the caffeine dose can produce a more gradual rise of caffeine in plasma, and therefore a reduction in the prevalence of pernicious side-effects. Interestingly, the repeated dose of caffeine did not affect performance in the first two combats but it increased PWPT performance before the third and fourth matches. Furthermore, the repeated dose of caffeine ameliorated the gastrointestinal complaints and reduced the dehydration index at the end of the tournament. Thus, it seems clear that a high dose of caffeine (> 5 mg/kg)([Aedma et al., 2013](#_ENREF_1)) is necessary to significantly improve performance during high-level wrestling and the division of the dosage can reduce non-desirable physical and physiological outcomes.

As an innovative approach for the use of caffeine in sports, we designed a method to administer low and repeated doses of caffeine (2 mg/kg) when the wrestlers were experiencing a reduction in physical performance resulting from the succession of matches. This approach gave the wrestlers the opportunity to avoid the use of caffeine before competition but allowed them to administer before the second and the remaining matches. With this protocol, the dose of caffeine used was moderate (6.16±1.58 mg/kg) but produced the maximal performance benefits at the end of the wrestling tournament (Figure 2). It has been recently suggested, only the use of low-to-moderate doses of caffeine can produce the antagonist action of caffeine at A1, A2A and A2B adenosine receptors ([Fredholm, Yang, & Wang, 2017](#_ENREF_16)). Thus, the use of a moderate dose of caffeine, distributed during a wrestling tournament and specifically administrated when the athlete is experiencing fatigue can be an effective form of caffeine use in elite wrestling. However, further investigation needs to determine the usefulness of this approach in other sport disciplines.

The experimental design used in this investigation presented several limitations that should be discussed to improve the application of the outcomes presented here. First, in real competitions, wrestlers are typically required to lose body mass to reach the specified weight category.

In the current study, we simulated a wrestling tournament without asking the athletes to lose body mass before the simulation. The ergogenic effects of caffeine on voluntarily dehydrated wrestlers should be considered experimentally, as this might limit the benefits of caffeine in combat sports ([J. P. Lopes-Silva et al., 2014](#_ENREF_22)). Secondly, the ergogenic effect of caffeine is highly variable; one of the most important variance is accounted for by genetic polymorphisms ([Womack et al., 2012](#_ENREF_32)). A (C/A) single nucleotide polymorphism at intron 1 of the cytochrome P450 (CYP1A2) gene is a key component of caffeine metabolism ([Cornelis, El-Sohemy, Kabagambe, & Campos, 2006](#_ENREF_8); [Womack et al., 2012](#_ENREF_32)). Furthermore, recent sport studies approved the CYP1A2 variant results in differences in the rate of caffeine breakdown and affected performance of athletes ([Guest, Corey, Vescovi, & El-Sohemy, 2018](#_ENREF_17); [Womack et al., 2012](#_ENREF_32)). Therefore, considering such Cytochrome P450 polymorphism cases and homogenizing subjects can lead to more accurate results. Thirdly, although we tried to produce a motivating atmosphere simulating a real competition, it is likely that the mental determination and motivation of athletes were lower than those observed in a real tournament. Fourthly, we measured physical performance before and after the matches but we were unable to obtain reliable information of performance during the execution of the matches. Finally, using other tools and technique, such as time-motion analysis, could add validity and accuracy to the research data. Therefore, it is suggested to use more extensive methods and techniques in future studies to investigate the role of caffeine in improving the performance of wrestlers.

In conclusion, a moderate-dose of caffeine (4 mg/kg) ingested before a wrestling tournament was ineffective to increase performance in wrestlers. On the other hand, an acute and high-dose of caffeine (10 mg/kg) increased physical performance before the first match, although this dose produced unwanted effects during the remaining matches of the wrestling tournament. The division of a high-dose of caffeine into several low-doses (5 × 2 mg/kg), taken before each match, was effective in increasing performance in the third and fourth matches. This dosage also reduced the side-effects associated with caffeine intake. However, the approach that provided the greatest benefits to wrestling performance was the use of a moderate dose of caffeine (~ 6 mg/kg) repeatedly administrated in low doses (~ 2 mg/kg). This appeared to be most beneficial when the wrestler was presenting reduced physical performance.

**References**

Aedma, M., Timpmann, S., & Oopik, V. (2013). Effect of caffeine on upper-body anaerobic performance in wrestlers in simulated competition-day conditions. [Randomized Controlled Trial

Research Support, Non-U.S. Gov't]. *Int J Sport Nutr Exerc Metab, 23*(6), 601-609.

Armstrong, L. E., Pumerantz, A. C., Fiala, K. A., Roti, M. W., Kavouras, S. A., Casa, D. J., & Maresh, C. M. (2010). Human hydration indices: acute and longitudinal reference values. [Research Support, Non-U.S. Gov't]. *Int J Sport Nutr Exerc Metab, 20*(2), 145-153.

Astley, C., Souza, D., & Polito, M. (2017). Acute Caffeine Ingestion on Performance in Young Judo Athletes. *Pediatr Exerc Sci, 29*(3), 336-340. doi: 10.1123/pes.2016-0218

Astorino, T. A., & Roberson, D. W. (2010). Efficacy of acute caffeine ingestion for short-term high-intensity exercise performance: a systematic review. [Review]. *J Strength Cond Res, 24*(1), 257-265. doi: 10.1519/JSC.0b013e3181c1f88a

Barbas, I., Fatouros, I. G., Douroudos, II, Chatzinikolaou, A., Michailidis, Y., Draganidis, D., . . . Taxildaris, K. (2011). Physiological and performance adaptations of elite Greco-Roman wrestlers during a one-day tournament. [Clinical Trial

Research Support, Non-U.S. Gov't]. *Eur J Appl Physiol, 111*(7), 1421-1436. doi: 10.1007/s00421-010-1761-7

Chaabene, H., Negra, Y., Bouguezzi, R., Mkaouer, B., Franchini, E., Julio, U., & Hachana, Y. (2017). Physical and Physiological Attributes of Wrestlers: An Update. [Review]. *J Strength Cond Res, 31*(5), 1411-1442. doi: 10.1519/JSC.0000000000001738

Conway, K. J., Orr, R., & Stannard, S. R. (2003). Effect of a divided caffeine dose on endurance cycling performance, postexercise urinary caffeine concentration, and plasma paraxanthine. *J Appl Physiol (1985), 94*(4), 1557-1562. doi: 10.1152/japplphysiol.00911.2002

Cornelis, M. C., El-Sohemy, A., Kabagambe, E. K., & Campos, H. (2006). Coffee, CYP1A2 genotype, and risk of myocardial infarction. *Jama, 295*(10), 1135-1141.

Del Coso, J., Munoz, G., & Munoz-Guerra, J. (2011). Prevalence of caffeine use in elite athletes following its removal from the World Anti-Doping Agency list of banned substances. [Research Support, Non-U.S. Gov't]. *Appl Physiol Nutr Metab, 36*(4), 555-561. doi: 10.1139/h11-052

Del Coso, J., Portillo, J., Munoz, G., Abian-Vicen, J., Gonzalez-Millan, C., & Munoz-Guerra, J. (2013). Caffeine-containing energy drink improves sprint performance during an international rugby sevens competition. *Amino Acids, 44*(6), 1511-1519. doi: 10.1007/s00726-013-1473-5

Demirkan, E., Koz, M., Kutlu, M., & Favre, M. (2015). Comparison of physical and physiological profiles in elite and amateur young wrestlers. [Comparative Study]. *J Strength Cond Res, 29*(7), 1876-1883. doi: 10.1519/JSC.0000000000000833

Diaz-Lara, F. J., Del Coso, J., Garcia, J. M., Portillo, L. J., Areces, F., & Abian-Vicen, J. (2016). Caffeine improves muscular performance in elite Brazilian Jiu-jitsu athletes. [Randomized Controlled Trial]. *Eur J Sport Sci, 16*(8), 1079-1086. doi: 10.1080/17461391.2016.1143036

Diaz-Lara, F. J., Del Coso, J., Portillo, J., Areces, F., Garcia, J. M., & Abian-Vicen, J. (2016). Enhancement of High-Intensity Actions and Physical Performance During a Simulated Brazilian Jiu-Jitsu Competition With a Moderate Dose of Caffeine. [Randomized Controlled Trial]. *Int J Sports Physiol Perform, 11*(7), 861-867. doi: 10.1123/ijspp.2015-0686

Dolan, P., Witherbee, K. E., Peterson, K. M., & Kerksick, C. M. (2017). Effect of Carbohydrate, Caffeine, and Carbohydrate + Caffeine Mouth Rinsing on Intermittent Running Performance in Collegiate Male Lacrosse Athletes. *J Strength Cond Res, 31*(9), 2473-2479. doi: 10.1519/JSC.0000000000001819

Felippe, L. C., Lopes-Silva, J. P., Bertuzzi, R., McGinley, C., & Lima-Silva, A. E. (2016). Separate and Combined Effects of Caffeine and Sodium-Bicarbonate Intake on Judo Performance. [Randomized Controlled Trial]. *Int J Sports Physiol Perform, 11*(2), 221-226. doi: 10.1123/ijspp.2015-0020

Fredholm, B. B., Yang, J., & Wang, Y. (2017). Low, but not high, dose caffeine is a readily available probe for adenosine actions. [Review]. *Mol Aspects Med, 55*, 20-25. doi: 10.1016/j.mam.2016.11.011

Guest, N., Corey, P., Vescovi, J., & El-Sohemy, A. (2018). Caffeine, CYP1A2 Genotype, and Endurance Performance in Athletes. *Medicine and science in sports and exercise*.

Hahn, R. G., & Waldreus, N. (2013). An aggregate urine analysis tool to detect acute dehydration. [Observational Study

Research Support, Non-U.S. Gov't]. *Int J Sport Nutr Exerc Metab, 23*(4), 303-311.

Kafkas, M. E., Taskiran, C., Sahin Kafkas, A., Ozen, G., Taskapan, C., Ozyalin, F., & Skarpanska-Stejnborn, A. (2016). Acute physiological changes in elite free-style wrestlers during a one-day tournament. *J Sports Med Phys Fitness, 56*(10), 1113-1119.

Kraemer, W. J., Fry, A. C., Rubin, M. R., Triplett-McBride, T., Gordon, S. E., Koziris, L. P., . . . Fleck, S. J. (2001). Physiological and performance responses to tournament wrestling. [Research Support, Non-U.S. Gov't]. *Med Sci Sports Exerc, 33*(8), 1367-1378.

Lopes-Silva, J. P., da Silva Santos, J. F., Branco, B. H. M., Abad, C. C. C., de Oliveira, L. F., Loturco, I., & Franchini, E. (2015). Caffeine ingestion increases estimated glycolytic metabolism during taekwondo combat simulation but does not improve performance or parasympathetic reactivation. *PloS one, 10*(11), e0142078.

Lopes-Silva, J. P., Felippe, L. J., Silva-Cavalcante, M. D., Bertuzzi, R., & Lima-Silva, A. E. (2014). Caffeine ingestion after rapid weight loss in judo athletes reduces perceived effort and increases plasma lactate concentration without improving performance. [Randomized Controlled Trial

Research Support, Non-U.S. Gov't]. *Nutrients, 6*(7), 2931-2945. doi: 10.3390/nu6072931

Rezasoltani, A., Ahmadi, A., Nehzate-Khoshroh, M., Forohideh, F., & Ylinen, J. (2005). Cervical muscle strength measurement in two groups of elite Greco-Roman and free style wrestlers and a group of non-athletic subjects. *Br J Sports Med, 39*(7), 440-443; discussion 440-443. doi: 10.1136/bjsm.2004.013961

Saldanha, M. d. S. A., Kons, R. L., & Detanico, D. (2018). Can Caffeine Intake Improve Neuromuscular and Technical-Tactical Performance During Judo Matches? *Journal of strength and conditioning research*.

Santos, V. G., Santos, V. R., Felippe, L. J., Almeida, J. W., Jr., Bertuzzi, R., Kiss, M. A., & Lima-Silva, A. E. (2014). Caffeine reduces reaction time and improves performance in simulated-contest of taekwondo. *Nutrients, 6*(2), 637-649. doi: 10.3390/nu6020637

Shearer, J., & Graham, T. E. (2014). Performance effects and metabolic consequences of caffeine and caffeinated energy drink consumption on glucose disposal. [Research Support, Non-U.S. Gov't

Review]. *Nutr Rev, 72 Suppl 1*, 121-136. doi: 10.1111/nure.12124

Spriet, L. L. (2014). Exercise and sport performance with low doses of caffeine. [Research Support, Non-U.S. Gov't

Review]. *Sports Med, 44 Suppl 2*, S175-184. doi: 10.1007/s40279-014-0257-8

Terbizan, D. J., & Seljevold, P. J. (1996). Physiological profile of age-group wrestlers. *J Sports Med Phys Fitness, 36*(3), 178-185.

Trexler, E. T., Smith-Ryan, A. E., Roelofs, E. J., Hirsch, K. R., & Mock, M. G. (2016). Effects of coffee and caffeine anhydrous on strength and sprint performance. [Randomized Controlled Trial]. *Eur J Sport Sci, 16*(6), 702-710. doi: 10.1080/17461391.2015.1085097

United World Wrestling. (2017). World Championships, from https://unitedworldwrestling.org/event/world-championships-27

Utter, A. C. (2001). The new National Collegiate Athletic Association wrestling weight certification program and sport-seasonal changes in body composition of college wrestlers. *J Strength Cond Res, 15*(3), 296-301.

Womack, C. J., Saunders, M. J., Bechtel, M. K., Bolton, D. J., Martin, M., Luden, N. D., . . . Hancock, M. (2012). The influence of a CYP1A2 polymorphism on the ergogenic effects of caffeine. *Journal of the International Society of Sports Nutrition, 9*(1), 7.

**Figure 1. Experimental design of the investigation.** Wrestlers performed five matches; each match consisted of 2×3-min rounds of competitive wrestling with 30 s of passive rest between the rounds.Wrestlers undertook 5 experimental trials include: a placebo, a high-dose of caffeine (10 mg/kg), a moderate-dose of caffeine (4 mg/kg), a repeated-dose caffeine (5 × 2 mg/kg), and selective caffeine consumption protocol based on the expected physical performance decrement previously measured (6.16±1.58 mg/kg).



**Figure 2: Effect of different forms of caffeine ingestion on Pittsburgh wrestling performance test during simulated wrestling competition with 5 matches.**

P: placebo, HC: high-dose of caffeine (10 mg/kg), MC: moderate-dose of caffeine (4 mg/kg), RC: repeated-dose of caffeine (5×2 mg/kg), SC: selective-dose (administration of caffeine based on performance decrement; 6.16±1.58 mg/kg).

(\*) indicates significant difference compared to baseline at p < 0.05

(^) High different to all the other trials at p < 0.05.

(#) indicates significant difference compared to Placebo, High and Medium at p < 0.05.

(ª) Selective different from all the other trials at p < 0.05.



**Table I. The effect of different forms of caffeine ingestion on heart rate, fatigue rating and blood lactate concentration during simulated wrestling competition with 5 matches.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Baseline | Match 1 | Match 2 | Match 3 | Match 4 | Match 5 |
|  |  |  | Pre | Post | Pre | Post | Pre | Post | Pre | Post | Pre | Post |
| Heart rate (bpm) | Placebo | 72±2 | 73±2 | 178±3 | 73±2 | 183±3 | 82±1 | 183±2 | 88±1 | 191±4 | 80±3 | 187±3 |
| High | 71±2 | 73±2 | 184±3 | 79±1^ | 186±3 | 80±3 | 183±2 | 89±4 | 192±4 | 81±1 | 185±2 |
| Medium | 70±3 | 69±2 | 181±2 | 73±2 | 183±2 | 78±3 | 188±1€ | 86±3 | 192±4 | 78±2 | 187±3 |
| Repeated | 70±1 | 71±3 | 173±1 | 75±3 | 184±3 | 79±2 | 188±3€ | 83±3€ | 194±3 | 83±2 | 185±2 |
| Selective | 71±3 | 74±4 | 182±3 | 74±3 | 182±4 | 84±3 | 180±4 | 91±2 | 190±4 | 82±3 | 171±4ª |
| Fatigue rating (A.U.) | Placebo | 0.0±0.0 | 0.0±0.0 | 6.5±0.3 | 1.2±0.4 | 7.5±0.5 | 2.5±0.4 | 10.1±0.9¥ | 3.6±0.4 | 11.6±0.8 | 3.0±0.6¥ | 9.9±1.1 |
| High | 0.0±0.0 | 0.0±0.0 | 6.1±0.5 | 1.1±0.5 | 6.6±0.3 | 2.1±0.6 | 7.4±1.1 | 3.3±0.5 | 10.4±1.2 | 1.9±0.7 | 9.5±1.3 |
| Medium | 0.0±0.0 | 0.0±0.0 | 6.3±0.6 | 1.2±0.3 | 6.9±0.6 | 2.4±0.5 | 7.9±1.3 | 3.5±0.3 | 11.5±1.1 | 2.3±0.6 | 9.8±1.4 |
| Repeated | 0.0±0.0 | 0.0±0.0 | 6.4±0.4 | 1.3±0.2 | 6.8±0.4 | 2.3±0.6 | 7.2±0.8 | 2.3±0.4# | 10.9±0.6 | 2.2±0.4 | 8.9±0.6 |
| Selective | 0.0±0.0 | 0.0±0.0 | 6.6±0.4 | 0.9±0.3 | 6.9±0.3 | 2.3±0.7 | 7.5±0.7 | 2.2±0.3# | 11.1±0.8 | 2.2±0.3 | 8.8±0.5 |

(Table I Continued)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| [Lactate] (mmol/L)  | Placebo | 1.2±0.3 | 1.4±0.2 | 15.4±0.6 | 1.2±0.2 | 16.3±0.4 | 2.2±0.3 | 14.2±0.8 | 3.2±0.1 | 12.1±0.9 | 1.1±0.2 | 16.9±0.6 |
| High | 1.1±0.1 | 1.2±0.4 | 19.3±0.7 | 1.2±0.1 | 19.6±0.6 | 2.1±0.3 | 14.9±0.6 | 2.9±0.1 | 12.3±0.7 | 1.1±0.6 | 17.0±0.4 |
| Medium | 0.9±0.2 | 1.1±0.3 | 18.5±0.6 | 1.4±0.2 | 17.2±0.7 | 1.6±0.2 | 13.8±0.5 | 3.1±0.2 | 13.4±0.8 | 1.0±0.4 | 16.4±0.8 |
| Repeated | 1.1±0.1 | 1.2±0.2 | 19.6±0.4 | 1.3±0.3 | 19.9±0.7 | 1.7±0.1 | 17.0±0.5# | 4.2±0.3# | 15.9±0.5 | 1.2±0.2 | 15.2±0.6 |
| Selective | 1±0.1 | 1.2±0.1 | 18.1±0.8 | 1.1±0.2 | 16.1±1.1 | 1.4±0.2 | 17.3±0.6# | 2.1±0.2ª | 17.2±0.3ª | 0.9±0.3 | 20.1±1.1ª |

(^) High different to all the other trials at p < 0.05.

(ª) Selective different from all the other trials at p < 0.05.

(¥) Placebo different to all the other conditions at p < 0.05.

(€) indicates significant difference compared to placebo, High and Selective at p < 0.05.

(#) indicates significant difference compared to placebo, High and Medium at p < 0.05.

**Table II. Hydration status with different forms of caffeine ingestion during simulated wrestling competition with 5 matches.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Urine osmolality (mOsm/kg H2O) | Urine specific gravity (A.U.) | Urine volume (mL) | Dehydration Index (A.U.) |
| Pre | Post | Pre | Post |
| Placebo | 590±142 | 623±216 | 1.013±0.006 | 1.016±0.005 | 425±86 | 2.2±1.1$ |
| High | 560±163 | 614±175 | 1.015±0.007 | 1.019±0.008 | 523±83**^** | 3.5±0.6**^** |
| Medium | 571±201 | 600±217 | 1.014±0.005 | 1.015±0.009 | 434±109 | 2.9±1.3 |
| Repeated | 582±169 | 640±241 | 1.014±0.006 | 1.015±0.004 | 449±89 | 3.0±0.5 |
| Selective | 596±204 | 620±117 | 1.014±0.008 | 1.014±0.006 | 442±124 | 2.3±0.6$ |

(^) High different to all the other trials at p < 0.05.

($) indicates significant difference compared to High, Medium and Repeated at p < 0.05.