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Revisión

Can caffeine improve your performance? Psychophysiological effects — A systematic review

¿Puede la cafeína mejorar tu rendimiento? Efectos psicofisiológicos: una revisión sistemática

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Abstract

Caffeine is a widely used ergogenic aid in society, which has made it a topic of interest due to its various benefits at cognitive, physiological, and sports levels, among others. This review aims to investigate the potential benefits of caffeine supplementation in psychophysiological performance through a structured search in the SportsDiscus/Scopus/MEDLINE and Web of Science databases (October 2022). This review followed the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guideline, and the inclusion criteria were defined based on the PICOS model. Double-blind, randomized/semi-randomized crossover articles comparing caffeine intake with an identical placebo condition were included. Filters by age or gender of the participants were not applied. The initial search gave a result of 201 articles, which after eliminating duplicates and applying the inclusion and exclusion criteria, the final sample for this review was 8 studies. The review concluded that 3 (37.5 %) found favorable ergogenic effects, 4 (50 %) found partial effects, and 1 (12.5 %) found no effects of caffeine supplementation on variables related to psychophysiological performance. In general, both partial and negative results could be linked to insufficient doses to produce any change, likewise, habitual caffeine consumption is also a variable that could be attenuating its potential ergogenic effect. In conclusion, moderate doses of caffeine 3-6 mg/kg seem to be an effective strategy to improve the psychophysiological response in various contexts without generating detrimental effects on performance, as long as the intervention designs consider the variables that could condition its effect.

Keywords:

Caffeine. Cognitive. Energy drink. Psychophysiological.

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Resumen

La cafeína es una ayuda ergogénica de amplio uso en la sociedad, lo que la ha convertido en un tema de interés por sus diversos beneficios a nivel cognitivo, fisiológico y deportivo, entre otros. Esta revisión tiene como objetivo investigar los beneficios potenciales de la suplementación de cafeína sobre el rendimiento psicofisiológico a través de una búsqueda estructurada en las bases de datos SportsDiscus/Scopus/MEDLINE y Web of Science (octubre de 2022). Esta revisión siguió la guía Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) y los criterios de inclusión se definieron en función del modelo PICOS. Se incluyeron artículos doble ciego, cruzados y aleatorizados/semialeatorizados en donde se comparó la ingesta de cafeína con una condición idéntica de placebo. No se aplicaron filtros por edad ni sexo de los participantes. La búsqueda inicial dio un resultado de 201 artículos, los cuales, después de eliminar los duplicados y aplicar los criterios de inclusión y exclusión, dieron una muestra final para esta revisión de 8 estudios. La revisión concluyo que 3 (37,5 %) encontraron efectos ergogénicos favorables, 4 (50 %) encontraron efectos parciales y 1 (12,5 %) no encontró efectos de la suplementación de cafeína sobre las variables relacionadas con el rendimiento psicofisiológico. En general, los resultados tanto parciales como negativos podrían estar ligados a dosis insuficientes para producir algún cambio; de igual forma, el consumo habitual de cafeína también es una variable que podría estar atenuando su potencial efecto ergogénico. En conclusión, dosis moderadas de cafeína de 3-6 mg/kg parecen ser una estrategia eficaz para mejorar la respuesta psicofisiológica en diversos contextos, sin generar efectos perjudiciales en el rendimiento, siempre y cuando los diseños de intervención consideren las variables que podrían condicionar su efecto.

Palabras clave:

Cafeína. Cognitivo. Bebida energética. Psicofisiológico.

INTRODUCTION

Caffeine is known as one of the most used stimulant substances by people. It is possible to find it in various plants, such as tea, cocoa, mate, among others. Today, due to its easy access and wide consumption at different levels by most segments of the population, caffeine has probably become the most widely used drug substance in the world (1). Its use is mainly due to its effect on the central nervous system (CNS) (2), which brings a series of potential benefits that support its wide use in various contexts. Due to this, have been investigated the beneficial effects that it generates both at the central level, perception of effort, levels of alertness, variables related to sports performance, among others (3,4).

The main mechanism of action is its impact on the CNS by blocking adenosine receptors, specifically on the A1 and A2a isoforms (5), which this action brings with it a late appearance of fatigue, increased motivation, alertness and vigilance (6-8). It is possible to find different isoforms of these receptors, which are in charge of mediating different effects (A1, A2A, A2B and A3), where A1 has a mainly inhibitory effect while the excitatory effects are related to A2a (9). It has also been shown that caffeine increases the release of calcium from the sarcoplasmic reticulum (10), which plays a fundamental role in the activation and interaction of cross-bridges to produce muscle contraction (actin-myosin interaction). In the research by Lindinger et al. it was observed that caffeine plays a role in the regulation of plasmatic and intracellular levels of potassium (K) by stimulating the Na-K pump (11). These mentioned phenomena could enhance the excitation-contraction coupling explaining the improvements in muscular aspects with the use of caffeine, however, the mechanisms are still not entirely clear.

Every day people are exposed to various stressful situations, whether physical, work, psychological, social, among others. All these variables, both external and internal, have an impact on the response of each individual. Physical fatigue is a phenomenon conditioned by various psychophysiological factors which are linked to responses such as: less alertness, less concentration and motivation; lower labor productivity; decreased neuromuscular performance; tremors and pain; respiratory, circulatory and neuromuscular overload; lower frequency in electromyographic signal; loss of resistance and duration in isometric efforts; increased lactate and increased core temperature (12).

Not only external stress can induce these psychophysiological changes, but also other variables such as visual and/or auditory stimuli can modify both the perception and the degree of response of each individual. Such is the case of the research carried out by Bigliassi et al. where it was shown that, in an exhaustive isometric exercise exposed to sensory stimuli, the motivational stimuli produced higher force levels during the last seconds of the contraction, improved situational motivation and positively impacted the modulation of low-frequency theta waves (fatigue suppression) and increased beta activity (arousal level) (13).

The variability of the responses is conditioned by the magnitude of the stressor (intensity of the exercise, degree of complexity of the task, among others). To the extent that this is smaller, the individual's attention is focused more on external sensory signals while in the opposite case, the greater the external magnitude the attention is focused on internal signals thus inducing a greater impact on the psychophysiological response. In this sense, a proposal that seeks to respond to this complex and multifaceted phenomenon is the dual mode theory which seeks to explain the possible mechanisms involved in the internal response induced by fatigue at high intensities. This theory proposes that affective responses to exercise are jointly influenced by cognitive factors and interoceptive signals (14).

It is also known that exposure to these stressful contexts brings with it a deterioration of cognitive functions, either acutely due to a high workload, situations under high pressure and/or a context of sports competition, as well as chronically as it is in the case of people suffering from neurodegenerative diseases. In any case, this situation will generate psychophysiological changes that will generate a deterioration in cognitive functions and, consequently, a lower response to stimuli and the ability to make decisions. In this context, it has been seen that caffeine has shown beneficial results in terms of improving cognitive function (15). Research has shown that caffeine supplementation not only has a potential effect in attenuating and retarding cognitive decline caused by various brain disorders and diseases such as Alzheimer's, Parkinson's, and sleep deprivation (16), but also generates positive effects in various tests also related to cognitive functions, such as: reaction time; election time; alertness; surveillance; response speed, among others (17,18). In the sports field, Khcharem et al. demonstrated that in recreational runners supplementation with 3 mg/kg of caffeine was also able to improve running performance, cognitive function, and psychological state, without affecting oxidative stress markers (19). Overall, the use of caffeine has shown positive results in improving performance in endurance running (20), better performance in team sports (21), combat sports (22), among others.

That said, and based on the information found in the literature on the psychophysiological effects of caffeine supplementation the objective of this systematic review is to investigate and update the effects of caffeine in any of its formats and different types of populations on variables associated with psychophysiological, sports and cognitive performance.

METHODS

SEARCH STRATEGY

The present systematic review was carried out following the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines. Inclusion criteria were defines using the PICOS model (Table I).

Table I. PICOS criteria for the inclusion of studies in the systematic review

Parameters	Inclusion criteria
Population	Healthy adults
Intervention	Caffeine supplementation
Comparators	Same conditions with placebo
Outcomes	Variables related to psychophysiological, psychomotor, cognitive, and sports performance
Study design	Randomized/semi-randomized, double-blind controlled trials

Searches were made in the MEDLINE, Web of Science, Scopus, and SportDiscus databases. The detail of the search equation and the respective filters used according to each bibliographic search engine are detailed below:

- MEDLINE search: (caffeine or coffee or energy drinks) AND (psychology or psychological) AND physiology. The filters used were clinical trials published from 01/01/2002 to 10/24/2022, published in English and humans.
- Web of Science Search: (caffeine or coffee or energy drinks) AND (psychology or psychological) AND physiology. The filters used were articles published in English from 01/01/2002 to 10/24/2022.
- Scopus search: (caffeine or coffee or energy drinks) AND (psychology or psychological) AND physiology. The filters used were articles published from 01/01/2002 to 10/24/2022, published in English and humans.
- SportDiscus search: (caffeine or coffee or energy drinks) AND (psychology or psychological) AND physiology. The filters used were articles in English, published in academic journals from 01/01/2002 to 10/24/2022.

SELECTION CRITERIA

The articles found in the search were subjected to a duplicate elimination, the filter was carried out by title and abstract, and finally, the inclusion and exclusion criteria were applied. Studies were considered where the variables evaluated were related to the psychomotor response such as: alertness, response speed, reaction time, among others.

The registries were included using the following criteria: Randomized/semi-randomized controlled trials published from January 1, 2002, to the present (10/24/2022), in English, in any type of population and also that, in any of their conditions the effect of caffeine is measured in isolation.

The following articles were excluded: Trials where caffeine supplementation was combined with some other ingredient, the dose administered was not specified, low study quality (≤ 6 on the PEDro scale), indirect psychophysiological response evaluation (through only use of questionnaires). Meta-analyses, systematic reviews and narratives were not considered.

For the collection and storage of documents, the RefWorks bibliographic manager was used.

STUDY SELECTION

One researcher was in charge of the search process in the databases (NSV). Relevant articles were identified by reading the title and abstract for subsequent full-text review and elimination of duplicates. On this basis of full-text articles considered eligible, the selection criteria were applied to determine the requirements to be part of the systematic review; this process was carried out by the same researcher (NSV). RDV and VCP were part of the search design, review of the document, and analysis and discussion of the results. The results and conclusions were discussed among the three researchers.

DATA EXTRACTION

Once the selection criteria were applied to each article, the following data was extracted: background (author/s, year of publication); sample characteristics (number and characteristics of participants, age, sex); design (characteristics of the intervention); administration (caffeine dose and format); variables evaluated and their respective results.

QUALITY EVALUATION

The Physiotherapy Evidence Database (PEDro) scale was used to determine the quality of the articles which has been shown to be reliable in use in reviews of randomized controlled trials (23). The objective of this scale is to help evaluate the internal validity of the investigations mainly granting scores based on the specification of the inclusion criteria, randomization, blinding, statistical analysis, among others. From a total scale of 11 points, with 10 being the maximum value that can be awarded, all the articles that obtained a score ≤ 6 were left out of the analysis.

RESULTS

SEARCH STRATEGY

The database search resulted in a total of 201 articles. Out of it, 14 duplicates were eliminated and 163 articles were excluded by title and abstract due to the following reasons: They were not found to be related to the topic of this review, narrative, systematic reviews, and meta-analyses. Twenty-four articles were selected for full-text review, where after applying the inclusion/exclusion criteria, 8 articles selected for the final systematic review were chosen (Fig. 1).

PARTICIPANTS

The total sample of the selected articles was 266 participants (n = 145 men; n = 121 women). The samples of all the articles analyzed in adults where the following characteristics: university population (24,25), recreational runners (26), team sports (27), armed forces (28), regular caffeine users (29) and healthy volunteers in general (30,31).

CAFFEINE SUPPLEMENTATION

Generally, in the literature it can be seen that most trials administer caffeine 60 minutes prior to the intervention; however, this may vary depending on both the research design, as well as its format and absorption time. Two ways have been established to determine the amount of caffeine administered for this type of intervention: absolute (standard amount for all participants) and relative (amount depending on the weight of each individual).

In the articles selected in this systematic review a great variety was observed both in time and in the amount administered where for example, it was found that Smith et al. administered small doses of 1.5 mg/kg in two different periods (1.5 and 3.5 hrs before both interventions, respectively) (24), similar to what was done by Khcharem et al. where three small doses of 2 mg/kg of caffeine were administered overnight as well as a single dose

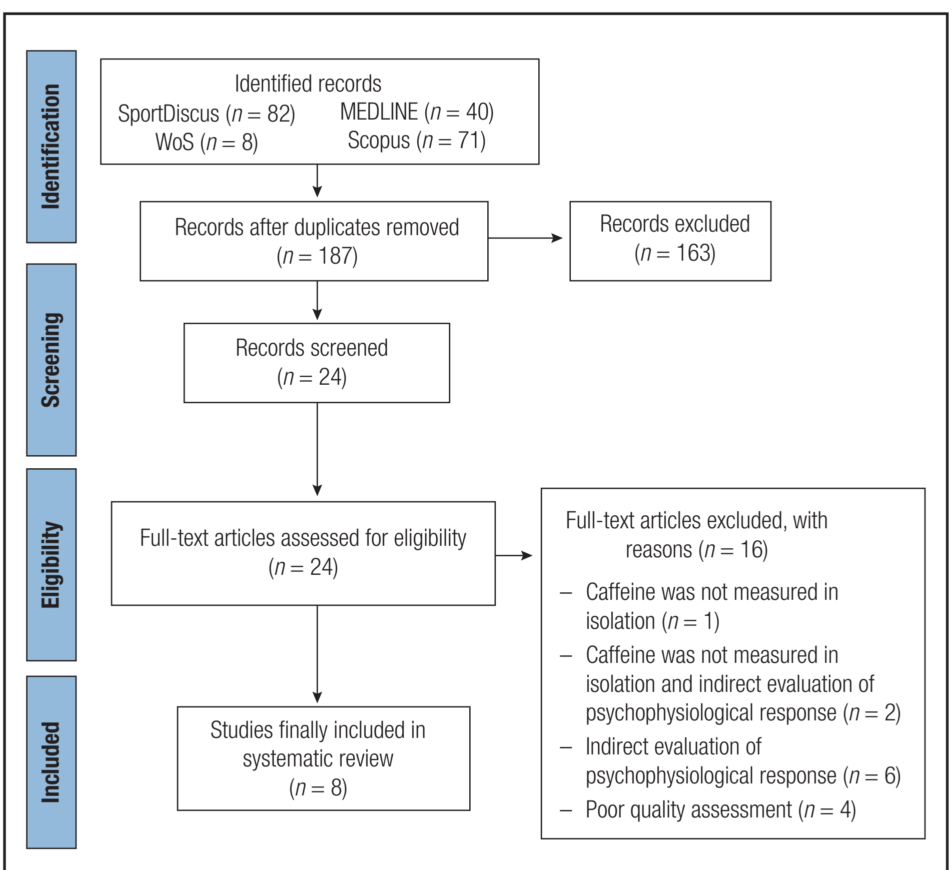

Figure 1.
Selection of articles (Preferred Reporting Items for Systematic Review and Meta-Analyses, PRISMA).

of 6 mg/kg (both the single dose and the last nightly dose were administered 60 minutes prior to the intervention) (26). In this sense, Ali et al. also administered a single dose of 6 mg/kg of caffeine 60 minutes before the intervention (27). Different from that was what was used in the study by Wesensten et al., who delivered a high absolute dose of 600 mg 10 minutes prior to the measurement, but these were performed consecutively every hour during the night (12 hours) (30). Among these investigations, it is also important to highlight that different administration formats were observed such as: caffeine in capsules, diluted in liquid, gelatin capsules and energy drinks. Research delivered a single dose of caffeine 45 minutes prior to the intervention, such is the case of Kammerer et al. where participants consumed an absolute amount of 80 mg (28), as well as in the study by Van Duinen et al. where a relative amount of 3 mg/kg was administered (31). Both Christopher et al., as well as Mackay et al. used shorter times from consumption to intervention, establishing a dose of 2 mg/kg 30 minutes before, and 110-120 mg 20 minutes respectively (25,29).

OUTCOME MEASURES

The articles included in this systematic review are shown in the following table (Table II), where information is provided regarding: author, characteristics of the population, detail of the intervention, the main results analyzed during the investigation and the conclusions of those results.

Table II. Summary of the articles included in the systematic review that investigated the effect of caffeine intake on variables related to psychophysiological performance

Author/s	Population	Intervention	Main results analyzed	Main conclusion
Smith et al.	24 men 18 to 35 years Student population	1.5 mg/kg caffeine solution in 150 ml decaffeinated coffee 1,5 h before 1st dose, 3.5 h after 2nd dose	– Mood – Performance (tracking/detection task, five-choice task, focused attention, categoric search, repeated digits detection, simple reaction time) – Memory (free recall, logical reasoning, semantic memory, recognition memory) – Saccadic eye movements	NS Anxiety or hedonic tone (caffeine or clonidine) ↑ Performance Focused attention and repeated digits detection task (caffeine vs placebo) ↑ Performance saccadic eye movements (caffeine vs clonidine condition) NS Caffeine effects on the other conditions of performance and memory
Ali et al.	10 women 24 ± 4 years Team sports	6 mg/kg caffeine Gelatin capsule 60 min before	– Mood (POMS) – Stroop test – Choice reaction time (CRT) – Perceptual responses (RPE, FS, FAS)	†Vigour and fatigue †Stroop, treatment x time (correct answers) †Stroop, treatment x time (reaction time) †CRT, reaction times ↑ Feeling scale (FS)
Christopher et al.	25 men 43 women 21 middle age (20 to 61)	2 mg/kg caffeine in 300 ml 30 min before	– Mood (anxiety, alertness, hedonic tone) – Focused attention task – Categoric search task – Simple reaction time task – Repeated digits vigilance task	↑ Alertness NS Focused attention NS Categoric search NS Reaction time ↑ Mean reaction time
Kammerer et al.	14 men 20 ± 1 years soldiers	80 mg caffeine 250 ml 45 min before	– Cardiorespiratory fitness – Strength (isometric strength) – Power (vertical jump) – Concentration (grid test) – Digit span WAIS subtest (digits)	NS Cardiorespiratory fitness NS Strength (isometric strength) NS Power (vertical jump) NS Concentration test NS Digit span WAIS subtest (digits)

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Table II (cont.). Summary of the articles included in the systematic review that investigated the effect of caffeine intake on variables related to psychophysiological performance

Author/s	Population	Intervention	Main results analyzed	Main conclusion
Wesensten et al.	37 men 13 women 22.4 middle age (18 to 30)	600 mg caffeine 10 min before (measurements every hour, for twelve hours)	– Mood (POMS) – Cognitive performance(add-subtract) – Reaction time (ten-choice) – Reaction time (four-choice) – Psychomotor vigilance (PVT) – Stanford Sleepiness Scale (SSS)	↑ Reduced fatigue and confusion (caffeine vs M100) ↑ Response speed (caffeine, M100 vs placebo). NS Accuracy speed (add-subtract) ↑ Reaction time (caffeine vs placebo). NS caffeine vs other conditions. NS Accuracy (ten-choice). NS Reaction time (four-choice) ↑ Response speed, PVT (caffeine vs placebo). NS caffeine vs M200, M400 ↑ Reduce sleepiness (caffeine vs placebo, M100)
Khcharem et al.	12 men 21.7 ± 0.9 years Recreational runners (students)	6 mg/kg (60 min before) 2-2-2 mg/kg (60 min before last dose, 3 and 6 hours before the previous ones during the night) capsules	– Exhaustive running test – Digit cancellation (correct detections) – Reaction time	↑ Caffeine performance vs placebo (in both conditions) ↑ Correct detections caffeine vs placebo (in both conditions) ↑ Reaction time caffeine vs placebo (in both conditions)
Van Duinen et al.	11 men 13 women healthy 24 ± 6 years	3 mg/kg 45 min before	– Right hands finger abduction force (MVC) – Simple task (auditory reaction time) – Double task (30 % cMVC + auditory reaction time)	NS MVC. †Small improvement in force production during submaximal contraction. ↑ Simple task reaction time (both types of stimulus). NS accuracy ↑ Dual-task response speed
Mackay et al.	22 men 42 women 21.3 middle age Student population	110-120 mg 20 min before 170 ml	– Four choice reaction time task (FCRT) – Digit symbol substitution task (DSST)	NS Reaction time caffeine vs placebo. ↓ Alcohol increased error rates (FCRT) ↑ DSST performance (caffeine/ alcohol vs alcohol)

↑: statically significant increase; †Improvement without statically significance; ↓: statically significant decrease; NS: no significant differences.

LIMITATIONS

Of the selected articles, only 2 stated the limitations of their research. Ali et al. stated that the protocol used in treadmill was already obsolete and that they only worked at 60 % of VO_2max, reported no physical measurements, small sample size, and could not mask the treatment (9 out of 10 participants guessed which trial they were in) (27). While Khcharem et al stated that it is unknown whether the amount and timing of administration was the best under such conditions, circadian activity-rest rhythms, small sample, unfamiliarity with sleep deprivation, and lack of reliability/sensitivity data were not verified (26).

DISCUSSION

The main objective of this systematic review was to summarize the existing scientific evidence regarding the effects of caffeine supplementation on the response of variables related to psychophysiological, psychomotor, cognitive and sports performance. Knowing that caffeine is one of the supplements most used by the population and with high support for the changes it produces both at a physiological and psychological level, this systematic review aimed to exhaustively determine the response and interaction of these two variables in different contexts.

In general, most of the articles showed that caffeine supplementation produced beneficial effects on variables related to psychophysiological performance. Different measures were also found both in the results and in their contexts of application, for which reason these aspects will be discussed in greater depth in the following sections.

EFFECT OF CAFFEINE ON PSYCHOPHYSIOLOGICAL PERFORMANCE

The different investigations analyzed in this systematic review showed that in general, caffeine supplementation generated an enhancing effect on psychophysiological performance; however, it was also seen that under certain contexts of application, it only produced effects on some of the variables evaluated. This difference in the results of some articles could be mediated by the diversity in the contexts and forms of application.

In this sense, investigations included in this review found that caffeine supplementation produced beneficial effects in the different variables analyzed. Such is the case of the research carried out by Khcharem et al. where they showed strong support for supplementation with low and repeated doses of caffeine (3 doses of 2 mg/kg during a waking night) in the different measured variables associated with physical and cognitive deterioration in a context of loss of sleep (26). Similar to this, Wesensten et al. also demonstrated that in a context of sleep deprivation and comparing the efficacy of two different drugs (caffeine and modafinil) on performance and alertness, the 600 mg caffeine condition was effective in maintaining speed response time (PVT), reaction time, response speed (addition/subtraction), improvement in drowsiness and decreased feelings of fatigue and confusion (30). On the other hand, Ali et al. showed that despite the fact that only the sensations scale test reached statistical significance, all the other variables showed a tendency to improve the perceptive responses of team sports players supplemented with 6 mg/kg, such such as: sensation of vigor and decreased fatigue, effect of treatment x time on the performance of the Stroop test, effect of the treatment on the mean reaction time (CRT) and variables associated with the subjective perception of effort (27).

Another part of the included articles found that caffeine supplementation produced partial benefits in the improvement of the psychophysiological response. Such is the case of Smith et al. where in a healthy student population with a repeated dose intervention (2 administrations of 1.5 mg/kg at different times), the caffeine condition improved performance in the saccadic eye movement test (vs clonidine condition), and in the tests of focused performance and detection of repeated digits (vs placebo), it had no effect on mood or on any of the other variables associated with performance and memory (24). Christopher et al. found that in habitual caffeine consumers, supplementation with 2 mg/kg was able to improve alertness (measured through a visual analog scale) and mean reaction time in repeated-digit vigilance tests, however, no changes were found in the other mood state variables nor in the performance of the focused attention, categorical search, and simple reaction time tests (29). In this context, Mackay et al. found that, in healthy students and regular caffeine consumers, supplementation with 110-120 mg was able to improve performance on the digit symbol substitution test (caffeine/alcohol vs. alcohol condition), thus attenuating the detrimental effects of alcohol on performance, however, had no effect on the reaction time test (caffeine vs. placebo) (25).

Curiously it can be seen that in the three previously mentioned articles, the dose administered was medium-low even more so considering that two of the articles were carried out on regular consumers, therefore it could be deduced that the lack of impact on some of the variables could also be conditioned by these reasons. It has also been seen that in the research carried out by Van Duinen et al. in a population of healthy young adults, supplemented with 3 mg/kg of caffeine, improvements were seen in the reaction time of a simple task, greater response speed in a double task (cognitive stimulation plus neuromuscular stimulation), a small improvement of force production in a sub-maximal contraction, but without changes in both the maximum voluntary contraction (MVC), and in the precision in the simple task (31). One of the possible reasons why in this investigation they could not find significant changes at the neuromuscular level which is also discussed by the same authors is because apparently there is a response depending on the amount of muscle mass involved which could be mediated by the greater stress generated by the stimuli to the larger muscle groups. This is consistent with the results reported by studies using large muscle groups and caffeine did show a significant effect on strength, endurance, and repetitions to fatigue (32-34).

On the other hand, in one of the articles included in this review no effect of caffeine supplementation was found. As investigated by Kammerer et al. where the effect of different conditions of energy drinks in soldiers was compared the amount of 80 mg of caffeine was not able to improve any of the variables evaluated (cardiorespiratory fitness, strength, power, concentration and immediate memory) (28). Possibly and also agreeing with the authors comment in the discussion the amount of caffeine used could have been insufficient to positively influence the variables analyzed.

It is important to mention that despite having a reduced number of articles selected for the review (8), these have the quality criteria and methodological structure required to be considered in the evaluation. In the literature it is possible to find additional articles on this topic which were also part of the selection process in the early stages of the search, however many of them presented deficiencies in blinding, randomization of participants, non-compliance with the inclusion criteria regarding the isolated measurement of caffeine, indirect measurement of the psychophysiological response, among others. For which regardless of the fact that many of these articles showed positive results regarding the use of caffeine, they were similarly excluded from the final selection due to non-compliance with the previously mentioned criteria. On the other hand, this situation can also be considered as a strength of this research because regardless of the final number of articles selected the inclusion criteria and the selection process was carried out in such a way that the conclusions can be made as objective as possible with respect to the subject in question.

In summary, and considering the results of research showing the effect of caffeine consumption in various contexts and application designs the use of medium-low doses seems to be a common factor when discussing their results. In general, and when the doses are appropriate according to the context and the type of population, caffeine supplementation showed beneficial effects of its use. It is also important to note that in none of these articles did caffeine produce a negative effect which makes it a reliable supplement in case you want to improve variables associated with psychophysiological, sports, cognitive performance, etc. It is important to take into account all the variables that could influence the effectiveness of its use, such as: adequate dose depending on the type of context, consider whether they are habitual users, consider the good and bad responders to its use, and all the others variables that could enhance or harm its application.

RECOMMENDED DOSAGE AND PRACTICAL APPLICATIONS

According to the results in this review and considering the rest of the information available in the literature regarding the use of caffeine, the recommended dose-response ranges from 3-6 mg/kg (35,36). Doses below 3 mg/kg seem to be controversial which is why it is important to carefully control the context of application and the study population. Findings have also been seen that in a sports setting doses between 6-9 mg/kg also seem to be effective in improving performance in competitive rowers (37), however as a consensus, both studies of Graham et al. and Pasman et al. (35,36), as well as other authors commented that higher doses of caffeine do not appear to have an additional effect on performance enhancement (38). As a recommendation it has been seen that doses of up to 400 mg/day have not shown adverse effects in healthy adults (39). The previous administration time that has been used in the vast majority of investigations is around 60 minutes, mainly due to the absorption time of caffeine and the delay time in reaching its peak in plasmatic concentrations (40,41), however, and as stated by the articles analyzed in this review improvements could also be seen in some variables related to the psychophysiological response with shorter administration times. To determine the magnitude of its ergogenic effect due to the inter-individual variability that usually presents the response of the subjects, the use of multiple and repeated comparisons is also suggested, and not only the effect on acute measurements (42). That being said 30 to 60 minutes seems to be an optimal time for administration of caffeine. It is also important to consider that regardless of the fact that not all of them are present in the articles selected for this review there is the possibility of finding other forms of caffeine administration where it is also important to consider them individually since the characteristics and absorption times can differ between formats (43,44). In general, the use of caffeine can cover different areas, where in a work context low-moderate doses (up to 3 mg/kg) seem to be sufficient to produce improvements, while in a sports and/or military context doses between 3-6 mg/kg would be the appropriate recommendation to improve the different variables related to psychophysiological performance.

CONCLUSION

In conclusion, when intervention designs are well planned caffeine supplementation has been shown to be an effective ergogenic aid to improve psychophysiological response in various contexts without detrimental effects on performance. Moderate amounts seem to have a greater effect in the sporting context (3-6 mg/kg). In general, it has been seen that 3 mg/kg would be a standard dose to produce significant effects however low/moderate amounts could also be an appropriate recommendation for other segments of the population mentioned in this review (≤ 3 mg/kg). The use of low doses is controversial, therefore and as mentioned above it is essential to be successful in the application to evaluate the context and all the variables that could influence it, such as; characteristics of the sports discipline or environment to be used, habitual consumption, individual response of each subject, time, quantity and application format, among others.

STRENGTHS AND LIMITATIONS

The present review presented some limitations in the selection of articles due to the diversity of intervention protocols that were applied many of them were excluded for reasons such as: the psychophysiological response was measured only through questionnaires, conditions where caffeine was used it was mixed with some other ingredient, among others. Likewise, within the included articles there were some where the dose was not adequate and/or the participants were habitual caffeine consumers which could underestimate the potential effect that this would have had.

On the other hand, and complementing what was previously said in the discussion part of these limitations were turned into strengths since regardless of the scarcity of specific articles on this topic in the literature together with the large number of articles excluded due to their intervention designs those that were selected met sufficient quality to be part of this review and this gives a clearer and more objective view of the effect of caffeine on the psychophysiological response. The criterion of limiting only to research where the effect of caffeine was measured directly allowed us to give a more objective view of the potential benefits of its use.

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