The effect of caffeine ingestion on functional performance in older adults

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Abstract: Caffeine is a widely used nutritional supplement which has been shown to enhance both physical and cognitive performance in younger adults. However, few studies have assessed the effect of caffeine ingestion on performance, particularly functional performance in older adults. The present study aims to assess the effect of acute caffeine ingestion on functional performance, manual dexterity and readiness to invest effort in older adults. *Methods:* 19 apparently healthy, volunteers (10 females and 9 males aged 61-79; 66±2 years) performed tests of functional fitness and manual dexterity post ingestion of caffeine (3mg*kg^{-1}) or placebo in a randomised order. Pre and 60 minutes post ingestion, participants also completed measures of readiness to invest physical (RTIPE) and mental (RTIME) effort. Results: A series of repeated measures ANOVAS indicated enhanced performance in the following functional fitness tests; arm curls (P = .04), 8 foot up and go (P = .007), six minute walk (P = .016). Manual dexterity was also improved in the presence of caffeine (P = .001). RTIME increased (P = .015) pre to post ingestion in the caffeine condition but not in the placebo condition. There were no significant main effects or interactions for RTIPE or gender in any analysis (all P>.05). Conclusions: The results of this study suggest that acute caffeine ingestion positively enhances functional performance, manual dexterity and readiness to invest effort in apparently healthy older adults.

Keywords: Ergogenic; Strength; Fitness; Function; Nutrition

Introduction

Acute caffeine ingestion is widely used within sport and exercise settings for its performance enhancing effects with evidence suggesting induced increases in endurance, strength and power activities (1, 2). Although the efficacy of acute caffeine ingestion for enhanced exercise performance is well established (2), the majority of evidence demonstrating caffeine's ergogenic properties is derived from studies using participants that are well trained or within the range of peak physiological maturity (see reviews 1, 2, 3). However, the ingestion of dietary caffeine is prevalent across the whole spectrum of society and with an increasingly ageing population worldwide, authors have suggested that nutritional ergogenic aids such as caffeine may be useful in enhancing, performance during daily living tasks and psychological well-being in older adults (4).

One potential way to enhance exercise performance in older adults may be to provide adjunctive ergogenic aids (4) with a range of substances including creatine, carnitine and caffeine being reported in the literature. The benefit of acute caffeine ingestion in younger adults has received substantial support with reported improvements in aerobic (1), anaerobic, strength and power (5) based exercise performance. Caffeine ingestion has also been associated with a lower rating of perceived exertion during exercise (6). Moreover, caffeine has been reported to improve concentration (7), attention, psychomotor performance (7, 8), and can help sustain attention during demanding tasks (7), with such changes being augmented as a result of exercise (8, 9). In light of this, a recent review identified that there was a dearth of data reporting the effects of caffeine on exercise in older adults and this topic merited further scrutiny due to the reported performance enhancing effects in younger populations (4). This topic is of particular interest because if such performance enhancing benefits can be elicited in an older adult population, acute caffeine ingestion might be one means by which to enhance locomotor function and ability to undertake activities of daily living (7, 10).

Psychological and cognitive based studies have documented a range of improvements following ingestion of 250mg caffeine in older adults, including enhanced simple and choice reaction time performance in 50-65 year olds (11), enhanced reaction time performance in older adults (mean age = 57 years) 60 minutes following ingestion (12) and improved anticipatory timing (10). One suggestion for these results is that caffeine ingestion may reverse the effects of cognitive aging by making greater energy reserves available in older adults (13, 14) with some evidence demonstrating that such effects of caffeine ingestion may be more marked in older adults compared to younger adults (11).

Despite this, there are relatively few studies which have investigated the effect of acute caffeine ingestion on physical performance in older adults and those that have report equivocal findings. Norager et al. (15) reported significant increases in cycling endurance (25%) and arm flexion endurance (54%), coupled with a reduction in rating of perceived exertion (RPE) in men and women aged over 70, following $6mg*kg^{-1}$ caffeine consumption. Likewise, Momsen et al. (16) demonstrated that $6mg*kg^{-1}$ of caffeine significantly increased maximal walking distance (20%) and maximal isometric knee extension strength (9.8%) in 68 year old patients with moderate intermittent claudication. In agreement with the work of Norager et al. (15), endurance was also significantly improved (21.4%), however there was no effect of caffeine supplementation on reaction time and cognition. A later study by Jensen et al. (17) adds further ambiguity after reporting that a 6mg*kg^{-1} caffeine supplement did not significantly improve maximal arm flexion strength and isometric submaximal endurance in subjects aged over 70. Furthermore, Jensen et al's study (17) indicated that there was no effect of caffeine on cycling endurance or RPE when compared to placebo. The use of RPE in prior studies is also worthy of further consideration. Although RPE is well established as a measure of perceived exertion in the literature its use as a sole measure of effort has been questioned (18). The use of RPE is commonly employed to assess perceived exertion during or post exercise (18). However, there are instances where psychophysiological changes occur prior to performance of physical and/or cognitive tasks (19, 20). In such instances other measures are required to gauge psychophysiological preparation for performance (19, 20). This state, also termed readiness to invest effort, may impact on future task perseverance and has been related to in-task coping (19, 20). Prior work has suggested that acute caffeine ingestion increases readiness to invest effort on young, trained adults (21) but no research has examined if caffeine ingestion augments an individual's desire or readiness to invest physical or mental effort for an upcoming task of tasks. Coupled with understanding any effect of caffeine ingestion on actual performance, examining whether caffeine ingestion might 'prime' older adults to invest more effort into any given task would seem useful to holistically consider caffeine's effect on older adults' functioning and performance.

Despite this emerging body of research few studies to date have examined the effects of caffeine ingestion on functional performance in older adults. Such an investigation is warranted as a potential positive impact of caffeine on functional performance may be useful in enhancing quality of life and independent living in this population (4).

The data in older adults have used a range of caffeine doses ranging from absolute doses of 200mg to relative doses ranging from 1.5mg*kg^{-1} to 9mg*kg^{-1} (1, 3). Caffeine doses in the range of 3-6mg*kg^{-1} are considered to be optimum for ergogenic effects in both physical (5) and psychological (22, 23, 24) tasks whilst minimising any adverse side effects of caffeine ingestion. The present study aims to assess the effect of acute caffeine ingestion on functional performance, manual dexterity and readiness to invest effort in older adults.

Materials and Methods

Participants

Following approval from the institutional ethics committee and informed consent, 19 volunteers (10 females and 9 males aged 61-79; 66±2.0 years; height 168±2.0cm; body mass 77±14.9kg; BMI 27±3.4 kg/m^2, mean±SD) agreed to participate. All participants habitually ingested caffeine although none were heavy caffeine users (mean ± SD of caffeine consumption = 149.2 ± 58 mg/day, range = 90-210 mg/day). Caffeine intake was established using a 24 hour recall questionnaire (25). All participants completed a health history questionnaire to ensure that they met all inclusion criteria. Inclusion criteria were being ‘apparently healthy’, physically active and accustomed to regular aerobic exercise. Participants were excluded if they had a musculoskeletal injury or cardiovascular condition which would restrict exercise performance or were a heavy habitual caffeine user.

Procedures

All testing took place between 9.00am and 12.00noon with each condition taking place at the same time of day for each participant to avoid circadian variation. Participants were asked to refrain from vigorous exercise and maintain normal dietary patterns in the 48h prior to testing and were asked not to consume caffeine after 6:00pm the night before testing to control for the effects of caffeine already consumed (26). Each participant undertook 3 visits to the human performance laboratory at Coventry University. In the first visit they were familiarised with the equipment and procedures involved in the study.

In the following two experimental trials participants completed measures of manual dexterity and the senior fitness test battery (27) as measures of functional performance 60minutes following ingestion of either caffeine or placebo. Pre and 60mins post substance ingestion participants also completed measures of readiness to invest physical effort (RTIPE) and readiness to invest mental effort (RTIME) on visual analogue scales ranging from 0-10. This measure was based on recommendations for assessing perceived readiness to invest effort in exercise testing (18, 19, 20) and asked participants to rate how physically and mentally ready they were to invest effort using visual analogue scales incorporating a range of 0-10 with higher scores reflecting greater readiness to invest effort

Prior to the experimental trials, participants ingested either 3 mg*kg^{-1} body mass of caffeine (Pure Source, UK) or a placebo (3 mg*kg^{-1} body mass dextrose) administered in gelatine capsules with 200ml water. Substances were presented double blind and in a counterbalanced order. This resulted in 5 females and 4 males receiving caffeine on their first trial. Substances were consumed 60 minutes before each exercise trial as plasma caffeine concentration is maximal 1 hour after ingestion of caffeine (2).

Functional Performance

The Minnesota Manual Dexterity Turning Test (28) and the Rikli and Jones (27) senior fitness test were employed to assess functional performance in the present study as a previously valid battery of tests related to functional capacity and daily living for older adults (29). All measures were completed according to recommended guidelines for administering this battery (28, 29).

Manual Dexterity: The Minnesota Manual Dexterity Turning Test (MMDT) was used as a measure of manual dexterity. In this test, participants are asked to pick up, turn over and place back down, 60 plastic discs into a frame in the fastest time possible using their dominant hand and in standing posture. This is a validated manual dexterity test recommended for use with older adults (28, 30) and recommended guidelines for administration were followed (28).

The Rikli and Jones (27) Senior fitness testing battery consisted of the following measures:

- *Arm Curl test:* This measures requires participants to complete as many bicep curls as possible in a 30 second period holding a hand weight of 2.27 kg for women and 3.63 kg for men with the total number of repetitions taken as a measure of upper body strength.
- *30-Second Chair Stand:* This test required participants to complete as many full sit to stand movements as possible from a seated position, with arms across the chest in a 30 second period.
- *8-Foot Timed Up and Go*: In this test, participants were asked to move from a seated position to standing, walk 8 feet, turn and return to a seated position as quickly as possible with the number of seconds to complete taken as a measure of agility/dynamic balance performance.
- *6-Minute walk test:* Participants were asked to walk for 6 minutes around a 20metre course with the total distance covered being taken as a measure of aerobic endurance.

Statistical Analysis

Any effect of substance ingested on performance in the functional performance tests and manual dexterity test was examined using a series of 2 (caffeine vs placebo) x 2 (gender) ways repeated measures analysis of variance. Any changes in readiness to invest physical or mental effort were examined using a series of 2 of 2 (caffeine vs placebo) x 2 (pre vs post ingestion) x 2 (gender) ways repeated measures analysis of variance. Where significant differences were found, Bonferroni post-hoc pairwise comparisons were used to determine where the differences lay. Partial eta squared (η^2)

was also used as a measure of effect size. Partial η^2 is commonly used in analysis of variance and provides a measure of the variance in the dependant variable attributable to the factor in question (31), in the present case the ingestion of caffeine or placebo. The Statistical Package for Social Sciences (SPSS, Version 20, Chicago, Il, USA) was used for all analysis and statistical significance was set, a priori, at p <.05. Data is reported as mean ± SE.

Results

Results indicated main effects for substance ingested for arm curls (F 1, 17 = 4.491, P = .04, Pη^2 = .209), 8 foot up and go (F 1, 17 = 9.443, P = .007, Pη^2 = .357), Six minute walk (F 1, 17 = 7.218, P = .016, Pη^2 = .298) and the Minnesota Manual Dexterity Test (F 1, 17 = 16.65, P = .001, Pη^2 = .495).The Pη^2 values across these tests indicated that the substance ingested accounted for 20.9% of the variance in arm curls, 35.7% in the 8 foot up and go, 29.8% in the six minute walk and 49.5% in the manual dexterity test. In all cases Bonferroni pairwise comparisons indicated that performance was significantly improved with caffeine compared to placebo. There was no main effect for substance ingested for the Chair stand test (P = .257). In all analysis gender was not significant (P>.05). Mean ± SE and 95% Confidence Intervals for functional performance tests and manual dexterity performance in caffeine and placebo conditions are presented in Table 1.

In regard to RTIME and RTIPE, results indicated a substance X time interaction for RTIME (1, 15 = 7.6, P = .015, Pη^2 = .337) whereby RTIME significantly increased pre to post ingestion in the caffeine condition but not in the placebo condition. There were no main effects or interactions for RTIPE and gender was not significant in either the RTIME or RTIPE analysis (all P>.05). Mean ± SE and 95% Confidence Intervals for Readiness to invest physical (RTIPE) and mental (RTIME) effort pre and 60mins post ingestion of caffeine and placebo are presented in Table 2.

Discussion

The present study demonstrates that acute caffeine ingestion (3 $mg*kg^{-1}$) enhances functional performance and manual dexterity in older adults. This was accompanied by increases in readiness to invest mental but not physical effort in anticipation of subsequent performance tasks. While prior research has documented the effect of acute caffeine ingestion on performance of muscular strength and aerobic endurance type activities (15. 16. 17), the current study extends this work by examining the effect of caffeine ingestion on variables which purportedly better relate to tasks of daily living (27) in older adults. As such the data presented here are novel and provide evidence for an effect of caffeine ingestion in older adults. Understanding any effect of caffeine on performance in this age group is particularly important as, in the United Kingdom, habitual caffeine ingestion increases with age, with highest values seen in men and women over 65 years of age (32).

Despite this, studies examining whether caffeine ingestion influences functional performance in older adults are scarce. In this respect our data are significant as older adults have been identified as a population at greater risk of accidents during tasks of daily living (33), with improvement in functional and motor performance identified as key in reducing accidents in older adults

(33, 34). As there are no studies on older adults reporting the impact of caffeine ingestion on functional performance, it is difficult to compare the results presented here with prior research.

In regard to performance on the functional test battery, improvements in the arm curl test, 8-foot timed up, 6-minute walk and go and Minnesota Manual Dexterity Test are important as they indicate caffeine may have a positive impact on variables requiring muscular strength, speed of limb movement, agility/dynamic balance, aerobic endurance and effective motor skills. Such data agree with prior work in young adults which has assessed these elements of performance, albeit using different assessment techniques (13, 35, 36). The current results are also consistent with research in older adults which has shown improved walking distance and isometric strength (16) and enhanced motor performance (12, 13). It is also important to note that the values recorded for the various tests within the Rikli and Jones (27) functional performance test battery were all within the 'normal' range for males and females aged 60-90 years. Whether caffeine has a different impact in an older population who score low for functional performance is not known and would be an interesting future research study.

The current results also agree with the prior research with younger adults (2) showing enhanced aerobic endurance following caffeine ingestion and research with older adults that has reported improvements in endurance performance as a result of caffeine ingestion (15, 16). However, the bolus of caffeine used in both these prior studies (15, 16) was double (6 mg*kg^{-1} body mass) than that used in the present study. This is an important point as the caffeine bolus used in the present study is more comparable to the volume of caffeine typically seen in brewed coffee which contains approximately 260mg caffeine per 12oz (37). The range of caffeine ingested in the present study in absolute terms was 193-332mg and as such may be more practical in terms of an acute dose of caffeine consumed in daily life.

Given the results presented here consideration of the mechanism for any performance enhancing effect is needed. Caffeine ingestion has been shown to enhance performance in physical tasks requiring aerobic endurance and muscular performance (38). This is in part due to its impact on the central nervous system (CNS) (39) through adenosine inhibition (40). In particular, adenosine increases in muscle and plasma during muscular activity and also in the brain during ‘stress’, negatively influencing neuron excitability and synapse transmission (40). Thus, antagonism of adenosine may facilitate exercise performance. Taken collectively and in the context of a testing battery that required increased muscular activity (e.g., arm curls), speed of limb movement, agility and dynamic balance (e.g., 8 foot timed up and go), increased distance covered in a set time (6-minute walk test) and more rapid fine motor skill (e.g., manual dexterity), such proposed mechanisms would explain the results presented in this manuscript.

Furthermore, prior research with resistance trained young adults has reported that caffeine ingestion results in increased RTIME (21). Few studies have examined this psychological construct, despite suggestions to do so (19, 20). The results of this study therefore align with prior work and suggest that caffeine ingestion results in psychological changes whereby participants feel more able to provide maximal mental effort prior to performance compared to ingestion of placebo, possibly due to the direct effect of caffeine on the CNS (39) and due to its role as a mood enhancer (7).

Limitations and directions for future research

In order to contextualise the broader application of these findings the limitations to this study should be considered. Initially the concentration of caffeine administrated to the participants is markedly lower than that given in other studies investigating the effects of caffeine in elderly and young population (Usually around 5-6mg*kg^{-1}; 3, 5, 15, 16, 17, 35). Future studies may therefore want to consider examining the dose-response relationship to caffeine ingestion in older adults. Also, although the present study employed a battery of tests purported to assess functional performance (27, 29), the individual tests involved are brief and future research may want to consider using a broader range of tasks that better reflect the multitude of dynamic muscular contraction, motor skills and perception-action coupling required in tasks of daily living. Furthermore due to the relatively strict inclusion criteria for this study we were unable to control for training status and caffeine habituation. Although difficult in a western population, examining the effect of caffeine in non-habitual elderly users would be an interesting area of further research. With the sample of participants used in the present work being overweight (BMI >25), it may also be interesting to examine the effects of body composition on the ergogenic effects of caffeine in older adults.

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