

**Mind Over Muscle: Investigating Expectancy and Ergogenic
Supplementation's Effects on Adolescents' Anaerobic Athletic Performance**

Yijia Xu

Western Academy of Beijing, Beijing, China

Abstract

This study investigated the extent to which expectancy, induced through placebo and nocebo framing, influences adolescent athletes' performance in anaerobic tasks, specifically 60-meter sprint speed (explosiveness) and grip strength (muscular strength). Participants ($N = 16$; 8 males, 8 females) were randomly assigned to one of four groups: real supplement (caffeine and taurine), placebo, nocebo, or control. A double-measure design was used, with participants completing sprint and grip tests both before and after the intervention. Psychological framing was manipulated through standardized scripts, and performance outcomes were analyzed using paired samples t-tests and one-way ANOVAs with Tukey HSD post hoc tests.

Results indicated that both the supplement and placebo groups demonstrated statistically significant improvements in sprint performance (*Group 1: -4.0% average sprint time, $p = 0.009$; Group 2: -1.4% , $p = 0.038$), while the nocebo group showed a decline (*Group 3: $+3.8\%$ minimum sprint time, $p = 0.033$*). Grip strength changes were not statistically significant across any group. Between-group ANOVAs revealed significant differences in sprint performance ($F(3,12) = 8.508$, $p = .003$), with the nocebo group performing significantly worse than both placebo and supplement groups. Survey data corroborated performance trends, reflecting the influence of belief on perceived exertion and energy.*

These findings suggest that expectancy alone can significantly influence explosive athletic performance, sometimes rivaling or even overriding pharmacological supplementation. However, isometric strength may be less susceptible to acute psychological manipulation. The study underscores the importance of mindset and framing in optimizing athletic performance in youth populations.

Keywords: Placebo, nocebo, adolescent athletes, anaerobic, expectancy, ergogenic aids

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Introduction

It is no surprise that all athletes aspire to perform their best in trainings, tryouts, and competitions. Explosiveness, or the product of speed and power, and muscular strength are skill- and health-related components of fitness foundational in most competitive sports (Bazyler et al., 2017; Suchomel et al., 2016). Both physical performance components are relatively difficult to improve due to their reliance on complex neuromuscular mechanisms, such as rapid motor unit recruitment, intermuscular coordination, and high-intensity loading (H Peter Clamann, 1993; McKinlay et al., 2018). While resistance training can increase strength, true gains require significant neural adaptation and structural remodeling (SALE, 1988). Explosiveness, in particular, demands training specificity and could be constrained by the athlete's proportion of fast-twitch muscle fibers (Gollnick & Matoba, 1984). Thus, marginal gains or improvements in such metrics are substantial in overall sports performance.

Given the inherent difficulty in improving strength and explosiveness through training alone, many athletes turn to ergogenic aids, which Tein et al. (1995) define as substances or techniques believed to enhance physical performance, before critical trainings and events. Among the most commonly consumed ergogenic aids are caffeine and taurine, both frequently present in energy drinks marketed to athletes. Caffeine is a central nervous system stimulant that antagonizes adenosine receptors, which has been demonstrated to improve reaction time and motor unit recruitment, thereby enhancing anaerobic output (Grgic et al., 2018). Taurine is an amino acid derivative, often amalgamated in performance-enhancing supplements with caffeine, and supports muscular contractility and reduces exercise-induced oxidative stress via intracellular calcium influx regulation and free radical scavenging (Foos & Wu, 2002; Zhang et

al., 2004). Together, these substances are believed to act synergistically, potentially enhancing athletes' performance.

However, beyond physiological effects elicited by the biochemicals of ergogenic aids lies an intricate psychological dimension—expectancy. As a broader term, expectancy refers to an individual's anticipation or belief about the outcome of a specific event, behavior, or intervention, which can shape perceptual, cognitive, and motor responses (Kirsch, 1985). Expectancy can be induced by placebo and nocebo effects.

The placebo concept originated in a 14th-century Christian hymn but was medicalized in the late 18th century (Beecher, 1955). It refers to inert treatments, such as sugar pills known as “dummies,” to satisfy patients when no effective therapy existed. Placebos became more prevalent in clinical trials in the 20th century. Beecher's 1955 paper quantified the placebo effect within the trials, demonstrating an average significant effectiveness of 35%, which altered subjective responses and symptoms. Therefore, the placebo effect was established as a salutary expectancy that contributed positively to subjective and objective outcomes.

On the other hand, a nocebo is regarded as the “evil twin” of a placebo, as Kennedy (1961) has labeled it. Identical to a placebo, a nocebo is also a harmless condition. Still, it is correlated with the belief that adverse effects can be engendered once implemented, therefore evoking negative outcomes despite the neutrality of the condition (Colloca & Miller, 2011). For instance, Colloca and Miller (2011) gave healthy subjects a sham radiofrequency stimulus and informed them that it was electrical currents. Surprisingly, the subjects reported that they experienced headaches, discomfort, and head pain due to the inertial waves. Thus, correspondingly, the nocebo effect refers to a detrimental expectancy that contributes negatively to both subjective and objective outcomes.

The two expectancy effects transcend clinical settings, having to reach the athletic domains. In sports psychology, expectancy refers to the perceived likelihood of success in completing a task (Ungvarsky, 2024). Recent research in such domains also highlights the results of expectancy effects at play, concluding that behavior or performance changes may arise purely from an individual's beliefs or anticipations about an intervention, significantly modulating both subjective and objective athletic measures, even independent of any active substance (Chhabra & Szabo, 2024). The expectancy effects are not merely psychological illusions but possess measurable neurobiological responses that modify one's performance. Positive expectancy, or the placebo effect, has been shown to increase dopaminergic activity, enhance corticospinal excitability, and reduce perceived exertion by modulating prefrontal and sensorimotor cortical networks (Benedetti et al., 2005; Fiorio, 2018). Conversely, negative expectancy, or the nocebo effect, can trigger increased anticipatory anxiety, elevate pain sensitivity, and impair motor output, illustrating how belief alone can shape neuromuscular performance (Benedetti et al., 2007).

While caffeine and taurine offer biochemical advantages, the findings of placebo and nocebo effects suggest a compelling role of expectancy and perception in sports performance. If belief alone can modulate neuromuscular output, perceived exertion, and motivational drive, then at least part of the performance benefit observed from supplements such as caffeine and taurine may stem not only from their pharmacological properties but also from the expectations athletes associate with them. This raises the question of which is more potent in determining performance outcomes.

This study employs a 2x2 factorial design, comprising a binary independent variable with two additional levels, resulting in four experimental conditions.

The first two levels refer to the substance participants actually receive—either a caffeine and taurine tablet or a starch tablet as a placebo. The second layer of the factorial design refers to what the participants are told they are receiving—either “caffeine and taurine, two performance-enhancing supplements” or “starch, a placebo.” Specifically, the participants will be subjected to one of the following: a caffeine and taurine tablet labeled as caffeine and taurine, a starch tablet labeled as a caffeine and taurine tablet (“performance-enhancing supplement”), caffeine and taurine labeled as a starch tablet (“a placebo”), and a starch tablet labeled as a starch tablet (“a placebo”). These variations were selected to explore the influence of both positive and negative expectations and mental states on physical output. Correspondingly, four groups form as the independent variable: Told caffeine and taurine, given caffeine and taurine (1), told caffeine and taurine, given placebo (2), told placebo, given caffeine and taurine (3), and told placebo, given placebo (4). The study applies a standardized script to facilitate the expectancy manipulation (Appendix B).

Group 1 tests the true effect of a mild performance enhancer, caffeine, on participants’ explosiveness and muscular strength. Group 2 tests for the placebo effect, while group 3 would allow examination of the antithesis, the nocebo effect. Group 4 is a control group, as the participants receive no expectation of performance enhancement and no actual substance that would affect their performance. Then, by conducting a between-group data analysis, the psychological and physiological effects can be separated for a holistic inspection of the collaboration between mind and body in an explosive and powerful act. For example, comparing groups 1 and 4 could isolate the expectancy and caffeine’s effect. In tandem, groups 2 and 4 comparisons can isolate the placebo effect, groups 3 and 4 comparisons can isolate the pure

caffeine effect, groups 1 and 3 comparisons can isolate the placebo effect group, and groups 2 and 3 comparisons facilitate a direct examination of whether psychological or physiological modifications dominate performance. Hence, this design allows for the simultaneous investigation of both placebo and placebo effects, offering insight into the effect of psychological expectancy alone, whether positive or negative, on explosiveness and muscular strength. By comparing the results between individuals of each group and across the four groups, the study seeks to delineate the psychological and physiological influences on performance, specifically how expectations and pharmacological interventions jointly impact athletic performance, the extent to which belief itself can act as a performance modifier, and whether psychological modifications can overpower physiological effects in adolescents.

Participants' explosiveness and muscular strength changes due to the supplement and expectancy manipulation will be operationalized through two quantitative performance-based tests: the 60-meter sprint test and the handgrip strength test using a dynamometer. These two variables provide a multidimensional assessment of both lower- and upper-body muscular output in predominantly anaerobic circumstances in response to experimental conditions related to expectation and caffeine and taurine administration.

The 60-meter sprint is tailored to measure explosiveness and anaerobic neuromuscular performance utilizing muscles from the core down to lower-extremity muscles after being subjected to one of the four conditions. It measures the participant's ability to accelerate rapidly from a static position. The performance of such explosive tasks is strongly associated with muscle activation levels, which are regulated by descending motor commands from the central nervous system (CNS)—particularly the motor cortex and spinal pathways (Shalit et al., 2011). The peripheral nervous system (PNS) then transmits these signals to the muscles via lower motor

neurons. The central nervous system's arousal state can be modulated by caffeine ingestion and psychological factors such as expectation or motivation. These changes in arousal influence neuromuscular output by altering motor unit recruitment, firing rate, and coordination, thereby affecting performance. Hence, the 60-meter sprint is an effective tool to capture changes in strength output under physiological and psychological influences, where perceived ergogenic or impairing effects can lead to measurable alterations in acceleration or sprint time.

On the other hand, the grip strength dynamometer test evaluates upper-body muscular strength through maximal isometric force output, particularly in the forearm and hand flexor muscles, which could compensate for some neglected muscles in the sprint test. Grip strength has been widely used in sports science and physiological studies as a valid indicator of general upper muscular strength and effort. Identically, since the hand grip strength test also reflects a voluntary contraction from the brachioradialis, its performance is highly responsive to alterations in the central nervous system, allowing direct measurements of force output as indicators of the perceived physiological and psychological effects on explosive performance.

For both tests, the participants will perform a baseline measurement before being subjected to any of the conditions, measuring three times to minimize coincidental results. They will also be asked to complete a short survey for qualitative introspection (Appendix D). The results will be recorded and used for later within-subject analysis. The participants will then experience one of the four conditions based on their randomly allocated groups, receiving caffeine, a placebo, and an expectancy manipulation. The participants will be tested on the sprint and grip tests, with quantitative indicators for the results recorded again, repeating three times for each task to minimize skewed results. The sprint test will be measured in seconds (s) using a stopwatch. The strength output from the grip strength test is measured in kilograms (kg). The

maximum output over a 5-second period of each trial will be recorded since participants typically reach peak voluntary contraction within this duration, and longer durations may lead to fatigue without additional benefit to data accuracy. Finally, the participants will be asked to take a post-intervention test survey again (Appendix D). Ultimately, this dual-assessment approach will enable quantitative and qualitative observations of the psychological and physiological effects on anaerobic performance.

Understanding the interaction between expectancy effects and physiological supplementation is crucial for designing effective, ethical interventions in youth sports. This study aims to investigate the comparative effectiveness of both methods for enhancing sports performance. It also aims to elucidate the interplay between psychological expectancy and physiological supplementation, examining the effects of placebo, nocebo, and ergogenic aids on the two key physical performance measures, explosiveness and muscular strength, in adolescent athletes—a population that has been less regarded within such a domain. By comparing pre- and post-intervention performance across these conditions, this study aims to delineate the relative contributions of belief and biochemistry to short-term anaerobic athletic output.

Due to the binary or factorial design of the experiment, various hypotheses were made based on different dimensions and comparison levels.

Within-Subject Hypotheses: Firstly, it is hypothesized that participants in the ergogenic supplementation (Group 1) and placebo conditions (Group 2) will both exhibit measurable improvements in both anaerobic performance tasks, demonstrated by a decrease in the 60-meter sprint time and an increase in grip strength via comparison of pre- and post-intervention tests within the same individual.

For participants within the physiological supplementation group receiving a tablet containing caffeine and taurine, statistically significant improvements in both metrics are expected due to the ergogenic and positive expectantancy effects. As mentioned, caffeine is a well-established ergogenic aid that enhances various aspects of sports performance, including muscular strength, endurance, power, reaction time, and cognitive function, all of which are components of fitness that elevate the overall athletic output (Calvo et al., 2021; Diaz-Lara et al., 2024; Komorowski et al., 2025; Salinero et al., 2018). It achieves such salutary effects via antagonizing the adenosine receptors in the CNS, reducing perceived effort, pain, and fatigue. This is because adenosine is an endogenous neuromodulator with mainly inhibitory effects in the CNS. By binding to A1 and A2A receptors, which are G protein-coupled receptors widely distributed in the nervous system, it reduces neural excitability and excitatory neurotransmitter exocytosis, promoting sedation, vasodilation, decreased arousal, and fatigue (Daly et al., 2020). By antagonizing A1 and A2A adenosine receptors, caffeine, therefore, inhibits or removes the inhibition driven by adenosine, promoting the release of excitatory neurotransmitters, increasing alertness, motor output, and muscle contractility, and decreasing pain and fatigue perception. Metabolic changes, such as increased blood catecholamines and lactate concentration, are also critical for peak athletic performance because they support anaerobic metabolism (Komorowski et al., 2025). The other substance in the performance-enhancing supplement, taurine, also acts as a neuromodulator in the CNS. It influences neuronal excitability by agonizing γ -Aminobutyric acid (GABA) receptors, promoting inhibitory signals that stabilize neural activity. Coupled with its neuroprotective properties by modulating intracellular calcium levels and preventing excitotoxicity, taurine, altogether, prevents overexcitement and helps maintain optimal CNS function during physical stress (Schaffer & Kim, 2018). Most importantly, taurine acts as an

osmolyte, balancing fluids within the body due to sweating and blood flow changes. It influences calcium and potassium channels, optimizing muscle excitation-contraction coupling (Gelder, 2025). Its antioxidant property reduces oxidative stress through mitochondrial superoxide formation inhibition and reactive carbonyl species scavenging, facilitating efficient respiration while preventing cellular damage due to the intense and persistent engagement (da Silva et al., 2014). Finally, as these supplements are widely acknowledged as efficacious substances, the anticipation of ingesting such aid fosters positive expectancy, which further catalyzes the beneficial physical and cognitive effects via boosted motivation and dopamine and endogenous opioids, leading to improved performance (Erez & Isen, 2002). Overall, due to caffeine's antagonism, taurine's agonism, and positive expectancy's efficacy, group 1 will experience an increase in both metrics.

For the placebo group, it is also hypothesized that there will be a significant improvement in the performance of the two tasks, though to a lesser degree, as no substances will evoke a physiological response—all changes witnessed will be attributed to psychological alterations. As mentioned, such positive expectancy can mimic physiological responses by activating dopaminergic pathways and corticospinal excitability (Benedetti et al., 2005; Fiorio, 2018). Research has shown that athletes who merely believe they've consumed a performance-enhancing substance can significantly improve output, even when the substance is inert (Beedie et al., 2007). Therefore, it is anticipated that adolescent athletes will have a similar degree of improvement due to the placebo effect.

Conversely, participants in the nocebo condition (Group 3) are hypothesized to experience a decline in performance for both tasks. As negative expectancy has been demonstrated to increase anticipatory anxiety and demotivation by activating the amygdala and

anterior cingulate cortex (ACC), the motor output of the participants will decline, as it is dependent on cognitive engagement (Benedetti et al., 2005; Benedetti et al., 2007).

Consequently, the reduction in motivation, focus, coordination, and muscle activation will ultimately impair explosive speed and muscular strength output.

Finally, the control group (Group 4) is hypothesized to demonstrate no statistically significant change, as they will not receive any ergogenic aid nor expectancy manipulation; therefore, they experience neither physiological nor psychological changes, serving as a baseline for natural variability in the experiment.

Between-Subject Hypotheses: In addition to the within-subject comparisons, it is hypothesized that, when comparing performance changes based on the average and best results across the four groups, groups 1 and 2 will display a significantly greater improvement in both tasks than groups 3 and 4. Due to the same rationale as hypothesis 1, the real supplement group is expected to show the most pronounced gains due to the combined effects of physiological and psychological stimulation, while the placebo group will benefit solely from expectancy-related mechanisms. On the other hand, group 3 is predicted to perform significantly worse than groups 1, 2, and 4, due to neurobiological mechanisms triggered by the negative expectancy mentioned.

Methods

Participants

Participants ($N = 16$) were selected via a combination of both stratified and convenience sampling method, with gender and athletic involvement being the major strata, as it aims to include a balanced representation of the adolescent population, increasing the population validity and generalizability of the results by minimizing performance variation due to sex or baseline fitness. An equal number of male and female participants (8 Male, 8 Female) were actively

recruited based on their physical activity levels. Among the participants, 63% were 15 years old, 31% were 16 years old, and 6% were 17 years old. After identifying eligible participants, individuals were invited to sign up for one of four designated testing days based on their personal availability. Based on the days they sign up for each test day, a balanced group of four (two males and two females) will be present. Once all groups were confirmed, participants were randomly assigned to one of the four experimental conditions using a spinning wheel. All participants satisfied the qualification criteria and completed all conditions of the study

Materials

This experiment involves ergogenic supplements and inert tablets. A bottle of caffeine and taurine tablets, 100 mg per pill, and starch tablets were applied in the study. Ideally, the 60-meter sprint time should be captured by a digital stopwatch to minimize human errors. Nevertheless, due to the limited supply of technology involved, a manual stopwatch was used instead, measuring up to hundredths of a second. For the isometric muscular strength grip test, a hand grip dynamometer measuring up to at least a tenth of a kilogram was employed. Finally, a minimal number of six cones were used in the study to mark the warm-up and running distances for the participants (8-meter, 10-meter, 20-meter, and 60-meter).

In addition to the physical materials, digital forms were sent to participants. As participants are required to ingest ergogenic aids, each received a consent form. A meal and sleep logbook was also handed out to participants. Logbook prompts include five sections: sleep 48 hours prior to testing, sleep 24 hours prior to testing, breakfast on the testing date, lunch on the testing date, and substance & activity check (Appendix C). Furthermore, a demographic survey was sent to participants, inquiring about ethnicity, fitness level, caffeine use, and health and medical history information, which was used to filter eligible participants (Appendix A). Before

the baseline and after the post-intervention testing, two additional surveys, each including five Likert-type scale rating questions, were utilized to examine the extent of supplementation and/or expectancy's effect (Appendix D).

Procedures

Participants were first briefed on the nature of the study and asked to review an information sheet outlining their rights, the study's purpose, and their option to withdraw at any time. Those who met the inclusion criteria (see Appendix A) provided informed consent and completed a demographic survey detailing their age, weight, height, athletic background, and current training or substance use habits. They were instructed to follow pre-test preparation guidelines, including obtaining 7–9 hours of sleep the night before testing, abstaining from stimulants for 24 hours, consuming a standardized meal 2–3 hours prior, and hydrating with 500 mL of water in the same window. Participants were then randomly and evenly allocated to one of four experimental groups, with balanced sex representation (2 males and 2 females per group).

On the testing day, all participants completed a standardized 5–10-minute dynamic warm-up, which included jogging, mobility drills (e.g., tiptoe walks, leg swings), dynamic stability movements (e.g., arabesque-to-hip lock, lunge variations), sprint-specific activation (e.g., high knees, A/B skips, short sprints), and grip-specific activation exercises (e.g., wrist stretches, tennis ball squeezes). During the recovery period, participants took the pre-test self-assessment survey, which regarded their physical and mental readiness and belief in ergogenic supplements. Following the warm-up and recovery period, the 60-meter sprint test was conducted on a marked field using a stopwatch for timing. Each participant completed three individual trials, in sequence, to prevent pacing or competition effects, with adequate rest between sprints. Grip strength was then assessed using a hand dynamometer. Participants completed three 5-second

maximal efforts with their dominant hand, and the highest output within the window was recorded.

Approximately 70 minutes prior to post-testing, participants ingested their assigned treatment: either caffeine (2 mg/kg body weight), a starch-based placebo tablet, or no substance (control). A standardized script (Appendix B) was read aloud before ingestion to induce either positive (placebo), negative (nocebo), or neutral expectancy. Participants then rested for 50 minutes before repeating the standardized warm-up.

Sample time schedule of post-intervention activities across the testing session, including supplement ingestion, rest, warm-up, and performance testing:

Time Period (min)	Activity
0 min	Caffeine/placebo tablet + script
0 – 50 min	Rest/light activities only
50 – 60-min	Warm-up
60 – 65 min	Recovery
65 – 75 min	Testing (sprint + grip)

Outcome testing followed the same protocol as baseline testing, including sprint and grip strength trials. Upon completion, participants completed a post-test survey assessing their mood, energy, and perceived effectiveness of the intervention. All participants were debriefed and appreciated for their time.

This study is void of significant safety hazards as all participants are pre-screened for caffeine sensitivity or medical contraindications. The study also adheres to the caffeine/placebo ingestion amount suggested by Cho (2018), and the intake of 2 mg/kg body weight caffeine is a moderate amount, while still enough (p. 287). They are informed of their right to withdraw at any time, and the adverse effects were monitored during the rest period after ingestion. Furthermore,

all the tablets used in this study are from reputable sources (Peking Union Medical College Hospital and Yong'an Kangjian Pharmaceutical). This study has been approved by the school.

Data Analytics Plan

All statistical analyses were conducted using Microsoft Excel. For each participant, sprint performance was quantified using both the mean sprint time across three trials and the best (minimum) sprint time, while grip strength performance was assessed using the maximum value of three dominant-hand contractions measured in kilograms. To examine within-subject changes, paired one-tailed samples t-tests (except for the placebo group) were performed comparing pre- and post-intervention scores for each group separately. To assess between-group differences in change scores, a one-way between-subjects ANOVA was conducted for both sprint and grip strength outcomes, using performance change scores (post - pre) as the dependent variable. When significant omnibus effects were found, Tukey's HSD post hoc tests were used to identify pairwise group differences. Percent change scores were calculated to standardize effect magnitude, and effect sizes (η^2) were computed for ANOVA tests. A significance level of $\alpha = .05$ was used for all inferential statistics. Descriptive statistics, including means, standard deviations, and percentage change, were reported for each performance measure. Qualitative data collected from pre- and post-intervention surveys were descriptively analyzed to supplement and contextualize the quantitative results.

Results

This investigation aimed to explore the extent to which expectancy, induced through placebo and nocebo framing, influenced adolescent athletes' performance in anaerobic tasks, particularly explosiveness measured by the 60-meter sprint and muscular strength measured by the grip test, in comparison to an ergogenic performance-enhancing supplement. Based on the

results of changes in pre- and post-intervention, ANOVA, and post hoc (Tukey HSD) analysis, it can be concluded that expectancy significantly influenced sprint performance but had no meaningful effect on grip strength.

From the within-subject analysis, both group 1 and group 2 displayed significant performance improvements in the 60-meter sprint (Table 1). Group 1 exhibited an overall change in sprint time of -0.41 seconds or $-4.0 \pm 0.6\%$ ($SD = 0.168$, $p = 0.009$) when compared based on the mean results across the trials and a mean change of -0.34 seconds or $-3.4 \pm 0.5\%$ ($SD = 0.218$, $p = 0.026$) when compared based on the best results (minimum time) across the trials after an ergogenic intervention. This demonstrates an overall evident reduction in sprint time for all participants in the group. Likewise, though to a lesser extent, Group 2 also displayed a significant change in time of -0.12 seconds or $-1.4 \pm 0.1\%$ ($SD = 0.092$, $p = 0.038$) when compared using the mean results across the pre- and post-intervention trials after a positive expectancy manipulation, with no actual substances to elicit biochemical changes. However, group 2 had a mean change in time of -0.09 seconds or $-1.1 \pm 0.1\%$ when participants' results were compared based on their best results, which was statistically insignificant ($p = 0.129$).

On the other hand, group 3 experienced a change in the 60-meter sprint time of +0.12 seconds or $1.1 \pm 0.1\%$ ($SD = 0.337$, $p = 0.269$) when compared based on the mean time across the trials and +0.39 seconds or $3.8 \pm 0.3\%$ ($SD = 0.272$, $p = 0.033$) when compared based on the minimum time (Table 1). Though the change in time compared based on the average times is not statistically significant, the change based on the best performance was significant ($p = 0.033$).

Finally, Group 4's change based on the comparison of time using the mean time across the trials and best effort was not significant ($p = 0.308$; $p = 0.839$), serving as a fair control group and baseline for later between-subject comparison.

For the grip strength, group 1's change in output when compared based on the maximum score was significant ($p = 0.046$). The change in isometric muscular output through the grip strength test was not significant for any other conditions ($p > 0.05$).

In addition, ANOVA results showed significant group differences in the change in sprint time when based on the mean and minimum time (*Mean*: $F(3,12) = 4.372, p = 0.027$; *Minimum*: $F(3,12) = 8.508, p = 0.003$), with large effect sizes ($\eta^2 = 0.522$ and 0.680). Post hoc tests were conducted to determine specifically the pairs that contributed to significant between-group results (Table 4; Table 5). The Tukey HSD revealed that group 3 performed significantly worse than group 2 when compared by the minimum time ($p = 0.030$) and group 1 when compared by both the best performance ($p = 0.002$) and mean performance ($p = 0.018$).

Lastly, observations and feedback were recorded from participants prior and after the intervention testing. There are a few noteworthy ones. Group 2 participants self-reported high levels of exertion (*Avg.* = 5.00) and medium-to-high perceived energy post-ingestion and change in performance (*Avg.* = 3.75). On the contrary, group 3 participants, despite receiving an actual supplement, reported low perceived performance change (*Avg.* = 1.75) and low energy levels (*Avg.* = 1.50). They also showed signs of low motivation, slower warm-ups, and reduced engagement post-intervention, which was the opposite of group 2, which claimed to “feel less tired after the sprints.”

Qualitative Data Table: Observations and Feedback from Participants Before and After Condition Administration

Group	Belief Condition	Actual Substance	Qualitative Observation—Objective observation, participants' verbal feedback, and participant reflections
Group 1	Caffeine and Taurine	Caffeine and Taurine	All four participants arrived energetic, and three out of the four demonstrated high focus during the warm-up before the baseline testing. Especially during the Arabesque to hip lock

			stability exercise, they were able to quickly find their balance and exploded as they drove their opposite arm and legs from the extended position. However, they seemed to be diffident and dubious about their upcoming performance for the baseline testing (Figure 1). During the testing phase, three out of the four participants appeared to be exerting maximum effort, with strict regulation of breathing as they sprinted and conscious flexion and extension of the legs. After the baseline testing, all participants were thrilled to hear that they were in the caffeine and taurine group. They conversed with each other almost incessantly throughout the fifty-minute subsequent to supplement ingestion. During the warm-up before the post-intervention testing, all participants displayed around the same level of focus during the pre-baseline testing warm-up, reacting quickly to commands. In the post-intervention testing, all participants demonstrated an increase in focus and a faster stride frequency. They also seemed to have wielded more arm muscles during the grip test, yielding a higher output. Three out of four participants claimed that they noticed a difference in their performance (Figure 2).
Group 2	Caffeine and Taurine	Placebo	Before the baseline testing and supplement ingestion, all four participants displayed relatively highly focused expression during warm-up. The participants were highly engaged and put in their maximum effort throughout all exercises. They were energetic during them and self-reported high energy levels after the warm-up (Figure 3). Subsequent to the baseline testing, all participants appeared to be relatively tired. Some decided to lie down to recover faster. There was no evident change in energy levels after the ingestion of the placebo, told as caffeine and taurine. Throughout the fifty-minute cool-down and recovery time, no significant changes in behavior were visible. The majority were chatting with each other. In the following warm-up, all participants got in their zone slower than during the warm-up for baseline testing. Nevertheless, during the sprint post-intervention testing, there was a visible increase in the male participants' stride frequency. They were also more confident in their breathing regulation throughout the three trials. However, the female participants did not demonstrate a visible increase in stride length or frequency, yet they were able to concentrate more on the grip strength assessment. Interestingly, despite receiving only a placebo, the participants in this group generally displayed high motivation levels during the

			post-intervention testing phase and even claimed that they “feel less tired after the sprints,” feeling that they are “motivated to/can even sprint more,” though one athlete on the track and field team suggests that the amount of rest between each sprint is not enough. The overall increase in confidence is reflected in their post-test self-assessment (Figure 4). Consequently, this placebo-induced performance mindset highlights how expectancy alone can shape subjective physical experiences.
Group 3	Placebo	Caffeine and Taurine	A few participants of this group appeared lethargic at first when they arrived, but they quickly adjusted and became more aroused after the slow jog, which elevated their heart rate. All were in tune for the subsequent dynamic stretches, mobility, stability, and sprint-specific exercises. Nevertheless, when they reached grip-specific warm-ups, all decided to find the closest place to sit down as they completed the warm-up instead of standing up, which could be interpreted as fatigue. No participant demonstrated visible excitement towards the baseline testing, especially when they had low confidence in their upcoming performance (Figure 5). All participants exerted maximum effort. After the baseline testing, when they were informed about their “placebo” condition, all appeared more despondent. There was barely any conversation throughout the fifty-minute break. Some of them even decided to take a nap. During the warm-up for the post-intervention testing, all emerged as slightly discouraged. The jog around the 400m track looked significantly slower due to their decrease in stride length and frequency. Although they were attempting to control and balance their body for the subsequent warm-up, it appeared difficult for them to do so. For instance, they were struggling to balance on one foot during the Arabesque to hip lock, even before lowering their hand to reach for the opposite leg. All participants appeared more fatigued and tired than at the baseline testing. The speed at which they used to walk back to the starting line for the 60-meter sprint decreased as the trial number increased, possibly due to fatigue or the lack of motivation to recover rapidly for the next trial. They were also passive during the grip testing. This is the only group that did not request to see their results after all the testing. Hence, this nocebo-induced effect appears to have an impact on the participant’s activeness, thus, their performance, as three out of four

			believe that they performed poorly and felt a reduction in energy and focus (Figure 6). This expectancy manipulation also prohibited some from being willing to exert maximum effort, illustrating how psychological effects may dominate the physiological enhancements.
Group 4	Placebo	Placebo	Participants of this group were highly engaged in the warm-up before baseline testing, starting from the beginning of the jog to the final grip-specific activations. Most had a relatively high confidence in their upcoming performance (Figure 7). Indeed, during the baseline 60-meter sprints, they focused not only on ensuring the stride speed, but also the movement of arms: they were engaged in arm swing strength and its coordination with their strides. Although participants were disengaged for a moment when they were notified about their condition, the information did not seem to affect them substantially. Before the warm-up for the post-intervention testing, participants complained about it occasionally in a joking tone. They still attempted their best throughout the warm-up and testing trials. There were no significant and noticeable extrinsic changes during the tests. The participants' opinions on their post-intervention performance were dissenting (Figure 8).

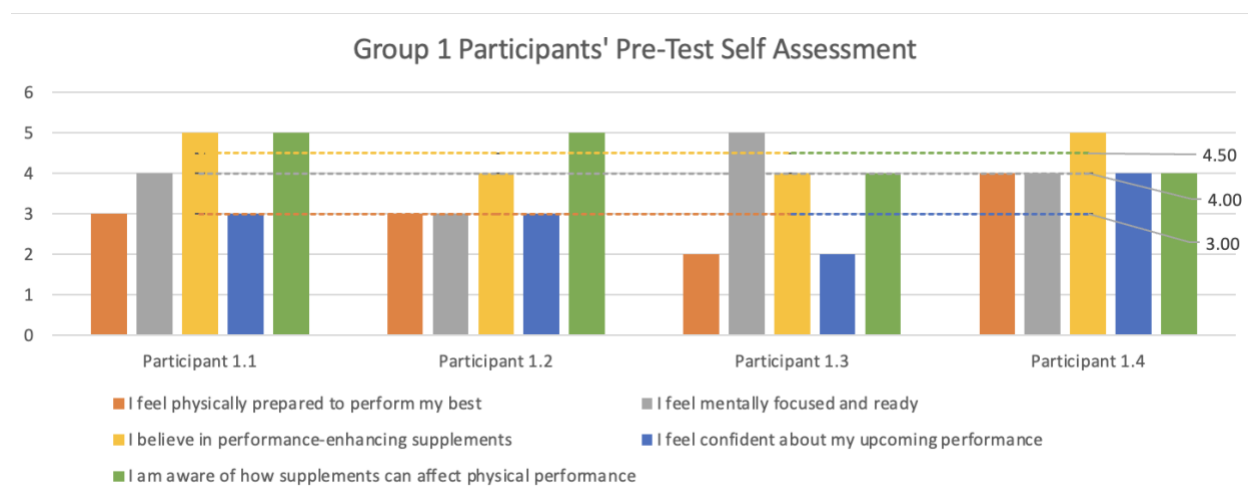


Figure 1. Group 1 Participants' Pre-Test Self-Assessment Scores. Participants ($N = 4$) rated their physical readiness, confidence, and beliefs about supplements before receiving the performance-enhancing supplement labeled caffeine and taurine tablet, using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Results indicate a relatively consistent medium-to-low physical preparedness and confidence ($Avg. = 3.00$), medium mental preparedness ($Avg. = 4.00$), and high belief and awareness of performance-enhancing supplements ($Avg. = 4.50$), contributing to an overall positive readiness and perceived effects.

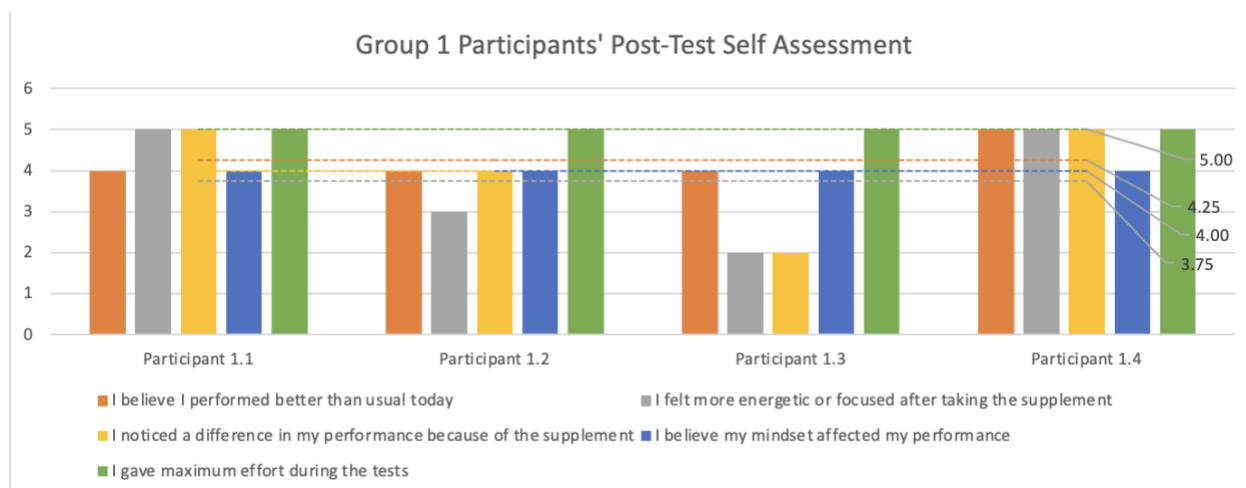


Figure 2. Group 1 Participants' Post-Intervention Test Self-Assessment Scores. Participants ($N = 4$) rated their perceived performance, energy, effort, and mindset influence following the post-intervention trials and before receiving their respective results, using the same 5-point Likert Scale as the pre-test self-assessment. Results imply a consistent perceived positive performance ($Avg. = 4.25$), high perceived mindset influence ($Avg. = 4.00$), and high effort exertion ($Avg. = 5.00$). The perceived energy level ($Avg. = 3.75$) and performance difference attributed to the supplement ($Avg. = 4.00$) are less consistent across the participants, though still perceived as generally medium-to-high.

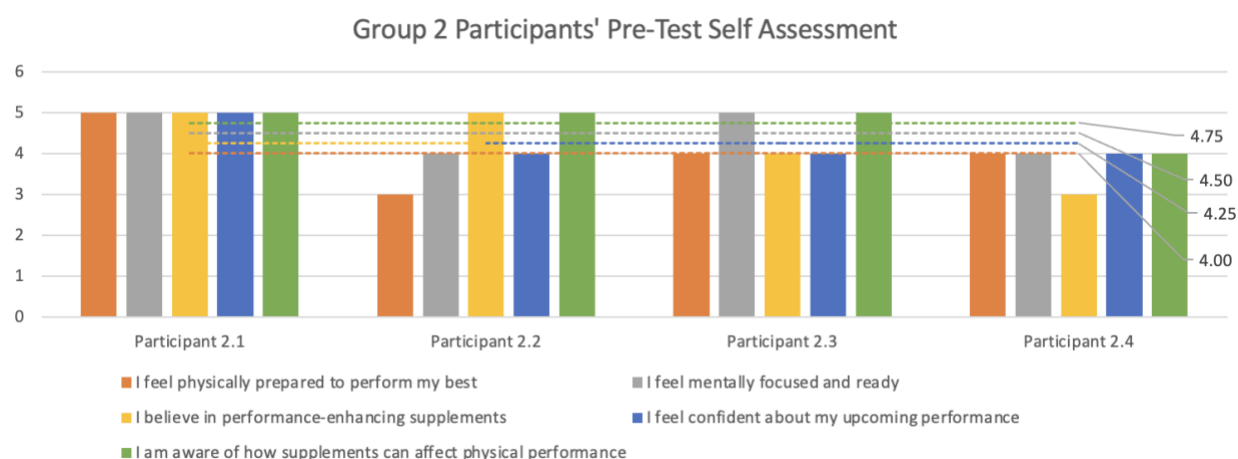


Figure 3. Group 2 Participants' Pre-Test Self-Assessment Scores. Participants ($N = 4$) rated their physical readiness, confidence, and beliefs about supplements before receiving the placebo-labeled caffeine and taurine tablet, using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Results indicate a relatively consistent, very high awareness of performance-enhancing supplements ($Avg. = 4.75$), consistent high mental readiness ($Avg. = 4.50$), high belief in performance-enhancing supplements ($Avg. = 4.25$) and general confidence ($Avg. = 4.25$), and medium-to-high physical readiness ($Avg. = 4.00$), indicating the participants' overall well-preparedness.

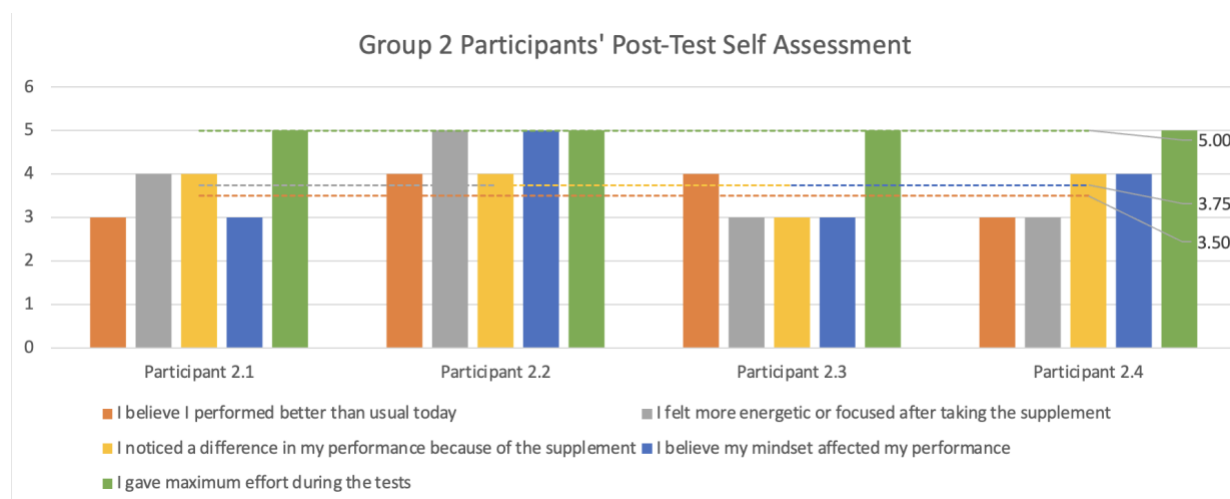


Figure 4. Group 2 Participants' Post-Intervention Test Self-Assessment Scores. Participants ($N = 4$) rated their perceived performance, energy, effort, and mindset influence following the post-intervention trials, ingesting a placebo, and before receiving their respective results, using the same 5-point Likert Scale as the pre-test self-assessment. Results demonstrate a constant in the effort participants exerted in the post-intervention trials ($Avg. = 5.00$); a mild variance from medium-to-high perceived energy post-ingestion ($Avg. = 3.75$) and mindset influence ($Avg. = 3.75$); a relatively consistent medium-to-high perception of the difference in performance post-ingestion ($Avg. = 3.75$); and a consistent, medium perception of personal performance better than usual ($Avg. = 3.50$), implying the placebo effect in action and possible fatigue post-testing.

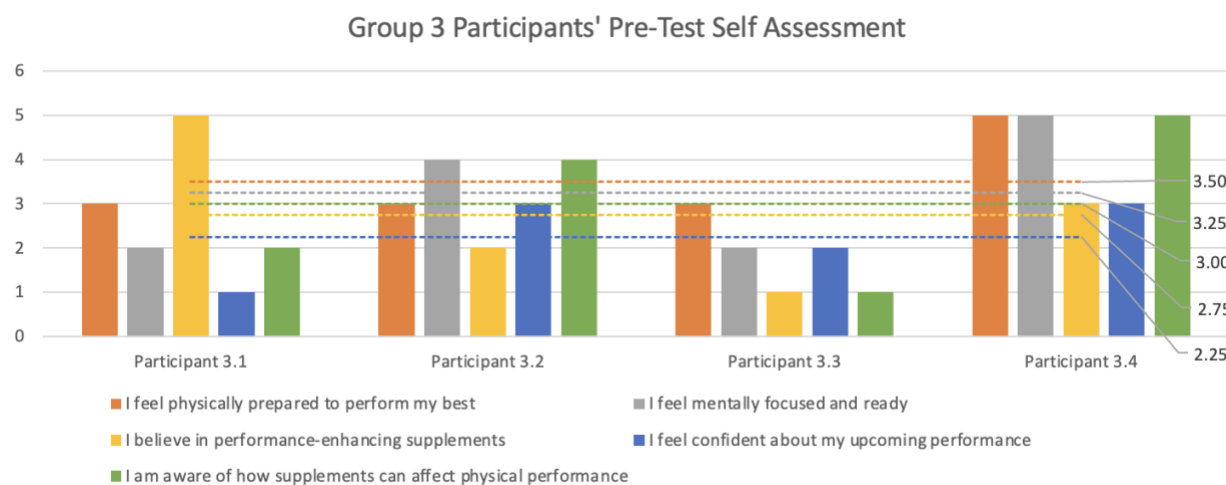


Figure 5. Group 3 Participants' Pre-Test Self-Assessment Scores. Participants ($N = 4$) rated their physical readiness, confidence, and beliefs about supplements before receiving the performance-enhancing tablet labeled placebo, using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Results indicate a considerable variation across almost all items. Group 3 participants displayed a medium physical readiness ($Avg. = 3.50$), a medium mental readiness ($Avg. = 3.25$), a medium awareness of performance enhancing supplements' effect ($Avg. = 3.00$), a medium-to-low belief in the supplements ($Avg. = 2.75$), and a low confidence in the upcoming tests ($Avg. = 2.25$), demonstrating the participants' overall relatively unpreparedness.

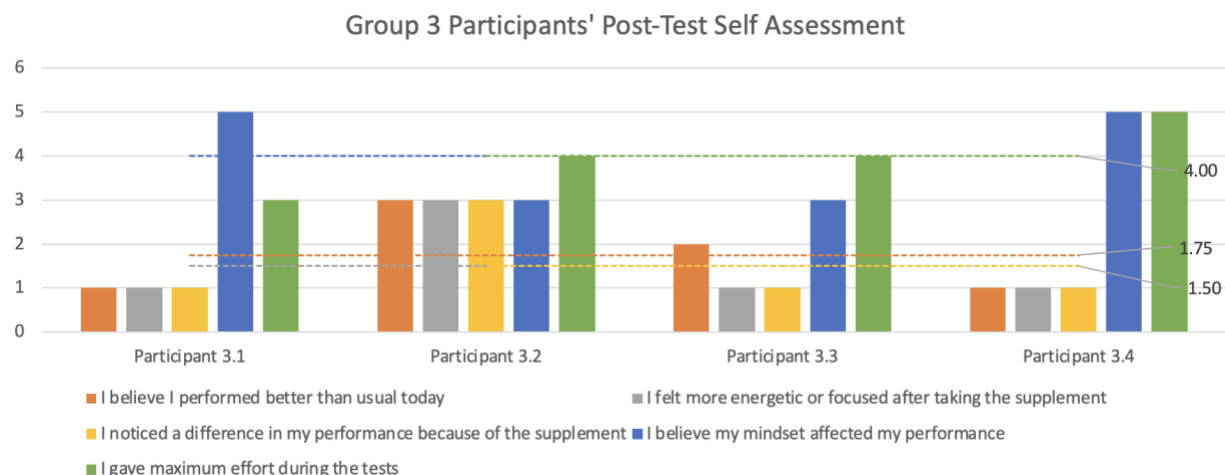


Figure 6. Group 3 Participants' Post-Intervention Test Self-Assessment Scores. Participants ($N = 4$) rated their perceived performance, energy, effort, and mindset influence following the post-intervention trials, ingesting a caffeine and taurine tablet, and before receiving their respective results, using the same 5-point Likert Scale as the pre-test self-assessment. Results exhibit a relative inconsistency across the items, including a medium-to-high effort exertion ($Avg. = 4.00$) and perceived effect of mindset ($Avg. = 4.00$), a low perceived performance enhancement ($Avg. = 1.75$), and very low perceived increase in energy levels ($Avg. = 1.50$) and perceived difference in performance post-intervention ($Avg. = 1.50$), demonstrating an overall incapacitation and deficiency in perceived influence due to condition administration, aligning with the placebo effect.

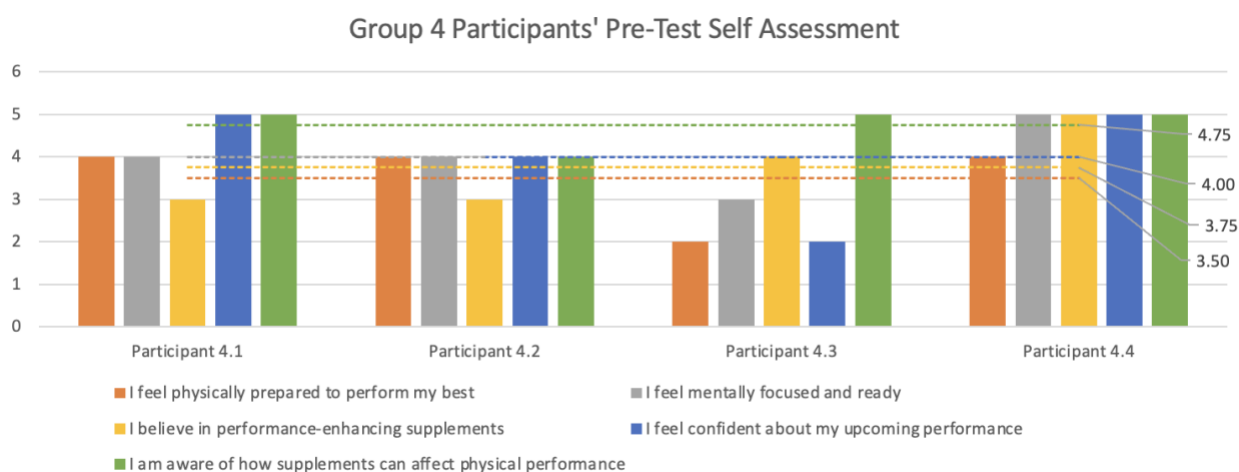


Figure 7. Group 4 Participants' Pre-Test Self-Assessment Scores. Participants ($N = 4$) rated their physical readiness, confidence, and beliefs about supplements before receiving the placebo, labeled placebo, using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Results indicate a consistently high awareness of performance supplements' effect ($Avg. = 4.75$), a high, yet relatively varied confidence for performance ($Avg. = 4.00$) and mental readiness ($Avg. = 4.00$), a medium-to-high varied belief in performance enhancing supplements ($Avg. = 3.75$), and a medium physical readiness ($Avg. = 3.50$), demonstrating a moderate level of overall preparedness for the baseline testing.

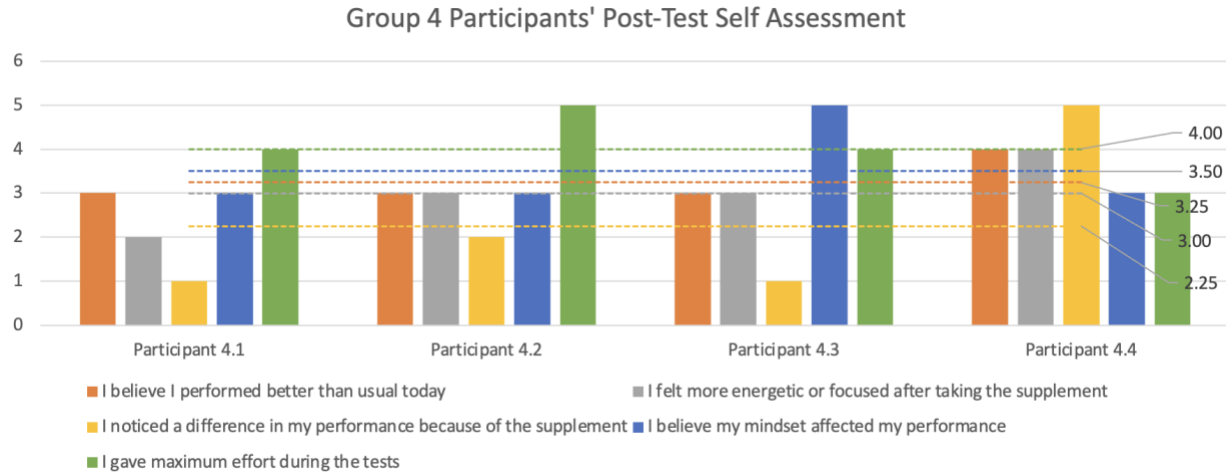


Figure 8. Group 4 Participants' Post-Intervention Test Self-Assessment Scores. Participants ($N = 4$) rated their perceived performance, energy, effort, and mindset influence following the post-intervention trials, ingesting a starch placebo tablet, and before receiving their respective results, using the same 5-point Likert Scale as the pre-test self-assessment. Results are mostly varied among participants. Participants gave medium-to-high effort in the post-intervention testing ($Avg. = 4.00$), a medium-to-high perception in the mindset's impact ($Avg. = 3.50$), a medium perception in performing better than usual ($Avg. = 3.25$), a medium energy elevation perception after place ingestion ($Avg. = 3.00$), and a highly varied and low perception of the placebo facilitating palpable changes ($Avg. = 2.25$), demonstrating the neutral condition of the placebo.

Table 1: Pre- and Post-Intervention 60-Meter Sprint Times and Performance Change Across Four Experimental Conditions

	Pre (s)					Post (s)					ΔM	$\% \Delta M$	SD	p -value	ΔMin	$\% \Delta Min$	SD	p -value
	$T1 \pm 0.2$	$T2 \pm 0.2$	$T3 \pm 0.2$	$M \pm 0.115$	$Min \pm 0.2$	$T1 \pm 0.2$	$T2 \pm 0.2$	$T3 \pm 0.2$	$M \pm 0.115$	$Min \pm 0.2$								
Group 1											-0.41	-4.0 ± 0.6	0.168	0.009	-0.34	-3.4 ± 0.5	0.219	0.026
Participant 1.1	8.91	9.12	9.28	9.10	8.91	8.72	8.44	8.65	8.60	8.44	-0.50	-5.5 ± 0.2	0.168	0.009	-0.47	-5.2 ± 0.2	0.219	0.026
Participant 1.2	11.97	12.75	11.97	12.23	11.97	11.41	11.56	11.94	11.64	11.41	-0.59	-4.8 ± 0.1	0.168	0.009	-0.56	-9.3 ± 0.3	0.219	0.026
Participant 1.3	9.19	8.93	9.25	9.12	8.93	8.97	8.66	8.84	8.82	8.66	-0.30	-3.3 ± 0.1	0.168	0.009	-0.27	-4.4 ± 0.1	0.219	0.026
Participant 1.4	9.91	10.10	10.75	10.25	9.91	10.09	10.13	9.84	10.02	9.84	-0.23	-2.2 ± 0.1	0.168	0.009	-0.07	-2.6 ± 0.1	0.219	0.026
Group 2											-0.12	-1.4 ± 0.1	0.092	0.038	-0.09	-1.1 ± 0.1	0.133	0.129
Participant 2.1	8.34	8.25	8.31	8.30	8.25	8.12	8.03	8.09	8.08	8.03	-0.22	-2.7 ± 0.1	0.092	0.038	-0.22	-2.7 ± 0.1	0.133	0.129
Participant 2.2	9.28	9.28	9.59	9.38	9.28	9.19	9.19	9.41	9.26	9.19	-0.12	-1.3 ± 0.0	0.092	0.038	-0.09	-1.0 ± 0.0	0.133	0.129
Participant 2.3	8.31	8.22	8.28	8.27	8.22	8.11	8.07	8.18	8.12	8.07	-0.15	-1.814 ± 0.1	0.092	0.038	-0.15	-1.8 ± 0.1	0.133	0.129
Participant 2.4	9.32	9.34	9.68	9.45	9.32	9.53	9.41	9.41	9.45	9.41	0.00	0.00	0.092	0.038	0.09	1.0 ± 0.0	0.133	0.129
Group 3											0.12	1.1 ± 0.1	0.337	0.269	0.39	3.8 ± 0.3	0.272	0.033
Participant 3.1	9.71	9.47	9.44	9.54	9.44	9.75	9.84	9.63	9.74	9.63	0.20	2.1 ± 0.1	0.337	0.269	0.19	2.0 ± 0.1	0.272	0.033
Participant 3.2	10.37	9.81	10.63	10.27	9.81	10.75	10.59	10.91	10.75	10.59	0.48	4.7 ± 0.1	0.337	0.269	0.78	3.2 ± 0.1	0.272	0.033

Participant 3.3	11.41	11.06	11.81	11.43	11.06	11.57	11.41	11.66	11.55	11.41	0.12	1.0 ±0.0	0.337	0.269	0.35	3.3 ±0.1	0.272	0.033
Participant 3.4	9.75	10.19	9.91	10.41	9.75	9.97	10.25	10.03	10.08	9.97	-0.33	-3.2 ±0.1	0.337	0.269	0.22	2.3 ±0.1	0.272	0.033
Group 4											-0.05	-0.5 ±0.1	0.155	0.577	0.01	0.1 ±0.0	0.179	0.939
Participant 4.1	10.50	10.75	11.00	10.75	10.50	10.88	10.81	10.75	10.81	10.75	0.06	0.6 ±0.0	0.155	0.577	0.25	2.4 ±0.1	0.179	0.939
Participant 4.2	8.23	8.13	8.10	8.15	8.10	8.31	8.27	8.06	8.21	8.06	0.06	0.7 ±0.0	0.155	0.577	-0.04	-0.5 ±0.0	0.179	0.939
Participant 4.3	11.84	11.63	11.87	11.78	11.63	11.63	11.72	11.84	11.73	11.63	-0.05	-0.4 ±0.0	0.155	0.577	0.00	0.00	0.179	0.939
Participant 4.4	9.59	9.88	9.71	9.73	9.59	9.41	9.44	9.53	9.46	9.41	-0.27	-2.7 ±0.1	0.155	0.577	-0.18	-1.9 ±0.1	0.179	0.939

Note: T1, T2, and T3 represent three trial times. M = Average time across three trials (s); Min = Best performance score across three trials (s); %ΔM = Percent change in average performance; SD = Standard deviation; p-value = significance of pre-post paired t-test (within-subject and one tailed for the three experimental conditions, two tailed for the control group); Raw scores and descriptive statistics (e.g., mean) are reported to two decimal places for clarity. Inferential statistics (e.g., SDs and p-values) are reported to three decimal places to retain statistical accuracy.

Table 2: Pre-Pre-d Post-Intervention Grip Strength Output and Performance Change Across Four Experimental Conditions

	Pre (kg)					Post (kg)												
	T1 ±0.1	T2 ±0.1	T3 ±0.1	M ±0.115	Max ±0.1	T1 ±0.1	T2 ±0.1	T3 ±0.1	M ±0.115	Max ±0.1	Δ M	% Δ M	SD	p-value	Δ Max	% Δ Max	SD	p-value
Group 1											1.42	4.2 ±1.0	2.575	0.176	3.23	9.2 ±2.1	2.629	0.046
Participant 1.1	43.50	42.70	43.00	43.07	43.50	47.10	45.30	37.20	43.20	47.10	0.13	-0.3 ±0.0	2.575	0.176	3.60	8.3 ±0.0	2.629	0.046
Participant 1.2	30.20	25.70	28.40	28.10	28.40	27.70	26.60	29.70	28.00	29.70	-0.10	-0.4 ±0.0	2.575	0.176	1.30	4.6 ±0.0	2.629	0.046
Participant 1.3	39.10	36.90	39.50	38.50	39.50	40.70	36.90	39.00	38.87	40.70	0.37	1.0 ±0.0	2.575	0.176	1.20	3.0 ±0.0	2.629	0.046
Participant 1.4	27.60	28.30	24.80	26.90	28.30	30.40	31.00	35.10	32.17	35.10	5.27	19.6 ±0.1	2.575	0.176	6.80	24.0 ±0.1	2.629	0.046
Group 2											0.03	0.1 ±0.0	3.232	0.494	0.77	2.0 ±0.4	6.217	0.410
Participant 2.1	46.30	44.90	43.30	44.83	46.30	43.40	43.90	44.00	43.77	43.90	-1.06	-2.4 ±0.0	3.232	0.494	-2.40	-5.2 ±0.0	6.217	0.410
Participant 2.2	28.60	31.80	31.20	30.53	31.80	28.60	31.90	28.70	29.73	31.90	-0.80	-2.6 ±0.0	3.232	0.494	0.10	0.3 ±0.0	6.217	0.410
Participant 2.3	46.10	46.10	43.40	45.20	46.10	43.80	41.80	41.80	42.47	41.80	-2.73	-6.0 ±0.0	3.232	0.494	-4.30	-9.3 ±0.0	6.217	0.410
Participant 2.4	32.60	30.10	32.80	31.83	32.80	34.00	42.50	33.10	36.53	42.50	4.70	14.8 ±0.1	3.232	0.494	9.70	29.6 ±0.1	6.217	0.410
Group 3											-0.75	-2.1 ±0.4	0.974	0.110	-0.33	-0.7 ±0.2	1.754	0.368
Participant 3.1	44.80	45.80	40.10	43.57	45.80	43.20	42.50	39.80	41.83	43.20	-1.74	-4.0 ±0.0	0.974	0.110	-2.60	-5.7 ± 0.0	1.754	0.368
Participant 3.2	35.10	34.50	33.90	34.50	35.10	36.30	34.80	34.00	35.03	36.30	0.53	1.5 ±0.1	0.974	0.110	1.20	3.4 ±0.0	1.754	0.368
Participant 3.3	26.50	28.30	28.90	28.90	28.90	21.80	28.50	29.80	26.70	29.80	-1.20	-4.3 ±0.0	0.974	0.110	0.90	3.1 ±0.0	1.754	0.368
Participant 3.4	40.60	37.80	35.80	38.07	40.60	35.00	37.60	39.80	37.47	39.80	-0.60	-1.6 ±0.0	0.974	0.110	-0.80	-2.0 ±0.0	1.754	0.368
Group 4											-1.39	-4.0 ±0.9	2.270	0.308	-0.28	-0.8 ±0.2	2.485	0.839
Participant 4.1	31.30	31.70	29.10	31.70	31.70	30.80	27.80	28.50	29.03	30.80	-1.67	-5.4 ±0.0	2.270	0.308	-0.90	-2.8 ±0.0	2.485	0.839

Participant 4.2	40.70	39.60	39.80	40.03	40.70	43.10	38.80	43.90	41.93	43.90	1.90	4.7 ±0.0	2.270	0.308	3.20	7.9 ±0.0	2.485	0.839
Participant 4.3	27.20	24.20	25.60	25.67	27.20	22.10	24.50	21.80	22.80	24.50	-2.87	-11.2 ±0.1	2.270	0.308	-2.70	-9.9 ±0.1	2.485	0.839
Participant 4.4	44.10	43.40	40.70	42.73	44.10	43.40	37.30	38.70	39.80	43.40	-2.93	-6.9 ±0.0	2.270	0.308	-0.70	-1.6 ±0.0	2.485	0.839

Note: T1, T2, and T3 represent three trial times. M = Mean of output across three trials (kg); Max = Best performance score across three trials (kg); % Δ M = Percent change in average performance; SD = Standard deviation; p-value = significance of pre-post paired t-test (within-subject and one tailed for the three experimental conditions, two tailed for the control group); Raw scores and descriptive statistics (e.g., mean) are reported to two decimal places for clarity. Inferential statistics (e.g., SDs and p-values) are reported to three decimal places to retain statistical accuracy.

Table 3: Summary of Between-Subjects One-Way ANOVAs Across All Tasks

Task	$F(df)$	F_{Crit}	η^2	p-value
Change in Sprint Time (Mean)	F(3,12) = 4.372	3.490	0.522	0.027
Change in Sprint Time (Minimum)	F(3,12) = 8.508	3.490	0.680	0.003
Change in Grip Strength Output (Mean)	F(3,12) = 1.011	3.490	0.202	0.422
Change in Grip Strength Output (Minimum)	F(3,12) = 0.807	3.490	0.168	0.514

Table 4: Post Hoc Test for Change in Time for Sprint Based on Average Time Across Four Experimental Conditions

Pair	Difference	Critical Mean	p-value
G1-G2	0.283	0.438	0.272
G1-G3	0.523	0.438	0.018
G1-G4	0.355	0.438	0.128
G2-G3	0.240	0.438	0.400
G2-G4	0.073	0.438	0.959
G3-G4	0.168	0.438	0.675

Table 5: Post Hoc Test for Change in Time for Sprint Based on Minimum Time Across Four Experimental Conditions

<i>Pair</i>	<i>Difference</i>	<i>Critical Mean</i>	<i>p-value</i>
G1-G2	0.250	0.435	0.362
G1-G3	0.728	0.435	0.002
G1-G4	0.350	0.435	0.132
G2-G3	0.478	0.435	0.030
G2-G4	0.100	0.435	0.902
G3-G4	0.378	0.435	0.097

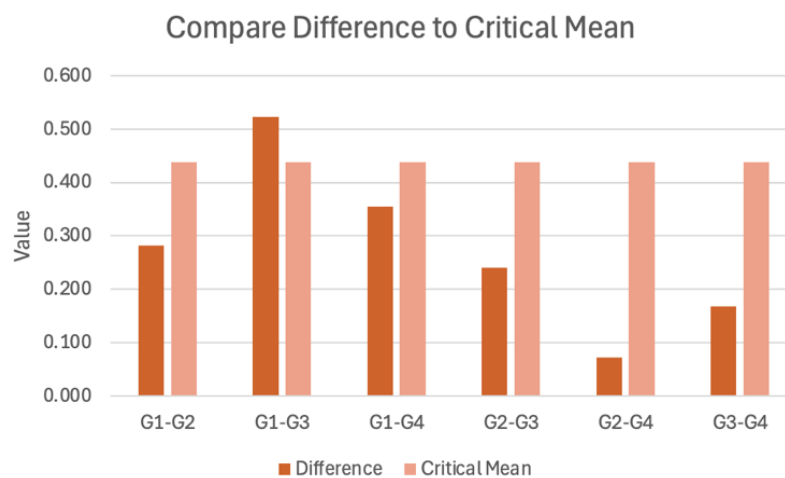


Figure 9. Comparison of Pairwise Mean Differences to the Critical Mean Threshold for Change in Time for Sprint Based on Average Time Across Four Experimental Conditions. This figure illustrates the differences between group means (e.g., G1–G2, G1–G3) in relation to the calculated critical mean difference for statistical significance. Bars in dark orange represent the observed mean differences, while light orange bars denote the critical value. Only the G1–G3 comparison exceeds the threshold, indicating a statistically significant difference; all other group comparisons are not significant.

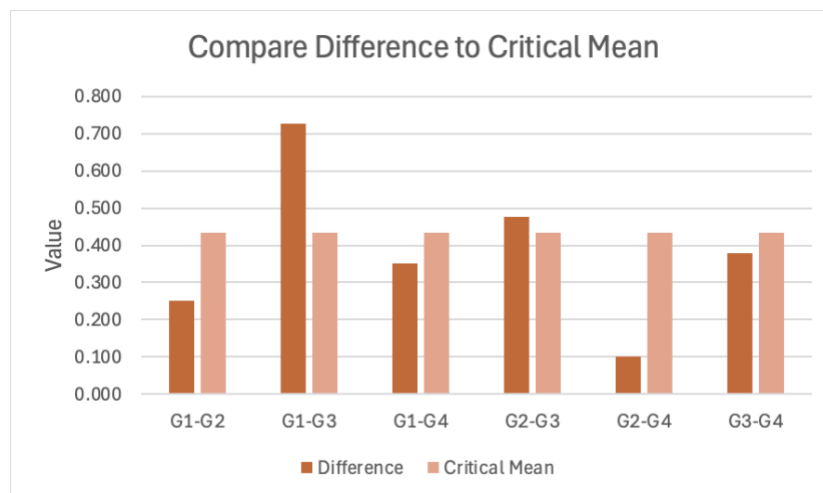


Figure 10. Comparison of Pairwise Mean Differences to the Critical Mean Threshold for Change in Time for Sprint Based on Minimum Time Across Four Experimental Conditions. This figure illustrates the differences between group means (e.g., G1–G2, G1–G3) in relation to the

calculated critical mean difference for statistical significance. Bars in dark orange represent the observed mean differences, while light orange bars denote the critical value. Only the G1–G3 and G2–G3 comparison exceeds the threshold, indicating a statistically significant difference; all other group comparisons are not significant.

Discussions

This research examined the extent to which expectancy induced by placebo or nocebo conditions influences adolescent athletes' explosiveness and muscular strength in anaerobic activities, compared to the effects of an actual performance-enhancing supplement. The findings imply that expectancy alone can significantly influence anaerobic performance, with positive expectancy engendering improvements comparable to actual supplementation, and negative expectancy impairing performance, even overriding the ergogenic effects. Nevertheless, the extent of the expectancy effects is task-dependent, as not all performance domains were equally influenced.

To begin with, the results partially supported the study's first hypothesis, which stated that participants would display measurable improvements in both the 60-meter sprint and grip strength tests. Group 1 exhibited an overall reduction in sprint time across the trials after an ergogenic intervention (*Mean: -0.41 seconds or $-4.0 \pm 0.6\%$, $SD = 0.168$, $p = 0.009$; Minimum: -0.34 seconds or $-3.4 \pm 0.5\%$, $SD = 0.218$, $p = 0.026$). This demonstrates an overall evident reduction in sprint time for all participants in the group. Likewise, though to a lesser extent, Group 2 also displayed a significant reduction of time (*Minimum: -0.12 seconds or $-1.4 \pm 0.1\%$, $SD = 0.092$, $p = 0.038$*), even though with no actual substances to elicit biochemical changes. However, group 2 had a mean change in time of -0.09 seconds or $-1.1 \pm 0.1\%$ when participants' results were compared based on their best results, which was statistically insignificant ($p = 0.129$). This indicates that positive psychological expectancy, manifesting in increased motivation, perceived exertion, and arousal (Figure 4), can be beneficial to explosive anaerobic*

speed performance due to the increased dopaminergic activity and corticospinal tract excitability induced by the placebo effect, though its influence is limited. Nevertheless, the more evident improvement observed in Group 1 reflects a greater extent of influence of the combined effects of direct physiological stimulation from caffeine and taurine and positive expectancy than pure positively mentality manipulation, which aligns with existing research showing that ergogenic aids and belief can work synergistically to boost anaerobic performance (Chhabra & Szabo, 2024). The low standard deviations and statistically significant p-values in both groups further validate the reliability of these changes.

Regarding an isometric muscular strength activity that is more reliant on a concentrated point of upper extremity muscles, group 1's change in output when compared based on the maximum score was significant ($p = 0.046$). Even though some individuals in group 1 had modest increases in the maximum grip strength post-intervention with a mean of 3.23kg or 9.2 $\pm$ 2.1%, the overall average group change was relatively inconsistent ($SD = 2.629$). This indicates a latent physiological effect of caffeine and taurine on isometric muscular output in the upper extremity muscles, though limited. Other than group 1, there were no statistically significant differences within groups across the remaining expectancy and control conditions ($p > 0.05$). This suggests that muscular strength, as an isometric single-joint task, may be less influenced by short-term psychological expectancy than explosive, speed-relevant tasks, possibly due to its reliance on maximal mechanical force production rather than psychological arousal and coordination that is more susceptible to changes in the CNS (Table 2) (Wilhelm et al., 2013).

Altogether, since both groups demonstrated significant improvements from pre- to post-test for the explosive anaerobic performance and neither group showed consistent statistically significant changes, the first hypothesis is partially supported by the results, as it aligns with the

findings regarding explosive anaerobic performance, but not for isometric muscular strength anaerobic performance.

Identical to the first hypothesis, the second hypothesis, which proposed that the group 3 participants would experience a decline in performance for both tasks, was supported for sprint performance, but not for grip strength. Group 3 experienced an increase in the 60-meter sprint time (*Mean: +0.12 seconds or 1.1 ±0.1%, SD = 0.337, p = 0.269; Minimum: +0.39 seconds or 3.8 ±0.3%, SD = 0.272, p = 0.033*). Though the change in time compared based on the average times is not statistically significant, the change based on the best performance was significant ($p = 0.033$). Group 3 participants' time increased after experiencing a negative expectancy manipulation. This displays the detrimental impact of negative expectancy on explosive anaerobic athletic performance, even when an ergogenic substance proven to be beneficial and enhance performance is consumed. The peak performance appears to be more susceptible to the expectancy manipulation under this condition due to reduced motivation and arousal, which may have impaired motor unit recruitment (Figure 6). The fact that negative belief framing overrides the supplement's ergogenic benefits highlights the substantial dominance of psychological perception over physiological input, aligning with neurobiological mechanisms of the amygdala, ACC, and stress hormone levels attributed to the placebo effect (Benedetti et al., 2007). The consistency of the effect is validated by the low standard deviation ($SD = 0.272$). As a result, the second hypothesis is partially supported by the findings.

The third hypothesis, which stated that group 4 participants would demonstrate no statistically significant change in either task, serving as a baseline, was also partially supported. Group 4's performance remained largely stable with no statistically significant pre-post changes for explosive anaerobic performance ($SD = 0.155, p = 0.577; SD = 0.179, p = 0.939$) and

isometric muscular output ($SD = 2.270, p = 0.308$; $SD = 2.485, p = 0.839$). Although no significant changes emerged, the considerable standard deviation values indicate possible extraneous factors at play, which have led to such great variance. This could have been due to the inclusion of outliers, such as participant 4.2's change in the maximum output post-intervention, which could have skewed the results, limiting the accuracy of the data. Therefore, the third hypothesis regarding within-subject analysis is only partially supported.

Regarding between-group comparisons, it was hypothesized that groups 1 and 2 would demonstrate greater improvements across both performance tasks than groups 3 and 4. This was also partially supported by the data. The pattern for improvement or aggravation of performance post-intervention was corroborated by the between-subject analysis (Table 3). ANOVA results showed significant group differences in the change in sprint time when based on the mean and minimum time (*Mean*: $F(3,12) = 4.372, p = 0.027$; *Minimum*: $F(3,12) = 8.508, p = 0.003$), with large effect sizes ($\eta^2 = 0.522$ and 0.680). The eta squared value indicates that 52.2% of the variance in performance changes based on mean time and 68.0% of the variance in performance based on the best performance can be attributed to the differences between groups. The large effect sizes observed strongly suggest that expectancy framing, positive or negative, and ergogenic supplementation accounted for a substantial proportion of variance in anaerobic explosive performance across the four conditions. Group 3 performed significantly worse than both group 2 and group 1, which reinforces the conclusion that negative expectancy can suppress physiological effects to impair physical performance, even when the substance is efficacious. This supports findings by Beedie and Foad (2009), who showed that placebo-induced reductions in performance could match or outweigh the improvements produced by placebo or caffeine ingestion.

Post hoc tests confirmed that group 3 performed significantly worse than group 1 ($p = 0.018$; $p = 0.002$) and group 2 ($p = 0.030$). These findings support the hypothesis in the sprinting task, as groups 1 and 2 experienced an improvement, with group 3 experiencing an increase in time. The statistically significant difference between Group 3 and Group 1 emphasizes the substantial extent to which psychological states can counteract physiological alterations. Participants in Group 3 consumed the same supplement as Group 1 yet underperformed due to the expectation of an adverse effect. This reflects the validity of expectancy and nocebo effects in sport psychology, which posits that an athlete's performance is strongly influenced by their perceived likelihood of success, which is vulnerable to extraneous factors like verbal indications from others. From a neurobiological standpoint, the negativity activates the amygdala and ACC, leading to increased stress and decreased motivation, which compromises overall motor output via a decline in neural recruitment (Benedetti et al., 2007).

Additionally, the qualitative data from surveys further delineated the psychological manipulation's effect. Group 2 participants' high self-reported levels of exertion ($Avg. = 5.00$) and medium-to-high perceived energy post-ingestion and change in performance ($Avg. = 3.75$) indicate a strong placebo effect at play, as they received an inert substance. On the contrary, group 3 participants, despite receiving an actual supplement, reported low perceived performance change ($Avg. = 1.75$) and low energy levels ($Avg. = 1.50$), contradicting the antagonizing effects of caffeine on the adenosine receptors. They also showed signs of low motivation, slower warm-ups, and reduced engagement post-intervention, which was the opposite of group 2, which claimed to "feel less tired after the sprints." Their indifference after the trials and avoidance of reviewing their own results is another behavioral marker of

disengagement and discouragement, demonstrating the effectiveness of the placebo and nocebo effects in influencing adolescents' explosive anaerobic performance.

Nevertheless, as there was no significant difference between groups for post-intervention grip strengths ($p = 0.422$; $p = 0.514$), the between-subjects hypothesis is only somewhat supported.

Practically, these findings underscore the pivotal role of mindset in competitive environments and its fragility among adolescents. Coaches, trainers, and educators should be aware of these psychological effects and implement more positive reinforcement in trainings to foster better performance. The conclusions also suggest that establishing positive belief, confidence, and motivation may be as important as physiological preparation to yield optimal performance from young athletes in explosive anaerobic tasks.

The strengths of the data elevated the confidence of the results that partially supported the hypotheses. Firstly, the use of both the mean and the best (maximum or minimum values) for data analysis allowed for a more nuanced interpretation of sustained versus peak performance changes. This revealed, for example, that some effects (like those in Group 2) were more evident in average effort, while others (like in Group 3) were more pronounced in best performance. Additionally, the balanced sex, ethnicity, and athletic expertise of the sample make it a fair representation of adolescents. By ensuring a diverse participant pool reflective of a broader adolescent demographic, the findings are more generalizable and applicable to real-world youth sport settings, particularly in school-based or recreational athletic contexts. Lastly, the use of a mixed-methods, within- and between-subjects experimental design strengthened the study's internal consistency. The within-subject comparisons helped control for individual variability, while the between-subject analysis highlighted group-level effects of expectancy. This dual

approach enabled more robust conclusions and allowed for the identification of both universal trends and individual sensitivity to expectancy. Together, these methodological choices enhance the study's internal validity, reduce the risk of error, and provide a clearer picture of the psychological and physiological factors influencing anaerobic performance.

However, there are some limitations to the data. It is noteworthy that, while group 1 demonstrated the highest improvement overall, its performance did not differ significantly from the control group. This may imply the limited effect of caffeine and taurine on adolescents. It may also be due to individual variation in response to the supplement, the limited sample size reducing statistical power, or a minor placebo-related performance gain in the control group, as control group is not always “flat” and the act of being in an experiment could be novel to the participants, affecting their performance. These results suggest that while the combined effect of belief and substance may trend toward improvement, it was not consistently greater than baseline performance in this sample. Other covariates, such as sleep, prior athletic ability, and fitness level, that could have influenced the data, were not included in the ANOVA analysis. The exclusion may have skewed the results due to their confounding nature, either exaggerating or masking the effects of expectancy, contributing to Type I and Type II errors. For instance, a participant in group 3 who slept poorly or had a low mood might perform worse even without negative expectancy. This limits the reliability of the data. Another limitation to the current conclusion is the lack of longitudinal data. The cross-sectional nature of the results may be coincidental, as data were only collected at one point in time. Thus, a repeated measure over time could elevate the robustness and validity of the findings by painting a bigger picture for consistency. Finally, though the participants were a heterogeneous group of adolescents, the

limited sample size per group increases group metrics' susceptibility to outlier influences and reduces statistical power.

Considering the strengths and limitations of this study, several suggestions are proposed regarding the methodology's improvement. Firstly, the study did not actively control the break time between trials, introducing inadequate and unstandardized break times between trials. As reflected by some of the participants, the break time between each trial feels insufficient. This could have prevented them from exerting maximum efforts for all trials, confounding the results. For example, currently, the resting period for each participant is dependent on other participants' testing time and walking speed back to the start line for the 60-meter sprint. This elicits various problems. Firstly, the lack of resting time between trials could have contributed to fatigue accumulation. Participants may have also interpreted their tiredness as a sign of supplement inefficacy, affecting their mindset and, consequently, their performance and responses in surveys, which potentially confounded the placebo, nocebo, caffeine, and taurine's effects, mildly blurring the psychological versus physiological contributions. Furthermore, since some groups contain faster runners, the participants receive less resting time due to others' fast completion and recovery time between the trials. Participants may also have purposely walked back slower to gain additional break time, which is slightly unfair to the group with the antithesis. This detail may have compromised the standardized procedure to an extent, introducing bias and limiting the accuracy and validity of the conclusions.

To address this, the break time between each trial should adhere to the recommended recovery duration for anaerobic tasks. Ideally, anaerobic sprints require a minimum of 3 minutes of pure resting to allow phosphocreatine (PCr) resynthesis, which reduces neuromuscular fatigue and reproduces ATP. Imposing a strict 3-minute rest interval between each test trial would

resolve this problem, as supported by ATP-PC system recovery guidelines (Bogdanis et al., 1995; McMahon & Jenkins, 2002). This implementation will ensure a standardized and sufficient resting time across all groups, enabling the participants to physically perform their best for every trial.

Secondly, the exclusion of covariates in the analysis also limits the validity and accuracy of the results. Confounding variables that cannot be fully controlled for, such as prior supplement belief strength, habitual caffeine use, and sleep, were measured via pre-test self-assessments and demographic surveys but were not statistically accounted for in the between-group comparisons. As a result, natural individual differences may have confounded group-level outcomes. For example, in Group 3, Participant 3.3 exhibited a notable decline in grip strength performance from a baseline average of 28.9 kg to a post-intervention average of 26.7 kg, despite being given a real caffeine and taurine supplement. However, this participant also reported very low belief in the effectiveness of performance-enhancing substances and low pre-test confidence, as indicated by their pre-test self-assessment (Figure 5). Without accounting for these psychological variables, within-group variability increases, making it more difficult to detect true effects and increasing the influence of outliers or atypical responses, leading to inaccurate judgment of expectancy and ergogenic effects' efficacy.

The use of ANCOVA (Analysis of Covariance) could be beneficial for statistically controlling the covariates mentioned on the left. Firstly, the variables need to be defined: the dependent variable (DV) is sprint/grip performance, the independent variable (IV) is the group condition, and the covariate is a continuous variable that could influence sprint time, like baseline fitness or belief in ergogenic aids. Before running the analysis, assumptions like linearity between the covariate and DV, as well as homogeneity of regression slopes across

groups, need to be checked. Then, by using a linear model that includes both the treatment group and the covariate, ANCOVA will adjust sprint performance based on the covariate. This could be done in Excel. ANCOVA allows the analysis to isolate the supplementation effect while reducing error variance from individual differences, enhancing the statistical power and interpretability, making the conclusions more reliable (Miller & Chapman, 2001).

Finally, the cross-sectional nature is another limitation of the study. Using data from one-time intervention design limits the ability to assess the influence of psychological and physiological alterations and how they fluctuate in temporal sequences, which could have hastily generalized both factors' extent of influence. Longitudinal design in this case is especially important because such psychological and supplementation effects can vary with repeated exposure. The one-time measurement may overestimate or underestimate the real-world influences. For instance, caffeine tolerance could reduce long-term benefit in Group 1 (Juliano & Griffiths, 2004). Because of the cross-sectional limitation, it is unclear if psychological manipulations could outweigh such tolerance in the long run, limiting the extent to which the research question can be answered with.

Ideally, this limitation can be addressed by using a longitudinal or repeated-measures design. The method would be similar. However, it would be repeated multiple times, exposing the participants to their conditions over a week or even a month. This would help answer the question to a more detailed and sophisticated level (Benedetti et al., 2005).

Future research could explore the long-term effects of repeated expectancy exposure by implementing multi-session interventions to examine whether placebo or nocebo effects persist, strengthen, or diminish over time. Even though the current caffeine and taurine combination is stronger than pure positive expectancy itself, whether an identical influence will persist due to

tolerance is relatively unknown. Additionally, this study only examined the psychological and physiological effects on anaerobic tasks, specifically explosiveness and muscular strength. Further investigation could expand into more domains, such as aerobic and more skill-dependent tasks like archery. These extensions could contribute more to elucidating the overall expectancy and ergogenic effects.

Conclusions

Overall, this study demonstrates that psychological expectancy and ergogenic supplementation can significantly modulate anaerobic performance in adolescents, with sometimes the psychological alterations being more dominant and pronounced over mere biochemical changes: this is manifested to a greater extent in tasks requiring explosiveness, likely due to their higher dependence on the CNS, than tasks tailored to isometric muscular strengths. Additionally, the significant improvement in both within- and between-subject analysis for group 1 points towards a possible synergistic effect of expectancy and ergogenic aid, where the combination of positive belief and active substance yields the most notable performance improvements, although a larger sample is required to strengthen this conclusion and explore its consistency. These findings have real-world implications for youth sports in training and competitions, where mental framing and athlete perception could be as determining as the nutrition and supplements themselves.

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Appendix

Appendix A

Full Name: _____

Date: _____

Please answer the following questions honestly.

Section 1: Demographics

1. **Age:** _____ years old
2. **Gender:** ☐ Male ☐ Female ☐ Other ☐ Prefer not to say
3. **Height:** _____ cm
4. **Weight:** _____ kg
5. **Ethnicity:** ☐ Asian (e.g., Chinese, Japanese, Korean, Filipino, etc.) ☐ Black or African
☐ White / European ☐ Hispanic or Latino/a/x ☐ Middle Eastern or North African ☐
 Indigenous / First Nations ☐ Mixed / Multiple ethnicities
6. **Nationality:** _____

Section 2: Physical Activity

5. Do you currently participate in regular physical activity or sports at least **two times per week**?
☐ Yes ☐ No
6. Please list the sports or types of exercise you participate in:

Section 3: Caffeine Use

7. Do you consume caffeine regularly (e.g., coffee, tea, soda, energy drinks)?
☐ Yes ☐ No
8. If yes, approximately how much caffeine do you consume per day?
 (e.g., 1 cup of coffee = ~100 mg, 1 energy drink = ~80 mg)
☐ Less than 100 mg/day
☐ 100–300 mg/day
☐ More than 300 mg/day

Section 4: Health and Medical History

9. Have you ever been diagnosed with any of the following medical conditions? (Check all that apply)
☐ Heart condition (e.g., arrhythmia, hypertension)
☐ Anxiety disorder or panic attacks

- ☐ Asthma or respiratory issues
☐ Neurological disorders
☐ None of the above

10. Are you currently taking any medications that affect your nervous system (e.g., ADHD medication, antidepressants)?

☐ Yes ☐ No

11. Do you have a known allergy or sensitivity to caffeine or any supplements?

☐ Yes ☐ No

Section 5: Study Preparation Agreement

12. Are you willing to:

- Get 7–9 hours of sleep the night before testing
- Avoid caffeine stimulants and alcohol for 24 hours before testing
- Record your meals within 48 hours before testing
- Stay hydrated (500 mL of water before testing)
- Refrain from intense physical activity the day before testing

☐ Yes ☐ No

Inclusion Criteria:

Criteria	Justification
Age 14–18 years old	Keep a relatively narrow age range (adolescents) so biological development stages are more consistent, such as muscle strength and metabolism
Currently active in sports or regular exercise (≥ 2 x/week)	Ensures participants have baseline neuromuscular fitness, reducing performance variability due to sedentary lifestyles
No known caffeine allergies or hypersensitivity	Ensures safety when ingesting caffeine pills
No current injury or medical condition affecting physical performance	Prevents pre-existing conditions (e.g., sprains, muscle pulls, asthma) from affecting sprint or grip test outcomes
No history of heart conditions, hypertension, or anxiety disorders	Caffeine can overload the sympathetic nervous system, thus exacerbating cardiovascular or psychological issues
Not currently consuming caffeine supplements regularly	Avoids tolerance effects, as habitual caffeine users might not respond the same way as users relatively new to caffeine. High tolerance may mask the effects of a single 100 mg dose
No current use of medications that affect CNS (e.g., ADHD medications, antidepressants)	These can interact with caffeine and affect arousal, performance, and placebo/nocebo effects

Willing to refrain from stimulants, alcohol, and unusual physical activity for 24h before testing	To protect the control of external variables affecting performance and mood
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Appendix B

Standardized Scripts:

Group 1: Told Caffeine and Taurine, Given Caffeine and Taurine

“This tablet contains 100 mg of caffeine and/or taurine, a performance-enhancing compound. According to a large number of studies and research, caffeine has been shown to significantly improve alertness, reaction time, and muscular power. Please take the tablet and swallow it with water. You will then have a 50-minute break.”

Group 2: Told Caffeine and Taurine, Given Placebo

“This tablet contains 100 mg of caffeine and/or taurine, a performance-enhancing compound. According to a large number of studies and research, caffeine has been shown to significantly improve alertness, reaction time, and muscular power. Please take the tablet and swallow it with water. You will then have a 50-minute break.”

Group 3: Told Placebo, Given Caffeine and Taurine

“This tablet is inert, which means that it contains no active ingredients. It’s only made of starch. It will NOT enhance or impair your physical performance. If you experience any effect, it is likely due to natural variation. You receive this tablet due to the study’s requisition to ensure fairness and impartiality. Please take the tablet and swallow it with water. You will then have a 50-minute break.”

Group 4: Told Placebo, Given Placebo

“This tablet is inert, which means that it contains no active ingredients. It’s only made of starch. It will NOT enhance or impair your physical performance. If you experience any effect, it is likely due to natural variation. You receive this tablet due to the study’s requisition to ensure fairness and impartiality. Please take the tablet and swallow it with water. You will then have a 50-minute break.”

Appendix C

Sleep/Meal Log Book

Section	Specific Question	Participant Response
Sleep - 48 hours (2 days) before testing date	Please indicate the time you went to bed:	
	Please indicate the time you woke up:	
	Please estimate the total hours of sleep:	
	Did you wake up during the night? (Yes/No)	
	If yes, how many times and why?	
	Rate your sleep quality (1 = Very Poor, 5 = Excellent)	
Sleep - 24 hours (the night) before testing date	Please indicate the time you went to bed:	
	Please indicate the time you woke up:	
	Please indicate the total hours of sleep:	
	Did you wake up during the night? (Yes/No)	
	If yes, how many times and why?	
	Rate your sleep quality (1 = Very Poor, 5 = Excellent)	
Meal Log - Breakfast On the Testing Date	Time of meal:	
	Food consumed (please give the best estimate of the amount you consumed too, e.g., white rice ~200g)	
	Is this what you usually eat (Yes/No)	
Meal Log - Lunch On the Testing Date	Time of meal:	
	Food consumed (please give the best estimate of the amount you consumed too, e.g., white rice ~200g)	
	Is this what you usually eat (Yes/No)	
	Did you drink 500 mL of water in the 2–3 hrs before testing? (Yes/No)	
Substance & Activity Check	Did you consume any caffeine in the past 24 hrs? (Yes/No)	
	Did you take any medications in the past 24 hrs? (Yes/No)	
	Did you perform any intense physical activity in the past 24 hrs? (Yes/No)	

Appendix D**Pre-Test Survey (Before taking the tablet)****Likert Scale Questions (1 = Strongly Disagree, 5 = Strongly Agree)**

I feel physically prepared to perform my best. _____

I feel mentally focused and ready. _____

I believe in performance-enhancing supplements. _____

I feel confident about my upcoming performance. _____

I am aware of how supplements can affect physical performance. _____

Post-Test Survey (After both tests are complete)**Likert Scale Questions (1 = Strongly Disagree, 5 = Strongly Agree)**

I believe I performed better than usual today. _____

I felt more energetic or focused after taking the supplement. _____

I noticed a difference in my performance because of the supplement. _____

I believe my mindset affected my performance. _____

I gave maximum effort during the tests. _____