Study Protocol

Effects of Caffeine Capsule Supplementation Combined With Tour Tempo Music on Golf-Specific Skill Performance Under Mental Fatigue

A Randomised, Placebo-Controlled, Double-Blind, Crossover Trial

1. Background and rationale

Mental fatigue can impair sport-specific skill performance, particularly tasks requiring sustained attention, executive control, movement timing and fine motor accuracy. Golf performance involves both high-speed full-swing actions and precision-based putting. Caffeine is a widely used ergogenic aid and may support alertness, perceived effort and performance under fatigue. Tour Tempo music is designed to support rhythmic timing during golf actions and may influence attentional focus, arousal and movement consistency. This trial will examine the acute and combined effects of caffeine capsule supplementation and Tour Tempo music on golf-specific performance after experimentally induced mental fatigue.

2. Objectives and hypotheses

2.1 Primary objective

To determine the acute effects of caffeine capsule supplementation, Tour Tempo music, and their interaction on golf-specific skill performance after experimentally induced mental fatigue in amateur male golfers.

2.2 Secondary objectives

- To examine whether the combined caffeine plus music condition provides additive or synergistic benefits compared with either condition alone.
- To evaluate changes in perceived mental fatigue, perceived exertion and affective state across the experimental procedure.
- To explore whether changes in performance are associated with movement-related measures recorded using inertial sensors.

2.3 Hypotheses

- The mental-fatigue induction task will increase subjective mental fatigue.
- Caffeine and Tour Tempo music will each attenuate the detrimental effects of mental fatigue on golf-specific skill performance.
- The combined caffeine plus music condition will produce the greatest improvement in performance relative to placebo plus no music.
- Performance changes will be associated with changes in movement stability and trunk-related inertial sensor variables.

3. Trial design

This is an acute, randomised, placebo-controlled, double-blind, four-condition crossover trial using a 2 x 2 factorial design. The two factors are capsule condition (caffeine vs placebo) and audio condition (Tour Tempo music vs no music). Each participant will complete all four experimental conditions, with the order of conditions randomised and counterbalanced across participants. A washout period of at least 7 days will separate consecutive experimental visits.

Condition code	Experimental condition
A	Caffeine capsule + Tour Tempo music
B	Caffeine capsule + no music
C	Placebo capsule + Tour Tempo music
D	Placebo capsule + no music

The caffeine-capsule experiment will last approximately five weeks for each participant. Week 1 will be used for familiarisation, anthropometric/body-composition assessment and baseline golf-performance testing. Weeks 2 to 5 will comprise four formal experimental visits, with one randomised crossover condition completed per week and a washout period of at least 7 days between consecutive treatment conditions. If required because of equipment capacity, participants may be tested across Wednesday, Thursday and Friday mornings within each experimental week; each participant will be scheduled in the same morning time window as consistently as possible to reduce circadian and caffeine-response variability.

4. Study setting

Testing will be conducted in a controlled indoor golf environment. Full-swing performance will be assessed using the same indoor golf simulator and standardised simulator settings across all visits. Putting performance will be assessed on a flat artificial putting surface. Environmental conditions, including testing location, lighting, noise and general room conditions, will be kept as consistent as practicable across visits.

5. Participants

5.1 Eligibility criteria

Participants will be amateur male golfers with stable golf practice experience and recent 18-hole scoring performance approximately within the range of 90 to 100 strokes over the previous 3 to 5 rounds. Participants must be aged 18 years or older, have normal or corrected-to-normal vision, have no colour blindness that would interfere with the Stroop task, report low habitual caffeine intake, and be free from acute injuries that would affect swing or putting performance.

5.2 Exclusion criteria

- Known allergy, marked intolerance or medical contraindication to caffeine.
- Cardiovascular conditions that make caffeine intake or golf testing inappropriate, including arrhythmia or uncontrolled hypertension.
- Neurological conditions or symptoms that may affect safety or performance, including epilepsy, frequent migraine or other relevant neurological symptoms.
- Recent musculoskeletal injury affecting the shoulder, elbow, wrist, lower back or other body regions involved in golf actions.
- Current use of medication that substantially affects central nervous system function, heart rate, alertness or motor performance.
- Hearing impairment that prevents standardised audio delivery through headphones.

6. Randomisation and allocation concealment

Randomisation will be performed at the level of treatment sequence because this is a crossover trial in which each participant receives all four conditions. A balanced Latin-square/Williams-type sequence will be used to counterbalance treatment order and reduce period and carryover effects. The four treatment sequences will be:

Sequence	Order of conditions

Sequence	Order of conditions
Sequence 1	A -> B -> D -> C
Sequence 2	B -> C -> A -> D
Sequence 3	C -> D -> B -> A
Sequence 4	D -> A -> C -> B

After completion of Week 1 baseline testing and assignment of a unique participant identification code, an independent researcher who is not involved in outcome assessment will generate the random sequence allocation using an online randomisation tool (random.org) or an equivalent computer-generated random number procedure. Participants will be assigned to one of the four sequences in approximately equal numbers. The allocation list will be kept in a password-protected file by the independent researcher. If paper allocation is used, sequentially numbered, opaque, sealed envelopes will be prepared and opened only after the participant has been enrolled, baseline eligibility has been confirmed and the participant identification code has been assigned.

The randomisation list will determine both the capsule condition and the music condition for each visit. The capsule code will be linked to the participant visit number by the independent researcher responsible for capsule preparation. Outcome assessors and participants will not have access to the capsule code during data collection.

7. Blinding

The caffeine/placebo capsule component will be double-blind. Caffeine and placebo capsules will be identical in external appearance and will be prepared and labelled by an independent researcher according to the randomisation schedule. Participants and testing staff responsible for administering tests and recording outcomes will be blinded to capsule condition. The audio condition cannot be fully blinded because participants can perceive whether music is playing; however, all participants will wear the same Bluetooth headphones for the same duration in both music and no-music conditions to control for the experience of wearing headphones, environmental isolation and procedural ritual. At the end of each experimental condition or during follow-up, participants will complete a blinding guess for capsule condition and will report adverse effects.

8. Interventions

The interventions are described according to the main elements of the TIDieR framework: what is delivered, who delivers it, how it is delivered, where it is delivered, the dose and timing, and how fidelity is maintained.

8.1 Caffeine capsule supplementation

Participants will ingest caffeine at a dose of 3 mg/kg body mass. The dose for each participant will be calculated using body mass measured at the familiarisation or baseline visit. The caffeine will be administered in capsule form with water approximately 60 minutes before the start of the formal golf-specific skill tests. The Stroop mental-fatigue task and subsequent audio/warm-up period will occur during the caffeine absorption period.

Caffeine capsules will be prepared using commercially available caffeine material (Nutricost, USA) and weighed using an appropriate precision scale. Capsules will be unmarked and identical in appearance to placebo capsules. Where needed, a food-grade inert filler will be used to standardise capsule appearance and handling. Capsule preparation, coding and dispensing will be completed by an independent researcher who is not involved in performance testing or outcome assessment.

8.2 Placebo capsule

The placebo condition will involve ingestion of identical capsules containing Nutricost maltodextrin, with each capsule containing 200 mg of maltodextrin and no caffeine. Maltodextrin was selected as an inert food-grade placebo substance. The placebo capsules will be matched to the caffeine capsules in appearance, capsule size, colour, and administration procedure as closely as possible. Participants will ingest the placebo capsules with

water at the same time point and under the same procedures as the caffeine capsules, approximately 60 minutes before the golf performance tests.

8.3 Tour Tempo music intervention

The music intervention will use Tour Tempo software or app-based audio suitable for golf tempo training. Each participant will select or provide one fixed preferred motivational Tour Tempo track before the experimental visits. The selected track will remain the same for that participant across all music-condition visits. Music will be delivered through standardised Bluetooth headphones for 15 minutes. Volume will be standardised using a fixed device setting or a target sound-pressure range calibrated with a smartphone decibel application, as appropriate for the testing environment.

8.4 No-music audio control

In the no-music condition, participants will wear the same Bluetooth headphones for the same 15-minute period, but no music will be played. This procedure controls for headphone wearing, environmental isolation, participant expectancy related to the testing routine, and the time spent before performance testing.

8.5 Standardisation and intervention fidelity

- All visits will use the same timing structure, equipment and testing order.
- Participants will be asked to maintain consistent sleep, diet and training habits before each visit and to avoid caffeine before testing; compliance will be checked at arrival.
- On each formal experimental visit, participants will consume a standardised breakfast at approximately 07:00 consisting of two slices of bread and 250 mL of milk, before arriving at the testing venue at approximately 08:00. The same breakfast procedure will be used across the four formal experimental visits where practicable.
- The same music track, audio device and headphones will be used for each participant across relevant visits where possible.
- All capsule administration, Stroop task duration, audio duration and testing procedures will be recorded on a session checklist.
- Any deviations, missed visits, adverse events or non-compliance will be documented.

9. Mental-fatigue induction and manipulation checks

Mental fatigue will be induced using a 30-minute Stroop task dominated by incongruent trials and continuous responses. This task is intended to impose sustained executive-control demands. Subjective mental fatigue will be assessed using a 0 to 100 visual analogue scale at baseline before the Stroop task, after the Stroop task, after the audio/warm-up period and after the golf-specific skill tests. Rating of perceived exertion and affective state will also be recorded at the predefined time points.

10. Outcomes

10.1 Primary outcomes

The primary outcome domain is golf-specific skill performance under mental fatigue. Primary performance outcomes will include:

- Putting accuracy, operationalised primarily as mean radial error, calculated as the Euclidean distance between the final resting position of the ball and the centre of the target hole.
- Full-swing performance measured in the indoor golf simulator, including shot distance, clubhead speed and ball speed for standardised 7-iron and driver trials.

10.2 Secondary and exploratory outcomes

- Putting success rate, left-right error, short-long error, bivariate variable error, and the standard deviations of lateral and longitudinal putting errors.
- Mental-fatigue visual analogue scale scores, rating of perceived exertion and Feeling Scale scores across the visit.
- Adverse reactions during the visit and 24-hour follow-up, including palpitations, nausea, anxiety, tremor, headache or other symptoms reported by participants.
- Participant blinding guesses for capsule condition.
- ZZT putting-trainer-derived variables collected during the two Week 1 baseline putting sessions may be used to assess test-retest reliability and preliminary measurement validity/feasibility of the putting measurement procedure.

11. Golf-specific testing procedures

11.1 Putting task

Participants will perform putting on a flat artificial putting surface toward a target located 9.14 m (10 yards) from the starting point. Participants will wear the ZZT putting training device during all baseline and experimental putting assessments. The final resting position of each ball will be recorded as two-dimensional coordinates relative to the centre of the hole. The x value will represent left-right error and the y value will represent short-long error. These coordinates will be used to calculate mean radial error and additional measures of accuracy and variability. At each formal experimental visit, participants will complete 20 putts, with the same number of trials and the same target distance used across all four conditions. During Week 1, each participant will complete the same 20-putt putting task on two separate baseline sessions while wearing the ZZT putting training device. These two baseline sessions will be used to assess test-retest reliability and preliminary measurement validity/feasibility of the ZZT putting-trainer-derived data, because the device is a Chinese-developed product with limited published validation evidence.

11.2 Full-swing simulator task

Full-swing performance will be measured using the same indoor golf simulator, equipment and simulator settings across visits. During Week 1, each participant will complete one baseline full-swing test using the same testing procedures. During each formal experimental visit, participants will complete standardised shots using a 7-iron and a driver. For each club, five valid shots will be recorded where possible. The main simulator-derived variables will include shot distance, clubhead speed and ball speed.

12. Visit schedule

Participants will complete a five-week caffeine-capsule trial schedule consisting of a Week 1 baseline and familiarisation phase followed by four formal experimental visits in Weeks 2 to 5. The Week 1 procedures will be conducted before randomisation to intervention sequence is implemented for the formal crossover visits.

12.1 Week 1 baseline and familiarisation phase

During Week 1, participants will be screened and familiarised with the study procedures. The research staff will explain the experimental protocol and precautions, collect participant names separately for administrative purposes, and assign a unique study identification code for randomisation and anonymised data management.

Procedure	**Details**
Consent, screening and study briefing	Provide the participant information sheet, obtain written informed consent, explain the protocol, testing procedures and precautions, and confirm eligibility.
Anthropometry and body composition	Measure body mass, BMI and height using a Huawei body-composition device and/or standard height measurement procedure. Body mass will be used to calculate the individual 3 mg/kg caffeine dose.
Baseline questionnaire	Complete baseline questionnaires, including the SAS-2 sport anxiety scale.
Participant identification	Assign each participant a unique study identification code before randomisation and store identifiable information separately from outcome data.
Baseline putting session 1	Complete 20 putts on the flat artificial putting surface at 10 yards while wearing the ZZT putting training device.
Baseline putting session 2	Repeat the 20-putt task on a separate day within the same week while wearing the ZZT putting training device, to assess test-retest reliability and preliminary measurement validity/feasibility.
Baseline full-swing test	Complete one baseline indoor-simulator test: five valid 7-iron shots and five valid driver shots.

12.2 Formal experimental visits in Weeks 2 to 5

During Weeks 2 to 5, each participant will complete one of the four randomised crossover conditions per week. Formal experimental visits will be scheduled in the morning and, if needed, distributed across Wednesday, Thursday and Friday to manage equipment capacity while keeping the time of day consistent. The intended visit duration is approximately 07:00 to 12:00, including standardised breakfast, arrival procedures, supplementation, mental-fatigue induction, audio/warm-up intervention and golf-specific performance testing.

Step	Procedure	Details
1	Standardised breakfast	At approximately 07:00, consume a standardised breakfast consisting of two slices of bread and 250 mL of milk at the canteen or testing venue.
2	Arrival and compliance check	Arrive at approximately 08:00; confirm caffeine abstinence, sleep, diet, training and absence of contraindications; record baseline VAS, RPE and Feeling Scale.
3	Capsule ingestion	Ingest caffeine or placebo capsule with water under double-blind conditions.
4	Mental-fatigue induction	Complete the 30-minute Stroop cognitive task.
5	Manipulation check	Record VAS mental fatigue, RPE and Feeling Scale.
6	Audio/warm-up period	Complete the 15-minute Tour Tempo music or no-music headphone control while performing a standardised warm-up.
7	Pre-test check	Record VAS mental fatigue, RPE and Feeling Scale.
8	Putting performance test	Complete the standardised 20-putt task on the artificial putting surface at 10 yards while wearing the ZZT putting training device.
9	Full-swing simulator test	Complete standardised indoor-simulator shots: five valid 7-iron shots and five valid driver shots.
10	Post-test measures	Record post-test VAS mental fatigue, RPE and Feeling Scale; the formal visit is expected to finish at approximately 12:00.
11	24-hour follow-up	Record adverse reactions and capsule-condition blinding guess one day after the visit.

13. Sample size

The sample size for the four-condition capsule crossover experiment was estimated a priori using G*Power 3.1 based on a repeated-measures ANOVA within-participant design. Parameters were set as follows: effect size f = 0.31, alpha = 0.05, power = 0.80, four repeated measurements, assumed correlation among repeated measures = 0.50, and nonsphericity correction epsilon = 1. This calculation indicated that at least 16 participants completing all four conditions would be required to achieve the planned statistical power. Therefore, this caffeine-capsule

trial will aim to include 16 amateur male golfers who complete the Week 1 baseline/familiarisation phase and all four formal experimental visits. If a participant withdraws or fails to complete the crossover schedule, a replacement participant may be recruited where feasible and in line with the ethics approval and ISRCTN record.

14. Data management

Each participant will be assigned a unique study identification code during Week 1 before randomisation. Participant names and contact information will be collected only for administrative scheduling and follow-up purposes and will be stored separately from outcome data. Identifiable information will be stored separately from body-composition, questionnaire, ZZT putting-trainer, simulator and performance data. Data will be recorded using standardised case-report forms and/or electronic spreadsheets with restricted access. Data entry will be checked for completeness, implausible values and consistency across visits. Protocol deviations, missing data, adverse events and withdrawals will be documented. Only authorised members of the research team will have access to the identifiable study files.

15. Statistical analysis plan

The primary analyses will be conducted using Bayesian linear mixed-effects models, for example using the brms package in R. Separate models will be fitted for continuous performance outcomes. Fixed effects will include capsule condition (caffeine vs placebo), audio condition (music vs no music), their interaction, testing period and intervention sequence/order to account for possible learning, period and order effects. Baseline sport anxiety, measured using the SAS-2 questionnaire, may be included as a covariate. Participant will be included as a random effect to account for repeated measurements within individuals. Model results will be reported as posterior estimates with 95% credible intervals and posterior probabilities for the direction of effects. Model convergence and quality will be assessed using R-hat, effective sample size and posterior diagnostic plots. Binary outcomes such as putt success rate may be analysed using appropriate Bayesian generalised mixed-effects models. Missing data will be described, and analyses will use all available valid observations under the assumptions of the selected mixed model.

16. Safety monitoring and stopping rules

Caffeine at the proposed dose may cause adverse symptoms including palpitations, nausea, anxiety, tremor, headache, sleep disturbance or gastrointestinal discomfort. Participants will be screened for contraindications before enrolment and will be reminded that participation is voluntary. Testing will be stopped if a participant reports significant discomfort, requests to stop, experiences symptoms that raise safety concerns, or if the research staff judge that continuation would be inappropriate. Adverse events will be recorded during each visit and at the 24-hour follow-up. Participants will be advised to seek medical care if any concerning symptoms persist after the session.

17. Ethics and consent

The study will be conducted in accordance with the approved ethics application and relevant institutional guidelines. Participants will receive an information sheet explaining the study purpose, procedures, potential risks and benefits, confidentiality arrangements and the voluntary nature of participation. Written informed consent will be obtained before any study-specific procedures. Participants may withdraw at any time without penalty.

18. Dissemination

The results may be disseminated through academic journal publication, conference presentation and/or registration record updates. No individual participant will be identifiable in any dissemination materials.

Appendix A. Short text for ISRCTN editorial response

Randomisation: Participants will be randomised to a counterbalanced order of the four crossover conditions using a balanced Latin-square/Williams-type sequence. An independent researcher who is not involved in outcome assessment will generate the allocation using random.org or an equivalent computer-generated random number procedure. Participants will be assigned to the four sequences in approximately equal numbers. Allocation will be concealed using a password-protected allocation list held by the independent researcher, and if paper allocation is used, sequentially numbered opaque sealed envelopes will be prepared. The caffeine/placebo capsule code will be concealed from participants and testing staff until data collection is complete.

Intervention: This registration concerns the caffeine-capsule experiment only. The caffeine-capsule trial will last approximately five weeks for each participant. Week 1 will include body-composition and anthropometric assessment, SAS-2 baseline questionnaire completion, two baseline 20-putt sessions wearing the ZZT putting training device for reliability and preliminary measurement-validity/feasibility assessment, and one baseline full-swing simulator test consisting of five 7-iron shots and five driver shots where possible. Weeks 2 to 5 will involve four formal crossover visits in randomised order: caffeine capsule plus Tour Tempo music, caffeine capsule plus no music, placebo capsule plus Tour Tempo music, and placebo capsule plus no music. Consecutive conditions will be separated by at least 7 days. Each formal visit will use a standardised morning schedule, including a standardised breakfast at approximately 07:00, arrival and compliance checks at approximately 08:00, capsule ingestion, a 30-minute Stroop task, a 15-minute Tour Tempo music or no-music headphone-control period with standardised warm-up, a 20-putt test at 10 yards while wearing the ZZT putting training device, and indoor-simulator testing using a 7-iron and driver. Caffeine will be administered as a 3 mg/kg body-mass dose in capsules approximately 60 minutes before performance testing. Placebo capsules will be identical in appearance and will contain Nutricost maltodextrin without caffeine. All sessions will follow the same testing order and timing structure, and 24-hour follow-up will record adverse reactions and capsule-condition blinding guesses.