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Influence of environmental pressure and inhibitory control capacity on anxiety, mental workload and shooting performance in multitasking basketball contexts

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ABSTRACT

Background: Basketball shooting performance is crucial for match outcomes, often influenced by environmental pressure and anxiety. This study investigates how increased task demands and outcome consequences affect anxiety, mental workload, and shooting performance in multitasking basketball contexts. Additionally, it examines the moderating role of inhibitory control (IC) on these effects.

Methods: Thirty-nine youth basketball athletes (26 males and 13 females; age 14.9 ± 1.3 years) participated in two experimental sessions with varying levels of environmental manipulation: Low Environmental Manipulation (LEM) and High Environmental Manipulation (HEM), differing in the cognitive-motor complexity of the task and the consequences associated with performance outcomes. An intrasubject, repeated measures design was used, where participants performed multitasking activities involving dribbling and shooting under different rules and scoring systems. Anxiety, mental workload, and shooting performance were measured, along with participants' baseline IC.

Results: The HEM condition significantly increased anxiety ($p < 0.001$) and mental workload ($p < 0.001$) compared to the LEM condition, leading to a notable decrease in shooting performance ($p < 0.001$). Participants with higher IC exhibited better performance ($p = 0.007$ for LEM, $p = 0.046$ for HEM) and lower mental workload. Regression analyses indicated that cognitive-motor performance accuracy ($p = 0.016$) and mental activity ($p = 0.004$) were significant predictors of shooting performance and state anxiety ($p < 0.001$).

Conclusions: Environmental pressure, through increased task demands and outcome consequences, elevates anxiety and mental workload, negatively impacting basketball shooting performance. Higher IC moderates these effects, suggesting that athletes with better inhibitory abilities can maintain performance under pressure. These findings highlight the importance of designing training programs that simulate competitive pressure and develop athletes' cognitive control capacities.

1. Introduction

The most decisive motor action within basketball is shooting the ball with its efficiency the key to match outcome (Cabarkapa et al., 2022). Success in action is inevitably associated with the possibility of obtaining the reward of scoring points leading to the player's perception of risk and performance pressure and resulting in increased anxiety (Vencúrik et al., 2022). For example, free throw success or performance has been

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reported consistently to worsen as the end of a close basketball match approaches (Goldschmied et al., 2022; Toma, 2017). The effect by which an athlete may experience a sudden deterioration in performance is called "choking under pressure" (Beilock & Carr, 2001; DeCaro et al., 2011) or "asphyxia under pressure" (Beilock & Gray, 2007), and has been identified as one of the main causes by which individuals may not reach their true potential.

In the experimental setting, the effect of pressure on sports performance has been explained through the mediating role of the resulting anxiety (Nieuwenhuys & Oudejans, 2017). State anxiety has been considered a reliable indicator of pressure during sporting performances (Gucciardi et al., 2010; Mesagno & Mullane-Grant, 2010). Consequently, the interaction between the anxiety state derived from pressure and athlete performance has received prominent attention (Eysenck & Wilson, 2016; Nieuwenhuys & Oudejans, 2012), particularly in basketball shooting (Goldschmied et al., 2022). Anxiety is considered a trigger for neurobiological and psychological responses that negatively affect cognition and performance (Nieuwenhuys & Oudejans, 2017). These associated physiological and behavioural responses have been consistent predictors of the level of stress experienced by athletes during sport's competition (Arruda et al., 2014, 2018; Moreira et al., 2013, 2018).

To model and understand the effects of pressure on performance in laboratory settings, researchers have manipulated tasks, performers and the environment in various ways (Stoker et al., 2016). Despite this work, the factors that generate pressure have yet to be clarified (Kent et al., 2018; Low et al., 2023). There is some consensus on the need to increase the consequences of participant performance through the use of rewards, punishments and judgements (e.g., being evaluated) to generate anxiety states (for a more comprehensive review, see Kegelaers & Oudejans, 2024). However, coaches routinely use other strategies to induce athlete stress, such as increasing task demands through difficulty or noise (Stoker et al., 2016). When analyzing the potential impact of manipulating consequences, either in isolation or in combination with manipulating task demands, results have been mixed (Mesagno et al., 2015). For example, Stoker et al. (2017, 2019) reported that isolated manipulation of demands had no impact on pressure, although it did impact performance. DeCaro et al. (2011) reported that increased difficulty through addition of secondary tasks (dual tasks) had no adverse effects on performance in learning tasks requiring low executive attention-dependent skills, but these did impair learning tasks requiring more working memory and attention. In contrast, Henderson et al. (2024) reported that task difficulty and time pressure separately increased pressure and decreased participants' sports performance. However, high-pressure situations are often composed of all of these elements (Kegelaers & Oudejans, 2024). Under combined pressure situations, participants performed worse in batting skills within golf and baseball (Gray, 2004). The impact of repeated exposure to these cognitive-motor demands immediately before motor execution is not yet fully established. This aspect is particularly relevant in interaction sports, where athletes must simultaneously respond to multiple stimuli under pressure.

Potentially discrepancies between prior studies may be attributed to the simplicity and lack of representativeness of the tasks used in experiments (e.g., laboratory tasks simple motor actions), in contrast to the inherent complexity of authentic sport tasks (Kent et al., 2018). One of the main factors for the lack of ecological validity within laboratory settings is the lower intensity of the situations compared to real sport competition (Christensen et al., 2015). In this regard, contexts in which high cognitive demands interact with high consequences associated with performance could help create more realistic scenarios, fostering the activation of similar cognitive mechanisms essential for adaptive decision-making in sport (Winkelman, 2020).

Additionally, verifying the magnitude of the actual laboratory stress experienced by the athlete would also be needed to ensure that it meets the conditions that occur in competition (Kivlighan & Granger, 2006). Salivary alpha-amylase (sAA) has been utilised as an objective, rapid and non-invasive biomarker of the sympathetic nervous system (Rohleder & Nater, 2009) and stress experienced (for more information, see Dehghan et al., 2019). Previous research has reported a positive link between elevated sAA levels and anxiety under stressful conditions during sports competition (Koibuchi & Suzuki, 2014; Rutherfurd-Markwick et al., 2017), including basketball (Arruda et al., 2018). Its ability to identify psychological or physical stress makes it a relevant tool for assessing psychophysiological demands experienced by athletes in the sporting environment (Foretic et al., 2020).

While verification of stress and manipulation of laboratory tasks to reflect real competition are recommended, athlete's trait characteristics might also moderate the effect of pressure on performance and have yet to be examined in detail (Low et al., 2023). Cognitive control moderates the effect of pressure on performance. Specifically, a deficit in inhibitory control (IC) in anxious individuals impairs performance in pressure contexts, such as exams (Zhang et al., 2019). Within cognitive control functions, motor IC is essential for adjusting behaviour to environmental changes, allowing individuals to suppress automatic responses and prevent inappropriate actions (Duque et al., 2017). In sports contexts, athletes exhibit greater IC than non-athletes (Bravi et al., 2022), which enables better self-regulation and decision-making under pressure (Swann et al., 2015).

This perspective is supported by the Grid Theory proposed by Christensen et al. (2016). According to this theory, in tasks of a relatively simple and brief nature, such as a short golf putt performed under laboratory conditions (Beilock & Carr, 2001), batting exercises with homogeneous pitches (Gray, 2004), free throw shooting in basketball (Oudejans & Pijpers, 2009), or goal kicking in Australian football (Beseler et al., 2016), less cognitive control is required. In simple tasks, the stability of the initial action parameters, such as force and direction, is sufficient to ensure adequate performance, given the limited need for real-time adjustments during execution. However, maintaining attentional focus becomes more challenging in sports tasks with increased complexity and variability, where athletes must continuously regulate their cognitive resources to adapt their actions (Christensen, 2019). This is particularly relevant in high-pressure situations, where athletes' attentional focus tends to shift toward external concerns rather than movement execution, a phenomenon that has been linked to performance decrements. Interviews conducted by Oudejans et al. (2011) revealed that athletes often describe an increased awareness of negative consequences and external evaluation when performing under pressure, which can interfere with their ability to regulate attentional resources efficiently. This pattern of attentional shift could reflect an increase in cognitive control demands, as athletes must selectively process relevant information while inhibiting distractions, a key aspect of cognitive regulation within decision-making (Christensen, 2019).

Thus, the individual characteristics of athletes could explain the observed differences, clarifying why certain manipulations generate significant pressure in some individuals while failing to produce the same effect in others (Kent et al., 2018). Given this variability, it is essential to analyze how pressure influences performance under different task demands simulating the physical and cognitive processes inherent to sports practice (Soderstrom & Bjork, 2015). This approach not only allows for the exploration of behaviors in more complex situations by better approximating task complexity to the actual demands experienced by athletes (Maselli et al., 2023), but also enhances our understanding of how to design tasks that induce genuine pressure in athletes and are relevant to specific sports contexts (Kegelaers & Oudejans, 2024; Kent et al., 2018). To address these objectives, this study aimed to: 1) examine the influence of manipulating environmental pressure, through increasing task demands and outcome consequences, on the anxiety, experienced mental workload and performance of players during complex cognitive-motor multitask situations; and 2) to analyze the possible moderating effect of inhibitory control. It was hypothesised that: 1) increasing the task cognitive demands and outcome consequences would increase the mental workload and the degree of perceived anxiety of the players and, as a consequence, a deterioration of shooting performance; and 2) participants' initial level of inhibitory control might modulate the magnitude of the effects produced by the environmental pressure.

2. Method

2.1. Ethics committee approval

This study was approved by the University of Granada Ethics Committee (nº. 3620/CEIH/2023) and was conducted as per the guidelines set out in the Declaration of Helsinki. Prior to participation, written informed consent was obtained from the parents of all participants, as well as the approval of the participants/players involved in the research.

2.2. Participants

A total of 39 youth basketball players participated in the present study and included 26 boys and 13 girls. Sample size was determined by an *a priori* power analysis using G*Power tool version 3.1.9.7 (Faul et al., 2009), assuming an effect size of 0.25, a significance level (α) of 0.05 and a power (1-β) of 0.95 for a two-way repeated measures ANOVA design based upon prior work (Gröpel & Mesagno, 2019). Based upon this analysis, a sample size of at least 36 participants was necessary to detect significant effects. Prior to the start of the study, all participants met the following inclusion criteria: a) at least five years of playing experience in federated basketball competitions and a minimum period of two years of playing experience with standard baskets [i.e. hoops located at a height of 3.05 m, following the regulations established by the International Basketball Federation (FIBA)]; b) completion of a minimum of ~270 min of basketball training per week (3 x 90-min session/week), and regular participation in federated competitive matches; c) did not experience cardiovascular, neurological, mental or psychiatric disorders, nor be taking medication/s during the research period; and d) had not suffered concussions within the last 30 days, nor have a history of muscular, musculoskeletal injuries or surgical interventions in the last year that could hinder their performance during the research. In addition, participants were asked to follow specific guidelines before each session as follows: (1) refrain from consuming caffeine in the previous 12 h; (2) avoid strenuous exercise in the previous 48 h; (3) undertake at least 7 h of sleep the night before; and (4) come to the sessions after a regular meal within the previous 3 h. Characteristics of the study participants are shown in Table 1.

2.3. Design

An intrasubject, repeated measures design was implemented to examine the influence of manipulating environmental pressure, through increasing task demands and outcome consequences, on participants' anxiety, experienced mental workload and cognitive-motor performance during complex multitasking situations. Additionally, the participants' initial level of IC was examined as a potential moderating effect on the magnitude of the effects on the results achieved. For this purpose, two experimental sessions were conducted in which participants performed multitasking activities related to basketball, responding to different behavioural rules that determined the direction of dribbling before executing a shot. The sessions differed in terms of the complexity applied during the task and the consequences of errors within the scoring system based on successful shots. Regarding task complexity, a session with low environmental manipulation (LEM) was conducted, in which participants had to attend to only one behavioural rule, reducing the demands of cognitive-motor processing. In contrast, in the high environmental manipulation (HEM) condition, participants had to process and respond to multiple rules based on different stimulus conditions, increasing task complexity. Additionally, the scoring system varied between conditions. In the LEM condition, scoring was based solely on successful shots, with no penalty for errors in rule execution or missed shots. Conversely, in the HEM condition, although successful shots contributed to the total score, errors in rule execution and missed shots led to a deduction of points, introducing an additional pressure component. The order of presentation of the sessions was counterbalanced among participants. Further details on the specific task rules and conditions for LEM and HEM are provided in the Applied environmental manipulation section (2.4.2.3.).

The choice to develop an LEM condition instead of including a control condition without any manipulation was based on that athletes are continuously confronted with a wide range of stressors that affect their performance, such as injuries and high expectations, as well as organizational factors, like leadership quality and conflicts within the team (Kegelaers & Oudejans, 2024). Therefore, it was essential to use demands that replicated competition to advance the understanding and management of these factors and to create contexts that more closely resemble reality and their ecological validity (Stoker et al., 2017). In this sense, the LEM condition acted as a control condition by reproducing a competitive scenario with minimal performance demands, ensuring the presence of environmental pressure inherent to competitive contexts, without imposing an additional high cognitive load or substantially impacting the final result. In addition, in order to achieve an adequate state of competition among participants, which allowed maintaining a high state of anxiety and ensuring an optimal level of interest and motivation among players, competitions were carried out among participants, establishing rules linked to performance during the task (see Vera et al., 2019). For this purpose, two financial prizes of 100 € each were established for the players who achieved the following outcomes for the two experimental conditions: 1) the highest cumulative total score, granted to the participant who obtained the highest number of points at the end of both experimental sessions, considering the scores achieved in both the LEM and HEM conditions (successful task execution according to rule compliance and successful and missed shots); and (2) the best overall shooting percentage, awarded to the participant with the highest shooting accuracy across both experimental sessions. This approach prevented the loss of points in the HEM condition from reducing participants' engagement, as the second competition, based on shooting accuracy, allowed them to continue competing for another prize regardless of their accumulated score. Additionally, to maintain a high level of competition, a researcher was in charge of informing the participants about the results they were achieving during the break periods of the sessions.

Table 1
Characteristics of participants.

Variables	All	Male	Female
N (M/F)	26/13	26	13
Age (yr)	14.9 (±1.3)	15.2 (±1.2)	14.2 (±1.4)
Body mass (kg)	59.6 (±8.8)	62.2 (±7.6)	54.3 (±8.8)
Height (m)	173.5 (±10.7)	178.1 (±9.1)	164.4 (±7.3)
BMI (kg·m^2)	19.8 (±2.4)	19.6 (±1.9)	20.1 (±3.2)
Basketball experience (yr)	7.5 (±2.0)	7.6 (±2.1)	7.4 (±1.7)
Maximum heart rate (bpm)	197.8 (±4.3)	198.6 (±3.9)	196.3 (±4.7)

Note: N: number of subjects; M: Male; F: Female; yr: years; kg: Kilograms; m: meters; BMI: Body mass index; bpm: beats per minute.

2.4. Procedure

The study consisted of five sessions including three pre-experimental and two experimental sessions. The pre-experimental sessions were conducted before the experimental conditions and aimed to familiarize participants with the study procedures and assess their baseline cognitive and physical characteristics. All sessions were conducted on separate days, with a minimum interval of 72 h between experimental sessions to minimize any potential residual effects between conditions.

Additionally, participants completed all sessions at similar times of the day to mitigate potential circadian influences on performance (Thun et al., 2015). The procedure carried out in each phase is described below, specifying the aspects addressed in each session.

2.4.1. Pre-experimental sessions

In the first pre-experimental session (1.5 h), a thorough explanation of all the instruments used in the study was provided and families and participants provided informed consent. In addition, participants undertook a preliminary practice of the computer-based IC test (described in section 2.5.3. Inhibitory control assessment) and were assessed for multitasking and comprehension (described in section 2.4.2. Experimental sessions). In the second pre-experimental session (30-min), participants completed a computer-based cognitive test of basal IC capacity. The third session (1 h) involved participants completing the trait anxiety questionnaire (described in section 2.5.5. Anxiety assessment), assessment of anthropometric characteristics (described in section 2.5.1. Anthropometric assessment), and performance of a maximal aerobic capacity test (described in section 2.5.2. Physical load control). The procedure in the pre-experimental sessions is shown in Fig. 1A.

2.4.2. Experimental sessions

2.4.2.1. Procedure for the experimental sessions. For each of the two experimental sessions, participants followed the same standardized procedure. Upon arrival at the laboratory, participants were taken to a quiet, isolated room in the same building as the basketball court. They were asked if they had any questions about how to complete the questionnaires or carry out any of the tasks included in the experimental sessions. Once it was confirmed that everything was in order to start, the participants completed the state anxiety questionnaire (described in section 2.5.5. Anxiety assessment). Upon completing the questionnaire, participants were informed about the experimental condition they would be undertaking and the corresponding scoring norms. This protocol was implemented to prevent thoughts related to the outcome of the practice from affecting the questionnaire responses. They then donned a heart rate monitor (Polar Electro, Kempele, Finland) and started with a warm-up that included 5 min of jogging, 5 min of dynamic stretching and 5 min of basketball shooting (Zhang et al., 2023). Once the warm-up was completed, the participants' first saliva sample was taken within 1 min (described in section 2.5.6. Saliva biomarkers). Subsequently, participants carried out the multitasking activity, which included five blocks of 20 trials (a total of 100 shots per experimental session), with rest intervals of 1 min between blocks. The approximate execution time of each block was between 2 min-23 s and 2 min-40 s, depending on each participant's individual execution pace. Once the last block was completed, the second saliva collection was collected within 1 min. Participants were escorted to a chair and table set up on the side of the court and completed the NASA-TLX questionnaire (described in section 2.5.4. Mental workload assessment) and the state anxiety questionnaire. Thereafter, participants cooled down for 5 min by performing stretching exercises guided by a researcher. The total duration of the experimental sessions was approximately 60 min. To ensure optimal performance of the participants during the two experimental sessions, standard

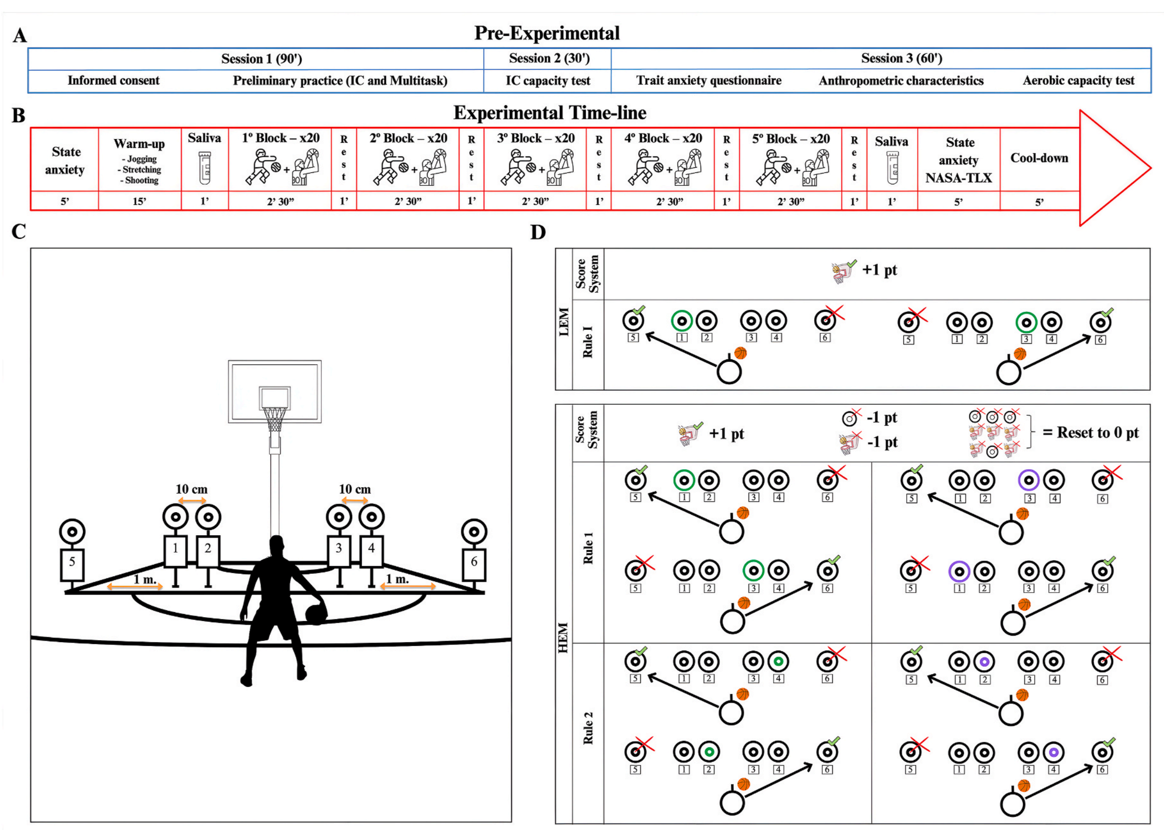

Fig. 1. Visual display of the complete experimental design. (A) Display of all procedures conducted during the pre-experimental sessions. (B) Display of the experimental sessions, illustrating the procedure followed throughout the session timeline. (C) Display of the task setup, specifying the protocol for configuring the task, including the placement of FITLIGHT devices. (D) Display all rules established for each condition, depending on the colour displayed by the FITLIGHT devices and whether the lights were activated in their inner or outer sections. This includes the behavioural rules that determine the direction of dribbling before executing a shot and the scoring system applied in each condition. N (1,2,3,4,5,6): Number of FITLIGHT devices; m: Meter; cm: Centimeter; IC: Inhibitory control; LEM: Low environmental manipulation; HEM: High environmental manipulation; pt: Points; ': Minutes. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

basketballs, size 7 for boys and size 6 for girls (TF-1000; Spalding; Kentucky, USA), were used in accordance with FIBA standards. During the shooting blocks, two researchers collected rebounds and passed the ball to the players between trials. These researchers were the same for all participants and were present in all sessions. The procedure in the experimental sessions is shown in Fig. 1B.

2.4.2.2. Basketball multitasking protocol. FITLIGHT Training System (FL; Model FL2201SLC, Canada; FITLIGHT®SYSTEM, n.d.) devices were used to conduct the multitasking activity. These devices incorporate both external and internal rings of lights, allowing the conditioning of different motor responses depending on the color emitted. Using these devices, the task was designed to manipulate cognitive difficulty through the integration of perception (sensory information) and action (motor execution), ensuring that participants processed visual stimuli in real-time and strategically adjusted their motor responses according to the uncertainty and variability conditions of the task (Winkelman, 2020), which are key elements in decision-making in open sports. To this end, a multitasking activity was designed in which participants had to respond to different visual stimuli associated with rules to execute specific motor actions, conditioning the direction of the dribble before performing a shot at the basket.

Participants started each attempt facing the basket at a distance of 6.75 m (i.e., outside the three-point line). From their starting position, they were presented with six FL distributed within their visual field. Four of them were positioned in front of the participant, above the free-throw line (official FIBA measurements), organized into two groups within their frontal field of view: two on the left side (FL numbers 1 and 2) and two on the right side (FL numbers 3 and 4), located 1 m from each end of the free-throw line and separated by 10 cm. These four FLs provided a visual stimulus by lighting up to indicate the required dribbling direction (left or right) before the shot. Additionally, two FLs (numbers 5 and 6) were placed at the ends of the free-throw line and served a dual function: (1) acting as a reference position to ensure that all shots were taken from a standardized distance of 4.9 m from the hoop center, and (2) functioning as photocells to record the accuracy of the participant's response based on compliance with the rule established according to the presented visual stimulus (originating from FLs 1–4) and their reaction time. A graphical representation is provided in Fig. 1C.

To establish the environmental manipulation conditions, four motor response rules were implemented based on the activation of visual stimuli (green or purple light) in either the external or internal segments of the FLs. FLs 1 and 3 were used for external light activation, while FLs 2 and 4 were assigned to internal light activation. The predefined rules were as follows: 1) Rule 1: If FL 1 or 3 on one side lit up green, the participant had to dribble the ball and pass in front of the FL located at the end of the same side (FL 5 or 6) before shooting. If FL 1 or 3 on one side lit up purple, the participant had to dribble toward the opposite side and pass in front of the FL at the opposite end (FL 5 or 6) before shooting; and 2) Rule 2: If FL 2 or 4 on one side lit up green, the participant had to dribble toward the opposite side and pass in front of the FL at the opposite end (FL 5 or 6) before shooting. If the FL 2 or 4 on one side lit up purple, the participant had to dribble and pass in front of the FL on the same side (FL 5 or 6) before shooting. After completing a trial, participants returned to the starting position to receive a pass from a researcher and prepare for the next attempt. To control execution pace, prevent anticipatory responses, and allow for an accurate assessment of cognitive-motor performance and physical load, a presentation time of 4000 ms was set for each trial, with an inter-trial interval of 1500 ms.

This activity allowed for the evaluation of task-related behavioural performance in each trial, including: (a) accuracy in rule compliance during dribbling movement in each experimental condition, that is, whether the participant correctly executed the displacement direction based on the stimulus colour and its location in the external or internal segment of the FL; (b) reaction time, defined as the interval between the presentation of the visual stimulus and the moment the participant crossed one of the FLs 5 or 6 (acting as photocells) at the instant of the shot; and (c) shooting performance, considering both successful and missed shots to calculate the total score obtained in the sessions and the overall shooting accuracy percentage. When participants familiarised themselves with the task, they received the following instructions to ensure correct execution: (1) maintain dribbling the ball in the initial position to control physical load during stimulus presentation; and (2) move as quickly and as closely as possible past FLs 5 or 6 to ensure that the shot was taken from the standardised distance of 4.9 m from the centre of the hoop and that the movement was correctly registered by the photocell.

2.4.2.3. Applied environmental manipulation. In the LEM condition, participants followed only Rule 1 throughout the session. To simplify the cognitive-motor complexity of the task, only the green light was used as an external stimulus. This rule was applied in 100 % of the trials. If FL 1 or FL 3 on one side turned green, the participant had to dribble the ball and pass in front of FL 5 or FL 6 on the same side before shooting. The stimulus presentation followed a predetermined sequence (Right-Left-Right-Left), ensuring a structured execution pattern. In this condition, the following consequence-based scoring system was applied: (a) participants earned one point for each successful shot; (b) no points were deducted for rule execution errors or missed shots. In this condition, participants were informed about the single rule to follow, the scoring criteria, and the fixed order in which the stimuli would be presented.

In the HEM condition, participants had to apply both Rule 1 and Rule 2, as described earlier, increasing the cognitive complexity of the task. Furthermore, to enhance cognitive-motor demands, the order of trials followed a Go-NoGo task format (Bezdjian et al., 2009). For this purpose, since each block included 20 trials, the probability of presenting a Rule 1 trial was 65 %, while the probability of a Rule 2 trial was 35 %. That is, out of 20 trials, 13 corresponded to Rule 1 and 7 to Rule 2. Additionally, within each rule, 35 % of the trials required players to execute the rule associated with movements toward the opposite side, which amounted to 5 of the 13 trials within Rule 1 and 2 of the 7 within Rule 2. The order of trial presentation was randomised across all participants. In this condition, correct executions contributed to the final score, while errors resulted in point deductions. The following consequence-based scoring system was applied: (a) participants earned one point for each successful shot; (b) they lost one point for errors in rule execution or missed shots; (c) if they accumulated three consecutive errors, whether in shooting, rule execution, or a combination of both, their score was reset to zero, introducing an additional pressure factor. At no time could a participant's score be lower than 0. Participants were informed about the number of rules to follow, the scoring system, and the consequences of execution errors, but they were not given information on the order or probability of stimulus presentation.

All details related to the full rules and scoring system established in the two experimental conditions are depicted in Fig. 1D.

2.5. Variables and instruments

2.5.1. Anthropometric assessment

Height and mass were assessed using a measuring ruler and a SECA 799 digital scale (Seca, Germany) with an accuracy of 0.1 kg. Body mass index was calculated from height and mass recordings.

2.5.2. Physical load control

In the experimental sessions, the tasks were designed to replicate the physiological demands experienced by players during competition. To this end, participants were required to perform the tasks within an intensity range of 80–90 % of their maximum heart rate (HRmax). This decision was based on the systematic review by Stojanović et al. (2018), which reported that HRmax values during active participation in matches fluctuate between 81.8 % and 94.6 %. To ensure that participants reached and maintained this intensity, all of them performed a maximal aerobic capacity test during the pre-experimental sessions to determine their HRmax (Leger et al., 1988). Subsequently, task intensity was assessed as a proportion of HRmax within five zones: 50–60 % of HRmax corresponded to zone 1, 60–70 % to zone 2, 70–80 % to zone 3, 80–90 % to zone 4, and 90–100 % to zone 5. Since the objective was to replicate competition conditions, zone 4 was established as the required intensity range for task execution. This procedure has previously been used in basketball to evaluate internal training load (Camacho et al., 2021; Gutiérrez-Capote et al., 2023, 2024) and was previously correlated with external load (Scanlan et al., 2014). To ensure control during the experimental conditions, participants were equipped with a Polar H10 sensor attached to a Polar Pro chest strap (Polar Electro, Kempele, Finland) to monitor heart rate in real time continuously. This system was synchronised with a Polar Vantage M smartwatch (Polar Electro, Kempele, Finland) held by the researchers, allowing continuous supervision and immediate feedback to adjust intensity if necessary.

2.5.3. *Inhibitory control assessment*

Participants were taken to a quiet room inside the basketball hall and were instructed to sit comfortably at approximately 60 cm in front of a 27-inch computer screen with a black background. The computer ran a Windows operating system, with a keyboard placed in front of each participant and a mouse positioned next to their dominant hand. The cognitive task to assess IC was carried out using Superlab v. 4.5 software (Cedrus Corporation, San Pedro, CA, USA) and was designed following the structure of the Go-NoGo task described by Vocat et al. (2008). This task was a simple response time assessment to measure simple processing speed. Participants were required to press a key on the keyboard as fast as possible on the appearance of any target stimulus. The structure of the task followed a single-trial, event-by-event, time sequence. During each trial, the screen was blank for 500 ms. Subsequently, a cross appeared in the centre of the screen, where the participant fixated their visual focus for another 500 ms. Then, the pre-stimulus (a black arrow) appeared with two possible orientations - up or down -, which remained on the screen for 1000 ms until the appearance of the target stimulus. At this point, the participant responded by pressing ("Go") or not pressing ("NoGo") the C key within a maximum time of 1500 ms. The "Go" and "NoGo" conditions with stimuli were as follows: 1) If the pre-stimulus was a black downward-facing arrow, the target stimulus would be: (a) "Go" if it changed to green and kept the same direction; (b) "NoGo" if it changed to teal and kept the same direction; (c) "NoGo" if it was green, but the orientation of the arrow changed to upwards; and 2) If the pre-stimulus was a black arrow facing upwards, the target stimulus would be: (a) "Go" if it changed to green and kept the same direction; (b) "NoGo" if it changed to teal and kept the same direction; (c) "NoGo" if it was green, but the orientation of the arrow changed to downwards. The test comprised a total of 180 trials, distributed into 122 "Go" trials and 58 "NoGo" trials (resulting in a 32.22 % probability of an incongruent stimulus appearing), and the appearance of the "Go" and "NoGo" stimuli was completely randomized. The task's behavioral performance was evaluated using two main variables: total accuracy, based on the number of correct responses, including both "Go" hits and correct "NoGo" rejections, and average reaction time calculated from the response time for all correct responses in Go trials. The test duration ranged from 7 to 8 min. For the correct development of this test, during the familiarisation session (session 1, pre-experimental), participants were provided with a practice block of 60 randomized trials. If needed, they were given an additional explanation and a second practice block of 30 trials to ensure that they fully complied with the test.

2.5.4. *Mental workload assessment*

The NASA-TLX questionnaire of Hart and Staveland (1988) was used to assess the subjective workload perceived by participants at the end of each session. This instrument comprised of six subscales exploring mental, physical, time, performance/outcome, effort and frustration demands. Participants rated each dimension of the questionnaire using a rating scale ranging from 0 to 100 points, reflecting a gradation from lower to higher values. In the case of the "performance/outcome" dimension, the values were inverted, denoting an inverse association between the quality of performance and the magnitude of the score assigned so that more favourable results were related to lower scores. Data analysis focused on the individual subscales and the overall score to identify specific patterns of workload or performance challenges experienced.

2.5.5. *Anxiety assessment*

The Spanish version of the State-Trait Anxiety Inventory (STAI) was used to measure participants' anxiety levels after each session (Spielberger et al., 1982). This tool consisted of two scales: State Anxiety, which assessed temporary anxiety in specific situations, and Trait Anxiety, which measured a person's general tendency to experience anxiety over time. With 20 items each, responses were scored on a four-point scale. For State Anxiety, the range goes from 0 ("Not at all") to 3 ("Very much so"), while for Trait Anxiety, the range is from 0 ("Almost never") to 3 ("Almost always"). Particular attention was paid to the analysis of state anxiety to examine immediate variations between a single session as well as between sessions.

2.5.6. *Saliva biomarkers*

Two saliva samples were collected per experimental session in order to identify sAA levels. The first sample was collected immediately after the warm-up, coinciding with the start of each experimental session, while the second sample was collected at the end of the last block of the session. These collections ensured that any changes or differences in the results were due to the session itself and not to the influence of the initial warm-up, thus avoiding possible disparities in the results of each participant. Samples were collected by unstimulated passive drooling using sterile 15 ml polypropylene tubes (Dimensions (Ø ext. x H, mm): 17 x 120; Scharlab, The Lab Sourcing Group, Barcelona, Spain) for 1 min per participant (Lopez-Jornet et al., 2016). Strict restrictions were implemented, such as prohibiting teeth brushing, chewing gum or consuming food and beverages, except water, in the 15 min before sample collection (Tsunekawa et al., 2023). Participants were also prohibited from consuming liquids throughout each session to standardize the sampling procedure (Rohleder & Nater, 2009). All saliva samples were immediately stored at −80 °C by a designated researcher until analysis, ensuring preservation of sample integrity for reliable interpretation of results (Tsunekawa et al., 2023). The activity of sAA was quantified using a commercial kit (a-Amylase, Beckman Coulter Inc., Fullerton, CA) on an automated biochemical analyzer (Olympus UA600, Olympus Diagnostica GmbH, Ennis, Ireland) (Tecles et al., 2014). Results were expressed as an alpha-amylase concentration (IU/L) and adjusted for salivary flow to minimize the influence of dehydration (Foretic et al., 2020).

2.6. *Statistical analyses*

Data summaries were calculated for the whole sample, and data were checked for normality using the Shapiro-Wilk test. Initially, the first analysis conducted was a manipulation check, aimed at identifying differences within each condition (intra-condition comparisons) in physical load, subjective anxiety, and sAA. For this purpose, repeated measures ANOVAs were performed separately for each condition to assess changes from pre-to post-condition, no checking the interaction between condition.

Following this, the main analysis was conducted to examine whether there were differences between the two experimental conditions (i.e., HEM and LEM) in the outcome variables: anxiety (calculated as the difference between baseline and post-experiment scores), shooting performance, and mental workload. To this end, linear mixed models

(LMMs) were applied. The LMM approach is particularly appropriate for repeated measures designs, as it considers specific patterns at the individual level by modeling them as random effects, which is especially relevant when observations across conditions are likely to be correlated (Meteyard & Davies, 2020). In this case, 'Condition' was included as a fixed effect and 'Participant' as a random effect. An example model specification would be: Difference_StateAnxiety ~ Condition + (1 | CODE).

After that, another LMM was performed to investigate whether individual cognitive capacity (i.e. IC) moderated the relationship between experimental condition and the outcome variables: shooting performance and mental workload. This analysis incorporated the results of a bimodal cluster analysis on cognitive performance, which classified participants into two IC strata—higher and lower—using the k-means clustering algorithm based on task accuracy and reaction time. The resulting cluster assignments were added to the dataset, allowing each participant to be objectively categorised. This classification was then used in a predictive model to test for a potential moderating effect. An example model would be: ShootPercentage ~ Condition * ClusterGroup + (1 | CODE).

Finally, a regression analysis was conducted to establish whether anxiety predicted shooting performance.

LMMs were fitted using the *lmer* function from the R package *lme4* (Bates et al., 2015). To obtain p-values for fixed effects, the *lmerTest* package was used (Kuznetsova et al., 2017). This package applies Satterthwaite's approximation to estimate degrees of freedom, allowing the use of t-values instead of z-values. This approach is particularly appropriate for datasets with moderate sample sizes or hierarchical structures, as it provides more accurate and conservative significance testing compared to asymptotic methods based on the normal distribution.

All quantitative predictors were standardized and zero-centred prior to inclusion in the analyses. Effect sizes were quantified using partial eta squared (η_p^2) from repeated measures ANOVA analyses and interpreted as small (0.01), medium (0.06), and large (≥0.14).

3. Results

3.1. Manipulation check

All participants maintained an average physical load of 85.1 ± 2.7 % HRmax (168.34 ± 4.23 bpm), confirming that the tasks were performed within the intended intensity range (zone 4). No significant differences were observed between blocks within each session or between sessions.

Regarding state anxiety (STAI), the LEM condition resulted in a significant increase in anxiety levels from pre-to post-condition [$F(1, 38) = 59.57$, $p < 0.001$, $\eta_p^2 = 0.109$]. A similar pattern was observed in the HEM condition, with a highly significant increase in anxiety levels [$F(1, 38) = 362.88$, $p < 0.001$, $\eta_p^2 = 0.633$; Table 2]. A comparable trend was found for sAA, with a significant increase in the LEM condition [$F(1, 38) = 22.90$, $p < 0.001$, $\eta_p^2 = 0.139$], and in the HEM condition [$F(1, 38) = 23.32$, $p < 0.001$, $\eta_p^2 = 0.187$; Table 2].

3.2. LMMs – differences between conditions for anxiety, shooting performance and mental load

Significantly greater perceived anxiety (STAI state) was observed during the HEM condition compared to the LEM condition ($t(38) = 8.074$; $p < 0.001$; $d = 0.606$) while sAA levels showed a marginally significant trend toward higher values in the HEM condition compared to the LEM condition ($t(38) = 1.866$; $p = 0.062$). Regarding shooting performance, the HEM condition resulted in a significantly lower value than the LEM condition ($t(38) = -5.194$; $p < 0.001$; $d = -0.648$, Fig. 2).

Regarding mental workload, significantly higher values were detected during the HEM condition for the dimensions of Mental Activity ($t(38) = 15.158$; $p < 0.001$; $d = 0. 34$), Frustration ($t(38) = 2.846$; $p = 0.007$; $d = 0.331$), and the overall Global score ($t(38) = 2.386$; $p = 0.022$; $d = 0.255$; Table 2). However, no significant differences were

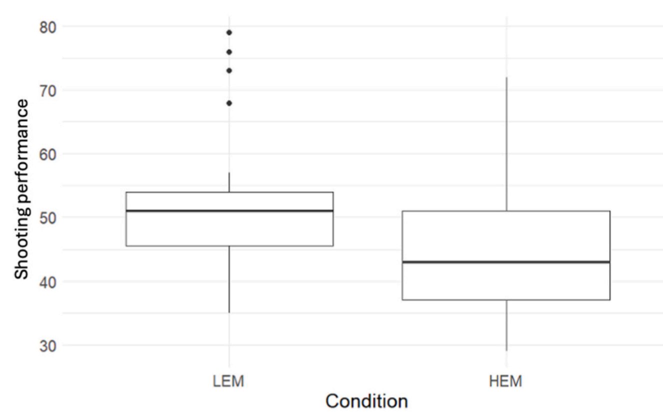

Fig. 2. Impact of high (HEM) and low (LEM) environmental manipulation conditions on shooting performance. HEM = condition with high environmental manipulation; LEM = condition with low environmental manipulation.

Table 2
Descriptive statistics of anxiety and cognitive workload variables categorised by inhibitory control (IC).

	LEM			HEM		
Outcome variable	*Entire*	*Better IC*	*Worse IC*	*Entire*	*Better IC*	*Worse IC*
Trait Anxiety	16.69 (±7.01)	16.44 (±5.30)	16.87 (±8.10)	16.69 (±7.01)	16.44 (±5.30)	16.87 (±8.10)
Anxiety state pre	11.54 (±5.08)	11.50 (±5.83)	11.57 (±4.62)	11.49 (±4.41)	11.25 (±4.34)	11.65 (±4.55)
Anxiety state post	15.26 (±5.67)**	16.06 (±6.54)	14.70 (±5.07)	24.72 (±5.70)**	25.19 (±6.78)	24.39 (±4.95)
Alpha-amylase pre	146081.69 (±114158.69)	151857.94 (±135178.67)	142063.43 (±100049.88)	136155.23 (±114432.36)	148420.88 (±121370.14)	127622.61 (±111306.03)
Alpha-amylase post	346620.92 (±339546.51)	385456.31 (±432882.48)	319605.00 (±263659.84)	454012.54 (±460524.70)	447094.13 (±355197.15)	458825.35 (±529381.29)
NASA Mental Activity	44.23 (±21.78)**	39.38 (±18.79)	47.61 (±23.45)	68.46 (±13.48)**	66.88 (±16.32)	69.57 (±11.37)
NASA Physical Activity	61.26 (±17.41)	63.38 (±19.96)	59.78 (±15.70)	66.79 (±17.45)	63.44 (±17.58)	69.13 (±17.36)
NASA Temporary Demand	38.59 (±21.49)	40.00 (±21.91)	37.61 (±21.63)	48.46 (±22.19)	53.75 (±18.57)	44.78 (±24.10)
NASA Execution and Result	41.54 (±20.43)	36.88 (±14.93)	44.78 (±23.28)	49.10 (±24.68)	50.94 (±23.68)	47.83 (±25.80)
NASA Effort	61.23 (±18.56)	59.88 (±21.98)	62.17 (±16.22)	66.79 (±18.55)	63.13 (±22.79)	69.35 (±14.95)
NASA Frustration	44.87 (±23.41)*	44.06 (±23.18)	45.43 (±24.07)	63.97 (±16.15)*	59.69 (±16.98)	66.96 (±15.21)
NASA Global	48.83 (±10.95)*	47.47 (±12.51)	49.78 (±9.91)	60.60 (±10.61)*	59.64 (±10.95)	61.27 (±10.57)

Note: Mean (± standard deviation) values are presented. HEM = condition with high environmental manipulation; LEM = condition with low environmental manipulation. Significant differences between LEM and HEM conditions for each variable were marked with: *$p < 0.05$; **$p < 0.001$.

found for the dimensions of Physical Activity (t(38) = 0.991; p = 0.328), Temporary Demand (t(38) = 0.336; p = 0.739), Execution and Result (t (38) = 1.15; p = 0.257), and Effort (t(38) = 1.453; p = 0.155; Table 2).

Lastly, shooting performance, defined as the total number of successful shots in each condition, was significantly lower during the HEM condition compared to the LEM condition (t(38) = −10.221; p < 0.001; d = 0.662; Table 3).

3.3. LMMs – moderation of inhibition control on shooting performance and mental activity

Table 4 shows the descriptive statistics of the IC performance (i.e. accuracy and reaction time) separated by the two clusters: better and worse IC.

When assessing the effect of IC capacity, the 'Better IC' cluster exhibited a significantly higher shooting performance percentage than the 'Worse IC' cluster during the LEM (t(38) = 2.771; p = 0.007) as well as HEM (t(38) = 2.039; p = 0.046) conditions (Fig. 3). Regarding mental activity, the 'Better IC' cluster exhibited an overall lower value compared to the 'Worse IC' cluster across both LEM and HEM conditions (most likely during the LEM conditions) (t(38) = 2.32; p = 0.026).

3.4. Relation between anxiety and shooting performance

A simple linear regression was conducted using data aggregated across both experimental conditions (HEM and LEM), as all participants completed both conditions. The model approached statistical significance (p = 0.053), with state anxiety (STAI) accounting for approximately 4.8 % of the variance in performance (R^2 = 0.048). The regression coefficient was negative (β = −0.125), suggesting that greater increases in state anxiety were associated with lower shooting performance. Descriptive statistics for state anxiety (M = 7.78, SD = 5.58, range = 0–20) and last block shooting performance (M = 8.86, SD = 3.17, range = 2–16) are reported.

4. Discussion

This study aimed to 1) examine the influence of environmental pressure manipulation through increased task demands and outcome consequences on participants' anxiety and basketball shooting performance during complex cognitive-motor multitasking situations; and 2) to analyze the possible moderating effect of participants' IC. The findings revealed that environmental pressure increased the anxiety experienced by participants at the end of both conditions, being higher for the HEM compared to the LEM condition. This resulted in lower shooting performance during the HEM condition. Finally, participants' basal IC was shown to moderate anxiety and mental workload, as well as shooting performance. These results support our hypotheses and provide novel findings on how participants' basal IC moderates the effects of environmental stress and anxiety on sports performance.

The increased levels of state anxiety and sAA during both conditions reflected similar results to those reported on the association between environmental stress and elevated levels of anxiety (Arruda et al., 2018; Causer et al., 2011; Cooke et al., 2011; Kamarauskas & Conte, 2022). However, the magnitude of this increase was significantly higher in the HEM than in the LEM condition for both variables. During the HEM condition, the number of rules to follow was greater, the order of stimulus presentation was not known, and errors in the multitask execution directly impacted the outcomes, unlike the LEM condition. Thus, in order to respond to the complexity of multitasking, anxiety resulted in greater use of cognitive resources to inhibit inappropriate automatic responses and attentional control (Eysenck & Wilson, 2016), which in turn likely elevated physiological responses and impacted upon coping mechanisms (Eysenck et al., 2007; Nieuwenhuys & Oudejans, 2012). The current results clarify how anxiety and task complexity influence participants' physiological and cognitive outcomes, highlighting the need for athletes to regulate attentional focus and employ adaptive strategies to manage pressure effectively, depending on task demands (Eysenck & Wilson, 2016).

As measured by the NASA-TLX, cognitive performance during multitasking was altered and confirmed that environmental pressure was adequately manipulated between LEM and HEM conditions in the current study. Increased environmental pressure led participants to perceive a greater mental workload, reflected in higher scores on the "mental activity" and "frustration level" dimensions of the NASA-TLX questionnaire. These results align with previous research highlighting mental demands as a reliable indicator of functional task difficulty (Shuggi et al., 2017). Similar findings have been observed during basketball activities (Camacho et al., 2021; Gutiérrez-Capote et al., 2023). For example, Gutiérrez-Capote et al. (2023) examined mental workload and motor performance during specific 1-on-1 drills in athletes with different levels of basketball practice experience. They reported that as the nominal task difficulty increased, participants experienced greater mental workload and functional difficulty. Similarly, Camacho et al. (2021) explored mental workload and motor performance during 3-on-3 drills, noting that frustration levels correlated with a decreased level of enjoyment as practice constraints increased and participants perceived more errors. The interaction between frustration and performance has been widely recognized in sports (Kegelaers & Oudejans, 2024). According to the Theory of Attentional Control (Eysenck et al., 2007), anxiety may lead individuals to experience more mental effort (compensatory effort) to maintain their performance, despite a possible reduction in operational efficiency. Additionally, the absence of significant differences for the "physical activity" or "effort" dimensions of the NASA-TLX questionnaire, as well as in the training load between conditions, reinforces that results were primarily due to the difficulty experienced by the participants in executing each condition, ruling out the possibility that physical factors moderated the results. Consequently, cognitive and emotional responses were primarily caused by the complexity of the task and environmental pressure rather

Table 4
Descriptive statistics of inhibitory control (IC) accuracy and reaction time by cluster (Better vs. Worse IC).

Accuracy of Basal IC			Reaction Time of Basal IC		
Entire	*Better IC*	*Worse IC*	*Entire*	*Better IC*	*Worse IC*
166.36 (±4.81)	168.29 (±4.79)	165.03 (±4.45)	354.18 (±51.07)	309.03 (±36.73)	385.59 (±32.58)

Note: Mean (± standard deviation) values are presented.

Table 3
Descriptive statistics of task-related motor performance variables categorised by inhibitory control (IC).

	LEM			HEM		
Outcome variable	*Entire*	*Better IC*	*Worse IC*	*Entire*	*Better IC*	*Worse IC*
Shooting Performance	51.69 (±10.06)**	56.25 (±12.49)	48.52 (±6.53)	45.21 (±10.31)**	48.06 (±10.46)	43.22 (±9.95)
Accuracy Cognitive-Motor	0.93 (±0.06)	0.96 (±0.05)	0.92 (±0.07)	0.89 (±0.07)	0.93 (±0.05)	0.86 (±0.07)
Reaction Time Cognitive-Motor	2636.36 (±266.47)	2616.07 (±303.67)	2650.48 (±243.45)	2908.30 (±468.64)	2765.72 (±661.14)	3007.48 (±237.20)

Note: Mean (± standard deviation) values are presented. HEM = condition with high environmental manipulation; LEM = condition with low environmental manipulation. Significant differences between LEM and HEM conditions for each variable were marked with: ***p* < 0.001.

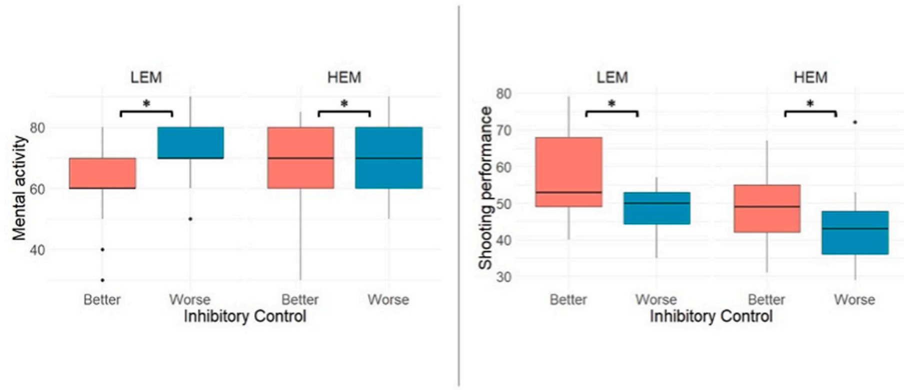

Fig. 3. Inhibitory control moderation of shooting performance and mental activity during LEM and HEM conditions. HEM = condition with high environmental manipulation; LEM = condition with low environmental manipulation. *p < 0.05 vs. Worse Inhibitory Control group.

than by physical effort.

The effect of environmental pressure on participants' performance was evident when comparing results during LEM and HEM conditions within the current study. The increased task difficulty during the HEM condition negatively affected cognitive-motor performance and shooting performance compared to the LEM condition. Specifically, cognitive-motor performance was impacted via worse response time and accuracy while shooting performance showed a notable decrease in successful shots by the end of the HEM condition. These effects can be explained by the increased anxiety and cognitive load observed under the HEM condition compared to the LEM condition, likely exceeding the athletes' capabilities, preventing them from maintaining an optimal performance state, and consequently decreasing their performance (Englert & Bertrams, 2012). This phenomenon has also been observed previously in studies of manipulated environmental pressure including accuracy and reaction times in sport-specific skills such as golf putting (Beilock & Carr, 2001), the throwing of darts (Englert et al., 2015), shooting accuracy (Causer et al., 2011; Nieuwenhuys & Oudejans, 2012) and archery (Behan & Wilson, 2008), as well as collective sports, such as free throw shooting in basketball (Vera et al., 2019), penalty kicks in football (Wilson et al., 2009), batting in baseball (Gray, 2004; Gray & Allsop, 2013), and hitting in table tennis (Williams et al., 2002). While these studies have provided valuable insights into the impact of environmental pressure on performance, many have analysed simple sports actions or, in the case of team sports, highly structured situations with little variability. Additionally, some have employed self-administered sports tasks or motor actions with limited decision-making involvement. While useful for evaluating individual responses under pressure, these approaches present limitations when analysing the complexity of actions that athletes face in practice or competition, where the interaction between multiple factors influences performance (Kegelaers & Oudejans, 2024). We have attempted to address this issue in our study by increasing task complexity, requiring participants to make decisions under pressure, and managing the consequences of their execution errors.

Finally, our study also investigated participants' IC as a possible moderator between anxiety and performance. The findings indicated that participants with better inhibitory abilities were more effective in maintaining better performance under pressure. This finding is consistent with prior studies that highlighted the importance of IC in regulating automatic responses and managing complex cognitive demands (Bravi et al., 2022). In this context, IC is defined by two distinct temporal components: proactive and reactive motor control (Meyer & Bucci, 2016). Proactive inhibition involves continuously monitoring of relevant information to adjust attention and actions, optimizing the inhibition of planned action. In contrast, reactive inhibition acts as a late correction in response to external stimuli that requires the interruption of an ongoing action (Aron, 2011). The increased task difficulty, resulting from higher environmental pressure, can hinder athletes' ability to maintain proactive motor control, leading them to rely more on reactive control when available resources are insufficient to meet environmental demands (Brick et al., 2016; Skau et al., 2021). This could explain why individuals with greater cognitive capacities experience less negative impact on their motor and cognitive skills, thereby achieving more consistent performance (Mäki-Marttunen et al., 2019). Furthermore, in the context of optimal challenge, it has been established that individual processing characteristics, together with accumulated experience and specific practice conditions, determine the difficulty experienced by the individual (Guadagnoli & Lee, 2004). In this sense, inhibitory capacity has emerged as an essential moderating factor, as discussed previously between mental workload and basketball performance (Gutiérrez-Capote et al., 2023, 2024). The current and prior studies suggest that participants with better IC abilities can handle the mental workload and additional demands effectively, enabling them to maintain better performance, even under pressure.

The results of this study were novel and provided a greater understanding of how environmental pressure and task complexity affect anxiety, mental workload, and motor performance during cognitive-motor, multitasking situations. Additionally, they offered a new perspective by highlighting participants' IC as a cognitive characteristic that can moderate and mitigate the effects of pressure on athletes. While most previous studies have been conducted in controlled environments with less complex motor actions (see Kegelaers & Oudejans, 2024; Kent et al., 2018; Nieuwenhuys & Oudejans, 2017), our results suggest that increasing task complexity by manipulating both cognitive demands and performance consequences, can significantly modify athletes' cognitive load and motor performance. This interaction was crucial in their response to pressure, as it increased anxiety, which, in turn, was associated with performance deterioration. In particular, the increase in performance consequences between experimental conditions (LEM and HEM) proved to be an effective variable for intensifying the pressure experienced by athletes. Given this, the structured and systematic application of this interaction could be leveraged to expose athletes to training environments with controlled high pressure, more closely resembling the competitive conditions they will face. Therefore, when integrating variations in environmental pressure into training, it is essential to implement them in a structured and progressive manner. This involves carefully adjusting task complexity and performance consequences to ensure that athletes are systematically exposed to increasing pressure levels (Hill et al., 2023, 2024). By gradually modulating these factors, athletes can develop adaptive mechanisms to manage stress more effectively, improving their ability to maintain performance under competitive conditions.

5. Limitations

The unique findings of this study provide practitioners with valuable insights into how environmental pressure and task demands can be manipulated to optimize cognitive load and motor performance in ecologically valid contexts that simulate the demands of competition. However, several limitations should be acknowledged. Firstly, this study was conducted with a modest sample size, and future research should include a larger sample to expand further upon our findings. Additionally, increasing the sample size may allow for analysing sex-based differences to better understand their potential impact on sports performance.

Secondly, although the basketball players met all the inclusion criteria, they were from three different sports clubs. Each club may have different approaches and resources, which may influence the preparation and development of specific skills, such as shooting. This lack of homogeneity in training programmes could have affected the current results. Similarly, the accumulated competitive experience could influence the ability of players to handle pressure and stress during highly demanding match situations that requires further investigation.

Third, while we aimed to rigorously control the effects of environmental pressure through the interaction between cognitive difficulty and error consequences on performance in a controlled setting with a highly demanding task, no direct opposition component was included—an essential factor in real competition scenarios.

Finally, our study design did not allow us to examine whether errors made during the task caused anxiety or whether anxiety caused errors during performance. Future work is recommended for research incorporating continuous or real-time monitoring of anxiety levels and task performance.

6. Future lines of research

Future studies should focus on quantifying, through repeated measures, the dose of environmental pressure applied to different groups of athletes with different practice experiences and assessing its possible effects (Hill et al., 2023). This would include measuring changes in anxiety, IC and other cognitive functions in response to different training and competition regimes. Including regular and detailed assessments of these parameters would allow for examination of how environmental stress influences athletes' sports performance and mental well-being, enabling coaches to adjust training strategies to optimize outcomes and mitigate its negative effects (Stoker et al., 2019). In this regard, a recent systematic review by Perrey (2022) highlights the emergence of portable neuroimaging methods, such as functional near-infrared spectroscopy (fNIRS) and electroencephalography (EEG), as viable tools for real-time cognitive load assessment in sports contexts. While these technologies have primarily been applied to controlled motor tasks, recent research has started integrating them into more dynamic settings, demonstrating their potential to analyze decision-making and stress management under high-performance conditions, including in team sports environments. Furthermore, it is essential to conduct research in ecologically valid environments that better reflect the actual conditions in which athletes train and compete, such as competitive scenarios that involve direct opposition and more dynamic game situations. Additionally, these studies should cover a variety of sport disciplines to gain a broader and comparative understanding of how environmental stress influences different contexts.

7. Practical applications

The currents study provides practical applications for athletes, coaches and practitioners. First, evaluating athletes' inhibitory capacity through both laboratory-based assessments (e.g., Go/No-Go Task, Stop-Signal Task) and sport-specific cognitive-motor tasks (e.g., dual-task exercises, response inhibition drills) provides crucial information for understanding how they manage anxiety in high-demand situations. Additionally, incorporating training strategies that include distractors, adaptive rule changes, and unpredictable stimuli can serve as indirect methods for assessing and enhancing this cognitive function by analyzing athletes' performance in these actions within practical settings (Alarcón et al., 2017). A baseline reference for each athlete's inhibitory capacity could allow coaches to anticipate their response to high-demand situations. This information is essential for designing personalized training programs that strengthen athletes' ability to manage situations by implementing specific tasks that challenge their inhibitory capacity. Second, creating tasks with sport-specific cognitive-motor requirements that demand optimal performance under high-pressure conditions (e.g., incorporating variable rules, time constraints, and direct performance consequences), is an effective strategy for recreating high-demand scenarios. Additionally, introducing scoring rules that directly impact performance during these tasks seems to be an effective measure to intensify the effects of high demands and improve the athlete's ability to perform under such conditions.

Finally, the use of the NASA-TLX questionnaire, particularly the "mental activity" dimension, has been proposed in previous research as a practical tool for assessing athletes' perceived cognitive load (Gutiérrez-Capote et al., 2023). This rapid assessment instrument, easy to apply and freely accessible, similar to other subjective scales used in sports (e.g., Rating of Perceived Exertion; RPE), could help coaches obtain valuable information about the athletes' perception and management of mental load, which has been linked to the demands they experience during sports practice. For its application in training contexts, coaches can ask athletes to rate these two dimensions on a scale from 0 to 100, where 0 represents minimal demand and 100 represents extreme demand. Regular use of this tool could help coaches monitor cognitive demands during training and make informed adjustments to optimize athletes' performance under high-pressure conditions. By integrating this assessment systematically, it would be possible to better regulate training intensity, reducing the risk of cognitive overload while ensuring a progressive adaptation to environmental stressors.

8. Conclusions

This study highlighted the complexity and impact of environmental stress on basketball sports performance, especially during combined cognitive and motor tasks. Most notably, it confirmed that environmental pressure increased anxiety and mental workload, negatively affecting performance, especially under conditions of high difficulty. This increased pressure led to a decrease in accuracy and speed of response, aligning with previous studies linking high pressure and reduced cognitive-motor performance. Furthermore, it highlighted the importance of participants' baseline inhibitory capacity as a significant moderator of the observed effects. The current study provided a more accurate understanding of the complex interplay between exercise-induced cognitive load, anxiety and performance and the need to train and develop inhibitory abilities in athletes to improve their resistance to pressure.

CRediT authorship contribution statement

A. Gutiérrez-Capote: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **J. Jiménez-Martínez:** Methodology, Investigation. **I. Madinabeitia:** Investigation, Formal analysis, Data curation. **E. Torre:** Investigation, Data curation. **A.S. Leicht:** Writing – review & editing, Writing – original draft, Conceptualization. **M. Botía:** Data curation. **F. Alarcón:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **D. Cárdenas:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Conceptualization.

Informed consent statement

Informed consent was obtained from all participants involved in the study.

Data availability statement

The corresponding author had full access to all the data in the study.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The database and R code for the analyses are available without restriction on the Open Science Framework (OSF) website (https://osf.io/wu4t9/files/osfstorage).

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