RESEARCH ARTICLE

The physiology and psychology of competitive sport: A comparative study

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ABSTRACT

Background: The Maastricht acute stress test (MAST) aims to trigger stress responses in both athletic and non-athletic populations, measuring blood pressure (systolic - SBP and diastolic - DBP), heart rate (HR), respiratory rate (RR), cortisol levels, state anxiety, trait anxiety, and depression. *Methods*: About 30 competitive male cricket players and thirty non-competitive males participated in trials involving mental and physical stress through the mental arithmetic test (MAT) and cold pressor test (CPT). Participants completed the State-Trait Anxiety Index (STAI) and the Depression Anxiety Stress Scales-21 (DASS-21). Measurements were taken at baseline, during the anticipatory phase, during MAST, and in the recovery phase. *Results*: Competitive individuals displayed lower SBP and DBP. Non-competitive individuals returned to baseline more slowly than competitive individuals. Instructions increased SBP, DBP, and HR, although pre-test values were lower than post-MAST. HR data showed minimal variation over time. Higher levels of despair and stress were correlated with significant SBP elevations. *Conclusion*: MAST effectively induces both physiological and subjective stress responses, highlighting the need for customized stress management, particularly for athletes who may lack adequate psychological support. This study aims to enhance the mental, emotional, and psychological care provided by healthcare professionals.

Keywords: Athlete, Anxiety, Competitive, MAST, Stress.

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INTRODUCTION

The human stress response serves an important adaptive function in daily life, potentially benefiting or harming the individual. This response largely involves physiological, psychosocial, and emotional elements, all of which interact to influence how people deal with and respond to stressors.[1] Acute stress activates two primary axes: the sympatho-adrenal-medullary (SAM) and hypothalamic-pituitary-adrenal (HPA) axes. Physical stressors, such as pain and temperature, mainly stimulate these axes, whereas psychosocial stressors are processed via the prefrontal cortex and the limbic system but also impact these axes.[1,2] The SAM axis triggers the fight-or-flight response, affecting arousal, alertness, blood pressure, heart rate, pulse rate, cardiac output, respiratory rate, and salivation. In contrast, the HPA axis influences the production of glucocorticoids, such as cortisol.[1,3]

In a cricket-loving nation like India, cricket is not just a sport—it's a religion. While lucrative, cricket demands planning, focus, and concentration. In essence, cricket psychology can influence performance. Psychological stress can significantly impair an athlete's ability to perform at their peak. Stress may manifest as anxiety, nervousness, or fear of failure, resulting in reduced focus, coordination, and decision-making abilities. It can even cause physical fatigue and elevate the risk of injury. In competitive scenarios, state anxiety often transitions into trait anxiety, adversely affecting performance.[4-7] Therefore, developing personalized coping mechanisms based on trait dominance is crucial.[7]

Competitive cricket players, especially those aged 14 and above, are highly susceptible to the effects of stress. Beyond physical skills, cricket requires sustained focus, intrinsic motivation, and self-confidence. Success in the sport relies on both visible and invisible feedback and anticipating the opponent's next move.[8] Performance is also influenced by the type of training and strategies imparted to players. Although acute stress can enhance arousal and focus, excessive stress can lead to fear of failure, physical fatigue, loss of focus, and diminished confidence.

This study aims to understand stress reactivity in competitive sports, particularly cricket so that players can integrate mental well-being training with physical training. Given the significant gap in this area of study, it has been chosen for investigation. The study seeks to elicit robust stress reactions to analyze and quantify various aspects of the stress response, both physiological and psychological, to improve psychological care for the often-overlooked population of competitive athletes.

The study was carried out to evaluate the physiological response to an acute psychological stressor using the

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MAST and compare the responses of competitively athletic individuals and non-athletic individuals. In addition, the subjective stress responses were also compared using the state-trait anxiety inventory (STAI) and depression anxiety stress scales (DASS) paradigms.

MATERIALS AND METHODS

Through purposive sampling, thirty male athletes indulging in competitive cricket training (semi-professional and state-level players) for more than 5 years aged between 14 to 19 years (Average 16 years) from a private cricket coaching academy (training at least 3 days a week for more than 3 hours a day) were included in the study. The comparator group had 30 males of the same age group playing non-competitive cricket only for fun. The study continued for 3 months. Individuals having a history of childhood trauma, PTSD and those suffering from psychiatric illness were not included in the study.

All the procedures followed were in accordance with the ethical standards of the institutional committee on human experimentation and with the Helsinki Declaration of 1975, as revised in 2000. This study has received approval from the Institutional Ethics Committee, obtaining informed consent from adult research participants and obtaining assent for children aged over 7 years participating in the study.

The following tests were conducted.

- Testing of the salivary cortisol content during the experiment, which is a biomarker for acute stress in both experimental and non-experimental groups.[11] Test used- Elecsys Cortisol II Assay [Range- 1.5–1750 nmol/L or 0.054–63.4 µg/dL, Sensitivity: Limit of Blank= 1.0 nmol/L (0.036 µg/dL), Limit of Detection= 1.5 nmol/L (0.054 µg/dL), Limit of Quantitation= 3.0 nmol/L (0.109 µg/dL)].
- Anticipatory, experiment and post-experiment testing of blood pressure, heart rate, pulse rate, respiratory rate and cardiac output.[1,3,4]
- State-Trait Anxiety Inventory[10]

It was developed by Charles D. Spielberger, Richard L. Gorsuch, and Robert E. Lushene in the late 1960s. The STAI consists of two separate scales, each comprising 20 items:

State anxiety scale (STAI-S)

The state anxiety scale assesses an individual’s current, temporary emotional state of anxiety at a particular moment in time. It measures how a person feels “right now,” reflecting their feelings of apprehension, tension, nervousness, and worry at the moment of completing the questionnaire. The responses are based on a 4-point Likert-type scale ranging from 1 (Not at all) to 4 (Very much so).

Trait anxiety scale (STAI-T)

The trait anxiety scale assesses an individual’s general propensity to experience anxiety as a stable personality trait over time. It measures how a person typically feels, regardless of the current situation, indicating their relatively stable and enduring anxiety levels. Like the state anxiety scale, responses are based on a 4-point Likert-type scale ranging from 1 (Almost never) to 4 (Almost always).

Scoring and interpretation

The total score for each scale (STAI-S and STAI-T) is calculated by summing the responses to the respective 20 items. Higher scores on the STAI-S indicate higher levels of current state anxiety, while higher scores on the STAI-T suggest a higher disposition towards experiencing trait anxiety.

Depression Anxiety Stress Scale 21[9]

The depression anxiety stress scale 21 (DASS-21) is a widely used psychological self-assessment tool designed to measure the severity of symptoms related to depression, anxiety, and stress. It is a shorter version of the original DASS, which has 42 items and was developed by researchers Lovibond and Lovibond in 1995. The DASS-21 consists of three subscales, each comprising seven items, and is scored on a 4-point Likert-type scale.

Depression scale

The depression scale of DASS-21 assesses the presence and severity of symptoms related to depression. It includes items that measure low mood, lack of interest or pleasure in activities, and feelings of hopelessness or worthlessness, among others. Participants are asked to rate how much each statement applies to them over the past week, ranging from 0 (Did not apply to me at all) to 3 (Applied to me very much or most of the time).

Anxiety scale

The anxiety scale of DASS-21 assesses the presence and severity of symptoms related to anxiety. It includes items that measure feelings of nervousness, fear, restlessness, and other physical and psychological symptoms of anxiety. Participants are asked to rate how much each statement applies to them over the past week, using the same 4-point Likert scale.

Stress scale

The stress scale of DASS-21 assesses the presence and severity of symptoms related to stress. It includes items that measure feelings of tension, irritability, difficulty relaxing, and other stress-related symptoms. Participants are asked to rate how much each statement applies to them over the past week, using the same 4-point Likert scale.

Scoring and interpretation

Each item in the DASS-21 is scored from 0 to 3, with higher scores indicating greater symptom severity. The scores from each subscale are summed to obtain a total score for depression, anxiety, and stress separately. The possible range of scores for each subscale is 0 to 21. The following grades were used for the interpretation – 0–4: Normal; 5–6: Mild; 7–10: Moderate, 11–13: Severe; 14+: Extremely severe.

Modified Stroke Volume Formula[8]

Stroke volume was calculated by using the formula 100–0.6

(Age) - 0.6 (Diastolic blood pressure) + 0.5 (Pulse Pressure) × Body Surface Area/1.7, and then the minute volume was calculated by multiplying the stroke volume with heart rate.

Procedures

- Participants were asked to arrive at 6.00 pm at the venue and the test was started at sharp 7.00 pm to maintain a uniform hormonal circadian rhythm. They were informed prior to the test that they should not have consumed alcohol/caffeine or smoked for 24 hours before the test, and no food or water should have been consumed at least 30 minutes before the test. Participants were asked to fill out the voluntary written informed consent and the entire experimental protocol was explained to them. Participants were asked to fill out both STAI and DASS-21 questionnaires. Basal readings of blood pressure, heart rate, respiratory rate and cardiac output were taken.
- This study involved the formation of an experimental group that underwent the MAST and a non-experimental group that underwent a no-stress placebo version of the MAST with little temperature variation in CPT, simplified counting, and no performance evaluation.
- For the experimental (competitive) group: The MAST began with a 5-minute preparation phase to allow the experimenter to convey the instructions to the participants. The blood pressure, heart rate, respiratory rate, stroke volume and cardiac output were measured again in the anticipatory phase. In the following 10-minute acute stress phase, physical stress (e.g., cold-induced pain) was combined with unpredictability, uncontrollability, and psychosocial stress due to social evaluation in a mental arithmetic task. Participants were informed that there would be alternating trials of immersing their hand into ice-cold water (maintained at 2°C), and engaging in a mental arithmetic task (counting aloud backward from 2043 in steps of 17) in front of a panel of 3 individuals. They were told that the duration of these trials would be randomly chosen by the computer to last between 45 and 90s and to use their non-dominant hand. In between the hand immersion trials, participants resumed the counting task while they rested their arms on a towel beside the water bath. If they made a mistake in accuracy or did not give a response within 5s, negative feedback and criticism were given by the panel and the participant had to start again at 2043. Participants were also informed that they would be video and audio recorded so as to later analyze their facial expressions and tone. The photographers and videographers were also instructed to invade the personal space of the participant in order to induce more social anxiety. In reality, the duration of all trials was pre-determined with the same protocol used for all participants. As shown in Figure 1, four hand immersion trials (HI) were alternated with three mental arithmetic trials (MA) in the following order and length – HI (30s), MA (45s), HI (60s), MA (60s), HI (60s), MA (45s), HI (60s).

Participants were unaware of the number of trials and the total duration of the stress phase. Throughout the hand-immersion phases, the sample for salivary cortisol was collected. Recovery readings of blood pressure, heart rate, respiratory rate, stroke volume and cardiac output were measured intermittently afterward.

- For the control (non-competitive) group: Here the MAST began at the same time at the same venue. Basal readings and anticipatory phase readings of blood pressure, heart rate, respiratory rate, stroke volume and cardiac output were taken. There were alternating trials of mental arithmetic and physical stress phases, but markedly less stressful than the experimental group. There was a 5°C change from normal body temperature in the water. Participants were asked to do simplified upward consecutive counting from 1 to 25. Even if they answered incorrectly or could not answer within 5 seconds, the panel gave no negative feedback. The salivary cortisol sample was collected during the stressful phase. Recovery readings of blood pressure, heart rate, respiratory rate, stroke volume and cardiac output were measured.

Statistical Analysis

Collected data were processed with Microsoft Excel and analyzed with SPSS (ver. 25) for normal distribution and comparison between the groups by t-test.

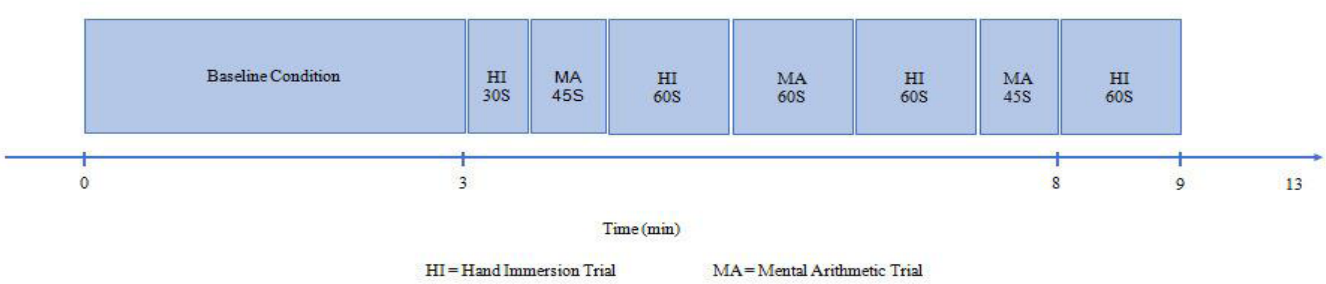

Fig: 1. Time line and order of the trials for the hand immersion trials (HI) and mental arithmetic (MA) task of the Maastricht Acute Stress Test (MAST)

Figure 1: Procedural sequences were used for the study

Table 1: Baseline (resting) cardiorespiratory parameters of the volunteers

Cardiorespiratory parameters at rest	*Competitive Group (n = 30)*	*Competitive Group (n = 30)*
Heart rate (beats/min)	73.92 ± 2.78	83.13 ± 3.35*
Systolic blood pressure (mm Hg)	119.25 ± 9.61	124.73 ± 8.90
Diastolic blood pressure (mm Hg)	72.75 ± 7.77	83.73 ± 6.81
Stroke volume (mL/beat)	71.18 ± 6.478	63.58 ± 7.35
Cardiac output (L/min)	5.26 ± 3.56	5.29 ± 5.119
Respiratory rate (breaths/min)	16.08 ± 2.21	16.47 ± 1.89

Data are Mean ± standard deviation. * indicates statistically significant (p <0.05) difference between the study groups.

Compared to non-competitive individuals (p = 0.257 and 0.09, respectively).

RESULTS

As presented in Table 1, the resting heart rate (HR) was significantly higher in non-competitive individuals (p = 0.04) than in competitive individuals. The resting systolic blood pressure (SBP) and diastolic blood pressure (DBP) were also higher in non-competitive individuals but it was not statistically significant (p = 0.73 and 0.14, respectively). The stroke volume (SV) was higher in competitive individuals, while minute volume (CO) and respiratory rate (RR) were slightly lower.

Both HR and SBP levels in both populations were slightly increased from baseline, while they were significantly higher in non-competitive individuals (p = 0.002, 0.03, respectively) than in competitive individuals. DBP is also higher in non-competitive individuals, but it is not statistically significant (p = 0.67). Both SV and CO are slightly higher in competitive individuals, while RR is slightly lower (Table 2).

During the hand immersion (cold pressor test, CPT), the HR, SBP, and DBP are significantly higher in non-competitive individuals than in competitive, while SV, CO, and RR are all lower in non-competitive individuals (Figure 2A). Similarly, both HR and SBP are significantly higher in non-competitive individuals, while DBP is nearly the same in both populations. SV is slightly higher in non-competitive individuals but CO and RR are lesser than competitive individuals (Figure 2B).

Figure 2C depicts the recovery of cardiorespiratory parameters, while Figure 2D shows that the HR, SBP and DBP took significantly longer time to recover in non-competitive individuals compared to competitive individuals. RR also recovered slightly later in non-competitive individuals than in competitive individuals.

Only a statistically nonsignificant (p = 0.1) difference was observed in the mean cortisol level during the overall MAST between the study groups – competitive and non-competitive cricket players (Table 3). On the other hand, mean STAI-S was found to be significantly (p = 0.004) higher in the non-competitive group without any significant (p = 0.1) difference for the STAI-T score (Table 3). The questionnaire study (DASS-21) revealed a higher level of anxiety (p = 0.02) and lower level of stress (p = 0.001) in the control (non-competitive) group in comparison to the experimental (competitive) group included in the study. Nevertheless, no statistically significant difference between the groups was noted in the depression scale of the same study (Table 3).

DISCUSSION

Our research engaged 30 competitive athletes with over 5 years of experience in semi-professional cricket, as well as 30 non-competitive players who engage in cricket for recreational purposes. Earlier, multifaceted stressors experienced by cricket batsmen during competitive performances, encompassing aspects such as self-perception, match-specific challenges, and technical concerns, were highlighted [12]. Many of these stressors are of a psychological

Table 2: Baseline (resting) cardiorespiratory parameters of the volunteers during the anticipatory phase post instructions.

Cardiorespiratory parameters at rest	Competitive Group (n = 30)	Competitive Group (n = 30)
Heart rate (beats/min)	75.66 ± 6.42	86.67 ± 8.21*
Systolic blood pressure (mm Hg)	120.98 ± 9.07	131.03 ± 8.69*
Diastolic blood pressure (mm Hg)	73.00 ± 8.45	84.09 ± 6.35
Stroke volume (mL/beat)	71.73 ± 9.69	67.58 ± 7.18
Cardiac output (L/min)	5.85 ± 4.32	5.42 ± 6.454
Respiratory rate (breaths/min)	17.56 ± 4.77	18.93 ± 6.02

Data are Mean ± standard deviation. * indicates a statistically significant (p <0.05) difference between the study groups.

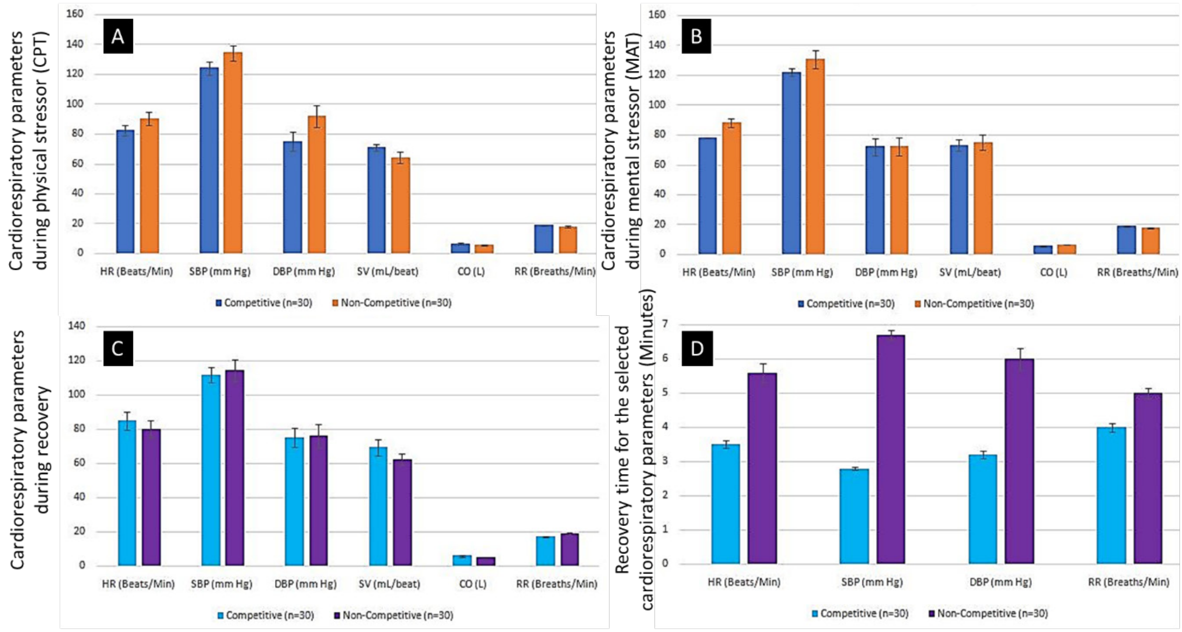

Figure 2. Cardiorespiratory responses and their recovery during the study. Data are presented as mean ± standard deviation (n = 30).

Table 3: Comparison of biochemical test results and psychological test scores of the two groups of volunteers who participated in the study.

Parameters	*Competitive group (n = 30)*	*Competitive group (n = 30)*
Cortisol (µg/100 mL)	3.20 ± 1.14	3.40 ± 3.22
STAI-S Score	54.58 ± 6.41	49.13 ± 5.72*
STAI-T Score	48.33 ± 7.091	48.07 ± 7.8
Depression scale	6.83 ± 7.66	6.67 ± 6.914
Anxiety scale	5.83 ± 4.204	6.13 ± 5.56*
Stress scale	8.08 ± 8.92	7.20 ± 6.63*

Data are Mean ± standard deviation. * indicates statistically significant (p <0.05) difference between the study groups.

nature and have an impact on overall performance. Among these stressors, we focused on two particular ones - CPT and MAT and examined their effects on both competitive and non-competitive individuals.

Shin *et al*. observed that aerobic and endurance training in athletes leads to autonomic imbalances, characterized by increased vagal tone coupled with diminished sympathetic tone [13]. These imbalances contribute to resting bradycardia and heightened baroreceptor reflex sensitivity. Baseline parameters were lower in competitive individuals (Table 1) due to parasympathetic dominance, leading to decreased heart rate (HR) and blood pressure (BP). Throughout the anticipatory and MAST phases, non-competitive individuals displayed more rapid increases in HR (Table 2), systolic blood pressure (SBP), and diastolic blood pressure (DBP) compared to their competitive counterparts. In athletes, gradual HR and BP increments were observed due to enhanced cardiovascular fitness, in contrast to the abrupt fluctuations seen in the non-competitive group (Figure 2A).[14] Although stroke volume (SV), cardiac output (CO), and respiratory rate (RR) rose in competitive individuals, the magnitude was comparatively lower. As anticipated, competitive players demonstrated elevated parameters in the anticipatory phase due to a heightened precompetitive sympathetic tone.[15] This trend was also noted in non-competitive individuals, albeit to a lesser extent. All parameters peaked during the acute stress phase (Figure 2B), a result of sympathetic stimulation of the sympathetic-adrenal medullary (SAM) and hypothalamic-pituitary-adrenal (HPA) axes. This phase saw sympathetic drive outweighing parasympathetic influence (Table 3).

Recovery phase data (Figure 2C) showed that competitive individuals returned to baseline levels within a maximum of 4 minutes, whereas non-competitive individuals took around 7 minutes (Figure 2D). The quicker recovery among competitively athletic individuals can be attributed to their higher vagal tone and greater cardiovascular endurance. Consequently, competitive individuals exhibited lower resting HR and BP, along with higher SV and CO, due to improved cardiovascular performance through athletic training. Katona *et al*. proposed that athletes' reduced resting heart rate is not solely attributable to heightened parasympathetic drive but also to intrinsic cardiac rate reduction.[16]

Leguizamo *et al*. highlighted that among the components of the Depression, Anxiety, and Stress Scale (DASS-21), athletes reported the highest perception of stress, though still within non-pathological ranges.[17] This observation is linked to the high-pressure environments in which athletes are expected to excel, leading to chronic stress levels over time. In alignment with these findings, our study revealed higher stress scale scores on the DASS-21 among athletes compared to their non-competitive counterparts (Table 3). The State-Trait Anxiety Inventory-State (STAI-S) scores further underscored that competitively athletic individuals are predisposed to elevated levels of state anxiety on a consistent basis (Table 3).

Our study effectively presents the autonomic and subjective stress responses within both populations, shedding light on factors that influence athletic performance. Additionally, it underscores the significance of mental well-being in athletes, highlighting distinctions from untrained individuals. This study stands as one of the few to apply MAST on an athletic cohort, thereby demonstrating the efficacy of the MAST protocol in inducing measurable physiological responses across different groups.

CONCLUSION

In summary, our investigation has harnessed the Maastricht Acute Stress Test as a tool to meticulously observe and document multifaceted physiological, behavioral, and psychosocial reactions in response to acute stressors of diverse natures. Through comprehensive analysis, discernible patterns within the aforementioned parameters have come to light. Non-competitive individuals manifest markedly elevated basal parameters and autonomic stress reactivity, coupled with prolonged recovery periods. Conversely, competitive athletes exhibit a contrasting profile. They initiate with lower heart rates and diminished blood pressure, among other metrics, gradually attaining peaks at levels less than their counterparts, and they swiftly revert to baseline within abbreviated durations. Additionally, competitive athletes exhibit heightened everyday stress levels compared to their non-competitive counterparts, thereby exhibiting a heightened predisposition toward crossing into the realm of pathological stress levels. This predisposition hinges on the crucial foundation of comprehensive training - both mental and physical - imparted to these athletes.

This research has introduced a fresh and innovative method for gathering data aimed at quantifying the psychological stressors that impact the realm of cricket. To further enrich our understanding and guide the formulation of effective strategies to recognize and address players' mental health requirements, it is imperative that we pursue a more extensive array of high-caliber epidemiological studies and intervention research.

LIMITATIONS

We recruited only male competitive and non-competitive athletes for the lack of the presence of female counterparts at Belgaum where we would have been better positioned to explain the role of endogenous gonadal hormones on reactivity to psychological and physical stressors.

IMPLICATION

Currently, issues of elite athlete mental health and psychological breakdown are gaining increasing importance and targeted remediation for this group is yet to be established. It is imperative to capitalize on early intervention principles to prevent such episodes and build a supportive framework. This is a key area of future inquiry, of the influence of psychological and physical stressors on autonomic reactivity. The learnings of which will be important for informing future policy and practice and developing coping strategies matching perceived task demands with regard to protecting and enhancing the well-being and careers of athletes.

CONFLICT OF INTEREST

Nil.

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PEER-REVIEWED CERTIFICATION

During the review of this manuscript, a double-blind peer-review policy has been followed. The author(s) of this manuscript received review comments from a minimum of two peer-reviewers. Author(s) submitted revised manuscript as per the comments of the assigned reviewers. On the basis of revision(s) done by the author(s) and compliance to the Reviewers' comments on the manuscript, Editor(s) has approved the revised manuscript for final publication.