JOURNAL OF EDUCATION, HEALTH AND SPORT
eISSN 2391-8306 · Open Access · Peer-reviewed
apcz.umk.pl/JEHS · Nicolaus Copernicus University in Toruń

Cite as: GRĘBOSZ, Damian, LIS, Krzysztof, KUKIEŁKA, Wojciech, GAŁWIACZEK, Jakub, DUDEK, Jarosław, PIEC, Jakub, KUBICKI, Mateusz, ZDEB, Wiktor, WNĘK, Mateusz and GLUZICKA, Anna. Testosterone–Cortisol Ratio as a Marker of Training Load and Recovery in Athletes: A Narrative Review. Journal of Education, Health and Sport. 2026;94:73183. https://doi.org/10.12775/JEHS.2026.94.73183

ARTICLE TIMELINE
Received: 08.06.2026 Revised: 12.07.2026
Accepted: 12.07.2026 Published: 17.07.2026

INDEXING & EVALUATION
MEiN points: 40 Unique ID: 201159
Disciplines: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).

The journal has been awarded 40 points in the parametric evaluation by the Polish Ministry of Higher Education and Science (Annex to the announcement of 05.01.2024, No. 32318). Unique Journal Identifier: 201159. Scientific disciplines: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).

Punkty Ministerialne z 2019 – aktualny rok 40 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).

Testosterone–Cortisol Ratio as a Marker of Training Load and Recovery in Athletes: A Narrative Review

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ABSTRACT

Background: Monitoring training load and recovery is essential in athlete management, as inadequate recovery may disturb endocrine regulation and impair adaptation. Among hormonal markers, the testosterone–cortisol ratio has been proposed as an indirect indicator of the balance between anabolic and catabolic processes in response to exercise and training stress.

Aim: This narrative review aimed to synthesize current evidence on the usefulness of the testosterone–cortisol ratio as a marker of training load and recovery in athletes**.**

Materials and methods: The review included peer-reviewed original studies, systematic reviews, and meta-analyses identified through PubMed, Scopus, and Google Scholar. The literature search focused on testosterone, cortisol, testosterone–cortisol ratio, training load, exercise stress, athlete monitoring, and recovery in athletic and physically active populations.

Results: Available evidence suggests that the testosterone–cortisol ratio is responsive to acute and chronic training stress, competition demands, and recovery status. Changes in the ratio may reflect shifts in anabolic–catabolic balance, but their interpretation is influenced by exercise type, training phase, circadian rhythm, individual variability, and environmental factors. Studies from different sports indicate that the ratio may be useful in longitudinal monitoring, especially when combined with external and internal load measures and subjective indicators of fatigue and recovery.

Conclusions: The testosterone–cortisol ratio may provide valuable information about physiological stress and recovery in athletes, but it should not be used as a standalone marker. Its practical value appears greatest when interpreted longitudinally and integrated with broader monitoring strategies.

Key words: testosterone–cortisol ratio, training load, recovery, athlete monitoring, hormonal responses, physiological stress, cortisol, testosterone

1. Introduction

Monitoring training load is a fundamental element of modern sports training and athlete management. Coaches and sport scientists aim to design training programs that provide sufficient stimulus to induce physiological adaptations while avoiding excessive stress that could impair performance or health. Training load is typically described through two complementary perspectives: external load, which refers to the physical work performed, and internal load, which reflects the individual physiological and psychological response to that work (1). Because athletes respond differently to the same training stimulus, monitoring internal responses has become increasingly important for understanding how training affects the body and for optimizing performance.

An equally important aspect of the training process is recovery. Adaptation to training occurs not only during the exercise itself but also during the subsequent recovery period. If recovery is insufficient relative to the imposed training load, fatigue may accumulate and lead to performance decline. In more severe cases, chronic imbalance between training stress and recovery may contribute to the development of overtraining syndrome, a complex condition characterized by long-term performance decrements and disturbances in multiple physiological systems, including the endocrine system (2). For this reason, identifying physiological indicators that reflect an athlete's stress and recovery status has become an important goal in sports science.

Hormonal responses are among the physiological processes most frequently studied in this context. Exercise acts as a stressor that activates the neuroendocrine system, triggering the release of various hormones involved in metabolism, energy regulation, and tissue adaptation. These endocrine responses help the body cope with the demands of exercise and support the adaptation process. During training however, when training stress becomes excessive or prolonged, hormonal regulation may be altered, which can reflect the cumulative physiological strain experienced by the athlete (3).

Particular attention has been given to the balance between anabolic and catabolic processes in the body. Anabolic hormones, such as testosterone, are associated with processes that support muscle growth, protein synthesis, and recovery, whereas catabolic hormones such as cortisol are involved in energy mobilization and the physiological response to stress (3, 4). While both hormonal pathways are necessary for normal adaptation to exercise, an imbalance between them may indicate excessive physiological stress or insufficient recovery.

To assess this balance, researchers have frequently used the testosterone–cortisol (T:C) ratio. This ratio is considered an indirect indicator of the relationship between anabolic and catabolic activity within the body. Changes in the T:C ratio have been observed in response to different types of training loads, competitive stress, and recovery status, suggesting that it may provide useful information about the physiological state of athletes (4, 5). Consequently, the T:C ratio has been proposed as a potential marker for monitoring training load and recovery in sports settings.

Given the growing interest in practical tools that can support athlete monitoring, it is important to examine the current evidence regarding the usefulness and limitations of the testosterone–cortisol ratio in sport. Therefore, the aim of this narrative review is to discuss the role of the testosterone–cortisol ratio as a marker of training load and recovery in athletes and to summarize findings from studies conducted across different sports and training conditions.

2. Methods (Literature Search)

This narrative review was based on a literature search focusing on studies examining hormonal responses to exercise, particularly testosterone, cortisol, and the testosterone–cortisol ratio in athletes. Relevant scientific publications were identified through research conducted major electronic databases commonly used in sports science and biomedical research, including PubMed, Scopus, and Google Scholar. The search queries aimed to identify peer-reviewed articles addressing hormonal responses to training load, recovery, and physiological stress in athletic populations (3, 4). The search strategy included combinations of keywords related to the main topic of the review, such as testosterone, cortisol, testosterone–cortisol ratio, training load, exercise stress, hormonal responses to exercise, athlete monitoring, and recovery. These terms were used individually and in combination to identify relevant studies investigating endocrine responses to different types of exercise, training conditions, and sports disciplines (4, 5).

Studies were considered eligible for inclusion if they examined hormonal responses to exercise or training in athletes or physically active individuals and provided information relevant to the interpretation of testosterone, cortisol, or the testosterone–cortisol ratio in the context of training load, recovery, or physiological stress. Priority was given to peer-reviewed original research articles, systematic reviews, and meta-analyses published in scientific journals related to sports science, physiology, and endocrinology (4, 6). Publications included in the review represent research conducted in various sports disciplines and training environments in order to provide a broader overview of the current evidence regarding the role of the testosterone–cortisol ratio as a potential marker of training load and recovery in athletes.

3. Results

3.1.1 Hormonal Responses to Exercise

Physical exercise triggers a wide range of physiological responses that involve multiple regulatory systems, including the endocrine system. Hormones play an essential role in coordinating metabolic processes, energy availability, tissue repair, and adaptation to physical stress. During exercise, hormonal responses help maintain homeostasis and support the body's ability to cope with increased physiological demands (4, 7). Among the many hormones affected by physical activity, testosterone and cortisol have received particular attention in sports science because they represent key components of the anabolic and catabolic processes associated with training and recovery (4).

3.1.2 Testosterone response to exercise

Testosterone is considered one of the primary anabolic hormones involved in muscle growth, protein synthesis, and recovery following exercise. Acute increases in testosterone concentrations have been observed after certain types of exercise, particularly high-intensity resistance training that involves large muscle groups, moderate to high training volume, and relatively short rest intervals (7). These transient increases are believed to contribute to the anabolic environment that supports muscle adaptation and strength development.

The magnitude of testosterone responses can depend on several factors, including exercise intensity, training status, and the type of exercise performed. For example, resistance training protocols using free weights and multi-joint movements have been associated with hormonal responses that support improvements in muscle strength and hypertrophy (8). In addition to acute responses, long-term training adaptations may also influence baseline hormonal levels and the endocrine response to repeated training stimuli (7).

Testosterone levels have also been linked to aspects of athletic performance. For instance, research involving young professional track and field athletes has shown associations between testosterone concentrations and sprint performance, suggesting that hormonal status may be related to certain performance characteristics in high-level athletes (9). However, testosterone responses can vary widely between individuals and across different types of exercise, indicating that hormonal measurements should be interpreted within the broader context of training load, recovery status, and athlete-specific factors.

3.1.3 Cortisol response to exercise

Cortisol is a glucocorticoid hormone released by the adrenal cortex in response to physical and psychological stress. Exercise is a potent activator of the hypothalamic–pituitary–adrenal (HPA) axis, leading to increased cortisol secretion during and after physical activity (3). Cortisol plays an important role in energy metabolism by promoting the mobilization of glucose, fatty acids, and amino acids to meet the increased energy demands associated with exercise.

The magnitude of cortisol responses largely depends on exercise intensity, duration, and overall physiological stress. Prolonged or exhaustive exercise, particularly in endurance activities, has been shown to produce substantial increases in cortisol concentrations. For example, studies examining endurance exercise have demonstrated dynamic changes in both cortisol and testosterone levels following exhaustive physical effort, reflecting the body's response to high physiological stress (10).

In addition to blood measurements, cortisol can also be assessed using non-invasive methods such as saliva sampling, which has become increasingly common in sports science research. Salivary cortisol measurements allow for repeated monitoring of hormonal responses without the need for invasive procedures and can provide useful information about exercise-induced stress responses (11). Inasmuch as cortisol reflects the activation of stress-related pathways, its response to training and competition is often used as an indicator of physiological strain in athletes (4).

Overall, the interaction between testosterone and cortisol responses provides insight into the balance between anabolic and catabolic processes during exercise. Understanding these hormonal dynamics is important for interpreting how different types of training stimuli influence physiological adaptation and recovery in athletes (4).

3.2 Measurement of Testosterone and Cortisol in Athletes

Accurate measurement of hormonal markers is an important aspect of athlete monitoring, particularly when testosterone, cortisol, and their ratio are used to assess physiological stress and recovery (4, 6). In sports science research and applied practice, these hormones are most commonly measured using blood or saliva samples. Both methods have advantages and limitations, and the choice of sampling technique often depends on the research design, practical considerations, and the need for repeated measurements in athletic settings. Blood sampling has traditionally been considered the reference method for assessing hormone concentrations because it allows for precise quantification of circulating hormones (6). However, blood collection is invasive and may not always be practical during frequent monitoring of athletes, especially in training environments. For this reason, salivary hormone analysis has become increasingly common in sports science. Saliva sampling is non-invasive, relatively easy to perform, and allows repeated measurements with minimal disruption to the athlete. Studies have shown that salivary measurements of testosterone and cortisol can provide useful information about endocrine responses to exercise and training stress (6, 11).

The timing of hormone measurement is another important methodological consideration. Both testosterone and cortisol exhibit circadian rhythms, with cortisol typically peaking in the early morning and gradually decreasing throughout the day. Due to these daily fluctuations, consistent timing of sample collection is essential to ensure meaningful comparisons between measurements. In many studies involving athletes, hormone samples are collected in the morning or at standardized times relative to training sessions in order to reduce variability related to circadian patterns (4).

Another factor affecting the interpretation of hormonal measurements is the reliability and variability of these markers. Hormonal responses to exercise can be influenced by numerous factors, including training load, psychological stress, nutritional status, sleep quality, and individual physiological differences (4, 5). As a result, single measurements may not always accurately reflect the overall physiological status of an athlete. Repeated monitoring over time is therefore often recommended to better understand trends in hormonal responses and to interpret changes in testosterone, cortisol, or their ratio within the broader context of the athlete's training process (6).

Overall, the measurement of testosterone and cortisol requires careful consideration of sampling methods, timing, and contextual factors that may influence hormonal responses.

When applied appropriately, these measurements can provide valuable insights into the physiological stress associated with training and competition and may contribute to more comprehensive monitoring of athlete readiness and recovery (4, 6).

3.3 Testosterone–Cortisol Ratio as a Marker of Physiological Stress

The testosterone–cortisol ratio is commonly used in sports science as an indirect marker of the balance between anabolic and catabolic processes (4, 5). In simple terms, testosterone is usually linked with anabolic functions such as protein synthesis, tissue repair, and maintenance of muscle-related adaptations, whereas cortisol reflects the catabolic and stress-related side of the physiological response (3, 4). For this reason, the ratio between these two hormones has been interpreted as a practical indicator of how the body is responding to training and other physical stressors. Rather than looking at testosterone or cortisol in isolation, the ratio is intended to capture their interaction and provide a broader picture of the athlete's physiological state (4, 5).

From a theoretical perspective, a higher testosterone–cortisol ratio is generally viewed as reflecting a more favorable anabolic environment, while a lower ratio may indicate a shift toward greater catabolic activity or accumulated stress. This interpretation has made the ratio attractive in both research and applied sport settings, especially when the goal is to monitor recovery status, tolerance to training, or possible signs of maladaptation. At the same time, the ratio should not be understood as a direct or isolated measure of performance capacity. It is better interpreted as one physiological signal that may suggest whether the current balance between training stress and recovery is more anabolic or more catabolic (5).

Evidence from salivary hormone studies supports the idea that the testosterone–cortisol ratio is responsive to exercise. A meta-analysis showed that exercise can alter salivary testosterone, cortisol, and their ratio, although the direction and magnitude of change depend on the characteristics of the exercise bout (4). This is important because it suggests that the ratio is sensitive to acute physiological stress, but also that its interpretation requires attention to exercise mode, intensity, and timing of measurement. A change in the ratio after exercise does not automatically indicate either positive adaptation or harmful fatigue; instead, it needs to be considered in relation to the broader training context.

This point is further illustrated by findings reporting discordant testosterone:cortisol ratio responses in runners and non-runners after exercise bouts (12). Their results suggest that the ratio does not always behave in a uniform way across individuals or groups with different training backgrounds. In practical terms, this means that the same exercise stimulus may lead to different hormonal patterns depending on prior adaptation, exercise familiarity, or individual physiology. Such findings reinforce the idea that the testosterone–cortisol ratio should be interpreted cautiously and preferably longitudinally, rather than on the basis of a single isolated value.

Overall, the testosterone–cortisol ratio appears to be a useful marker of physiological stress because it reflects the dynamic relationship between anabolic and catabolic hormonal activity. Its main value lies in helping to contextualize endocrine responses to exercise and training rather than in serving as a stand-alone diagnostic tool. When used carefully, the ratio may contribute to the assessment of athlete readiness, fatigue, and recovery, but its interpretation should always take into account the type of effort performed, the timing of sampling, and individual variability (4, 5, 12).

3.4 Testosterone–Cortisol Ratio and Training Load

Training load is one of the key factors influencing hormonal responses in athletes. Both acute exercise sessions and long-term training programs can affect testosterone and cortisol concentrations, which in turn influence the testosterone–cortisol (T:C) ratio (3, 4). Because this ratio reflects the balance between anabolic and catabolic processes, it has been widely investigated as a potential marker of physiological stress associated with training load and recovery.

Changes in the T:C ratio can occur in response to both acute and chronic training stimuli. During periods of high training intensity or volume, cortisol levels may increase as part of the body’s stress response, while testosterone responses may vary depending on the type of exercise and the athlete’s recovery status (3). As a result, the T:C ratio may decrease when the physiological stress associated with training becomes dominant. For example, research on elite judokas has shown that variations in weekly training load can influence both testosterone and cortisol awakening responses, suggesting that hormonal patterns may reflect differences between lighter and heavier training weeks (13). Such findings support the idea that endocrine markers may respond to fluctuations in training stress during different phases of a training cycle.

Longitudinal monitoring of athletes throughout a competitive season also provides insight into how training and competition demands influence hormonal balance. In professional football players, variations in training and competition load across the season were associated with changes in neuromuscular recovery as well as hormonal markers, including testosterone and cortisol (14). These results indicate that endocrine responses may be linked with both physical load and performance outcomes, highlighting the potential value of hormonal monitoring in team sports environments.

Similar observations have been reported in other sports contexts. In tennis players, the relationship between training load, physiological stress, and immune-endocrine responses during a training period was investigated (15). The findings suggested that hormonal markers, including testosterone and cortisol, can reflect the overall physiological demands imposed by training and competition schedules. These responses may therefore provide additional information about how athletes are coping with accumulated training stress.

Competition itself can also influence hormonal responses, particularly in sports where matches involve high physical and psychological demands. For example, elite Australian Rules football players were examined and notable endocrine responses following match play were reported (16). These responses reflect the combined impact of physical exertion, psychological stress, and recovery demands associated with competition. In such contexts, changes in testosterone and cortisol may contribute to fluctuations in the T:C ratio during different stages of the competitive season.

Overall, existing evidence suggests that the testosterone–cortisol ratio may respond to variations in training load, including differences between lighter and heavier training periods, accumulated seasonal stress, and competition demands. Although the ratio should not be interpreted as a standalone indicator of training status, monitoring changes over time may provide useful information about the balance between training stress and recovery in athletes (4, 13-16).

3.5.1 Evidence from Different Sports

Research examining the testosterone–cortisol ratio has been conducted across a variety of sports, providing insight into how hormonal responses may differ depending on the specific demands of training and competition (4, 5). Because sports vary widely in terms of physical load, duration, intensity, and psychological stress, endocrine responses and the resulting testosterone–cortisol balance may also vary (3). Studies from team sports, individual disciplines, and endurance or mixed sports offer valuable perspectives on how hormonal markers respond to different athletic environments.

3.5.2 Team sports

Team sports are characterized by intermittent high-intensity efforts combined with tactical and psychological demands. These factors can influence endocrine responses during both training and competition (3). For example, research conducted during a professional football season demonstrated that fluctuations in training and match load were associated with changes in testosterone and cortisol concentrations, which were also linked to neuromuscular recovery and performance indicators (14). This suggests that hormonal markers, including the testosterone–cortisol ratio, may reflect the physiological stress experienced during demanding competitive schedules.

Similar interactions between stress and hormonal responses have been observed in other team sport settings. Professional women's basketball players were investigated and relationships between stress levels, hormonal responses, and aspects of sports performance were reported (17). Their findings highlight that hormonal markers may be influenced not only by physical training demands but also by psychological stress related to competition and performance expectations.

Hormonal responses have also been studied in high-intensity functional training competitions, where repeated demanding workouts can produce significant physiological stress. Notable changes in testosterone and cortisol concentrations during multiple competition workouts have been observed, illustrating how acute competitive stress can influence endocrine responses (18). These findings further support the idea that hormonal markers may provide useful information about the physiological demands placed on athletes in competitive team or group-based sport environments.

3.5.3 Individual sports

Studies conducted in individual sports also provide evidence of hormonal responses associated with training and competition. In swimmers undergoing preseason training, physiological stress responses accompanied by muscle damage and soreness during periods of intensive training have been reported (19). Such findings suggest that endocrine markers may reflect the accumulated stress associated with heavy training phases in individual sports.

Research involving adolescent elite swimmers performing maximal exercise tests has also shown significant physiological and psychological responses to intense effort (20). Although such studies focus on broader physiological responses, hormonal markers like testosterone and cortisol are often considered a part of the overall stress response to maximal or near-maximal exercise (4).

Additionally, investigations conducted during major international competitions provide insight into how elite athletes respond to competitive stress. Track and field athletes competing during the European Games were examined, and associations between stress-related factors and performance outcomes were identified (21). Similar relationships have also been observed in rowing athletes, where the testosterone–cortisol ratio has been linked to competitive performance outcomes, suggesting that hormonal balance may influence the likelihood of achieving podium results (22). These results highlight that physiological and psychological stress responses may influence performance during high-level competitions, and hormonal markers may contribute to understanding these processes.

3.5.4 Endurance and mixed sports

Endurance and mixed-discipline sports often involve prolonged physical effort combined with complex training demands. Studies in these sports have also examined hormonal responses to training load and competition stress. For example, a multifactorial assessment of elite paratriathletes during a training camp analyzed several physiological indicators associated with training stress and adaptation (23). Such investigations illustrate the complex interactions between training load, recovery, and physiological responses in endurance-based sports.

Hormonal responses have also been examined in strength and mixed training interventions. Salivary testosterone and cortisol responses during a seven-week blood flow restriction training program in collegiate American football players were investigated (24).

Their findings demonstrate that different training strategies can influence endocrine responses over time, further highlighting the potential role of hormonal monitoring in evaluating training adaptations.

Overall, evidence from different sports indicates that testosterone and cortisol responses—and consequently the testosterone–cortisol ratio—are influenced by the specific characteristics of training and competition in each discipline (4, 5). While the patterns may vary depending on sport type, training intensity, and competitive demands, these hormonal markers may provide useful information about physiological stress and recovery when interpreted within the context of sport-specific conditions.

3.6 Limitations of Testosterone–Cortisol Ratio

Although the testosterone–cortisol (T:C) ratio is widely used in sports science as an indicator of the balance between anabolic and catabolic processes, several limitations should be considered when interpreting this marker (4, 5). Hormonal responses to exercise are influenced by numerous physiological and environmental factors, which means that the T:C ratio should not be viewed as a standalone indicator of training status or recovery (3, 4).

One important limitation is the large degree of individual variability in hormonal responses. Testosterone and cortisol concentrations can differ substantially between athletes due to factors such as age, sex, training status, genetic background, and long-term training history. Because of this variability, baseline hormonal values and responses to exercise may differ significantly between individuals. As a result, changes in the T:C ratio are often more meaningful when monitored longitudinally within the same athlete rather than compared directly between different individuals or groups (4, 5).

Another factor that complicates the interpretation of the T:C ratio is the circadian rhythm of both hormones. Cortisol typically follows a pronounced daily pattern, with the highest concentrations occurring in the early morning and gradually decreasing throughout the day. Testosterone also exhibits diurnal fluctuations, although the pattern may differ between individuals. Because of these natural variations, the timing of sample collection plays a critical role in hormonal measurements. Inconsistent sampling times may lead to misleading interpretations of changes in the T:C ratio, particularly when comparing values obtained at different times of the day (4, 5).

Environmental and contextual factors can also influence hormonal responses. Variables such as psychological stress, sleep quality, nutritional status, travel, and competition schedules may affect testosterone and cortisol levels independently of training load. Research examining hormonal measurements in athletes has emphasized that endocrine responses can be affected by multiple external conditions beyond physical exercise alone (3, 6). These factors may introduce additional variability into hormonal measurements and complicate the interpretation of the T:C ratio in applied sport settings.

Furthermore, the relationship between the T:C ratio and performance or recovery is not always straightforward. While decreases in the ratio are sometimes interpreted as a shift toward greater catabolic activity or accumulated fatigue, the magnitude and direction of hormonal changes can vary depending on the type of exercise, training phase, and individual adaptation (4). Consequently, relying solely on the T:C ratio may oversimplify the complex physiological processes involved in training adaptation.

For these reasons, many researchers emphasize that the testosterone–cortisol ratio should be interpreted alongside other physiological, psychological, and performance-related indicators. Combining hormonal monitoring with additional measures of training load, recovery, and athlete well-being may provide a more comprehensive understanding of the athlete's physiological status (4-6).

3.7 Practical Applications for Athlete Monitoring

In applied sport settings, the testosterone–cortisol ratio may be most useful when it is treated as one element of a broader athlete-monitoring framework rather than as an isolated marker (4, 5). Training load is now commonly understood as having both external and internal dimensions, and effective monitoring depends on linking the work performed by the athlete with the athlete's individual response to that work (1). In this context, the testosterone–cortisol ratio can provide additional information about the endocrine response to training stress and recovery demands, especially when measurements are repeated over time under standardized conditions (4).

From a practical perspective, the value of the ratio lies less in any single measurement and more in its longitudinal use. Regular assessment may help practitioners identify patterns associated with heavy training phases, congested competition periods, or insufficient recovery.

When interpreted alongside other markers, hormonal trends may support decisions related to training adjustment, recovery strategies, or closer observation of athletes who appear to be under elevated physiological stress (5). However, because hormonal values are influenced by many factors, the ratio should be interpreted carefully and always in relation to the wider training process rather than as a direct indicator of readiness on its own (4).

An important practical implication is that hormonal monitoring should be integrated with established training-load models. Internal and external load should be considered together, since the same external stimulus may produce different internal responses in different athletes (1). The testosterone–cortisol ratio fits within this logic as a possible indicator of internal response, complementing data such as session load, competition exposure, or other physiological measures. Used in this way, it may help practitioners better understand whether a training program is being tolerated as intended.

Another key application is the combination of hormonal monitoring with subjective measures. Evidence from a long-term prospective study in elite athletes showed that subjective and objective indicators of stress and load are meaningfully associated, supporting the value of a multidimensional monitoring approach (25). In practice, this means that the testosterone–cortisol ratio may be more informative when interpreted together with self-reported fatigue, stress, mood, sleep quality, or perceived recovery. Such integration may improve the detection of maladaptive responses that might not be visible when relying on hormonal or workload data alone.

Overall, the practical role of the testosterone–cortisol ratio is not to replace existing monitoring tools, but to complement them. When used alongside external load data, internal load indicators, and subjective athlete-reported outcomes, it may contribute to a more complete picture of how athletes respond to training and recover across time (1, 4). This combined approach is likely to be more useful for day-to-day athlete management than relying on any single marker in isolation.

4. Discussion

This review set out to evaluate whether the testosterone–cortisol (T:C) ratio can actually be useful when monitoring training load and recovery in athletes. Based on the available evidence, it seems that the ratio does react to physiological stress, but using it in practice is not as straightforward as it might initially appear (4, 5).

Across the studies included in this review, a consistent pattern can be seen: the T:C ratio changes both after single training sessions and over longer training periods. Fluctuations in testosterone and cortisol are observed not only immediately after exercise, but also across different phases of the season (3, 4). This suggests that the ratio can reflect how the body responds to training stress. At the same time, these responses are not always consistent. Similar training loads can produce different hormonal outcomes, depending on factors such as exercise intensity, the stage of the training cycle, or simply the athlete's current condition (4, 12).

Differences between sports add another layer of complexity. The reviewed studies show that hormonal responses vary depending on the type of discipline — whether it is a team sport, an endurance activity, or an individual event (4, 5). This is likely linked to differences in effort characteristics and psychological demands (3). Due to this fact, interpreting the T:C ratio without considering the specific sport context may lead to oversimplified conclusions.

Another issue that comes up repeatedly is individual variability. Hormonal responses are affected by many factors beyond training itself, including circadian rhythms, sleep, nutrition, and psychological stress (4–6). For that reason, a single measurement of the T:C ratio does not say much on its own. What seems more meaningful is looking at how the ratio changes over time in the same athlete and relating it to their typical values (4, 5).

It is also important to point out that the T:C ratio should not be treated as a standalone marker. Although it gives some insight into the balance between anabolic and catabolic processes, it does not capture the full picture of training adaptation (4, 5). In practice, changes in the ratio can be difficult to interpret without additional context. This is why combining hormonal data with other measures — such as training load or subjective assessments of fatigue and recovery — appears to be a more practical solution (1, 4, 25).

From an applied perspective, the main value of the T:C ratio seems to be its use as part of a broader monitoring approach. When measured regularly and interpreted together with other indicators, it may help identify periods of increased stress or insufficient recovery (4, 5). However, relying on it alone could be misleading.

Overall, the findings suggest that the testosterone–cortisol ratio can be a useful addition to athlete monitoring, but only when used with caution. Its real value comes from tracking changes over time and combining it with other sources of information, rather than focusing on single measurements in isolation (1, 4, 5).

5. Conclusions

Monitoring physiological responses to training is an important component of modern athlete management. Inasmuch as training adaptations depend on the balance between workload and recovery, identifying markers that reflect the athlete's internal response to exercise remains a key goal in sports science (1). Hormonal indicators, particularly testosterone and cortisol, have received considerable attention due to their roles in anabolic and catabolic processes and their involvement in the body's response to physical stress (2, 3).

The testosterone–cortisol ratio has been proposed as a practical indicator of the relationship between these two hormonal pathways. As discussed in this review, research across different sports suggests that changes in this ratio may reflect variations in training load, competition stress, and recovery status (13-15). Studies involving athletes from team sports, individual disciplines, and endurance-based sports indicate that testosterone and cortisol concentrations can respond to both acute exercise and longer-term training cycles, which in turn may influence the balance between anabolic and catabolic processes (4, 5).

At the same time, the available evidence shows that the testosterone–cortisol ratio should be interpreted with caution. Hormonal responses can vary widely between individuals and are influenced by factors such as circadian rhythms, psychological stress, environmental conditions, and differences in training background (4-6). For this reason, the ratio is unlikely to provide a complete picture of training status when used in isolation. Instead, it appears to be most useful when monitored longitudinally and interpreted alongside other indicators of training load, recovery, and athlete well-being (4, 5).

From a practical perspective, integrating hormonal markers with other monitoring strategies may improve the understanding of how athletes respond to training. Combining endocrine measurements with information on external and internal training load, as well as subjective measures of fatigue and stress, may provide a more comprehensive assessment of the athlete's physiological state (1, 25).

Future research should continue to explore the role of the testosterone–cortisol ratio in different sports, training environments, and athlete populations. In particular, long-term studies investigating how hormonal patterns change across entire training seasons may help clarify the practical value of this marker for optimizing training programs and supporting athlete health and performance (4, 13).

Disclosures:

Author's contribution:

Conceptualization: DG, KL,MK;

Methodology: DG, WK, MW;

Software: JK, JP, KL;

Check: JD, JK, WZ;

Formal analysis: DG, MK, AG, JK;

Investigation: JD, KL;

Resources: WK, AG WZ;

Data curation: MK, JP, KL;

Writing-rough preparation: MW, WZ;

Writing -review and editing: JD, MK, AG;

Visualization: JP, JK, DG; Supervision: DG, JD, MW;

Project administration: DG, MK, WK

Funding: The study did not receive external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgements: Not applicable.

Conflicts of Interest: The authors declare no conflicts of interest.

All authors have read and agreed with the published version of the manuscript.

Declaration of the use of generative AI and AI-assisted technologies in the writing process:

In preparing this work, the authors used ChatGPT for the purpose of improving language and readability. After using this tool, the authors have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

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