INPLASY

Matcha and Green Tea Bioactives Modulate the Testosterone-to-Cortisol Ratio: A Systematic Review of Endocrine Stress Regulation by L-Theanine and EGCG

INPLASY202640072
doi: 10.37766/inplasy2026.4.0072
Received: 21 April 2026
Published: 21 April 2026

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ADMINISTRATIVE INFORMATION

Support - No external funding. Supported by King Saud bin Abdulaziz University for Health Sciences, Riyadh, Saudi Arabia.

Review Stage at time of this submission - Completed but not published.

Conflicts of interest - None declared.

INPLASY registration number: INPLASY202640072

Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 21 April 2026 and was last updated on 21 April 2026.

INTRODUCTION

Review question / Objective This systematic review addresses the following question: What is the evidence from experimental and clinical studies for the effects of matcha (Camellia sinensis) and its characteristic bioactive compounds, principally epigallocatechin gallate (EGCG) and L-theanine, on testosterone concentrations, cortisol concentrations, and the testosterone-to-cortisol (T/C) ratio as an index of anabolic-catabolic hormonal balance?
Population: Human participants of any age or sex in clinical trials; animal models in controlled experimental studies where outcomes are directly relevant to human hormonal health; in vitro cell or tissue systems relevant to steroidogenesis, glucocorticoid metabolism via 11 beta-hydroxysteroid dehydrogenase type 1 (11B-HSD1), or neuroendocrine stress regulation.
Intervention: Matcha administered as whole-leaf powder, beverage, capsule, or food matrix; or isolated characteristic bioactive compounds of matcha including EGCG, L-theanine, or catechin-rich matcha extracts.
Comparator: Placebo control; no-treatment control; vehicle control in in vitro studies; standard diet control in animal studies.
Outcomes: Primary outcomes are testosterone concentration, cortisol concentration, and the testosterone-to-cortisol ratio as a composite hormonal index. Secondary outcomes include salivary alpha-amylase, luteinizing hormone, follicle-stimulating hormone, 11B-HSD1 enzyme activity, skeletal muscle mass, and gut microbiota composition where reported in relation to hormonal outcomes.
Study designs: Randomized controlled trials; non-randomized controlled trials; crossover trials; controlled animal intervention experiments; in vitro experimental studies.

Rationale Disruption of the testosterone-to-cortisol (T:C) ratio is a critical indicator of hormonal stress imbalance and impaired anabolic–catabolic homeostasis, with significant implications for

athletic performance, metabolic health, obesity, and ageing. Matcha provides substantially higher concentrations of EGCG and L-theanine than conventionally brewed green tea, making it a promising candidate for hormonal stress regulation. Despite growing mechanistic evidence, no systematic review has comprehensively evaluated these effects on the T:C ratio as an integrated clinical outcome.

Condition being studied The condition of interest in this review is hormonal imbalance characterized by dysregulation of the testosterone-to-cortisol ratio, a composite endocrine index reflecting the relative dominance of catabolic over anabolic hormonal processes. This imbalance is clinically relevant across several overlapping health domains.

In sports medicine and exercise physiology, a suppressed testosterone-to-cortisol ratio is recognized as a reliable marker of overreaching and insufficient recovery, predicting performance decrements and increasing injury susceptibility in both elite and recreational athletes. The ratio responds dynamically to training load, psychological stress, nutritional status, and sleep quality, making it a sensitive indicator of physiological resilience.

In metabolic health, chronic elevation of cortisol relative to testosterone is implicated in the pathogenesis of sarcopenic obesity, a condition in which excess adipose tissue accumulation and progressive skeletal muscle loss occur concurrently. Hypertrophic adipocytes generate a systemic oxidative and inflammatory burden that simultaneously suppresses testicular steroidogenesis and amplifies hypothalamic-pituitary-adrenal axis reactivity, creating a self-reinforcing cycle of hormonal imbalance and metabolic deterioration.

In aging populations, the natural age-related decline in testosterone combined with stress-related cortisol elevation accelerates sarcopenia and frailty, contributing to reduced functional capacity, increased fall risk, and diminished quality of life. The testosterone-to-cortisol ratio therefore serves as a clinically meaningful target in preventive medicine strategies aimed at preserving musculoskeletal health across the lifespan.

The present review examines the capacity of matcha and its bioactive compounds to modulate this hormonal balance through three converging mechanistic pathways: peripheral cortisol regeneration inhibition via 11 beta-hydroxysteroid dehydrogenase type 1 suppression, hypothalamic-pituitary-adrenal axis attenuation mediated by L-theanine, and gut microbiota-mediated anabolic adaptation through short-chain fatty acid signalling. The review spans evidence from in vitro enzyme assays, controlled animal experiments, and human randomized controlled trials to provide the most comprehensive mechanistic synthesis currently available on this topic.

METHODS

Search strategy Primary electronic searches were conducted across five bibliographic databases: PubMed (MEDLINE), Scopus, ScienceDirect, SpringerLink, and Web of Science Core Collection. Google Scholar was searched supplementarily to capture grey literature not indexed in the primary databases. No date restrictions or geographic restrictions were applied. English language only.

The PubMed search string was: ((matcha[tiab] OR "Camellia sinensis powder"[tiab] OR "powdered green tea"[tiab]) AND (epigallocatechin[tiab] OR EGCG[tiab] OR "epigallocatechin gallate"[tiab] OR "L-theanine"[tiab] OR theanine[tiab]) AND (testosterone[tiab] OR cortisol[tiab] OR "testosterone-to-cortisol"[tiab] OR "anabolic-catabolic"[tiab] OR "T/C ratio"[tiab] OR "11beta-HSD1"[tiab] OR "hydroxysteroid dehydrogenase"[tiab])) NOT (review[pt] OR editorial[pt] OR comment[pt]).

Equivalent search strings using appropriate field codes were applied in Scopus (TITLE-ABS-KEY), Web of Science (TS field), ScienceDirect, and SpringerLink. Reference lists of all included studies and relevant systematic reviews were hand-searched following completion of primary database searches, identifying four additional eligible records: Shigeta et al. (2023), Soliman et al. (2025), Unno et al. (2018), and Baba et al. (2021). The searches were conducted in April 2026. This registration is retrospective; the review was completed prior to formal registration, which is disclosed transparently in the manuscript.

Participant or population Human participants of any age, sex, or health status in clinical trials and intervention studies. Animal models of any species in controlled experimental studies where outcomes are directly relevant to human hormonal health. In vitro cell or tissue systems relevant to steroidogenesis, glucocorticoid metabolism via 11 beta-hydroxysteroid dehydrogenase type 1, or neuroendocrine stress regulation of the hypothalamic-pituitary-adrenal axis. No restriction on athletic status, body composition, or disease state. Exclusions: paediatric populations where hormonal outcomes reflect developmental rather than intervention effects; pregnant or postpartum women where gestational physiology confounds hormonal profiles.

Intervention Matcha (Camellia sinensis) administered as whole-leaf powder, beverage, capsule, or food matrix at any dose or duration. Isolated characteristic bioactive compounds of matcha including epigallocatechin gallate, L-theanine, or catechin-rich matcha extracts administered in any dose or form. Studies must clearly distinguish the intervention from general brewed green tea infusion and provide sufficient characterisation to allow dose assessment. Both acute single-dose and chronic multi-week interventions are eligible. Exclusions: general brewed green tea without whole-leaf characterisation; caffeine-only interventions; topical or intravenous administration routes.

Comparator Placebo control matched for appearance, taste, and volume without active compounds; no-treatment control; vehicle control in in vitro studies; standard diet control in animal studies. Studies without a comparator group are eligible if they report quantitative pre-post hormonal outcome data sufficient for mechanistic assessment. Exclusions: active pharmaceutical comparators directly targeting testosterone or cortisol unless matcha or its bioactives are the primary intervention.

Study designs to be included Randomized controlled trials; non-randomized controlled trials; crossover trials; controlled parallel-group animal intervention experiments; in vitro experimental studies using cell or tissue systems relevant to steroidogenesis or glucocorticoid metabolism. Mechanistic review papers included where they synthesize primary experimental data not otherwise available as individual eligible primary studies; acknowledged as a methodological limitation. Excluded: case reports; case series; conference abstracts without full data; editorials; commentaries; letters.

Eligibility criteria Studies published in any year are eligible. English language only. No restriction on geographic location or clinical setting. Both acute and chronic intervention durations are eligible. Mechanistic review papers are included where they synthesize primary experimental data not available as individual eligible primary studies; this exception is acknowledged as a limitation. Excluded: case reports; case series; conference abstracts without full data; editorials; commentaries; letters; studies using non-matcha polyphenols without mechanistic relevance to testosterone or cortisol; duplicate publications.

Information sources PubMed (MEDLINE), Scopus, ScienceDirect, SpringerLink, Web of Science Core Collection, Google Scholar (supplementary grey literature). Reference lists of all included studies and relevant systematic reviews were hand-searched. No trial registries or dissertation databases were formally searched. Searches conducted April 2026.

Main outcome(s) Testosterone concentration measured by ELISA or immunoassay in serum, plasma, or saliva at any time point during or following the intervention. Cortisol concentration measured by ELISA or immunoassay in serum, plasma, or saliva. Testosterone-to-cortisol ratio calculated as the composite anabolic-catabolic hormonal index. Effect direction, magnitude, and statistical significance reported where available.

Additional outcome(s) Salivary alpha-amylase as proxy stress biomarker. Luteinizing hormone and follicle-stimulating hormone concentrations. 11 beta-hydroxysteroid dehydrogenase type 1 enzyme activity in microsomal or cell-based assays. Skeletal muscle mass measured by DXA or equivalent. Resistance training-induced strength gains. Gut microbiota composition, specifically abundance of short-chain fatty acid-producing genera including Ruminococcus, Butyricimonas, and Oscillospira.

Data management Data were extracted using a pre-specified form capturing study design, experimental model, intervention details including matcha form, dose, and CE/TA molar ratio where reported, outcome measures and measurement methods, and key statistical results. Extracted data are summarized in a comprehensive evidence table presented in the manuscript. Records were managed using reference management software.

Quality assessment / Risk of bias analysis Risk of bias was assessed using validated tools appropriate to each study design. Cochrane Risk of Bias 2.0 tool was applied to human randomized controlled trials across five domains. The SYRCLE tool was applied to controlled animal intervention studies. ToxRTool was applied to in vitro studies. Overall evidence certainty was assessed informally using GRADE principles for each key outcome domain: moderate certainty for L-theanine cortisol effects in humans; low certainty for gut microbiota anabolic pathway; very low certainty for testosterone modulation due to absence of human data and bidirectional preclinical findings.

Strategy of data synthesis Quantitative meta-analytic pooling was not performed owing to substantial methodological heterogeneity across included study designs, populations, interventions,

and outcome measurement methods. Evidence is synthesized narratively, organized by mechanistic pathway and study model type. Three mechanistic pathways are examined: peripheral cortisol regeneration inhibition via 11 beta-HSD1 suppression by EGCG; HPA axis attenuation by L-theanine; and gut microbiota-mediated anabolic adaptation through SCFA-ERK-p70S6K signalling. For each pathway, direction, magnitude, and consistency of effects are described across studies. A comprehensive tabular summary of all 16 included studies is presented.

Subgroup analysis Subgroup analyses were not performed owing to the small number of human trials and substantial heterogeneity across study designs. Where data permitted, findings are described separately by study model type (human, animal, in vitro), intervention type (whole-powder matcha versus isolated EGCG versus isolated L-theanine), and outcome type (testosterone, cortisol, T/C ratio). The CE/TA molar ratio is examined as a categorical moderator of cortisol outcomes where reported.

Sensitivity analysis Formal sensitivity analyses were not conducted owing to the narrative synthesis approach and small number of human trials. The robustness of mechanistic conclusions is assessed qualitatively by examining consistency of findings across independent studies and across different experimental models. The impact of including mechanistic review papers as primary evidence sources is acknowledged as a sensitivity consideration and discussed explicitly in the manuscript limitations.

Language restriction English language only.

Country(ies) involved Saudi Arabia.

Other relevant information This registration is retrospective. The review was completed prior to formal registration on INPLASY. The review protocol, eligibility criteria, and search strategy were established prior to data extraction and were not modified after data collection began. This retrospective registration is disclosed transparently in the manuscript Methods section. The review identified a categorical gap in the published literature: no human trial has measured testosterone or the testosterone-to-cortisol ratio as a primary endpoint following matcha-specific intervention. This gap defines the central contribution of the review and the foremost agenda for future clinical trials. A critical formulation parameter is identified: the CE/TA molar ratio must be below 2 for stress-reducing efficacy to manifest, resolving longstanding inconsistency in the matcha stress literature.

Keywords matcha; Camellia sinensis; testosterone; cortisol; testosterone-to-cortisol ratio; EGCG; L-theanine; 11beta-HSD1; HPA axis; gut microbiota; sarcopenia; systematic review.

Dissemination plans The findings of this systematic review will be submitted for publication in a peer-reviewed Q1 nutrition journal, with Food and Function and Nutrients as primary targets. The review will be made available as open access where possible to maximize accessibility to clinicians, sports scientists, and researchers working in nutritional endocrinology and functional food science.

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