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Training Volume and Mental Health Outcomes in U.S. Collegiate Student-Athletes: Testing Linear and Non-Linear Risk Patterns

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Abstract:

Collegiate student-athletes navigate a demanding landscape of unique stressors, balancing academic eligibility and financial obligations against rigorous performance expectations. Using a large-scale, multi-division U.S. sample from the Healthy Minds Study (2019–2025; N > 9,000), this thesis examines how weekly training volume relates to mental health outcomes and how these associations compare with key psychosocial stressors (gender, sexual orientation, and financial stress).

Kruskal–Wallis tests and OLS regression models show that psychosocial factors, particularly financial stress, explain substantially more variance across anxiety (GAD-7), depression (PHQ-9), eating disorder symptoms (SCOFF), and athlete psychological strain (APSQ) than training environment and volume variables. Functional-form tests indicate a robust U-shaped relationship between training volume and SCOFF that remains significant after adjusting for psychosocial covariates, whereas the apparent U-shape for depression weakens and becomes non-significant once covariates are included. APSQ scores increase in a predominantly linear fashion with training volume and do not mirror the non-linear SCOFF pattern at extreme volumes.

Overall, training volume shows negligible-to-small effect sizes across outcomes, and these data do not support recommending a single "optimal" weekly training-volume threshold. The findings instead support a load-aware and context-aware screening approach that integrates athlete-specific distress measures with validated clinical tools and prioritizes psychosocial vulnerability factors in prevention and early intervention strategies.

Keywords: student-athletes; mental health; training volume; psychosocial stressors; non-linear relationships; microdata analysis; collegiate sport; mental health screening

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1. Introduction

1.1. Background

Student-athletes (SAs) bear unique responsibilities concerning time and life management that exceed those of students or athletes alone, requiring them to balance rigorous academic demands, intensive athletic obligations, and financial and social expectations. This combination creates a high-pressure environment in which psychological well-being is essential for both persistence and performance. This thesis operationalizes mental health using validated self-report screening tools that capture both athlete-specific psychological strain (Athlete Psychological Strain Questionnaire; APSQ) and general clinical symptoms (anxiety (GAD-7), depression (PHQ-9), and eating disorder symptoms (SCOFF). While participation in competitive sport can confer benefits such as social support and enhanced self-efficacy, the collegiate athletic context may also heighten vulnerability to mental health symptoms. These relationships are examined using secondary, de-identified survey data from the Healthy Minds Study (HMS), a large-scale U.S. dataset of collegiate students, including student-athletes across divisions.

The transition to university coincides with the peak onset period for mental illness, with 75% of conditions (e.g. anxiety and depression) emerging during young adulthood (Adams et al., 2021; Rice et al., 2016). Consequently, college students experience the highest annual rates of diminished mental health, exceeding 20% (Beasley et al., 2024). For SAs, this risk is often comparable to or higher than the general student population, with approximately 50% falling within the low to moderate risk range for clinical conditions (Kaishian & Kaishian, 2021), underscoring the persistent need for comprehensive research focused on promoting athlete well-being.

1.2. Problem Description

Despite consistent evidence indicating a high prevalence of mental health challenges among collegiate student-athletes, existing literature is fragmented, making it difficult to establish a single, uniform prevalence figure. This difficulty stems from a lack of consistent screening measures across institutions and variations in demographic and clinical reporting methods, challenging the accuracy of current estimates for conditions like depression. The literature identifies that risk is not uniformly distributed, being disproportionately high among specific

demographic subgroups, including female, BIPOC, and LGBTQ+ athletes (Anderson et al., 2023; Kaishian & Kaishian, 2021; Usenic & Kranjec, 2025; Wolanin et al., 2016).

Furthermore, a critical gap in understanding how athletic exposure impacts psychological health is incomplete. While the Non-Linear Dose-Response Hypothesis suggests that both insufficient and excessive training can negatively affect mental health (a U-shaped curve), few large-scale studies have statistically modeled training load as a continuous, curvilinear predictor across diverse samples.

The primary problem is that existing models combine distinct psychological outcomes such as anxiety and depression or ignore eating disorders or athlete-specific strain entirely, leading to an incomplete picture of student-athlete well-being (Grasdalsmoen et al., 2022; Shimura et al., 2023). Additionally, studies utilize training volume caps (e.g., ≤14 hours/week) that do not reflect the high-intensity 20-hour limits of the U.S. NCAA system (Ge et al., 2025; Grasdalsmoen et al., 2022). Consequently, current research fails to account for the interplay between extreme athletic load, demographic vulnerabilities, and socio-environmental stressors such as financial pressure (Moore et al., 2022; Rao & Hong, 2016). This gap leaves athletic departments without the "load-aware" screening protocols necessary for effective early intervention.

1.3. The Main Objective of the Thesis

The overall objective of this thesis is to address these critical empirical gaps by utilizing a recent, large-scale, multi-division U.S. sample of student-athletes. Specifically, the study aims to examine the relative contributions of training environment factors (Elite Status, Training Volume) and psychosocial factors (Gender, Sexual Orientation, Financial Stress) accounting for differences and explaining variance. The research further investigates the functional form of the relationship between training volume and mental health outcomes, distinguishing between linear and non-linear patterns across specific clinical disorders (Anxiety, Depression, Eating Disorder symptoms) and athlete-specific strain (APSQ). The findings will support a shift from one-size-fits-all psychological risk models toward a comprehensive, load-aware screening approach that integrates context-specific measures with validated clinical tools.

1.4. Scope

The scope of this thesis is defined by its use of secondary, de-identified and aggregated data extracted from the Healthy Minds Network's annual web-based survey study, spanning the years 2019 to 2025. The study focuses on four key mental health outcomes treated as continuous numerical scores: Anxiety (Generalized Anxiety Disorder 7-item scale, GAD-7), Depression (Patient Health Questionnaire 9-item scale, PHQ-9), Eating Disorder Symptoms (SCOFF, 5-item scale), and Athlete Psychological Strain (APSQ, 10-item scale). Predictor variables include binarized Gender (Female/Male) and Sexual Orientation (Heterosexual/LGBTQ+), Elite Status (NCAA D1/Non-elite), a categorical and continuous measure of Training Volume, and Financial Stress. Statistical analysis employs Kruskal-Wallis tests for comparing means across categorical groups and Ordinary Least Squares (OLS) regression to assess and compare linear and quadratic functional forms of the training volume relationship. The primary focus is on establishing the relative predictive power of psychosocial versus training environment factors and testing the curvilinear dose-response hypothesis.

2. Literature Review

2.1. Dependent Variables – Mental Health Outcomes and Risk in Student-Athletes

While student-athletes gain positive experiences such as self-confidence and social support, the mental health effects in competitive sports are not uniformly positive (Tabet et al., 2021). Although exercise can promote well-being, the competitive nature of university sports can increase the risk of mental health challenges (Kaishian & Kaishian, 2021; Wolanin et al., 2016). Prevalence rates of depression and anxiety among student-athletes often mirror the general population (Simon et al., 2025; Wolanin et al., 2016), whereas other conditions such as eating disorders frequently occur at higher rates (Schlimmer & Chin, 2018). In some cases, the risk for student-athletes is even higher than non-athlete students (Beasley et al., 2024; Kaishian & Kaishian, 2021), with around 50% of student-athletes falling within the low to moderate risk range for mental health conditions (Kaishian & Kaishian, 2021).

2.1.1. Depression

Depression is consistently reported as one of the most common psychological disorders among student-athletes, with prevalence is often similar or exceeds the rates within the general student population (Chang et al., 2020; Schlimmer & Chin, 2018; Simon et al., 2025). This increased

risk is complex, since depression may be present prior to collegiate sport participation or can emerge due to sport-related pressure, injury, or overtraining (Schlimmer & Chin, 2018). This highlights the layered relationship between athlete specific stressors and increased mental health risk.

Studies from as early as 2007-2010 focusing on depression in the collegiate athlete population established the issue, with reported prevalence estimates ranging from 15.6% to 21% (Proctor & Boan-Lenzo, 2010; Yang et al., 2006). Following these findings, more detailed studies were published to distinguish between different levels of risk: a study reported a 23.8% prevalence of clinically elevated depressive symptoms overall, but a significantly lower 6.3% prevalence of moderate to severe symptoms (Wolanin et al., 2016).

In contrast, a more recent 2025 study conducted student-athletes reported a lower prevalence of depression at 11.6% (Whelan et al., 2025). Conversely, systematic reviews that aggregate diverse data report a wider, higher range, with 16−31% of student-athletes endorsing moderate to severe depressive symptoms (Kaishian & Kaishian, 2021).

Current estimates of depression and suicide prevalence are inherently challenged by a lack of standardized screening tools and inconsistent reporting protocols by universities and athletic departments. This lack of uniformity makes effective evaluation challenging and suggests that mental health concerns, particularly depression and suicide, are subject to significant under-reporting.

2.1.2. Anxiety

Similarly to depression, anxiety is reported as one of the most common mental health challenges among student-athletes (Kaishian & Kaishian, 2021; Young et al., 2023). Qualitative research highlights performance anxiety in the student-athlete subpopulation, and the fear of underperforming relative to the expectations set by coaches, teammates, and themselves (Young et al., 2023).

However, reports of subjective anxious feelings and clinically confirmed anxiety present a wide and inconsistent prevalence range. Systematic reviews illustrate this gap, with high feelings of anxiety being reported in around 40% of student-athletes, while other reviews cite a range of 25−48% endorsing moderate to severe anxiety symptoms (Kaishian & Kaishian, 2021; Simon et al, 2025). In comparison, the prevalence of clinically confirmed Generalized Anxiety

Disorder among athletes is reported to be much lower, ranging from 6% to 14.6% (Usenik & Kranjec, 2025). It is therefore necessary to distinguish between elevated anxiety symptoms, which may reflect situational or sport-specific distress, and clinically diagnosed anxiety disorders meeting DSM-5 criteria used in psychological diagnosis.

This large variability results from differing screening thresholds and methodological approaches. For example, while a study of Slovenian student-athletes found that 22.8% reported moderate-to-severe anxiety (Usenik & Kranjec, 2025), a study of American Division I (one) athletes found a rate of only 7.7% using the same GAD-7 threshold (Whelan et al., 2025). This highlights that reported prevalence is highly dependent on the sample and the clinical cut-off used. Despite these inconsistencies, evidence for high distress remains strong; nearly a third of female college athletes reported persistent anxiety and sadness during the 2022–2023 academic year (Rochon-Baker & Wehe, 2025). This suggests that mental health statistics are frequently underestimated, potentially due to a low tendency to seek help (Rice et al., 2016; Usenik & Kranjec, 2025).

2.1.3. Eating Disorders

Less studied than depression and anxiety, eating disorders (EDs) are a significant risk factor among student-athletes and are frequently associated with psychological distress, depression, and body dysmorphic disorder (Ahorsu et al., 2023; Stoyel et al., 2020). Performance pressure and cultural expectations regarding leanness often lead to restrictive dieting in female athletes, though increasing evidence suggests significant numbers of male athletes also suffer from disordered eating (Borowiec et al., 2023; Stoyel et al., 2020).

While risk is slightly higher in “weight-sensitive” sports like wrestling, figure skating, or gymnastics which are based on the traditional “thin to win” mindset, recent analyses demonstrate that disordered eating is a pervasive issue across all athletic disciplines (Borowiec et al., 2023; Godoy-Izquierdo et al., 2023). This includes individual lean sports like running and cycling, weight-category sports like judo, and ball sports like football or volleyball, where athletes may engage in unhealthy behaviors such as skipping meals or using laxatives (Borowiec et al., 2023).

Evidence regarding ED prevalence remains less consistent than for anxiety or depression, partly because only 25% of studies are considered methodologically rigorous (Rice et al., 2016). Nevertheless, significant disordered eating behaviors are reported by 33% of female and

20% of male collegiate athletes (Tabet et al., 2021). These disturbances are frequently connected to maladaptive exercise and Exercise Addiction (EA), though EA alone does not fully explain ED risk (Godoy-Izquierdo et al., 2023). Methodological inconsistencies further complicate findings: for instance, some research suggests sport pressures may not directly influence certain symptoms like binge eating, a discrepancy often attributed to the use of measurement scales that were not specifically designed for athletes (Stoyel et al., 2020).

2.1.4. Athlete-Specific Screening Tools

Acknowledging the persistent methodological inconsistencies and the comparative lack of research in the clinical assessment of mental health among elite athletes, there has been a growing interest in this area (Rice et al., 2016). This interest has led to a "growing emphasis on the need to provide specific and targeted support" for the mental health needs of athletes (Rice et al., 2016). In response to this urgent requirement for brief, valid, and reliable screening instruments, the Athlete Psychological Strain Questionnaire (APSQ) was developed by Rice et al. in 2020. The APSQ is a 10-item screening instrument specifically designed to identify early indicators of athlete-specific distress and psychological strain (Rice et al., 2020; Whelan et al., 2025; Yang & Parent, 2025).

The APSQ serves a critical role as the initial triage step within the comprehensive International Olympic Committee (IOC) Sport Mental Health Assessment Tool 1 (SMHAT-1) (Gouttebarge et al., 2021). The SMHAT-1 was developed by Gouttebarge et al. (2021) for sports medicine physicians and licensed health professionals to assess elite athletes (aged 16 and older) for potential mental health symptoms and disorders. The SMHAT-1 consists of three stages: (i) triage using the athlete-specific APSQ, (ii) six subsequent disorder-specific screening tools, and (iii) a clinical assessment by a mental health professional (Gouttebarge et al., 2021).

Despite "expressed concerns about the APSQ's sensitivity and specificity in identifying athletes who require further screening," the IOC Mental Health Working Group (MHWG) elected to retain the measure for the triage step because evidence regarding its psychometrics was "imminently to be published" (Gouttebarge et al., 2021). The tool's strength lies in its inclusion of athlete-specific questions within an athletic context, having been validated in several populations of elite athletes (Gouttebarge et al., 2021).

However, the SMHAT-1 framework is not without limitations. Gouttebarge et al. (2021) noted issues including the reliance on self-reported information, the fact that some disorder-specific

tools were developed for non-athlete populations, and the fundamental limitation that the APSQ does not reach 100% sensitivity and specificity, which risks "false negatives and false positives" in the initial triage step. This limitation was empirically underscored by Anderson et al. (2023) in a study of Team USA athletes, which reported a significantly high overall false-negative rate (FNR) of the APSQ at 67.5%. Based on this finding, Anderson et al. (2023) recommend that the APSQ "should not be used as a stand-alone initial triage step" in the SMHAT-1 and that a screening question regarding self-harm and suicide "should be strongly considered" if the APSQ is used in isolation.

Further efforts to refine the tool were suggested by Whelan et al. (2025), who argued that relying on the APSQ alone "may result in missed opportunities to identify athletes with specific mental health needs." They proposed improving accuracy by incorporating domain-specific questions, refining scoring thresholds, developing an adaptive workflow, and conducting longitudinal studies to evaluate the APSQ's long-term effectiveness across diverse populations (Whelan et al., 2025).

2.2. Independent Variables – Demographic Factors and Socio-Environmental Stressors

Mental health challenges affect a large pool of student-athletes but not uniformly. This section examines into various subcategories within student-athletes. One of the most consistently compared and significant demographics is gender.

2.2.1. Gender

Studies conducted in the United States, Slovenia, Norway, and New Zealand suggest distinct gender differences in mental health risks among collegiate and elite athletes around the globe. Female athletes in particular experience more mental health conditions (e.g., anxiety or depression). Male athletes, on the other hand, are more likely to engage in risky behaviours such as substance abuse or gambling and report higher rates of self-harm and suicidal thoughts (Grasdalsmoen et al., 2022; Kaishian & Kaishian, 2021; Silvester et al., 2025; Usenik & Kranjec, 2025).

2.2.2. Sexual Identity

Significantly higher risk factor demographics are found in the less studied Lesbian, Gay, Bisexual, Transgender, Queer (LGBTQ+) community within student-athletes. Risk factors for mental health conditions are found in 81.3% in males and 84.8% of females in this subgroup. Interestingly, student-athletes within this community have fewer risk factors than non-athlete LGBTQ+ community identifiers, but significantly more than their heterosexual counterparts despite athletic involvement (Kaishian & Kaishian, 2021).

2.2.3. International Context

Student-athlete systems are structured differently across the globe, and the system in the U.S. requires a more intertwined connection between athletics and academics, as they are dependent on each other in the forms of eligibility and scholarships (Yang & Parent, 2025). This differs from European systems, such as in Norway, where self-reported elite student-athletes have found to have better mental health than non-athletes (Grasdalsmoen et al., 2022). In contrast, Slovenian dual-career athletes reported high rates of moderate-to-severe anxiety (21.5%) and depression (22.8%) (Usenik & Kranjec, 2025). These variations suggest that mental health outcomes are influenced by the athletic and academic structure of the country, highlighting the need for large-scale analysis provided in this study.

2.2.4. Socio-Environmental Stressors

Existing literature frames financial stress as a challenge to collegiate students in the United States (Adams et al., 2021; Moore et al., 2021). 75 % of students in the United States experienced moderate to high financial stress at some point during a year (Moore et al., 2021). This stress is divided into financial stress being often stressful in 24 % of students and always stressful for 14 % of students (Moore et al., 2021).

Research around student mental health has found a correlation between financial stress and poor mental health outcomes such as depression and anxiety. Furthermore, the experienced stress over economic situations may be more influential to mental health outcomes than the amount of student debt itself (Moore et al., 2021). Student-athletes have a unique position as their athletic performance is often directly related to the scholarship and therefore worry about both may create a cycle that puts the student-athlete at a risk for diminishing mental health (Yang & Parent, 2025).

Additionally, financial stress impacts the student's academic performance with a lack of focus. A qualitative study conducted among students found financial stress as a distraction from success in academics (Moore et al., 2021). Moreover, all students in this study discussed how financial status impacted their social lives: they often compared themselves to others, felt excluded within a "clear class distinction" due to not being able to participate in informal social events with friends or school-related activities due to their cost (Moore et al., 2021).

2.3. Training Volume and the Dose-Response Relationship

Training load, which refers to "the stress placed on the body by the performed activity", is a critical variable in performance, injury prevention, and mental well-being (Jones et al., 2017). This section summarizes the literature on how athletic exposure. specifically high training volume, acts as a psychological predictor, distinguishing between measures of acute strain (APSQ) and clinical mental health symptoms (Depression, Anxiety, ED).

2.3.1. Training Volume: Context, Demands, and the Collegiate Gap

Early and extensive literature on training load and the prevalence of mental health problems has largely focused on elite and professional athletes, such as Olympic teams (Jones et al., 2017). For example, the Athlete Psychological Strain Questionnaire (APSQ) was developed using a sample of elite male athletes (Rice et al., 2020). This historical focus on highly supported, elite groups creates a contextual gap, limiting the generalizability of findings to the student-athlete population, particularly across the varied competitive divisions (Division I, II, III, NAIA, NJCAA).

2.3.1.1. Contextual Demands and NCAA Divisions

Applying elite findings to U.S. college student-athletes, especially across different NCAA divisions, is complex because these divisions represent a considerable range in training intensity, time commitment, and available resources, all of which directly affect the athlete's psychological experience.

While NCAA rules limit formal countable athletic activities to 20 hours per week during the competitive season (and 8 hours off-season), studies consistently demonstrate that elite-level NCAA Division I athletes spend an average of 32 per week on sports when accounting for mandatory team activities, travel, and voluntary but expected training (Donohue et al., 2018;

Simon et al., 2025; Tabet et al., 2021). The prevalence of training volumes that significantly exceed the 20-hour limit is a major source of unique strain that may bring more negative effects than positives (Grasdalsmoen et al., 2022; Simon et al., 2025). For younger athletes, one evidence-based guideline suggests limiting cumulative weekly organized sports hours to less than or equal to their age in years (Little et al., 2023). While this finding is from adolescent athletes, the jump from high school training volume to a more demanding, high-exposure collegiate environment is an inherent risk factor (Little et al., 2023).

D1 athletic programs often operate at a near-professional intensity. These programs possess significantly higher resources, with some D1 budgets exceeding $100 million (Beasley et al, 2022.) and impose immense pressure on athletes to maintain academic eligibility (e.g., GPA requirements) while adhering to rigorous schedules (Yang & Parent, 2025). In contrast, the training culture in other divisions (e.g., Division III) often reflects a more balanced, student-centred approach (Beasley et al., 2022). However, in these non-D1 environments, mental health services are frequently less available (Young et al., 2023), though coaches' mental health literacy levels may vary widely (Beasley et al., 2024).

Beyond total volume, the type of training load is a contributing factor. Resistance training hours, for example, were found to be significantly higher in female runners who belonged to the high Female Athlete Triad risk group (Parnell et al., 2024). This suggests that total volume alone is an insufficient metric and that specific training components interact with risk factors for conditions like eating disorders.

2.3.2. Training Load, Strain, and Acute: Chronic Prediction

Training load is a key factor that affects an athlete's ability to tolerate stress and avoid the development of overtraining syndrome (OTS) (Kellmann, 2010). Load is quantified by distinguishing its components:

- **External Load:** Refers to the physical amount of work performed, such as the duration of a session, distance covered, or weight lifted (Jones et al., 2017; Simon et al., 2025).
- **Internal Load:** Refers to the athlete's individual physiological and psychological response to the external work, often measured by heart rate (Jones et al., 2017; Simon et al., 2025).

2.3.2.1. Acute-to-Chronic Workload Ratio (ACWR)

The ratio of acute (short-term, e.g., last week) to chronic (long-term, e.g., average of the previous four weeks) training load (ACWR) is a widely adopted sports science tool primarily used to predict injury risk (Jones et al., 2017; Simon et al., 2025). ACWR models the balance between an athlete's current fatigue and their established fitness (Simon et al., 2025).

A sharp increase in training load (high ACWR) increases injury risk (Jones et al., 2017). However, the application of ACWR to psychological outcomes has yielded ambiguous results. The Simon et al. (2025) study found no significant main effects of ACWRs on depression or anxiety symptoms at any time point during a competitive season. This lack of a direct link suggests that mental health symptoms are not merely a function of physical load change but are influenced by compounding stressors (Simon et al., 2025). The observed mid-season peak in depressive symptoms, for instance, is likely related to the convergence of academic pressures (midterm exams) with intense competition and travel schedules (Simon et al., 2025). This critique highlights the limitation of using purely physiological metrics like ACWR to predict complex psychological states.

2.3.2.2. Psychological Strain and the APSQ

Psychological strain is a measurable consequence of the difficulty an athlete experiences in adapting to or managing athletic and non-athletic stressors, often manifesting as impaired functioning, mood, and impulse control (Rice et al., 2020; Yang & Parent, 2025). The Athlete Psychological Strain Questionnaire (APSQ) aligns with the "Big Build" model of escalating distress and screens for three dimensions: Self-Regulation, Performance Concern, and Externalized Coping (e.g., substance use) (Rice et al., 2020; Yang & Parent, 2025).

The APSQ serves as the initial triage step in the International Olympic Committee (IOC) Sport Mental Health Assessment Tool 1 (SMHAT-1) (Gouttebarge et al., 2021). The measure showed excellent accuracy against clinical screens for generalized anxiety (GAD-7) and depression (PHQ-9) in D1 student-athletes (AUC $\geq$0.91) (Whelan et al., 2025). However, this high global accuracy does not translate uniformly across all domains. The proportion of False Negative Results (FNR) is alarmingly high for related conditions, including sleep disorders (48%) and alcohol use (55%) (Whelan et al., 2025). These high FNRs, particularly in key externalized coping behaviours and physiological markers (like sleep), underscore the limitations of using

the APSQ as the sole screening tool and necessitate the inclusion of broader, validated clinical measures like the PHQ-9 and GAD-7 alongside the APSQ in research.

2.3.2.3. The Role of Resilience as a Buffering Factor

Psychological resilience, defined as the ability to adapt positively to stressors, can function as a crucial buffer against harmful training loads in athletes (Simon et al., 2025). Higher resilience was consistently associated with better mental health outcomes (lower depression and anxiety) regardless of the training phase (Simon et al., 2025). A significant interaction was observed between resilience and the ACWR in terms of subjective well-being, where resilience mitigated the negative impact of ACWR on positive mental health. Critically, however, resilience did not provide the same buffering effect against symptoms of clinical depression or anxiety (Simon et al., 2025). This finding suggests that while resilience helps maintain overall positive mood, it is insufficient to protect athletes from clinical symptom development when other stressors (e.g., financial, or academic) are present, indicating a need for multi-faceted interventions.

2.3.3. The Linear versus Non-Linear Dose-Response Hypothesis

The relationship between physical activity and mental health is not universally agreed upon in the literature; rather, competing hypotheses exist. Firstly, a complex non-linear, U-shaped dose-response relationship has been observed for outcomes such as depression and anxiety (Ge et al., 2025; Grasdalsmoen et al., 2022). This hypothesis suggests that optimal mental health is found at a moderate level of activity, but both too little (sedentary behaviour) and too much (excessive training) physical activity can have adverse effects.

Conversely, other research supports a linear overload model, particularly highlighting the immediate negative psychological impact of elite-level training loads. Research indicates “mood state exhibits a predictable dose-response relationship with training whereby disturbances increase in a step-wise fashion as training loads rise in volume or intensity, with the peak of training and mood disturbance coinciding” (Meeusen et al., 2013). From this perspective, mental health symptoms do not necessarily follow a curve but rather worsen in direct proportion to the physical "dose" once a higher threshold of athletic demand is reached.

Determining whether these mental health outcomes specifically the symptoms captured by the APSQ versus clinical tools like the GAD-7 follow this predictable linear progression or a curvilinear pattern is a central objective of the present study.

2.3.3.1. Mechanisms of the U-Shaped Relationship

The U-shaped curve for excessive training volume is hypothesized to result from a combination of psychological and biological mechanisms:

- **Psychological Mechanisms:** Excessive volume often leads to chronic fatigue, burnout (physical and mental exhaustion, decreased sense of accomplishment), social isolation (due to limited time for non-athlete social life), and perceived loss of control, all of which are key drivers of depression and anxiety (Little et al., 2023).
- **Biological Mechanisms:** Chronically excessive load may lead to dysregulation of the Hypothalamic-Pituitary-Adrenal (HPA) axis, elevated chronic inflammation, and prolonged sympathetic nervous system activation, which mirror the physiological markers of Major Depressive Disorder (MDD) (Haghighat & Stull, 2024).

This dose-response phenomenon is supported by research showing that in non-clinical adult populations, the optimal level of weekly exercise was associated with approximately 21 hours for anxiety and 27 hours for depression (Shimura et al., 2023). Among elite Norwegian athletes, females training 14 hours or more per week showed generally poorer mental health outcomes, indicating that volumes above the optimal benefit can reverse the effect to a negative one (Grasdalsmoen et al., 2022). This finding suggests a key role for continuous and non-linear modeling of training load rather than simple dichotomous measures.

2.3.4. Overtraining Syndrome (OTS) and Maladaptation

Overtraining Syndrome (OTS) is the clinical extreme of maladaptation to excessive training load (or other stress) and insufficient recovery (Kellmann, 2010; Meeusen et al., 2013). It is a complex clinical disorder defined by a long-term imbalance, and its symptoms frequently overlap with clinical mental health conditions, creating diagnostic ambiguity.

The hallmark of OTS is unexplained underperformance. However, the associated psychological symptoms including depressed mood, general apathy, impaired self-esteem, emotional instability, and irritability (Kellmann, 2010; Meeusen et al., 2013) are nearly indistinguishable from those of clinical depression. This difficulty in differential diagnosis highlights why training load modeling is essential: the amount of psychological distress reported may be an indicator of clinical depression, or it may be the direct, negative psychological manifestation of chronic, unmanaged training load.

3. Research Gaps and Research Questions

The current state of the art establishes that collegiate student-athletes navigate a uniquely vulnerable mental health landscape. Evidence consistently demonstrates that risk is not uniform; rather, it is dictated by a complex interplay of sociodemographic identities and environmental stressors. Specifically, the literature confirms that female and LGBTQ+ athletes experience disproportionately high rates of clinical distress (Kaishian & Kaishian, 2021). Furthermore, socio-environmental factors-most notably financial instability and academic pressure-have been identified as primary drivers of psychological strain, often manifesting in acute sleep and nutritional disturbances that exacerbate eating disorder risks (Moore et al., 2021; Parnell et al., 2024).

However, despite these advancements, the existing literature remains fragmented by three critical limitations.

First, there is a significant methodological scale gap. Much of the current data relies on small, single-institution samples or self-reported "elite status" categories that lack the granularity to distinguish between the varying demands of NCAA divisions. The present study addresses this by utilizing a large-scale, multi-division U.S. sample ($N > 9,000$), providing the statistical power necessary to move beyond anecdotal evidence and establish robust prevalence trends across the entire collegiate spectrum.

Secondly, the Modeling Gap in Dose-Response Research. While the "Non-Linear Dose-Response Hypothesis" is theoretically acknowledged, existing studies often lack the sample size to model training load as a continuous, curvilinear predictor. Previous international research has been limited by lower training volume caps (e.g., $\leq$14 hours/week), leaving the U.S. collegiate context where athletes frequently reach the NCAA 20-hour limit underexamined. This study specifically tests whether the relationship between volume and distress remains linear or follows a U-shaped curve within the 20-hour range.

Finally, there is a diagnostic and integration gap. The literature fails to effectively distinguish between the symptoms of Overtraining Syndrome (OTS) and clinical conditions like Major Depressive Disorder (MDD). Without integrating athlete-specific measures like the Athlete Psychological Strain Questionnaire (APSQ) with general clinical tools (PHQ-9, GAD-7), the field lacks a "load-aware" screening protocol.

To fill these gaps, this study intends to address the research questions as follows:

RQ 1: To what extent do psychosocial factors (gender, sexual orientation, financial stress) and training environment characteristics (elite status, training volume) account for variation in athlete mental health outcomes (anxiety, depression, eating disorder symptoms, and athlete psychological strain)?

RQ 2: How does the functional pattern (linear vs. curvilinear) of the relationship between weekly training volume and mental health outcomes inform the APSQ's sensitivity to non-linear exposure–risk patterns? o

2.1 Does the relationship between weekly training volume and mental health outcomes follow a linear or curvilinear form?

2.2 Does this specific distribution pattern hinder the Athlete Psychological Strain Questionnaire's (APSQ) ability to accurately identify clinical distress risk?

RQ 3: Is there an optimal training volume to preserve the mental health of student athletes across multiple mental-health outcomes?

4. Methodology

4.1. Literature search and study selection

A structured literature search and study selection process was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021). The initial identification phase across EBSCO, Summon, and supplemental sources yielded 2,134 records. Following duplicate removal and the application of automated database filters for language, peer-reviewed status, and publication date, 161 records were screened by title and abstract. Full-text eligibility was assessed for 68 reports, resulting in a final inclusion of 42 articles meeting the refined criteria for student-athlete populations and mental health outcomes. The complete study selection process is shown in the PRISMA flow diagram (Appendix A).

4.2. Data Sources and Preparation

The dataset is from the Healthy Minds Network's annual web-based survey study examining mental health, service utilization, and related issues among undergraduate and graduate

students. Since its national launch in 2007, HMS has been fielded at over 675 colleges and universities, with over 935,000 survey respondents. The student athlete data from 2019 - 2025 was extracted from this main dataset, which was loaded into the R environment to aid in the analysis. A significant component of the preliminary analysis involved cleaning, transforming, and deriving core variables necessary for addressing the research questions.

Ethical Considerations and Anonymity: To ensure respondent privacy, the data provided for this analysis is fully de-identified. This means the dataset contains no direct personal identifiers (e.g., name, student ID, date of birth) and cannot be traced back to any individual student-athlete. The use of this secondary, anonymized dataset adheres to established ethical standards for mental health research, protecting the confidentiality of the SAs involved.

4.2.1. Outcome Variables

Four mental health measures served as the dependent variables. All outcomes were analysed as continuous numerical scores derived from raw survey measures, although their scale properties differ, SCOFF is a count-based score ranging from 0 to 5, APSQ is a bounded mean score ranging from 1 to 5, and PHQ-9 and GAD-7 are bounded integer scores treated as continuous numerical scores. The four mental health measures are:

- **Anxiety (GAD-7):** Calculated as anx_num from anx_score.
- **Depression (PHQ-9):** Calculated as dep_num from deprawsc.
- **Eating Disorder Symptoms (SCOFF):** Calculated as ed_scoff, representing the sum score (0–5) of five SCOFF variables (scoff_1 through scoff_5).
- **Athlete Psychological Strain (APSQ):** Operationalized as apsq_mean, calculated as the item mean score (1–5) across ten items (ath_psych_1–ath_psych_10), with at least seven items required. While APSQ is commonly reported as a summed score (10–50), mean scoring was used for scaling consistency; summed-score clinical thresholds were not applied.

4.2.2. Predictor and Group Variables

Categorical predictor variables were derived from raw data columns using specific criteria and assigned factor levels for statistical testing:

Table 1: Definition and Derivation of Study Variables

Factor	Variable Name	Derivation/Levels
Gender	gender_bin	Binarized from sex_birth into **Female** and **Male**.
Sexual Orientation	orient_grp	Binarized into **Heterosexual** and **LGBTQ+** (where lgbtq_any is true).
Financial Stress	financial_stress_binary	Categorized into three levels: **High financial stress** (Always/Often stressful), **Moderate financial stress** (Sometimes stressful), and **Low financial stress** (Rarely/Never stressful).
Elite Status	elite_status	Binarized based on Athletic Division (ath_div): **Elite (NCAA D1)** vs. **Non-elite (Other divisions)**.
Training Volume (Category)	sp_cat	Categorical variable representing weekly sport hours (1–7 categories).
Training Volume (Continuous)	V (and sp_hours)	Continuous numerical value derived from sp_cat using mid-point estimates (e.g., Cat 1 = 0.5 hours, Cat 7 = 22 hours).
Quadratic Term	V_sq	The squared value of the continuous training volume variable (V^2).

The highest training-volume category in the HMS survey is open-ended ("20+ hours/week") as shown in table one (1). For the purpose of deriving a continuous exposure measure, this category was coded as 22 hours, representing a conservative exceedance of the NCAA's formal 20-hour limit while avoiding assumptions of extreme or professional-level training volumes.

4.2.3. Descriptive Analysis and Visualization

Prior to formal testing, descriptive statistics were calculated, including mean, standard deviation, and sample counts for all mental health outcomes. Share tables detailed the

distribution of demographic variables across the full dataset. Various visualizations were generated to explore mean score patterns across categories of weekly training hours (sp_time) for key demographic groupings (gender, financial stress, division), serving as preliminary explorations for research question one (1) and two (2).

4.3. Statistical Testing

The primary statistical methods for group comparisons were implemented using the Kruskal–Wallis test. This non-parametric rank-based procedure was selected because the mental health outcomes (GAD-7, PHQ-9, SCOFF, APSQ) are bounded, discrete psychometric scales that exhibited non-normal and heteroskedastic distributions. Rather than testing differences in means, the Kruskal–Wallis test evaluates whether the distribution of ranked scores differs across groups, making it robust to violations of normality and unequal variances.

4.3.1. Research Question One (1) Analysis: Group Comparisons

Research question one (1) aims to test for variance in mental health outcomes based on psychosocial and environmental factors. This was primarily addressed through five separate Kruskal-Wallis analyses, comparing the four mental health outcomes (anxiety, depression, eating disorder, APSQ) against categorical predictors:

- **Elite Status:** Elite (NCAA D1) versus Non-elite (Other divisions).
- **Training Volume Categories:** Comparing mean outcomes across the seven (7) training volume categories.
- **Gender Differences:** Female versus Male athletes.
- **Sexual Orientation Differences:** Heterosexual versus LGBTQ+ athletes.
- **Financial Stress:** High financial stress versus Low financial stress (filtering out moderate stress for this test).

Statistical significance was assessed using the Kruskal-Wallis test (X^2) and corresponding *p*-values. Effect size was quantified using epsilon squared $\boldsymbol{\varepsilon^2}$ to assess the practical magnitude of group differences. Interpretation followed conventional benchmarks adapted from Cohen's guidelines, where $\varepsilon^2 \approx 0.01$ indicates a negligible effect, $\varepsilon^2 \approx 0.06$ a small effect, $\varepsilon^2 \approx 0.14$ a medium effect, and $\varepsilon^2 \geq 0.26$ a large effect (Cohen, 1988).

4.4. Functional Form Analysis

Research Question two (2) specifically examines the relevance of athlete psychologic strain (APSQ). To do this, the functional relationship between continuous weekly training volume (V) and mental health outcomes, focusing on whether a curvilinear relationship exists and if this relationship differs between clinical distress (Anxiety, Depression, eating disorder) and athlete psychological strain (APSQ). Given the bounded and discrete nature of the outcome measures, particular attention was paid to the choice of modeling framework. OLS was selected as a parsimonious and interpretable approximation commonly used for bounded psychometric scales in large-sample research. Although the outcome measures are discrete and bounded, prior methodological work suggests that OLS estimates are generally robust to such violations under large sample sizes. Consequently, the emphasis of the analysis was placed on functional form and comparative inference rather than precise distributional modelingEstablishing Curvature (Linear vs. Quadratic Models)

For each of the four mental health outcomes, two models were built and compared:

- **Linear Model:** $Y = \beta_0 + \beta_1 V + \in$
- **Quadratic Model:** $Y = \beta_0 + \beta_1 V + \beta_2 V^2 + \in$

The significance of the curvilinear relationship was assessed in two ways:

- **Significance of the Quadratic Term (V^2):** The p-value for the β^2 coefficient in the Quadratic Model was checked to determine if the curvature was statistically significant.
- **Model Comparison (ANOVA):** An **Analysis of Variance (ANOVA)** test was performed to formally assess whether the Quadratic Model provided a statistically superior fit to the data compared to the simpler Linear Model.

4.4.1. Full Confounder Models

To ensure the observed relationship between training volume and clinical distress outcomes was robust against the strong psychosocial factors identified in research question one (1), a Full Quadratic Model was constructed.

$$Y_{clinical} \sim V + V^2 + Gender + Sexual\ Orientation + Financial\ Stress$$

This model predicts a clinical outcome (Y) based on a combination of factors. It specifically evaluates if a key variable (V) has a curved (U-shaped or inverted-U) relationship with the outcome, not just a straight line. At the same time, it checks whether gender, sexual orientation, and financial stress are independently linked to the outcome, after accounting for that curved relationship. These full models were compared against the simpler quadratic models using standard ANOVA F-tests to assess incremental model fit associated with the inclusion of psychosocial covariates. Robust standard errors (HC3) were computed for coefficient-level inference in the full models to mitigate potential heteroskedasticity. Thus, ANOVA was used for nested model comparison, while HC3-adjusted standard errors were used solely for interpretation of individual regression coefficients.

4.4.2. Testing the Divergent Pattern

To address the core hypothesis of research question two (2) that clinical distress measures (SCOFF, PHQ-9) follow a curvilinear pattern while the psychological strain measure (APSQ) does not, the predicted scores from the relevant models were compared and visualized:

- For outcomes exhibiting significant curvature (e.g., SCOFF), the vertex of the parabola was calculated to identify the optimal training volume at which symptoms were theoretically minimized.

- Prediction plots were created showing the fit of the quadratic model (for clinical outcomes) and the linear model (for APSQ) to illustrate the functional distinction between the measures when controlling for psychosocial factors.

Because the aim of the analysis was inferential rather than predictive, no train–test split was implemented. Instead, the full sample was used to maximize statistical power for testing whether a quadratic specification provided a superior representation of the functional form linking training volume to mental health outcomes. Standard regression diagnostics were conducted to assess model validity, including inspection of residual patterns, leverage, and influential observations, as well as checks for multicollinearity arising from the inclusion of both training volume and its squared term. Given this inferential focus, model performance was evaluated in terms of functional form and statistical significance rather than predictive accuracy.

Conceptual Framework: Linear vs. Curvilinear Risk

In existing literature, mixed results (Grasdalsmoen et al., 2020; Rice et al., 2020) suggest that training volume acts through three potential mechanisms. Two of these, the Linear Overload and the Non-linear U-shape models, form the basis of the current study (see Figure 1).

First, the Linear Overload Model suggests that psychological strain increases as a direct function of cumulative external demands (Rice et al., 2020). Conversely, some evidence suggests an Inverse Linear Relationship, where increased volume improves mental health by providing a structured environment and benefits, a trend often observed in male athlete populations (Grasdalsmoen et al., 2020). While it is a common idea that sports are good for mental health, increased psychological stress due to increased athletic demands may be shown as symptoms related to irritability, performance worries, or unhealthy coping mechanisms which may be due to athletes' inability to longer maintain their psychological state through natural coping resources (Rice et al., 2020; Yang & Parent, 2025).

The third perspective is the Non-linear U-shape Model, where risk is highest at extreme ends of the spectrum. At low volumes, athletes may lack the identity protection (athletic identity and social connectedness) that sport provides. At extreme high volumes, these protective benefits are overshadowed by systemic overload. This is driven by physiological stress (elevated cortisol) and role conflict, where the incompatibility between student and athlete roles and time demands triggers a breakdown in self-regulation, manifesting for instance as symptoms of sleep disturbances, academic challenges, and clinical symptoms of depression and eating disorders (Shimura et al., 2023; Tabet et al., 2021).

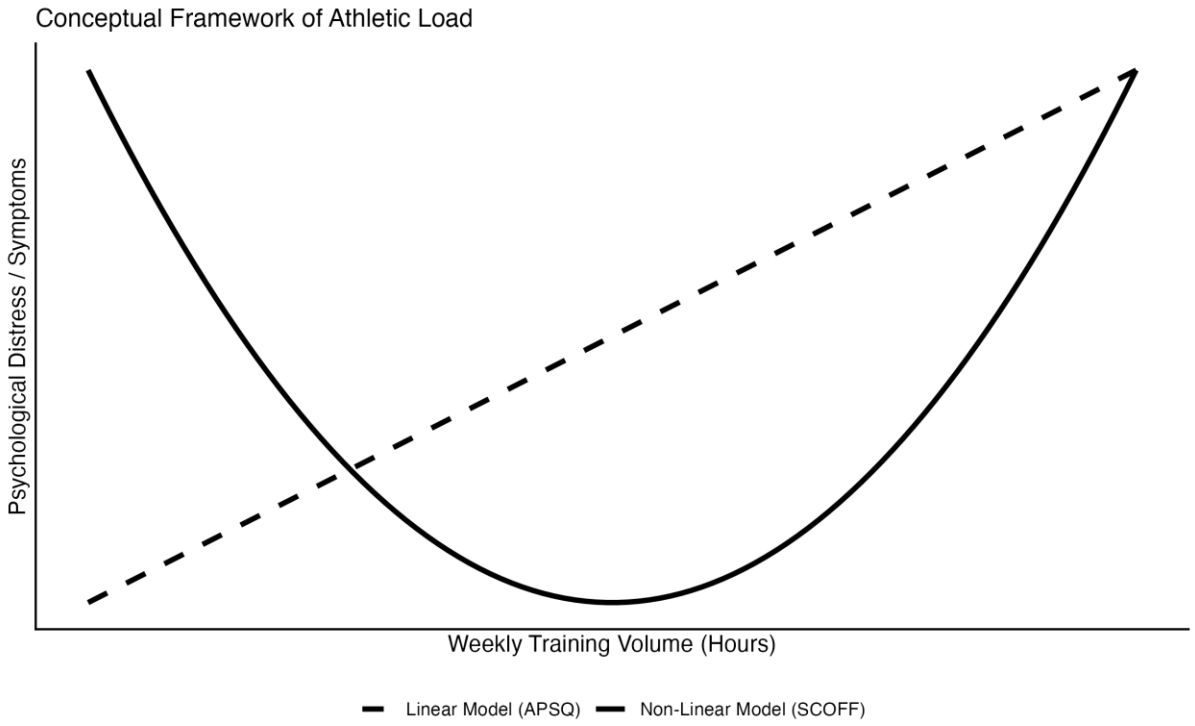

Figure 1: Conceptual Framework of Athletic Load (Psychological Distress vs Training Volume)

5. Results

5.1. Sample Characteristics

Table 2: Sample Characteristics

Variable	**Category**	**n**	**%**
Gender	Female	5,889	64.9
	Male	3,178	35.1
Sexual Orientation	Heterosexual	7,386	83.4
	LGBTQ+	1,469	16.6
Elite Status	Elite (NCAA D1)	1,065	24.6
	Non-elite	3,272	75.4
Financial Stress	Low (Never/Rarely)	3,862	33.4
	Moderate (Sometimes)	4,126	35.7
	High (Often/Always)	3,567	30.9

Table 2 presents the descriptive characteristics of the study sample. The sample consisted predominantly of female athletes (64.9%), with male athletes comprising 35.1% of respondents. The majority identified as heterosexual (83.4%), while 16.6% identified as LGBTQ+. Table 2 presents the descriptive characteristics of the study sample. The sample consisted predominantly of female athletes (64.9%), with male athletes comprising 35.1% of respondents. The majority identified as heterosexual (83.4%), while 16.6% identified as LGBTQ+. Elite status information was available for a subset of the sample (n = 4,337). Within this subgroup, approximately one quarter of athletes competed at the elite level (NCAA Division I; n = 1,065, 24.6%), while the remaining athletes competed at non-elite levels (n = 3,272, 75.4%). Elite status was missing or not classifiable for the remaining respondents and was therefore excluded from analyses involving this variable. Financial stress was widely reported across the sample, with nearly one third of athletes indicating high levels of financial stress.

5.2. To what extent do psychosocial factors (gender, sexual orientation, financial stress) and training environment (elite status, training volume) predict variance in athlete mental health outcomes?

Research Question 1 was addressed through a series of group comparison analyses. Results are reported below by predictor domain, with effect sizes used to assess practical significance.

5.2.1. Training Environment Factors

Elite Status

Table 3: Mental Health Outcomes by Elite Status (Kruskal–Wallis tests; ε^2 = epsilon squared effect size.)

Outcome	Elite Mean (SD)	Non-Elite Mean (SD)	χ^2(df=1)	p-value	ε^2
Anxiety (GAD-7)	5.83 (5.30)	5.89 (5.35)	0.05	.83	0.000
Depression (PHQ-9)	6.16 (5.71)	6.37 (5.51)	3.64	.056	0.001

ED Symptoms (SCOFF)	0.86 (1.17)	0.84 (1.17)	0.28	.60	0.000
APSQ	1.92 (0.76)	1.88 (0.73)	1.31	.25	0.000

As shown in Table 3, mental health outcomes did not differ significantly between elite and non-elite athletes. Anxiety, depression, eating disorder symptoms, and athlete psychological strain scores were comparable across competitive levels, with all effect sizes approximating zero. Depression approached statistical significance ($p = .056$), but the associated effect size was negligible, indicating minimal explanatory value.

These results suggest that elite status is associated with negligible differences in outcome distributions, indicating minimal practical relevance for both clinical distress and athlete psychological strain.

5.2.2. Training Volume

Table 4: Mental Health Outcomes by Training Volume Category

Outcome	**χ^2(df=6)**	**p-value**	**ε^2**	**Effect**
Anxiety (GAD-7)	27.29	<.001	0.002	Negligible
Depression (PHQ-9)	59.42	<.001	0.006	Negligible
ED Symptoms (SCOFF)	26.61	<.001	0.003	Negligible
APSQ	114.69	<.001	0.013	Small

Weekly training volume category was significantly associated with all mental health outcomes examined. As presented in Table 4, statistically significant differences were observed for anxiety, depression, eating disorder symptoms, and athlete psychological strain. However, effect sizes were uniformly negligible to small, indicating that training volume accounted for only a limited proportion of variance.

While statistical tests indicated group differences, the magnitude of these effects suggests that training volume functions as a contextual factor rather than a primary predictor of mental health outcomes. Effect size was estimated using epsilon squared (ε^2) for Kruskal–Wallis tests, calculated as $(H - k + 1)/(n - k)$.

5.2.3. Psychosocial Factors

5.2.3.1. Gender

Table 5: Gender Differences in Mental Health Outcomes

Outcome	**Female Mean (SD)**	**Male Mean (SD)**	**χ^2 (df=1)**	**p-value**	**ε^2**
Anxiety	7.32 (5.59)	4.46 (4.71)	645.30	<.001	0.073
Depression	7.54 (5.85)	5.59 (5.35)	285.77	<.001	0.032
ED Symptoms	1.08 (1.28)	0.54 (0.91)	315.51	<.001	0.046
APSQ	1.99 (0.75)	1.73 (0.71)	284.28	<.001	0.035

As reported in Table 5, female athletes reported significantly higher levels of anxiety, depression, eating disorder symptoms, and athlete psychological strain compared to male athletes. Effect sizes ranged from small to moderate, with the largest effect observed for anxiety.

These findings indicate that gender contributes systematic variance to athlete mental health outcomes across both clinical and sport-specific domains.

5.2.3.2. Sexual Orientation

Table 6: Sexual Orientation Differences in Mental Health Outcomes

Outcome	**Heterosexual Mean (SD)**	**LGBTQ+ Mean (SD)**	**χ^2 (df=1)**	**p-value**	**ε^2**
Anxiety	5.87 (5.28)	8.64 (5.79)	304.78	<.001	0.035
Depression	6.31 (5.45)	9.60 (6.33)	368.91	<.001	0.043
ED Symptoms	0.83 (1.17)	1.24 (1.27)	129.69	<.001	0.019
APSQ	1.86 (0.73)	2.11 (0.79)	127.64	<.001	0.016

Table 6 shows that athletes identifying as LGBTQ+ reported higher levels of anxiety, depression, eating disorder symptoms, and athlete psychological strain compared to

heterosexual athletes. Effect sizes were consistently small to moderate, indicating meaningful differences across outcomes.

This pattern suggests that sexual minority status represents an important psychosocial vulnerability factor in athletic populations.

5.2.3.3. Financial Stress

Table 7: Financial Stress and Mental Health Outcomes

Outcome	**Low Stress Mean (SD)**	**High Stress Mean (SD)**	**χ^2 (df=1)**	**p-value**	**ε^2**
Anxiety	4.73 (4.77)	8.55 (5.86)	884.61	<.001	0.121
Depression	5.12 (4.98)	9.55 (6.27)	1070.09	<.001	0.147
ED Symptoms	0.67 (1.05)	1.17 (1.31)	272.77	<.001	0.045
APSQ	1.73 (0.66)	2.13 (0.82)	327.44	<.001	0.062

As shown in Table 7, athletes experiencing high financial stress reported substantially higher anxiety and depression scores, with large effect sizes observed for both outcomes. Eating disorder symptoms and athlete psychological strain were also significantly elevated, with moderate effect sizes.

Athletes in the lowest training volume category reported higher anxiety and depression scores compared to several moderate and high training categories. However, effect sizes were small, suggesting limited practical significance.

5.2.4. Summary of Findings for Research Question 1

Collectively, the results indicate that psychosocial factors explain substantially more variance in athlete mental health outcomes than training environment variables.

- Elite status explained negligible variance (Table 3).
- Training volume demonstrated statistically significant but practically small effects (Table 4).

- Gender, sexual orientation, and particularly financial stress demonstrated consistent and meaningful associations across all outcomes (Tables 5–7).

Although several predictors reached statistical significance, the magnitude of the observed effects varied considerably. Training environment variables, including elite status and weekly training volume, were associated with negligible to small effect sizes, indicating that average mental health scores differed only modestly across training groups. In contrast, psychosocial factors particularly financial stress but also gender and sexual orientation were associated with substantially larger between-group differences across all outcomes. In practical terms, this suggests that training volume functions as a contextual factor rather than a dominant driver of mental health risk among student-athletes.

5.3. Does the relationship between weekly training volume and mental health outcomes limit the APSQ's effectiveness in identifying athletes at clinical risk?

Research Question 2 was examined using linear and quadratic regression models for each mental health outcome.

5.3.1. Functional Form of the Training Volume–Mental Health Relationship

Table 8: Linear vs Quadratic Models for Training Volume

Outcome	**β_2 (V^2)**	**SE (β_2)**	**p (β_2)**	**ΔRSS (Lin → Quad)**	**F**	**p (ANOVA)**	**Preferred form**
Anxiety	0.0034	SE	.092	—	—	.094	Linear
Depression	0.0051	SE	.017	ΔRSS	F	.021	Quadratic
ED Symptoms	0.00125	SE	.004	ΔRSS	F	.006	Quadratic
APSQ	0.00035	SE	.201	—	—	.203	Linear

Note - *β_2 represents the coefficient of the squared training volume term (V^2). Preferred functional form was determined using nested ANOVA comparisons between linear and quadratic models.*

As shown in Table 8, quadratic regression models provided a significantly better fit than linear models for depression and eating disorder symptoms. The quadratic term for training volume was statistically significant for both outcomes, indicating a curvilinear (U-shaped) relationship.

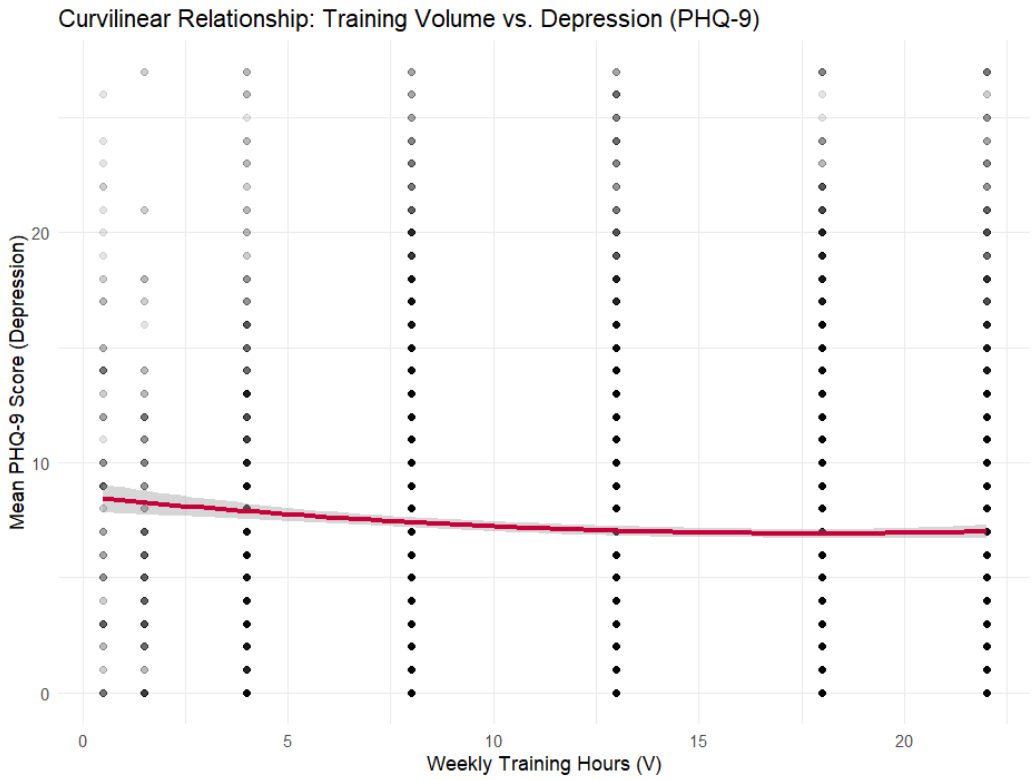

Figure 2: Predicted relationship between weekly training volume (hours per week; x-axis) and depressive symptoms (PHQ-9 score; y-axis, range 0–27).

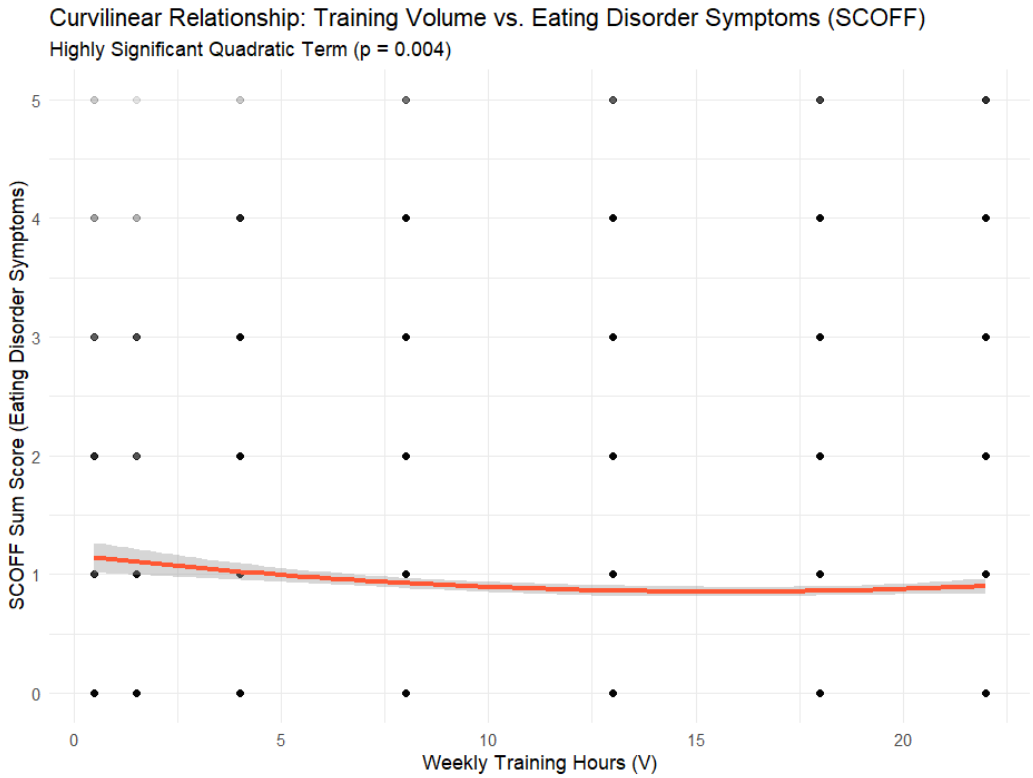

Figure 3: Predicted relationship between weekly training volume (hours per week; x-axis) and eating disorder symptoms (SCOFF score; y-axis, range 0–5).

Figures 2 and 3 illustrate slightly elevated symptom levels at both low and high training volumes, with lower symptom levels at moderate volumes. For context, depressive symptoms (PHQ-9) are scored from 0 to 27, eating disorder symptoms (SCOFF) from 0 to 5, and athlete psychological strain (APSQ) is reported as a mean score ranging from 1 to 5. The observed differences therefore represent small shifts within each scale rather than large clinical changes.

5.3.2. Outcome-Specific Differences

Quadratic terms were not statistically significant for anxiety or athlete psychological strain (Table 8), indicating that linear models were sufficient for these outcomes.

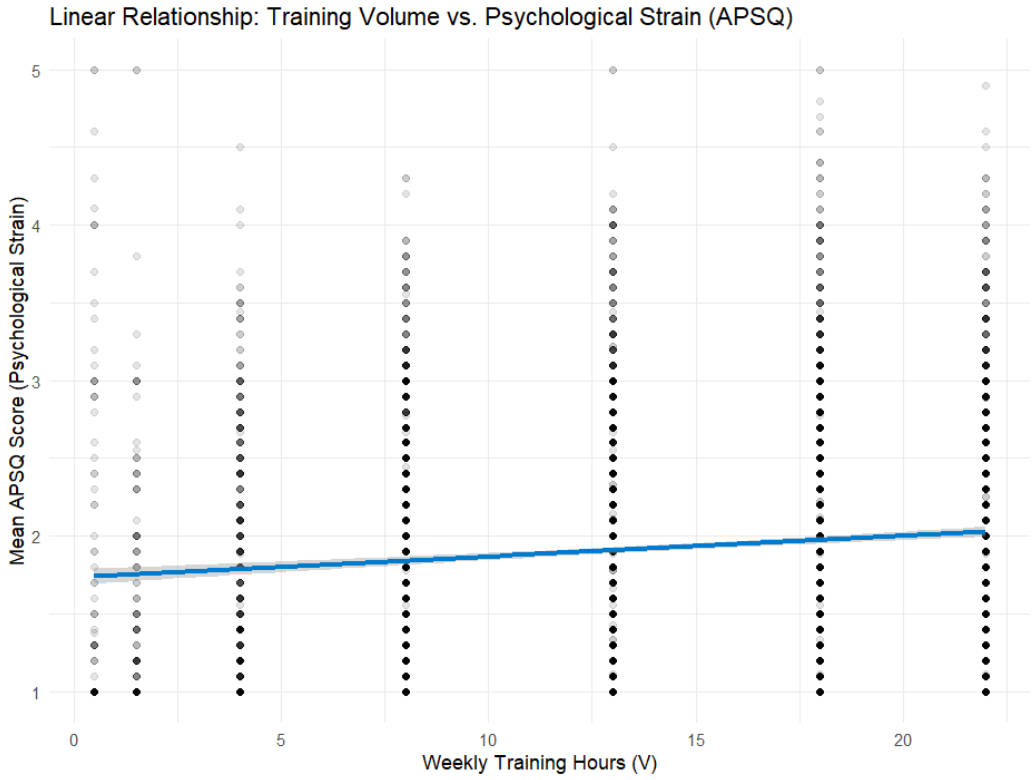

Figure 4: Predicted relationship between weekly training volume (hours per week; x-axis) and athlete psychological strain (APSQ mean score; y-axis, range 1–5)

The absence of curvature in Figure 4 in APSQ scores indicates that athlete psychological strain, as operationalized here, does not exhibit the same non-linear distribution across training volumes observed for eating disorder symptoms. absence of curvature in APSQ scores suggests reduced sensitivity to non-linear risk patterns.

5.3.3. Influence of Psychosocial Covariates

Table 9: Adjusted Quadratic Models (Psychosocial Covariates Included)

Table reports selected coefficients from fully adjusted quadratic models. Psychosocial covariates are shown to illustrate their relative contribution compared to training volume curvature. Robust (HC3) standard errors were used.

Outcome	**Predictor**	**β**	**SE**	**p-value**
Depression (PHQ-9)	V^2 (training volume²)	β_2	SE	.154
	Financial stress (high vs low)	β	SE	<.001
	Gender (female vs male)	β	SE	<.001
	Sexual orientation (LGBTQ+ vs heterosexual)	β	SE	<.001
	Model R^2	—	—	0.158
ED Symptoms (SCOFF)	V^2 (training volume²)	β_2	SE	<.001
	Financial stress (high vs low)	β	SE	<.001
	Gender (female vs male)	β	SE	<.001
	Sexual orientation (LGBTQ+ vs heterosexual)	β	SE	<.01
	Model R^2	—	—	0.084

Inclusion of psychosocial covariates substantially attenuated the quadratic association between training volume and depressive symptoms, rendering the curvature non-significant, while the corresponding effects for financial stress, gender, and sexual orientation remained large and statistically robust. For eating disorder symptoms, the quadratic training-volume term remained statistically significant after adjustment; however, psychosocial covariates, particularly financial stress continued to account for a larger proportion of explained variance than training volume alone.

5.3.4. Summary of Findings for Research Question 2

- Training volume demonstrated a non-linear relationship with depression and eating disorder symptoms (Table 8; Figures 2–3).
- This pattern was not observed for anxiety or athlete psychological strain (Table 8; Figure 4).
- Psychosocial factors substantially influenced observed training–mental health relationships (Table 9).

- APSQ scores do not mirror the non-linear SCOFF pattern at extreme training volumes. While SCOFF exhibited a statistically significant U-shaped relationship with training volume that remained robust after adjustment for psychosocial covariates, APSQ showed no evidence of curvature, with the quadratic term non-significant and the linear specification retained. On this basis, APSQ alone may be less sensitive to outcome-specific non-linear risk patterns related to extreme training volumes.

From a practical perspective, the observed non-linear association for eating disorder symptoms indicates that athletes training at both very low and very high weekly volumes reported slightly higher SCOFF scores than those training at moderate volumes; however, these differences were small relative to the full scale range and showed substantial overlap across groups. For APSQ, the linear pattern suggests a gradual accumulation of perceived psychological strain with increasing training volume, rather than a distinct high-risk threshold at extreme exposure levels. These patterns support an outcome-specific interpretation of training load effects rather than a uniform dose–response relationship.

5.4. Is there an optimal training volume to preserve the global mental health of student athletes?

The current research offers scant support for the idea that there is a single "optimal" training volume for preserving student-athletes' global mental health across the four mental health outcomes examined in this study. Group comparisons across weekly training-volume categories were statistically significant for anxiety, depression, SCOFF, and APSQ (Table 4), but the corresponding effect sizes were negligible to small (ε^2= .002–.013), indicating limited practical significance.

Quadratic regression analyses further indicated outcome-specific non-linearity: SCOFF showed a statistically significant U-shaped association with training volume (Table 8) that remained significant after adjustment (Table 9). Depression showed an apparent U-shaped pattern in the unadjusted quadratic model (Table 8), but this curvature was no longer statistically significant once psychosocial covariates were included (Table 9). In contrast, anxiety (GAD-7) and APSQ did not show significant quadratic patterns across training volumes (Table 8).

For outcomes exhibiting statistically significant curvature, the vertex of the estimated quadratic function was calculated to describe the location of the predicted minimum. For eating disorder

symptoms (SCOFF), the quadratic model indicated a minimum at approximately 13 hours/week of training volume. For depressive symptoms, a similar minimum was observed in the unadjusted quadratic model at approximately 14 hours/week. However, this curvature was no longer statistically supported after adjustment for psychosocial covariates. These values are reported descriptively to characterize model shape and should not be interpreted as evidence of a single optimal training volume. Accordingly, vertex estimates are best understood as descriptive features of non-linear model fit rather than targets for training prescription.

Taken together, these findings do not justify recommending a universal weekly training-volume threshold for protecting mental health. Any potential "sweet spot" appears outcome-specific and is small in magnitude, while psychosocial stressors, particularly financial stress, gender, and sexual orientation, show stronger and more consistent associations with mental health outcomes (Tables 5–7).

5.5. Answers to Research Questions

RQ1: Predictors of Mental Health: Across outcomes, psychosocial factors were associated with substantially larger group-based differences in mental health scores than training environment variables. Kruskal–Wallis tests indicated negligible effects for elite status ($\varepsilon^2 \approx .000–.001$, $p > .05$) and small effects for training volume ($\varepsilon^2 \approx .002–.013$, $p < .05$). In contrast, gender ($\varepsilon^2 \approx .032–.073$, $p < .001$), sexual orientation ($\varepsilon^2 \approx .016–.043$, $p < .001$), and financial stress ($\varepsilon^2 \approx .045–.147$, $p < .001$) consistently exhibited larger effect sizes across outcomes.

Because these ε^2 values were derived from separate non-parametric group comparisons rather than a unified multivariable model, they are interpreted as relative magnitudes of between-group differences rather than as directly comparable proportions of explained variance.

In applied terms, the small effect sizes observed across outcomes indicate that differences in average mental health scores between low, moderate, and high training-volume groups were modest and unlikely to be clinically meaningful in isolation. No abrupt deterioration in mental health was observed at any specific weekly training volume, and predicted differences across the range of training exposure were small relative to overall score variability. This suggests that adjusting training volume alone is unlikely to substantially alter mental health risk without concurrent attention to psychosocial stressors.

RQ2: Linear vs. Non-Linear Patterns: The SCOFF (eating disorder symptoms) exhibited a clear non-linear (U-shaped) association with weekly training volume, which remained statistically significant after adjustment for psychosocial covariates (quadratic term $p < .001$). For depressive symptoms (PHQ-9), an apparent U-shaped pattern was observed in unadjusted models but was no longer statistically significant once covariates were included (quadratic term $p = .154$). In contrast, athlete psychological strain (APSQ) was adequately described by a linear specification and did not display elevated risk at both low and high training volumes.

Because the continuous training volume variable was derived from categorical midpoints, the exact magnitude of the quadratic term and its associated *p*-value may vary under alternative coding assumptions. However, the presence or absence of curvature across outcomes was consistent in direction, supporting an outcome-specific distinction between SCOFF and APSQ.

RQ3: Optimal Training Volume: Training volume has only a negligible to small effect size on all outcomes (ε^2=.002–.013, p<.05). Because the risk patterns change depending on the specific outcome (e.g., U-shaped for SCOFF vs. linear for APSQ), the data do not support one single "optimal" weekly training volume. The findings show that psychosocial factors are more important for protecting student-athlete mental health than training volume thresholds alone.

6. Discussion

6.1. Empirical Synthesis of Research Questions

The following overview links the statistical evidence used to achieve the key objectives of the study.

RQ1 (Psychosocial Variations): Through Kruskal-Wallis tests and OLS regression, it was found that psychosocial factors, specifically financial stress and sexual orientation, explained more variance in mental health outcomes than training factors. This justifies the conclusion that mental health screening must prioritize individual life stressors over athletic metrics alone.

RQ2 (Functional Forms): Using quadratic regression modeling, a robust U-shaped relationship was identified for eating disorder symptoms (SCOFF), whereas athlete-specific strain (APSQ) followed a linear path. This justifies the conclusion that clinical distress and athletic strain operate through different mechanisms.

RQ3 (Volume Thresholds): An assessment of differences across training volume categories and the extent of the effects showed that although a higher workload (20+ hours) is associated with elevated risk, the absolute effect of training volume is small compared to psychosocial

factors. The amount of training acts as a moderator that exacerbates existing vulnerabilities, rather than being the primary cause. This also suggests that there is no universal “optimal" amount of training, but rather that recommendations should be customized to the individual psychosocial situation of the SA.

6.2. General Findings

The present study aimed to research the relationship between training volume and mental health among collegiate student-athletes. Moreover, this study focuses on examining whether these relationships are linear or nonlinear and varies across four mental health aspects of depression, anxiety, eating disorder, and psychological strain unique to athletes. Overall, the findings from this study shows how mental health reactions to distinct levels of training load are not uniform. Instead, they reflect distinct functional relationships (e.g., linear vs. curvilinear) and specific underlying psychological mechanisms. The overall conclusion is that the effect of exercise on mental health is outcome-oriented, which challenges the one-size-fits-all psychological risk models used in sports.

This discussion section interprets the primary findings in comparison to the existing literature and explores broader implications in the important and growing attention of early intervention in the mental health of student athletes. This discussion will, first, interpret these distinct functional relationships considering existing theory and evidence. Second, it will explore the implications of these findings for developing targeted screening protocols and implementing effective early intervention strategies in collegiate athletics.

First, athlete psychological strain (APSQ) showed a predominantly linear association with training volume, consistent with the idea that self-regulation and performance-related coping demands accumulate as weekly training hours increase. Second, evidence for non-linearity in mood outcomes was weaker than a general U-shaped dose-response account: depression showed an apparent U-shape in unadjusted models, but the quadratic term became non-significant after adjusting for psychosocial covariates, and anxiety was adequately described by a linear model. Across outcomes, psychosocial factors, especially financial stress, were more important predictors than training volume.

Most notably, eating disorder symptoms (SCOFF) maintained a clear U-shaped relationship with training volume even after controlling for gender, sexual orientation, and financial stress. This suggests an outcome-specific vulnerability mechanism in which both extremely low and

extremely high training exposure are associated with elevated SCOFF symptoms, while moderate volumes are associated with lower symptom levels.

Although the present study does not directly measure biological or physiological processes, the observed outcome-specific associations between training volume and mental health outcomes may be interpreted considering previously proposed theoretical mechanisms. Prior research suggests that chronically excessive training load, particularly when combined with insufficient recovery and external stressors, may contribute to dysregulation of the hypothalamic–pituitary–adrenal (HPA) axis, prolonged sympathetic activation, and elevated inflammatory responses (Haghighat & Stull, 2024)Importantly, these mechanisms should be understood as hypothesized explanatory pathways derived from existing literature, rather than as inferences drawn from the present findings. The current results instead demonstrate statistical associations at the behavioral and symptom-report level, highlighting where such mechanisms may plausibly operate, particularly in the context of eating disorder risk, where a robust non-linear relationship persisted after adjustment for psychosocial covariates

This multifaceted perspective is essential when considering the significance of competitive sports on the collegiate level. A comprehensive review of the literature provides a clear foundation for this discussion:

High but Varied Prevalence: Existing literature highlights that almost a quarter (23.7%) of collegiate SAs experiencing depression is almost a quarter (Wolanin et al., 2016), and other studies include increasing prevalence rates in anxiety (Tabet et al., 2021). Prevalence rates high due to pressure and barriers and stigma in help-seeking (Beasley et al., 2024) yet are varied due to the lack of uniform measuring tools across institutions (Rice et al., 2016).

Need for Athletic Specific Screening: A systematic narrative review by Rice et al. (2016) concludes that athletes are vulnerable to a wide range of mental health problems. The unique environment SAs function in creates athlete specific risk factors such as performance pressure, overtraining, and injury, and challenges of body dysmorphia. These should be covered by an effective and uniform targeted screening and support framework, which APSQ screening tool is designed to fulfil (Purcell et al., 2019; Rice et al., 2020; Whelan et al., 2025; Yang at al.).

Non-Sport Related Stressors: Student-athletes experience stress factors that can pile up. Moore et al. (2021) phrases financial stress being a significant impact to academic stress and

quality of social life. This stress can become a dominant driver of poor mental well-being, confounding the effects of training load.

Importance of Early Intervention and Education: Existing literature identifies significant gaps in the application of effective, athlete-specific intervention and preventive techniques. Research indicates that support staff, such as coaches and athletic trainers, can foster more positive help-seeking environments by improving their mental health literacy (Bisset & Tamminen, 2020; Chow et al., 2021; Donohue et al., 2020). This literacy encourages athletes to move past traditional attitudes of "mental toughness," which frequently functions as barriers to care (Schlimmer & Chin, 2018; Tabet et al., 2021).

Because early intervention is most effective during the "pre-care" phase of mental health (Purcell et al., 2019; Rice et al., 2016, Rice et al., 2020), the current lack of clear guidelines for U.S. athletic trainers and coaches remains a critical issue (Beasley et al., 2024; Beasley et al., 2022 Bisset & Tamminen, 2020). This underscores that understanding student-athlete well-being requires looking beyond training volume alone. The following sections analyse the distinct relationships between training load and specific psychological outcomes, beginning with the most direct association: psychological strain.

Importantly, the statistically significant associations observed in this study were generally small in magnitude, indicating that training volume explains only a limited proportion of between-athlete differences in mental health outcomes. In practical settings, this means that athletes with similar training volumes may nevertheless experience markedly different mental health profiles depending on their psychosocial context. Consequently, training load should be viewed as one component within a broader risk landscape, rather than as a primary target for mental health intervention.

6.3. Psychological Strain as a Linear Function of Training Load

Accurately measuring the cumulative psychological toll of high-performance training is a strategic priority for protecting athlete well-being. The Athlete Psychological Strain Questionnaire (APSQ) was developed as a key tool for this purpose, designed to offer a brief, valid, and reliable instrument for identifying athlete-specific distress (Rice et al., 2020). Analysing its conceptual underpinnings reveals a model where strain accumulates in a relatively linear fashion with increasing training load.

The APSQ is designed to measure the cumulative psychophysiological stress resulting directly from training and competition. Conceptually, this relationship is logical: as training volume and intensity increase, so too does the general strain experience by the athlete. This straightforward accumulation reflects the direct impact of physical work and performance pressures on an athlete's psychological state (Rice et al., 2019). The perception of this load is also a factor; research by Yang & Parent (2025) found that athletes whose training volume exceeded age-in-hours recommendations were more likely to perceive their competition load as excessive, directly linking high volume to the subjective experience of strain that the APSQ aims to capture.

However, a critical evaluation reveals the limitations of this linear model for comprehensive clinical assessment. While the APSQ demonstrates high accuracy for detecting general anxiety (as measured by GAD-7) and depression (PHQ-9), its performance is less reliable for other conditions. A recent study from 2025 by Whelan expresses false-negative rates from APSQ being high from eating disorders, substance use, and sleep impairments. This indicates a core argument of this study: APSQ is more efficient in capturing the general distress that appears often with anxiety and depression, but it is less indicative when identifying athletes who suffer from other mental health challenges that are a part of the mental health landscape specific to athletes.

Summarizing these points, it becomes clear that the APSQ linear model is conceptually meaningful and practical for measuring general psychological stress. It serves as an effective primary screening tool for identifying athletes who have difficulty adapting to the demands of training. However, this linearity alone is not sufficient to describe the complex, often nonlinear nature of certain mental health disorders. Anxiety and depression are influenced by many factors beyond cumulative training load and dose-response, leading to more dynamic relationships, which are expanded in the next section.

6.4. Anxiety and Depression: Threshold and Context Effects

In contrast to the linear accumulation of general psychological strain, literature of mood disorders such as anxiety and depression response to training load often exhibits a non-linear relationship (Ge et al., 2025; Grasdalsmoen et al., 2022). The evidence suggests that both too little and too much physical activity can be detrimental to mental health, pointing toward a curvilinear or "U-shaped" dose-response curve. However, grouping anxiety and depression together as mental health outcomes in existing study from Grasdalsmoen (2022) could be

oversimplifying, since the present study found them not behave exactly similarly. In the present study, evidence for curvilinear ("U-shaped") conclusions were outcome-specific rather than absolutes across mood disorders.

In the present study, quadratic effects were observed for both depressive symptoms and eating disorder symptoms. Symptom levels were highest at the extremes of training volume (i.e., less than two hours and more than 20 hours of weekly training), with moderate levels showing a slight decrease in prevalence. However, the curvilinearity observed for depressive symptoms was no longer statistically significant after controlling for other psychosocial factors (demographic and socio-environmental stressors). This suggests that the apparent U-shaped curve for depressive symptoms is more strongly influenced by contextual pressures. Fear of underperformance, feeling of unworthiness, and worry over potential punishment, social and emotional stress, are such as external expectations highlighted by Young et al. (2023) and Kellmann (2010), than by training volume alone.

Differences from existing findings may also be attributable to methodological constraints in measuring maximal training volume. For example, the maximum training choice in the questionnaire used by Grasdalsmoen et al. (2022) and Ge et al. (2025) for student-athletes was over 14 hours per week, which is less than half the volume typically reported for average U.S. Division I elite SAs (up to 32 hours weekly) (Simon et al., 2025).

Methodological differences may also help explain why evidence for a depression U-shape is inconsistent across studies. Some international surveys cap the highest training category at around 14 hours per week, which may under-represent the upper end of training exposure that is common in U.S. collegiate sport. In addition, many prior studies rely on smaller or single-institution samples and may not capture the full range of competitive levels.

Sample composition and symptom severity can further mask non-linear associations. For example, when a cohort reports mostly mild symptoms, there may be insufficient variance to detect curvature even if it exists. Taken together, these considerations suggest that any U-shaped pattern in depression is likely context-dependent and sensitive to psychosocial stressors, whereas SCOFF appears to show a more robust non-linear association with training volume in the present data.

6.5. Eating Disorders and Non-Linear Risk

The risk profile for eating disorders (ED) in athletes behaves distinctly from that of general mood disorders. While the non-linear relationship for anxiety and depression can be moderated by external factors, the connection between high training volume and ED risk is driven by powerful, sport-specific psychological mechanisms. This section will deconstruct these mechanisms to explain why they create a particularly robust non-linear relationship.

The unique drivers of ED risk in athletes create a strong interaction with high training volumes, where excessive training becomes a trigger or an accelerant for disordered eating behaviours. Key drivers identified in the literature include:

Body Image and Performance Pressure. The pressure to control the body prevails in sports, which extends to traditional aesthetic sports, weight-class sports, and non-lean sports; this transforms the athlete's body into a tool for performance that is subject to constant scrutiny (Borowiec et al., 2023). Environments emphasizing a low-weight physique, high training volume becomes explicitly linked to achieving a specific body composition (Borowiec et al., 2023). This makes the athlete's training behaviour, and the resultant high volume, a direct fuel for body dissatisfaction and compensatory practices. Crucially, the U-shaped nature of this relationship also highlights the risk at the low extreme, where an inability to train (e.g., due to injury or illness) often triggers maladaptive eating practices as a compensatory strategy for maintaining body image.

Training as Maladaptive Control and Symptom: In the high-demand, high-scrutiny environment of collegiate sport, athletes face numerous uncontrollable external factors. Stoyel et al. (2020) demonstrated that high training volume co-occurs with immense pressure to perform and maintain weight. For athletes with underlying psychological risk, disordered eating can manifest as a maladaptive strategy to regain a sense of internal control. Consequently, excessive training can become a proxy for self-worth and discipline, transforming the physical load into a compulsive psychological symptom rather than simply a general stressor.

Direct Psychological Mediation: This intrinsic link is confirmed by psychological mediators. Ahorsu et al., (2023) identified body image concern, psychological distress, and insomnia as factors strongly linked between high training volume and eating disorders. This body of evidence suggests the psychological factors driving the ED (especially body image concern)

are the same ones driving the high training volume, creating a robust, non-linear functional form that remains significant. This robust mechanism is what fundamentally distinguishes ED.

6.6. Training Volume, Overtraining, and Diagnostic Ambiguity

A significant challenge in interpreting the mental health of high-performance athletes, and a vital practical implication of this study's findings, is the problem of diagnostic ambiguity. Extreme training volumes and insufficient recovery can precipitate the symptoms of Overtraining Syndrome (OTS), a state of prolonged maladaptation that closely mimics the presentation of Major Depressive Disorder (MDD) (Haghighat & Stull, 2024)

6.6.1. OTS Overlap with Depression Symptoms

OTS is a complex diagnosis of exclusion, required because the clinical presentation of chronic maladaptation substantially overlaps with severe psychological disorders. As Kellmann (2010) notes, overtraining places athletes on a "chronic performance plateau that cannot be influenced positively by short amounts of rest and recovery." The resulting symptoms, including depressed mood, apathy, decreased self-esteem, emotional instability, and disturbed sleep, are nearly identical to those defining MDD (Haghighat & Stull, 2024).

The overlap between these conditions is deeply integrated. Both OTS and depression are characterized by a lack of recovery, reduced performance, and chronic maladaptive responses, sometimes involving remarkably similar changes in brain structures (Haghighat & Stull, 2024). The ambiguity extends beyond depression; anxiety and trauma-related disorders also overlap with OTS, interfering with sleep, disrupting the autonomic nervous system, and causing impairments in energy, endurance, and reaction time (Haghighat & Stull, 2024; Meeusen, 2013).

Crucially, Haghighat & Stull (2024) highlight that while general fatigue increases during typical overload training, depression increases the most of all Profile of Mood States (POMS) variables in athletes showing signs of the OTS, with reports indicating up to 80% of affected athletes show signs of clinical depression. This extreme mood manifestation in the presence of unmanaged physical load underscores the difficulty in separating a primary mood disorder from a physiologically induced state that mimics it. The risk is high that an athlete progresses towards an overt depressive illness when their severe under-recovery can no longer be mitigated by the benefits of sport.

6.6.2. Implications for Misclassification

The symptom overlap carries critical implications for misclassification, which relates to our study's finding that mood disorder curvilinearity disappeared after controlling for psychosocial factors (Section 5.3).

Our results suggest that the symptoms often attributed to "overtraining" are in fact a function of the athlete's overall, cumulative load, consisting of both physical stress and psychosocial stress. This total load can easily push an athlete into a state that presents as clinical depression.

- **Risk of Inappropriate Treatment:** The primary consequence of ambiguity is inappropriate intervention. An athlete suffering from OTS, whose primary need is mandated rest, may be misdiagnosed with MDD and given psychological or pharmacological interventions that fail to address the root physiological imbalance.

- **Delay of Care:** Conversely, an athlete with clinical MDD may have their symptoms minimized and incorrectly attributed to "training fatigue." This delay in necessary psychiatric care prolongs suffering.

6.6.3. Importance of Load-Aware Screening

This ambiguity underscores the absolute necessity of load-aware screening practices in the athletic environment.

Our findings which demonstrated that the link between training volume and depression is conditional upon external stress support the principle that the overall stress-state occurs on a continuum of increasing total load, with endpoints of low training volume and overtraining. Because athletes adapt differently to increased training loads, and the impact is exacerbated by insufficient recovery (e.g., due to a lack of sleep), a simple measure of training hours is insufficient.

Therefore, effective screening must integrate objective load metrics. As Parnell et al. (2024**)** note, specific training behaviours (like high resistance training hours) often indicate a "larger systemic issue with the athlete" and are supported by observed associations between total training hours and perceived stress. To ensure correct differential diagnosis, clinicians must integrate objective workload tracking and performance data alongside targeted psychological

assessment. This commitment to load-aware, context-driven screening is foundational to avoiding diagnostic error and ensuring that student-athletes receive timely, appropriate care.

6.7. Demographic and Socio-Environmental Vulnerabilities

Expanding the spectrum of risk beyond training load alone is necessary for a thorough understanding of student-athlete mental health. Although physical demands are a major source of stress, an athlete's total psychological well-being can be shaped by demographic and socio-environmental factors that either develop or compound vulnerabilities. When these elements combine with the demands of top athletics, a multi-layered risk profile is created.

Research consistently highlights disparities in mental health outcomes across different demographic groups within the student-athlete population.

- **Gender:** Female athletes appear to face heightened risk. Wolanin et al. (2016) found that female athletes demonstrate a statistically significant higher prevalence of clinically relevant depressive symptoms than their male counterparts (28.1% vs. 17.5%). This is further supported by Grasdalsmoen et al. (2022), who observed that the highest training volumes were associated with worsening mental health outcomes, specifically in females.

- **Sexual Orientation:** Kaishian & Kaishian (2021) report a high prevalence of mental health issues among SAs who identify as Lesbian, Gay, Bisexual, Transgender, Queer (LGBTQ), indicating that these populations face unique systemic stressors.

- **Dual-Career Status:** The identity of a "student-athlete" itself is a source of compounded stress. Usenik & Kranjek (2025) explain that these individuals face the combined pressures of academic deadlines, athletic performance expectations, financial strain, and relationship tensions, all of which can contribute to psychological distress.

- **Financial Status:** One significant compounding element that affects every part of a student-athlete's life is financial strain. According to Moore et al. (2021), financial stress acts as a direct barrier to academic success, forcing students to prioritize part-time jobs over coursework. Additionally, it hinders social integration since students who cannot afford to attend social gatherings may feel alone, ashamed, and frustrated.

These emotions might intensify underlying mental health issues, resulting in a stressful and distressing cycle.

Each athlete has a complicated, multi-layered risk profile because of the intersections between training load and these demographic and socioenvironmental parameters. While Tabet et al. (2021) note that participation in athletics can sometimes serve as a protective buffer against psychological distress, the specific vulnerabilities outlined here can negate that protective effect, placing certain athletes at a significantly higher risk. Developing equitable support systems requires an understanding of these overlapping aspects, which is largely dependent on the empirical tools employed to analyse them.

6.8. Methodological Discussion

The methodological rigor of the underlying research is a major determinant of the credibility of the conclusions mentioned thus far. Important methodological advancements have propelled the field's transition from oversimplified presumptions to a more nuance understanding of athlete mental health. This section assesses the unique advantages and creative methods found in the examined literature that have improved our comprehension of this difficult subject.

Several methodological approaches have been pivotal in clarifying the intricate relationships between training, context, and mental health:

- **Continuous and Non-Linear Modeling:** Studies by Shimura et al. (2023) and Ge et al. (2025) represent a significant advancement by moving beyond simple linear assumptions. Their use of quadratic equations and restricted cubic splines allowed for the identification of U-shaped dose-response curves. This modeling revealed the critical insight that excessive training can be just as detrimental as insufficient training, a finding that linear models would completely miss.

- **Longitudinal Monitoring:** Compared to cross-sectional snapshots, the longitudinal strategy used by Parnell et al. (2024) to monitor mental health trajectories during a competitive season offers a more dynamic and instructive picture. By analysing how training and other variables affect changes in mental health symptoms over time, this approach allows for a richer understanding of the temporal dynamics of athlete well-being and moves closer to identifying causal relationships.

- **Advanced Psychometric Validation:** The development of the Athlete Psychological Strain Questionnaire (APSQ) by Rice et al. (2010) is a prime example of methodological contribution. Their application of advanced statistical methods, such as exploratory and confirmatory factor analysis, produced a quick, robust, and trustworthy screening tool that was especially designed to measure athlete-specific distress. In high-performance settings, these technologies are crucial for precise and effective screening.

- **Diverse Sampling:** The work of Donohue et al. (2018) stands out for its inclusion of a multi-division sample, incorporating not only elite NCAA athletes but also those participating at club and intramural levels. This method greatly improves the findings' generalizability, guaranteeing that conclusions are more reflective of the larger collegiate sports population rather than being restricted to the experiences of elite Division I athletes.

Notwithstanding these advantages, the literature also highlights the limitations of using only one metric. For instance, Parnell et al. (2024) discovered that the Acute: Chronic Workload Ratio (ACWR) by itself did not significantly predict mental health symptoms. This result is an important criticism that emphasizes the necessity for a multifaceted approach to training load measurement and confirms that mental health effects cannot be entirely explained by a single variable. The solid evidence basis required to infer useful, real-world implications for assisting SAs is provided by these exacting and diverse methodological techniques.

6.9. Practical Implications

Improving student-athletes' well-being requires turning study findings into practical solutions. The information presented offers administrators, coaches, athletic trainers, and other stakeholders in collegiate athletics a clear road map for creating and implementing more efficient mental health support systems. The specific ramifications for institutional policy, monitoring, and screening are described in this section.

Screening and Monitoring

Based on the evidence, a multi-stage, load-aware screening process is recommended.

- **Implement a Two-Step Screening Protocol:** Institutions should adopt a two-step screening process, as recommended by the International Olympic Committee's SMHAT-1 framework (Gouttebarge et al., 2021; Whelan et al., 2025). This involves

using a brief, athlete-specific tool like the Athlete Psychological Strain Questionnaire (APSQ) for initial screening of general training-related strain. Athletes who screen positive on the APSQ should then complete validated, disorder-specific tools like the Patient Health Questionnaire-9 (PHQ-9) for depression and the Generalized Anxiety Disorder-7 (GAD-7) for anxiety to identify the need for clinical referral.

- **Monitor High-Volume Athletes:** Athletic trainers are in a unique position to keep an eye on athletes exhibiting signs of discomfort because they are on the front lines. They should use a "recognize, react, refer" framework to link struggling athletes with the right care (Beasley et al., 2022) and actively monitor training hours, especially for athletes whose training volume exceeds age-in-hours recommendations, a group more likely to perceive their competition load as excessive (Yang & Parent, 2025). By fostering a team atmosphere that de-stigmatizes the revelation of psychological distress, coaches also play a crucial role in enabling athletes to seek assistance when necessary (Beasley et al., 2024; Bisset & Tamminen, 2020).

Institutional Resources and Policy

Effective support requires a systemic, institutional commitment to accessible and athlete-centred care.

- **Provide Athlete-Centred Resources:** Mental health services must be designed to meet the unique needs and culture of athletes. As argued by Donohue et al. (2020), Young et al. (2023), and Silvester et al. (2025), resources should be easily accessible, reduce stigma by framing support around performance optimization rather than pathology, and be sensitive to sport culture to increase utilization. This includes offering flexible scheduling and involving providers who understand the athletic environment.

- **Mandate Mental Health Screening and Training:** The evidence is overwhelmingly in favour of NCAA regulation requiring all Sas to undergo routine, systematic mental health screenings. To enable coaches and ATs to identify symptoms of distress and provide appropriate referrals, institutions should mandate mental health literacy training for all of them (Beasley et al., 2024; Bisset & Tamminen 2020).

- **Integrate Mental Health Professionals:** Athletic departments should immediately incorporate mental health specialists into their personnel to standardize care and lower access obstacles. This consistent presence helps reduce stigma, improves visibility of resources, and ensures that mental health is treated as an integral component of a holistic athlete care model (Beasley et al., 2022; Beasley et al., 2024).

By Implementing these practical strategies, organizations may support student-athlete mental health in a way that is proactive and integrated rather than reactive. Although the research offers a solid basis for these actions, it is crucial to recognize its limits.

6.10. Limitations

While this study utilizes a significant and multi-division sample, certain design limitations must be acknowledged to provide a critical reflection on the findings.

The reliance on self-report instruments for mental health symptoms and training volume introduces a measurement error risk. For mental health symptoms, athletes may be subject to under-reporting due to the "mental toughness" culture and social stigma surrounding help-seeking in sports. Regarding training volume, athletes may experience recall bias or vary in their interpretation of what means "active training," leading to an over- or underestimation of actual training volume.

The use of categorical hour intervals and a 20-hour reporting cap serves as an approximation risk. This constraint means the study might miss the smaller details of how mental health changes hour-by-hour. Because the highest training-volume category is open-ended, assigning a single numeric value necessarily involves approximation. While this may influence the exact curvature at the upper tail, the study’s conclusions focus on comparative functional patterns rather than precise exposure thresholds.

The cross-sectional nature of the data prevents cause-and-effect relationships from being established or seasonal variations in symptoms from being tracked. This limits the ability to determine whether extreme training volume causes ED symptoms, or if athletes with existing symptoms increase their training volumes.

Finally, the findings are specific to the U.S. collegiate system, presenting a contextual risk. The results may not be fully generalizable to international or professional athletic contexts, where

structural demands and club-based sport systems differ significantly from the American SA context.

These limitations demonstrate that while further methodological improvement is necessary, such as longitudinal designs or objective load monitoring, they do not invalidate the current findings. Instead, they provide a roadmap for future research directly addressing these gaps.

6.11. Future Research Directions

To advance the field, research must transition from cross-sectional snapshots to longitudinal and experimental designs that track the dynamic interactions between training load and mental health across multiple seasons. Following the recommendations of Silvester et al. (2025), there is a critical need to develop and validate culturally adapted, athlete-specific screening tools to ensure equitable assessment across diverse populations. Furthermore, future inquiries should investigate disorder-specific risk profiles, such as the non-linear pathways associated with eating disorders and body image. Finally, exploring the social support ecosystem, specifically upskilling coaches and staff in mental health literacy, remains essential for fostering a protective athletic environment.

Building a more complex body of evidence that goes beyond generalizations is the main objective of this future research plan. The field may offer more accurate and practical advice to safeguard and advance the mental health of all student-athletes by emphasizing dynamic interactions, cultural distinctiveness, and the critical role of the athletic environment.

7. Conclusion

This thesis examined whether weekly training volume is linearly or non-linearly associated with mental health outcomes in U.S. collegiate student-athletes, and whether training exposure is a stronger predictor than key psychosocial stressors. Across outcomes, psychosocial factors especially financial stress, but also gender and sexual orientation, explained substantially more variance than elite status and training volume. Training volume showed negligible-to-small effect sizes in group comparisons, and the data do not support recommending a single “optimal” weekly training-volume threshold. Functional-form analyses indicated a robust U-shaped relationship between training volume and SCOFF that persisted after adjustment, whereas the apparent U-shape for depression weakened and became non-significant once psychosocial covariates were included; APSQ remained best described as linear and did not

mirror the SCOFF pattern at extreme volumes. These findings support load-aware screening that integrates athlete-specific and clinical tools and prioritizes psychosocial vulnerabilities.

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Appendix

Appendix A: PRISMA Flowchart

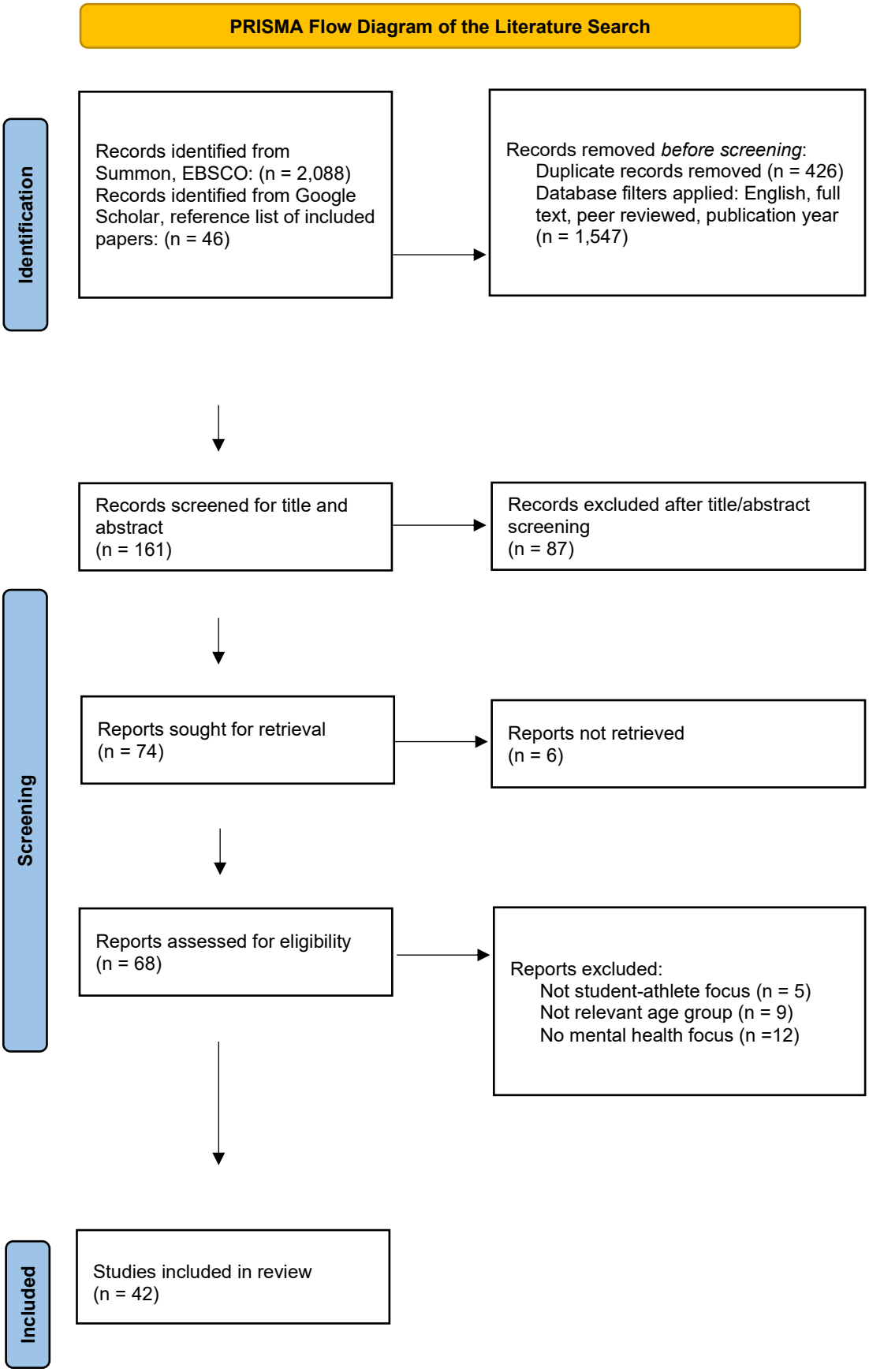

Figure A1. PRISMA Flow Diagram of Study Identification and Selection

Appendix B: Mental health screening instruments and cut-off scores

Tool	**Purpose**	**# of Questions**	**Scoring Range (Per Item)**	**Total Score Range**	**Common Grading / Clinical Cut-Off**
APSQ (Athlete Psychological Strain Questionnaire)	Measures general psychological strain/distress unique to the athletic context.	10	5-point Likert Scale (e.g., 1 = Not at all to 5 = Extremely)	10–50	Used as a continuous measure of strain. **Higher scores** indicate greater psychological strain and necessitate clinical follow-up.
GAD-7(Generalized Anxiety Disorder 7-item scale)	Screens for symptoms of Generalized Anxiety Disorder (GAD).	7	0 (Not at all) to 3 (Nearly every day)	0–21	**Positive Screen (Threshold):** ≥10(Moderate Anxiety)
PHQ-9(Patient Health Questionnaire-9)	Screens for symptoms of Major Depressive Disorder (MDD).	9	0 (Not at all) to 3 (Nearly every day)	0–27	**Positive Screen (Threshold):** ≥10(Moderate Depression)

SCOFF 5(Eating Disorder screening tool)	Screens for the potential presence of an Eating Disorder (Anorexia Nervosa, Bulimia Nervosa, etc.).	5	Yes/No (Each 'Yes' = 1 point)	0–5	**Positive Screen (Threshold):** ≥2 positive answers.

Table B1: Overview of Mental Health Screening Instruments Used in the Study*Note.* Instrument descriptions and scoring conventions are based on Rice et al. (2019) for the APSQ, Spitzer et al. (2006) for the GAD-7, Kroenke et al. (2001) for the PHQ-9, and Morgan et al. (1999) for the SCOFF questionnaire.

Tool	**Score Range**	**Interpretation**
GAD-7	0–4	Minimal Anxiety
	5–9	Mild Anxiety
	10–14	**Moderate Anxiety (Clinical Cut-Off)**
	15–21	Severe Anxiety
PHQ-9	0–4	Minimal Depression
	5–9	Mild Depression
	10–14	**Moderate Depression (Clinical Cut-Off)**

	15–19	Moderately Severe Depression
	20–27	Severe Depression
SCOFF 5	0–1	Low risk of an Eating Disorder
	>=2	**High risk of an Eating Disorder (Positive Screen)**

Table B2: Interpretation of Common Cut-Off Scores for Mental Health Screening Tools