Longitudinal Analysis of Training Load Across Two Competitive Seasons in Collegiate Women's Soccer

Original Research

Open Access

RESEARCH in STRENGTH and PERFORMANCE

Dates
Submitted: March 25, 2026
Accepted: April 15, 2026
Published: April 16, 2026

Research in Strength and Performance: *2026, Volume 6 (Issue 1): 12*

ISSN: 3069-0765

Victor Romano[1], Jennifer Austin McCrae[1]

[1]*Rocky Mountain University of Health Sciences, Provo, UT/USA*

Abstract

Introduction: Monitoring training load is essential for optimizing performance and supporting long-term adaptation in team sport athletes. While heart rate and GPS technologies are widely used in applied settings, limited longitudinal data exist describing how internal and external load interact across multiple seasons in collegiate women's soccer.

Methods: A retrospective longitudinal cohort design was used to examine NCAA Division II women's soccer athletes monitored across the 2023 and 2024 competitive seasons. Internal training load was assessed using heart rate–derived metrics from a FirstBeat monitoring system, including Training Impulse (TRIMP), average and maximal heart rate, and percentage of time spent above 85% HRmax. External load was quantified using GPS measures, including total distance, high-speed running distance, sprint count, sprint distance, and work rate. Data from training sessions and matches were aggregated by season. Linear mixed effects models evaluated seasonal differences with the athlete treated as a random effect.

Results: Internal training load remained stable across seasons, with no significant differences in mean session TRIMP (2023: 308.0 ± 74.6 AU; 2024: 309.7 ± 71.2 AU; $p = 0.68$) or average exercise intensity (71.2 ± 6.4 vs. 71.5 ± 6.1% HRmax; $p = 0.61$). In contrast, match play imposed substantially greater external demands than training in both seasons ($p < 0.001$), with large to very large effect sizes across all GPS variables. Despite increased external demands, the TRIMP to distance ratio decreased from 64.1 to 57.2 TRIMP/mile^{-1}, indicating improved physiological efficiency.

Conclusions: Collegiate women's soccer athletes demonstrated stable internal load despite large competition demands, supporting effective long-term load regulation and adaptation. Integrating heart rate and GPS metrics provides a comprehensive framework for monitoring training stress and informing evidence-based periodization strategies.

Key Words: athlete monitoring, training impulse, physiological efficiency

Corresponding author: Victor Romano, victor.romano@rm.edu

Introduction

Monitoring training load is a central component of strength and performance programs in team sports, as it supports the optimization of adaptation while reducing the risk of excessive fatigue and injury. External load reflects the mechanical and locomotor demands imposed on the athlete, while internal load represents the physiological response to those demands.[1] Internal load is particularly valuable because it captures how an athlete tolerates imposed stress rather than simply what is prescribed.[2] Heart rate (HR) derived measures have long been used to quantify internal load due to their objectivity, feasibility, and relevance to cardiovascular strain.[1-3] In soccer contexts HR monitoring allows practitioners to evaluate accumulated physiological stress across training and competition demands.[4]

Training Impulse (TRIMP) is one of the most widely adopted heart rate based internal load metrics and integrates session duration with exercise intensity in a weighted exponential manner.[1] This approach was originally developed to model the relationship between training stress fitness and fatigue and remains relevant for monitoring cumulative cardiovascular load.[1-3] In intermittent sports such as soccer HR can fluctuate substantially yet time spent near high intensity thresholds remains physiologically meaningful.[4] Studies have shown that soccer match play often elicits sustained HR responses near or above 85% of maximal heart rate (HRmax) reflecting considerable cardiovascular demand.[4,6] As such, HR derived internal load metrics remain appropriate for evaluating stress responses in team based intermittent activity.

Despite widespread use of internal load monitoring, much of the existing soccer literature remains limited in scope. Recent systematic reviews highlight most training load studies are conducted over a single season and often limit analysis to a single competitive cycle, restricting insight into multi-season adaptation..[4] Few investigations have examined training responses across multiple competitive years which limits understanding of long term adaptation.[5] Additionally, women are significantly underrepresented in soccer training load research despite increasing participation and competitive physiological demands.[4] The lack of female specific longitudinal data constrains evidence based decision making in collegiate sport environments.

Longitudinal monitoring is particularly important in collegiate women's soccer where athletes are exposed to recurring seasonal cycles of preparation, competition, and recovery. Prior research in this population has demonstrated meaningful physiological adaptation across training periods yet few studies have examined cardiovascular load regulation across entire competitive seasons and multiple years.[5] Examining whether internal load increases remain stable or decrease across seasons provides insight into the effectiveness of long-term training design. Understanding these trends can inform decisions related to progression recovery and performance sustainability. Therefore, the purpose of this study was to examine longitudinal trends in HR derived internal training load across competitive seasons in collegiate women's soccer athletes.

Methods

Participants

Collegiate women's soccer athletes competing during the 2023 and 2024 seasons at a small NCAA Division II university in the southeastern United States were included in this study (Table 1). A total of 30 athletes were monitored during the 2023 season and 33 athletes during the 2024 season. Mean age of participating athletes was 20.8 ± 0.82 years in 2023 and 20.2 ± 0.16 years in 2024. Across the 2023 season, a total of 67 sessions were monitored, comprising 44 training sessions and 23 match sessions. During the 2024 season, 56 sessions were monitored, including 35 training sessions and 21 match sessions. Across the two competitive seasons, a subset of athletes was monitored in both 2023 and 2024, resulting in a partially overlapping longitudinal cohort. Athlete identities were retained across seasons, allowing repeated measures analysis within returning players (Table 2).

All HR and GPS data were collected as part of routine performance monitoring conducted by the sport performance staff. Goalkeepers were excluded from GPS-derived external load analyses due to substantially different movement demands; however, HR-based internal load measures were retained where applicable. The use of previously collected monitoring data qualifies this investigation as a retrospective observational study. Athletes with limited training or match participation were excluded to reduce skewed internal load values associated with minimal exposure, particularly during match play.

Protocol

A retrospective longitudinal cohort design was used to assess internal training load across consecutive competitive seasons, consistent with prior applied sport science research.[8] Internal load was monitored using a FirstBeat HR monitoring system, which provides beat-to-beat HR data. GPS data was captured using Sport Performance Tracking's SPT2 device and Gametraka GPS analytics platform (Melbourne, Australia). Primary internal load variables included TRIMP, average HR, maximal heart rate (HRmax), and percentage of time >85% HRmax. Secondary variables included session duration and session type (training or match). TRIMP was calculated using an exponential weighting of exercise intensity and duration, as originally proposed by Banister and subsequently refined for intermittent sports.[1,3]

Table 1. Descriptive characteristics of collegiate women's soccer athletes.

Variable	2023 (Mean ± SD)	2024 (Mean ± SD)
Number of athletes (n)	30	33
Age (years)	20.8 (±0.82)	20.2 (±0.16)
Total monitored sessions	67	56
Training sessions	44	35
Match sessions	23	21

Table 2. Roster continuity across seasons.

Category	n
Athletes in 2023 Only	15
Athletes in 2024 Only	18
Athletes in Both Seasons	15

A session was defined as a single organized team activity, including either a scheduled training session or a competitive match. Training sessions typically lasted 75-105 minutes, occurring 4-5 times per week during the competitive season. Match sessions included athletes with recorded heart-rate exposure during competition, while training sessions reflected organized team training independent of match participation. Heart rate zones were defined relative to individual HRmax, with >85% HRmax representing high-intensity cardiovascular stress.[4] HRmax was determined as the highest value recorded across training and match sessions within each season.

Statistical Analysis

Athlete identity was retained across sessions and seasons using unique identifiers, and linear mixed-effects models included athlete as a random effect to account for repeated measures within individuals.[7] Post-hoc comparisons were adjusted using Bonferroni correction. Statistical significance was set at $p < 0.05$, and effect sizes (Cohen's *d*) were calculated to assess practical significance.[9] Invalid recordings were defined as sessions with incomplete heart-rate capture, signal dropout, or computational errors (e.g., division by zero) and were excluded prior to analysis. .HR data were standardized across sessions, and session-level data were aggregated by season and session type.

Results

Internal Training Load Across Seasons

Across the two competitive seasons, heart rate–derived internal training load remained stable. Mean session Training Impulse did not differ between seasons, with values of 308.0 ± 74.6 TRIMP units in 2023 and 309.7 ± 71.2 arbitrary units in 2024 ($p = 0.68$). Similarly, average relative exercise intensity expressed as percentage of HRmax was nearly identical between seasons. HRmax in 2023 was 71.5 ± 6.1% and 2024 it was 71.2 ± 6.4% ($p = 0.61$) (Table 2).

Table 2. HR-derived internal load variables across competitive seasons.

Variable	2023 Season (Mean ± SD)	2024 Season (Mean ± SD)	p Value
Training Impulse (TRIMP)	308.0 ± 74.6	309.7 ± 71.2	0.68
Average HRmax (%HRmax)	71.2 ± 6.4	71.5 ± 6.1	0.61

Data are Mean ± SD. HRmax = maximum heart rate beats per minute

Linear mixed-effects modeling confirmed the absence of a main effect of season on Training Impulse ($p = 0.68$), average heart rate ($p = 0.61$), maximal heart rate ($p > 0.05$), or high-intensity heart rate exposure ($p > 0.05$). These findings indicate that cumulative cardiovascular stress associated with training and competition was maintained at a consistent level across seasons (Figure 1).

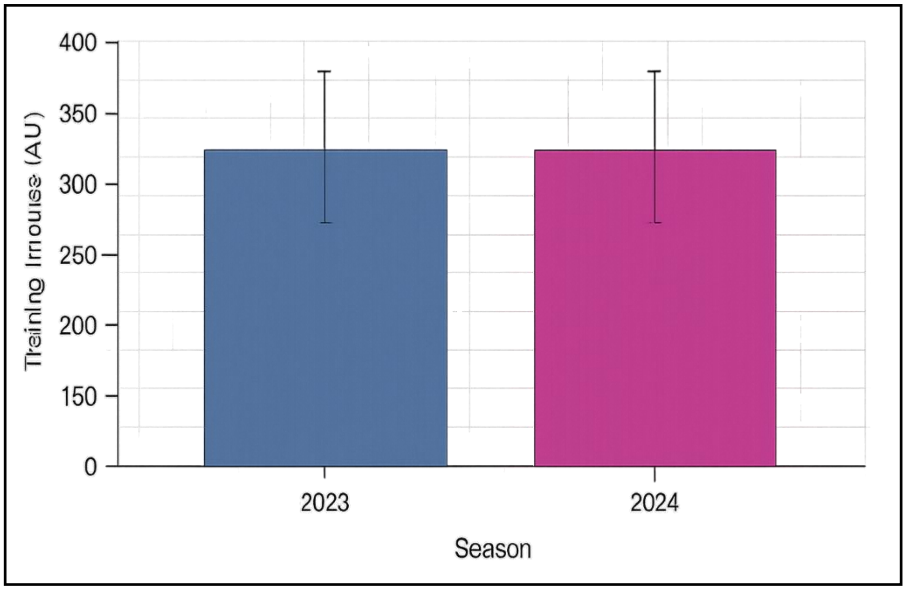

Figure 1. Mean session training impulse by season. Values represent mean ± SD. No significant seasonal differences were observed.

External Training and Match Load Differences

In contrast to the stability of internal load, external movement demands were substantially greater during match play compared with training sessions in both seasons. All training versus match comparisons were statistically significant ($p < 0.001$) and associated with large to very large effect sizes (Table 3).

Table 3. Match versus training external load comparison for 2023 and 2024 seasons.

Variable	2023 Training	2023 Match	Cohen's d	2024 Training	2024 Match	Cohen's d
Total Distance (miles)	3.15	4.77	2.05	3.52	5.42	2.21
High Speed Running (yds)	128.7	326.9	2.31	164.7	432.6	2.63
Hard Runs (count)	5.8	14.8	2.18	11.3	21.3	1.76
Sprint Distance (yds)	19.9	37.4	1.41	29.4	70.4	1.98
Sprint Count	0.38	1.34	2.06	0.82	2.31	1.84

All training vs match comparisons were statistically significant $p < 0.001$. Effect sizes were interpreted as small (0.2), moderate (0.5), large (0.8), and very large (>1.2).

During the 2023 season, matches produced greater external load than training across all GPS derived metrics. Mean total distance covered during matches was 4.77 miles, compared with 3.15 miles during training sessions (Cohen's $d = 2.05$). High speed running distance was also markedly greater during matches (326.9 vs. 128.7 yards; $d = 2.31$), as was the number of hard runs (14.8 vs. 5.8; $d = 2.18$). Sprint demands were elevated in matches, with greater sprint distance (37.4 vs. 19.9 yards; $d = 1.41$) and a higher number of sprints (1.34 vs. 0.38; $d = 2.06$).

Similar patterns were observed during the 2024 season, with external demands during match play equal to or exceeding those observed in 2023. Match total distance increased to 5.42 miles, compared with 3.52 miles during training ($d = 2.21$). High speed running distance further increased during matches (432.6 vs. 164.7 yards; $d = 2.63$), along with the number of hard runs (21.3 vs. 11.3; $d = 1.76$). Sprint distance (70.4 vs. 29.4 yards; $d = 1.98$) and sprint count (2.31 vs. 0.82; $d = 1.84$) also remained substantially higher during matches (Figure 2).

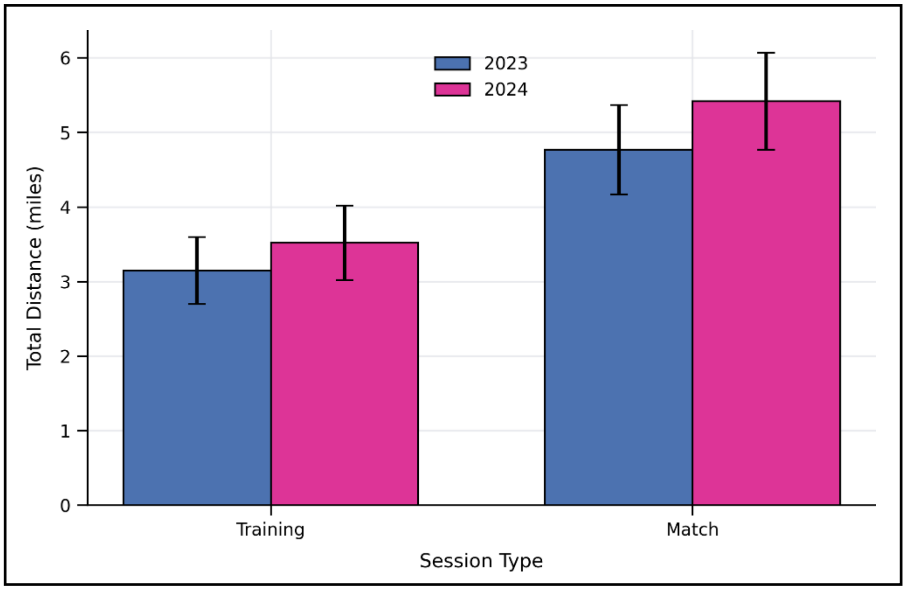

Figure 2. Comparison of total distance covered during training and match sessions across the 2023 and 2024 seasons. Bars represent mean values, and error bars indicate standard deviations. Match play elicited significantly greater external load than training in both seasons ($p < 0.001$).

Internal and External Load Relationships
Despite pronounced increases in external workload during match play, internal cardiovascular responses remained tightly regulated. Descriptive analysis of internal to external load relationships demonstrated a reduction in the TRIMP to distance ratio from 64.1 arbitrary units per mile in 2023 to 57.2 arbitrary units per mile in 2024, indicating that greater external work was completed per unit of cardiovascular stress in the second season (Table 4).

Table 4. TRIMP to distance ratio across seasons.

Season	TRIMP per Mile (AU·mile⁻¹)
2023	64.1
2024	57.2

Lower values indicate greater external work completed per unit of cardiovascular stress.

Mixed-effects modeling identified a strong main effect of session type ($p < 0.001$), confirming that matches elicited greater physiological, and movement demands than training sessions. However, no significant main effect of season ($p > 0.05$) and no season × session type interaction ($p > 0.05$) were observed, indicating that internal load responses to training and match play were preserved across seasons despite changes in external demands

Discussion
The purpose of this study was to examine changes in HR-derived internal training load across multiple competitive seasons in collegiate women's soccer. The primary finding was that internal load remained consistent from season to season despite substantial differences between training and match demands. This pattern suggests effective management of cardiovascular stress and supports the presence of long-term physiological adaptation rather than accumulation of excessive strain.[1-3]

The lack of meaningful seasonal differences in Training Impulse and average HR indicates that athletes maintained a similar physiological response to training and competition across years. Within a collegiate environment where competition density, travel demands, and academic stress can vary considerably, this stability reflects intentional load regulation rather than incidental similarity.[3-5] Maintaining stable internal load across seasons suggests that conditioning strategies supported repeated exposure to competition demands without increasing cardiovascular cost. Internal load reflects how athletes respond to workload rather than the workload itself.[2] Stable cardiovascular responses across seasons imply improved tolerance to training stress and preserved recovery capacity. This finding aligns with physiological models of adaptation which describe improved performance as the ability to complete required work with reduced relative strain over time.[1]

Although internal load remained stable across seasons, match play consistently elicited greater cardiovascular stress than training sessions. This observation reinforces prior research demonstrating that competition represents a unique stressor in soccer that exceeds training demands.[6-8] Higher match stress did not translate into increased seasonal internal load indicating that training exposure was sufficient to prepare athletes for competition demands without inducing chronic overload.[5] For strength and conditioning professionals, this supports the principle that training quality and structure are more important than simple exposure to match level volumes. Appropriately dosed training appears to promote preparedness while allowing athletes to tolerate competitive stress efficiently[13]. Continuous HR monitoring allows practitioners to confirm that training loads support readiness rather than contribute to maladaptation.[2-3]

These findings highlight the utility of longitudinal internal load monitoring as one component of a comprehensive athlete management strategy, rather than as a standalone indicator of training stress. This pattern is consistent with improved aerobic capacity movement economy or recovery processes and has been previously described in longitudinal monitoring studies.[5-7] While direct fitness assessments were not included, internal load responses provide indirect evidence of favorable adaptation. Efficiency gains are particularly relevant in congested competitive schedules where repeated competition places sustained stress on athletes. Athletes able to tolerate match demands without increased cardiovascular strain may better maintain performance and reduce cumulative fatigue.[4-7] In this context, internal load monitoring provides insight not captured by external metrics alone.

A key contribution of this study is its focus on a female collegiate population addressing a documented gap in training load literature. Recent reviews have highlighted the scarcity of longitudinal workload data in women's soccer and the need for population specific evidence to guide applied practice.[4-5] By examining internal load across seasons this study contributes meaningful data to support evidence-based programming in collegiate women's soccer. Sex specific considerations including recovery patterns, hormonal influences, and competition structure may affect training tolerance in female athletes[14]. Longitudinal internal load data helps establish appropriate expectations for adaptation and provide a framework for individualized load management.[4]

From an applied perspective, these findings emphasize the value of tracking internal load trends over time rather than reacting to individual high load sessions. Stable internal load across seasons may reflect effective strength conditioning design, recovery strategies, and athlete readiness management. Conversely progressive increases in internal load across years may signal emerging maladaptation and warrant program modification.[1-2] HR-based monitoring is a practical and accessible method for evaluating these patterns particularly in collegiate sport environments where resources may be limited. [3]

Internal load captures only one component of athlete stress. The absence of external workload, neuromuscular fatigue markers, and injury outcomes limits mechanistic interpretation.[8] Roster turnover characteristic of the modern collegiate environment, including transfers between seasons, may have influenced between-season comparisons independent of training structure. Playing time and starter status were not explicitly stratified in the present analysis. As such, session-level loads reflect exposure average across participating athletes rather than individual match minutes. Future research should integrate GPS based metrics, perceptual measures, and injury surveillance to better characterize the relationship between training stress adaptation and performance. Additionally, examining positional roles as well as differences between starters and non-starters across multiple seasons would further enhance understanding of individualized training responses.[5-8]

Conclusions
Collegiate women's soccer athletes demonstrated stable internal training load across consecutive seasons despite pronounced match demands. These findings support the effectiveness of load regulation strategies and reinforce the value of longitudinal HR monitoring as a core component of performance-oriented strength and conditioning practice.

Conflict of Interest. The authors declare no conflicts of interest.

References

1. Banister EW. Modeling elite athletic performance. *Phys Sportsmed*. 1991;19(3):106-116.
2. Impellizzeri FM, Marcora SM, Coutts AJ. Internal and external training load: 15 years on. *Int J Sports Physiol Perform*. 2019;14(2):270-273.
3. Morton RH, Fitz-Clarke JR, Banister EW. Modeling human performance in running. *J Appl Physiol*. 1990;69(3):1171-1177.
4. Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of soccer. *Sports Med*. 2005;35(6):501-536.
5. Julian R, Hecksteden A, Fullagar HHK, Meyer T. The effects of menstrual cycle phase on physical performance in female athletes. *Sports Med*. 2021;51(9):1813-1827.
6. Costa JA, Rago V, Brito P, et al. Training in women soccer players: a systematic review on training load monitoring. *Front Psychol*. 2022;13:943857.
7. Jagim AR, Askow AT, Carvalho V, et al. Seasonal accumulated workloads in collegiate women's soccer. *J Funct Morphol Kinesiol*. 2022;7(1):11.
8. Perrotta AS, Day BD, Correa CJ, et al. Physiological adaptations across a two-year preseason in female collegiate soccer players. *Front Sports Act Living*. 2024;6:1353129.
9. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Lawrence Erlbaum; 1988.
10. Issurin VB. New horizons for the methodology and physiology of training periodization. *Sports Med*. 2010;40(3):189-206.
11. Stevens TG, de Ruiter CJ, van Niel C, van de Rhee R, Beek PJ, Savelsbergh GJP. Monitoring training load in soccer. *Int J Sports Physiol Perform*. 2017;12(Suppl 2):S2-6–S2-16.
12. Gabbett TJ. The training-injury prevention paradox. *Br J Sports Med*. 2016;50(5):273-280.
13. Afshar Naseri MB. Beyond performance: A narrative review of prioritizing recovery and mental conditioning of athletes in times of crisis. *J Sport Rehabil Sci*. 2025;3(1):26-38.
14. Goulart KN, Coimbra CC, Campos HO, Drummond LR, Ogando PH, Brown G, Couto BP, Duffield R, Wanner SP. Fatigue and recovery time course after female soccer matches: a systematic review and meta-analysis. *Sports Med Open*. 2022;8(1):72.