

Effects of seasonal training on physical fitness and heart rate variability in amateur Futsal players

THANAKORN KAIMUSIK¹, VORRAMATE PRAJONGJAI², NIROMLEE MAKAJE³

^{1,2} Sports Science Division, Faculty of Science, Chandrakasem Rajabhat University, Bangkok , THAILAND

³ Department of Sports Science, Faculty of Sports Science and Health, Kasetsart University, THAILAND

Published online: February 28, 2026

Accepted for publication: February 15, 2026

DOI:10.7752/jpes.2026.02033

Abstract

Amateur futsal training, particularly in university settings, often faces limitations in training load regulation and recovery management, which may increase the risk of accumulated fatigue and maladaptive physiological responses. This study aimed to examine within-subject changes in physical fitness and heart rate variability (HRV) across pre-season and in-season training phases in amateur futsal players. Twenty male university-level futsal players completed physical fitness assessments and resting HRV measurements at three time points: baseline, after a 6-week pre-season, and after a 6-week in-season training period. Physical fitness variables included countermovement jump (CMJ), 10-m sprint performance, aerobic capacity assessed by the Beep Test (estimated $\dot{V}O_{2\max}$), and repeated shuttle sprint ability. Internal training load was monitored using the session rating of perceived exertion (session-RPE) method. Data were analyzed using repeated-measures analysis of variance, with statistical significance set at $p < 0.05$. The pre-season phase was characterized by higher training load, monotony, and strain, which were associated with stagnation or reductions in selected physical fitness variables and unfavorable autonomic responses. In contrast, the in-season phase, marked by reduced training load and monotony, resulted in significant improvements in physical fitness and a more favorable autonomic balance. These findings indicate that seasonal training structure plays a critical role in shaping physical fitness adaptations and autonomic regulation in amateur futsal players. Monitoring HRV in conjunction with training load may serve as a practical approach for optimizing training management and supporting recovery throughout the competitive season.

Keywords: training periodization; autonomic nervous system; physical performance; training load monitoring

Introduction

Futsal is a five-a-side indoor football sport characterized as a high-intensity intermittent activity, played in a restricted area and allowing unlimited substitutions. These game-specific conditions result in rapid transitions between offensive and defensive phases, thereby imposing substantial physical and physiological demands on players. During match play, futsal athletes are required to repeatedly perform high-intensity actions such as sprinting, rapid accelerations and decelerations, and abrupt changes of direction, while simultaneously executing technical skills under severe spatial and temporal constraints. Consequently, players experience high levels of physiological fatigue, accompanied by a progressive reduction in high-intensity activities as the match progresses. Previous research has consistently demonstrated that these demands are key determinants of competitive performance in futsal and other indoor football codes (Bangsbo et al., 2008; Barbero et al., 2008; Nakamura et al., 2021).

Accordingly, possessing physical fitness characteristics that align with the specific demands of futsal is considered fundamental to achieving high-level performance. The effective development of physical preparedness requires a structured and periodized training process that is appropriately aligned with each phase of the competitive season, while also incorporating adequate recovery to support physiological adaptation (Buchheit & Laursen, 2013; Issurin, 2010). A substantial body of evidence indicates that the pre-season period plays a crucial role in enhancing repeated sprint ability, intermittent endurance, and aerobic capacity, all of which are essential components of futsal performance (Bangsbo et al., 2008; Barbero et al., 2008; Soares-Caldeira et al., 2014). However, pre-season training programs are typically characterized by high training volume and intensity. Although such workloads are necessary to stimulate adaptive responses, they simultaneously increase the risk of functional overreaching, which is defined as a temporary stagnation or decline in physical and psychological performance (Lehmann et al., 1998; Meeusen et al., 2013). When appropriately managed with sufficient recovery, functional overreaching may facilitate supercompensation and long-term performance development. Conversely, if excessive training stress persists without adequate recovery, it may progress to overtraining syndrome, resulting in detrimental effects on performance, health, and competitive readiness. Evidence from various sports disciplines supports the negative impact of excessive

training loads on physical performance and physiological function. Reductions in muscle strength, aerobic capacity, and competitive performance have been reported following prolonged periods of high-intensity training (Callister et al., 1990; Fry et al., 1994; Hooper et al., 1993; Jeukendrup et al., 1992; Snyder et al., 1995). From an autonomic regulation perspective, compelling evidence indicates that heart rate variability (HRV) decreases during periods of elevated training load, reflecting increased sympathetic activity and reduced parasympathetic modulation (Plews et al., 2013; Urhausen & Kindermann, 2002). In addition, hormonal markers such as the testosterone-to-cortisol ratio have been shown to exhibit significant imbalance in athletes experiencing overtraining (Adlercreutz et al., 1986; Fry et al., 1991). During the in-season phase, although overall training volume may be reduced compared with the pre-season, the increased frequency of matches and competitive pressure continue to impose substantial physical and psychological stress. Studies have reported a decline in resting HRV toward the end of the competitive season in professional athletes, indicating accumulated fatigue and altered autonomic nervous system regulation (Rave et al., 2020; Thorpe et al., 2017). Therefore, monitoring athletes' responses to training loads across both the pre-season and in-season phases is essential for effective performance management. In this context, HRV has been proposed as a non-invasive marker of autonomic nervous system function that is sensitive to changes in training load and recovery status and can be effectively applied in practical settings (Buchheit & Simpson, 2020; Flatt et al., 2018; Flatt & Howells, 2019; Plews et al., 2013). Nevertheless, Buchheit (2014) emphasized that HRV should not be interpreted in isolation but rather in conjunction with training load characteristics, the phase of the competitive season, and individual athlete responses. This perspective is supported by recent strength and conditioning literature, which suggests that HRV provides maximal value when combined with additional indicators of training load and fatigue (Addleman et al., 2024).

Despite the growing body of research examining training load management and HRV monitoring in professional football and futsal players, limited evidence is available regarding the effects of seasonal training on physical fitness and autonomic regulation in amateur futsal players, particularly at the university level. This population is characterized by distinct training structures, recovery resources, and competitive contexts compared with elite athletes, which limits the direct transferability of findings derived from professional cohorts. Therefore, the purpose of this study was to investigate within-subject changes in physical fitness and heart rate variability in university-level amateur futsal players across the pre-season and in-season phases within the same seasonal training structure. Physical performance assessments included measures of power, speed, aerobic capacity, and repeated sprint ability, alongside resting HRV measurements collected at three time points: baseline, post pre-season, and post in-season. Training load was concurrently monitored using the session rating of perceived exertion (session-RPE) method to facilitate interpretation of training-induced responses. The findings of this study are expected to provide empirical insight into seasonal training adaptations in amateur futsal players and to offer practical guidance for monitoring and adjusting training loads in university-level futsal settings.

Materials and Methods

Research Design

This study employed a one-group repeated-measures experimental design. Key outcome variables were assessed at three time points: baseline (pre-training), after a 6-week pre-season training period, and after a 6-week in-season (pre-competition) training period. The purpose was to examine within-subject changes in physical fitness and heart rate variability (HRV) in response to seasonal training.

Participants

Twenty male university-level futsal players from Chandrakasem Rajabhat University (age: 19.60 ± 1.01 years; body mass: 65.50 ± 9.35 kg; height: 170.50 ± 7.01 cm) participated in the study. Participants were recruited using simple random sampling. Sample size estimation was performed using G*Power software, assuming a statistical power of 0.95, alpha level of 0.05, and a large effect size ($f = 0.95$), based on previous related studies. The minimum required sample size was 15 participants; therefore, 20 participants were recruited to account for an anticipated dropout rate of approximately 20%.

All participants provided written informed consent prior to participation. The study protocol was approved by the Human Research Ethics Committee of Chandrakasem Rajabhat University and conducted in accordance with the Declaration of Helsinki.

Experimental Procedures

Participants completed physical fitness and HRV assessments at baseline, after the pre-season period (week 6), and after the in-season period (week 12). All assessments were conducted under standardized environmental conditions and consistent time-of-day schedules to minimize external variability.

The training program was divided into two phases:

Pre-season (Weeks 1–6): Training emphasized the development of fundamental physical capacities, including strength, power, speed, and high-intensity endurance. Training frequency was six sessions per week, with a total weekly training volume of approximately 520–600 minutes. Sessions consisted of resistance and power training (two sessions per week), speed and agility drills, interval and Fartlek running, and technical-tactical exercises. Training volume and intensity were progressively increased across the pre-season.

In-season (Weeks 7–12): The in-season phase focused on performance maintenance and recovery optimization. Training frequency remained at six sessions per week, while weekly training volume was reduced to approximately 438–486 minutes. Training content emphasized tactical preparation, small-sided games, position-specific drills, and the maintenance of speed, power, and agility.

Internal training load was assessed using the session rating of perceived exertion (session-RPE) method. Participants reported their perceived exertion (RPE) following the completion of each training session. The session-RPE was then calculated by multiplying the RPE score by the duration of the training session (minutes). Weekly training load, training monotony, and training strain were calculated according to the methods proposed by Foster et al. (2001).

Heart Rate Variability Assessment

Resting HRV was assessed using a BioRex Biofeedback device (BioRex, Russia). Participants remained seated and breathed spontaneously in a quiet, temperature-controlled room (25–26 °C) for 10 minutes. RR intervals were recorded at a sampling rate of 1,000 Hz, with the final 5 minutes used for analysis via BioRex software. Time-domain HRV indices included mean RR interval, the root mean square of successive differences (RMSSD), and the standard deviation of normal-to-normal RR intervals (SDNN). Frequency-domain analysis was performed using a 1,024-point fast Fourier transform (FFT) with 50% overlap and Welch's periodogram. Power spectral density was calculated for low-frequency (LF: 0.04–0.15 Hz) and high-frequency (HF: 0.15–0.40 Hz) bands. Absolute power values were expressed in ms^2 , and normalized units (nu) were calculated after removal of the very low-frequency component. The LF/HF ratio was used as an indicator of sympathovagal balance. Participants were instructed to abstain from caffeine, alcohol, and strenuous physical activity for at least 24 hours prior to HRV testing and to maintain normal sleep and dietary routines.

Physical Fitness Testing

Muscular Power: Lower-body power was assessed using the countermovement jump (CMJ) performed on a force platform (Australia). Participants executed maximal vertical jumps from an upright standing position. Jump height, peak force, and peak power ($\text{W} \cdot \text{kg}^{-1}$) were recorded.

Sprint Performance: Linear sprint speed was assessed using a 10-m sprint test with electronic timing gates (Smart Speed, Australia). Participants started from a standing position, and sprint time was recorded with a resolution of ± 0.01 s.

Aerobic Capacity: Aerobic fitness was estimated using the multi-stage 20-m shuttle run test (Beep Test). Estimated maximal oxygen uptake ($\text{VO}_2 \text{ max}$) was calculated based on the final stage completed.

Anaerobic Capacity: Anaerobic performance was evaluated using the repeated shuttle sprint ability (RSSA) test. Participants completed six maximal 2×20 m shuttle sprints interspersed with 20 s of passive recovery. Best sprint time, mean sprint time, and fatigue index were calculated.

Data Collection

Heart rate variability (HRV) and physical fitness assessments were conducted at three time points under identical testing conditions. On Day 1, participants underwent a health history screening to confirm their health status and ensure safety prior to testing. The screening included a review of medical history and recent injuries, an assessment of current musculoskeletal conditions, and verification of the absence of contraindications to exercise, in accordance with standard pre-participation guidelines. Resting HRV was then assessed between 09:00 and 11:00 h. Subsequently, between 15:00 and 17:00 h, participants performed the countermovement jump (CMJ), sprint, and repeated sprint ability (RSSA) tests. On Day 2, aerobic fitness was evaluated using the Beep Test between 09:00 and 11:00 h. All running tests were performed on a rubberized indoor court familiar to the participants.

Statistical Analysis

Descriptive statistics are presented as mean $\pm$ standard deviation. Prior to inferential analyses, data distribution was examined for normality using the Shapiro–Wilk test, and visual inspection of histograms and Q–Q plots was performed to confirm distributional assumptions. Changes in physical fitness and HRV variables across the three assessment time points were analyzed using repeated-measures analysis of variance (ANOVA). When significant main effects were observed, Bonferroni-adjusted post hoc comparisons were applied. Differences in weekly training load, training monotony, and training strain between the pre-season and in-season phases were examined using paired-samples t-tests. Statistical significance was set at $p < 0.05$.

Results

The results are presented in three sections: (1) participant characteristics and training load, (2) changes in physical fitness across training phases, and (3) changes in heart rate variability (HRV).

1. Participant Characteristics and Training Load

Twenty male amateur futsal players completed the study. Participant characteristics are presented in Table 1. The mean age was 19.60 ± 1.01 years, body mass was 65.50 ± 9.35 kg, and height was 170.50 ± 7.01 cm. Weekly training load, training monotony, and training strain differed significantly between the pre-season and in-season phases (Table 2). During the pre-season (weeks 1–6), players exhibited higher weekly training load ($1,490.55 \pm 129.12$ AU), training monotony (5.02 ± 0.83), and training strain ($7,506.32 \pm 1,504.25$ AU). All

training load indices were significantly lower during the in-season phase (weeks 7–12), with a weekly training load of $1,043.70 \pm 91.98$ AU, monotony of 2.12 ± 0.54 , and strain of $2,247.77 \pm 632.60$ AU ($p < 0.001$).

Table 1. General characteristics of the participants (N = 20)

Variable	Mean $\pm$ SD
Age (years)	19.60 $\pm$ 1.01
Body mass (kg)	65.50 $\pm$ 9.35
Height (cm)	170.50 $\pm$ 7.01

Table 2. Weekly training load, monotony, and strain during pre-season and in-season

Variable	Pre-season (Weeks 1-6)	In-season (Weeks 7-12)	p-value
Weekly training load (AU)	1,490.55 $\pm$ 129.12	1,043.70 $\pm$ 91.98	<0.001
Training monotony	5.02 $\pm$ 0.83	2.12 $\pm$ 0.54	<0.001
Training strain (AU)	7,506.32 $\pm$ 1,504.25	2,247.77 $\pm$ 632.60	<0.001

Note: Values are mean $\pm$ SD. AU = arbitrary units. p-values were derived from paired-samples t-tests.

Table 3. Changes in physical fitness variables across training phases

Variable	Baseline (Mean $\pm$ SD)	Post pre-season (Mean $\pm$ SD)	Post in-season (Mean $\pm$ SD)	p-value
Muscular power ($W \cdot kg^{-1}$)	51.40 $\pm$ 4.45 ^a	50.32 $\pm$ 6.35 ^a	56.50 $\pm$ 5.60 ^b	<0.001
CMJ height (cm)	35.70 $\pm$ 4.08 ^a	33.20 $\pm$ 3.20 ^b	39.20 $\pm$ 4.48 ^c	<0.001
10-m sprint (s)	2.86 $\pm$ 0.22 ^a	2.88 $\pm$ 0.26 ^a	2.79 $\pm$ 0.24 ^b	0.015
Anaerobic power (W)	358.73 $\pm$ 53.40 ^a	356.07 $\pm$ 53.77 ^a	369.40 $\pm$ 62.63 ^b	0.037
Anaerobic capacity (W)	346.20 $\pm$ 51.31 ^a	339.13 $\pm$ 47.82 ^b	352.73 $\pm$ 54.79 ^c	<0.001
VO ₂ max ($ml \cdot kg^{-1} \cdot min^{-1}$)	46.31 $\pm$ 5.71 ^a	45.33 $\pm$ 5.32 ^b	50.34 $\pm$ 5.31 ^c	<0.001
Fatigue index	3.75 $\pm$ 1.39 ^a	5.24 $\pm$ 1.57 ^b	4.68 $\pm$ 2.00 ^{ab}	0.009

Note: Values are presented as mean $\pm$ standard deviation. Different superscript letters (a, b, c) within the same row indicate statistically significant differences at $p < 0.05$ based on post hoc pairwise comparisons, whereas means sharing the same or common superscript letters (e.g., ab) indicate no statistically significant differences.

2. Changes in Physical Fitness across Training Phases

Changes in physical fitness variables across baseline, post pre-season, and post in-season assessments are presented in Table 3. Following the pre-season training phase, CMJ height, anaerobic capacity, and estimated VO₂max were significantly lower than baseline values ($p < 0.05$). No significant changes were observed in muscular power, 10-m sprint time, anaerobic power, or fatigue index following the pre-season period. Following the in-season training phase, significant improvements were observed in all physical fitness variables. Muscular power, CMJ height, anaerobic power, anaerobic capacity, and estimated VO₂max were significantly higher compared with both baseline and post pre-season values ($p < 0.05$). In addition, 10-m sprint time was significantly reduced following the in-season phase ($p < 0.05$). Fatigue index values were significantly lower than post pre-season values but did not differ significantly from baseline.

3. Changes in Heart Rate Variability across Training Phases

HRV parameters measured at baseline, post pre-season, and post in-season are presented in Table 4. Resting heart rate increased significantly following the pre-season phase compared with baseline and post in-season values ($p < 0.05$). RR interval was significantly reduced following the pre-season period ($p < 0.05$). Following the in-season phase, resting heart rate, LF power, and LF/HF ratio were significantly lower than both baseline and post pre-season values ($p < 0.05$). Conversely, RR interval, RMSSD, and HF power were significantly higher following the in-season phase compared with baseline and post pre-season measurements ($p < 0.05$).

Table 4. Changes in heart rate variability parameters across training phases

HRV Variable	Baseline (Mean $\pm$ SD)	Post Pre-Season (Mean $\pm$ SD)	Post In-Season (Mean $\pm$ SD)	p-value
HR ($beats \cdot min^{-1}$)	67.00 $\pm$ 5.07 ^a	74.00 $\pm$ 7.47 ^b	62.00 $\pm$ 4.53 ^c	<0.001
RR interval (ms)	887.00 $\pm$ 78.91 ^a	806.00 $\pm$ 94.18 ^b	956.00 $\pm$ 90.11 ^c	<0.001
RMSSD (ms)	50.00 $\pm$ 25.10 ^a	44.00 $\pm$ 28.30 ^a	70.00 $\pm$ 33.11 ^b	0.013
HF (nu)	49.10 $\pm$ 21.30 ^a	38.08 $\pm$ 23.22 ^a	58.56 $\pm$ 15.76 ^b	0.005
LF (nu)	50.90 $\pm$ 21.30 ^a	61.92 $\pm$ 23.22 ^a	41.49 $\pm$ 15.74 ^b	0.005
LF/HF ratio	1.87 $\pm$ 2.30 ^a	3.90 $\pm$ 4.57 ^b	0.85 $\pm$ 0.61 ^c	0.004

Note: Values are presented as mean $\pm$ standard deviation. Different superscript letters (a, b, c) within the same row indicate statistically significant differences at $p < 0.05$ based on post hoc pairwise comparisons, whereas means sharing the same or common superscript letters (e.g., ab) indicate no statistically significant differences.

Discussion

The purpose of this study was to examine the effects of seasonal training structure on physical fitness and heart rate variability (HRV) in amateur university-level futsal players. The principal findings indicate that the structure of training load across different phases of the season elicited distinct physiological responses and athlete adaptations. Specifically, the pre-season phase was characterized by high training load, monotony, and training strain, which resulted in stagnation or transient declines in several physical fitness components, along with alterations in autonomic nervous system regulation that were not conducive to recovery. In contrast, the in-season phase, during which training load was appropriately reduced, led to significant improvements in both physical fitness and HRV indices, reflecting a more favorable restoration of physiological homeostasis and autonomic regulation.

Effects of Pre-season Training Load on Physical Performance

The findings of the present study indicate that, during the pre-season phase, university-level amateur futsal players were exposed to a high average weekly training load, accompanied by persistently elevated training monotony and training strain. This pattern reflects a training structure primarily designed to increase both training volume and intensity in order to elicit short-term physiological adaptations. However, when physical fitness outcomes were examined at the end of the pre-season period, measures of lower-limb power assessed by the countermovement jump (CMJ), short-distance sprint performance, and aerobic capacity tended to remain unchanged or exhibit slight reductions compared with baseline values. These results suggest that, during this phase, the applied training stimulus was not yet conducive to optimal performance expression. Such responses are consistent with the concept of functional overreaching, which arises from the accumulation of training load in combination with insufficient recovery. Foster et al. (1998) proposed that sustained exposure to high training monotony and training strain increases the risk of transient performance decrements and unfavorable physiological adaptations. This pattern closely aligns with the pre-season training characteristics observed in the present study. Furthermore, Bell et al. (2020) described a continuum between functional and non-functional overreaching in sports with high neuromuscular demands, emphasizing that prolonged periods of high-intensity and monotonous training may suppress short-term performance expression, even in the absence of long-term impairment to athletic potential. Previous research in team-sport settings has also reported clear associations between training load variables and changes in physical performance. Clemente et al. (2017) demonstrated that the accumulation of high training load in conjunction with elevated training monotony was associated with stagnation or reductions in maximal aerobic speed and estimated VO_2 max, even among well-trained athletes. Similarly, Fry et al. (1994) reported that rapid increases in training load in resistance-trained athletes can induce short-term overreaching, manifested by increased fatigue and reductions in muscular strength. In addition, studies by Callister et al. (1990) and Hooper et al. (1993) documented performance decrements in athletes exposed to sustained heavy training without adequate recovery.

When considered within the specific physiological and mechanical demands of futsal—a sport characterized by repeated explosive actions, rapid accelerations, and frequent changes of direction performed under limited recovery intervals—the accumulation of high and monotonous training load may directly impair the capacity to generate muscular power and movement speed. This effect may be particularly pronounced in university-level athletes, who often face additional constraints related to sleep quality, academic demands, and limited recovery resources, thereby exacerbating short-term suppression of physical performance during the pre-season phase.

Effects of In-Season Training Load on Physical Fitness

Upon entering the in-season phase, a clear reduction in overall training load was observed, encompassing decreases in training volume, training monotony, and training strain. This shift reflects a strategic modification of the training structure from the pre-season emphasis on inducing physiological adaptations toward the maintenance of physical performance and athlete freshness to accommodate the demands of continuous competition. Such an approach is consistent with the principles of periodized training, which advocate the attenuation of accumulated training stress to allow previously induced adaptations to be optimally expressed (Buchheit & Simpson, 2020). The present findings demonstrated that, following the in-season period, university-level amateur futsal players exhibited significant improvements across multiple physical fitness components, including lower-limb power assessed by the countermovement jump (CMJ), short-distance sprint performance, anaerobic capacity, and aerobic fitness, compared with post pre-season values. These adaptations align with previous evidence from team-sport research indicating that reductions in training load during the competitive season are associated with the restoration and enhancement of power, speed, and endurance capacities (Clemente et al., 2017; Foster et al., 2001). These performance improvements are also consistent with the concept of the delayed training effect or supercompensation, whereby the reduction of training stress following a period of high load enables previously suppressed performance capacities to manifest more fully (Issurin, 2010; Urhausen & Kindermann, 2002). In this context, the recovery of physical fitness during the in-season phase can be attributed to a reduction in accumulated fatigue and an optimization of recovery processes, which collectively facilitate neuromuscular function and enhance both aerobic and anaerobic energy production pathways. Supporting this interpretation, previous studies have reported that internal training load indicators, such as session rating of perceived exertion (session-RPE) and training impulse (TRIMP), are positively

associated with improvements in endurance performance and aerobic capacity in team-sport athletes when training load is appropriately regulated during the competitive season (Bourdon et al., 2017; Impellizzeri et al., 2019). In futsal specifically the reduction of training load during the in-season phase plays a critical role in restoring neuromuscular readiness and preserving the quality of high-intensity movement execution.

The present findings further support earlier reports indicating that the attenuation of training stress following intensive training phases promotes aerobic fitness and repeated high-intensity performance capacity (Jeukendrup et al., 1992). Collectively, these results reinforce the recommendations of Bourdon et al. (2017), which emphasize that effective training management in team sports should rely on the integrated monitoring of multiple load and recovery indicators to ensure informed, context-sensitive decision-making throughout the competitive season.

Effects of Pre-Season and In-Season Training Load on Autonomic Nervous System Responses and HRV Adaptations

Heart rate variability (HRV) analysis provides a sensitive and non-invasive approach for examining autonomic nervous system responses to seasonal training structure and accumulated training stress. In the present study, the pre-season phase was characterized by an increase in resting heart rate alongside concomitant reductions in RR interval, RMSSD, and HF power, accompanied by elevations in LF power and the LF/HF ratio. When interpreted collectively, these changes indicate a shift in autonomic regulation toward sympathetic predominance and parasympathetic withdrawal, a pattern commonly associated with accumulated training stress and functional overreaching (Lehmann et al., 1998; Urhausen & Kindermann, 2002). This interpretation is consistent with previous findings demonstrating that reductions in RMSSD, particularly when accompanied by elevated resting heart rate, represent sensitive markers of insufficient recovery and accumulated fatigue in team-sport athletes exposed to high training load and monotony (Bellenger et al., 2021; Plews et al., 2013). Furthermore, Urhausen and Kindermann (2002) reported pronounced reductions in HRV indices during periods of intensified and monotonous training, reflecting increased sympathetic drive and altered autonomic control. Although hormonal variables were not assessed in the present study, prior research has shown that sustained training stress may be accompanied by marked reductions in the testosterone-to-cortisol ratio, reflecting broader dysregulation of physiological stress responses under conditions of excessive load (Adlercreutz et al., 1986; Fry et al., 1991). Collectively, these findings support the notion that the autonomic alterations observed during the pre-season phase reflect a state of heightened physiological stress rather than optimal adaptive readiness. From an applied perspective, these pre-season HRV responses align with recent recommendations emphasizing that HRV metrics should be interpreted in conjunction with training load indices and seasonal context rather than in isolation (Addleman et al., 2024; Flatt & Howells, 2019). In the present study, HRV alterations were examined alongside objectively quantified training load, monotony, and strain, thereby strengthening the physiological plausibility of the observed autonomic responses.

In contrast, the in-season phase was characterized by a normalization of autonomic function, as evidenced by reductions in resting heart rate and concurrent increases in RR interval, RMSSD, and HF power, alongside a decrease in the LF/HF ratio. These adaptations reflect enhanced parasympathetic modulation and improved autonomic balance, indicative of sufficient recovery and positive physiological adaptation under reduced training stress. Consistent with this interpretation, RMSSD has been identified as a robust and stable HRV index for monitoring recovery status and readiness in intermittent team sports (Buchheit & Laursen, 2021; Schneider et al., 2018). Moreover, increases in RMSSD during competitive phases have been associated with improved performance consistency and recovery capacity in both football and futsal players (Milanez et al., 2021). Taken together, the present findings reinforce the concept that HRV responses reflect the dynamic balance between training-induced stress and recovery processes across seasonal phases. When integrated with training load monitoring, HRV represents a valuable applied tool for guiding load regulation, minimizing the risk of maladaptive fatigue, and supporting sustainable performance development in university-level amateur futsal players, who often operate under greater recovery constraints than professional athletes.

Conclusion

The purpose of this study was to examine the influence of seasonal training structure on changes in physical performance and autonomic nervous system regulation in university-level amateur futsal players, using an integrated analytical framework that combined physical performance outcomes, training load characteristics, and physiological response indicators. The present findings clearly demonstrate that the organization and management of training structure across different phases of the season play a central role in shaping physiological adaptations and performance trajectories, rather than the isolated effect of any single monitoring variable considered outside the training context. During the pre-season phase, which was characterized by high training loads, elevated training monotony, and increased training strain, several components of physical performance tended to stagnate or decline. These changes were accompanied by alterations in heart rate variability (HRV) indicative of heightened physiological stress. This response pattern suggests that although pre-season training is essential for establishing physical foundations, training structures involving excessive load accumulation, low variability, and insufficient recovery allocation may constrain adaptive potential and promote maladaptive physiological responses. In contrast, the in-season phase, during which training load and monotony

were more appropriately regulated, was associated with improvements in multiple aspects of physical performance alongside HRV responses reflecting improved autonomic balance and recovery status. These findings emphasize the importance of designing seasonal training structures that balance training stress and recovery demands to support favorable physiological adaptations and the maintenance of performance throughout the competitive period in amateur futsal players.

A key contribution of this study lies in demonstrating that seasonal changes in physical performance and HRV primarily reflect the characteristics of the training structure to which athletes are exposed, rather than providing direct evidence of the effectiveness of specific monitoring tools or methods. From a theoretical perspective, this research extends current knowledge on the interaction between seasonal training planning, autonomic nervous system regulation, and performance adaptation in high-intensity intermittent team sports such as futsal, particularly within the under-represented context of university-level amateur athletes.

In summary, sustainable performance development in amateur futsal players cannot be explained solely by training volume or intensity. Instead, it is closely linked to the overall seasonal training structure, the continuity and distribution of training load, and the adequacy of recovery strategies. Accordingly, the present findings support the concept of designing and evaluating balanced seasonal training structures that are aligned with the practical realities of university-level futsal training.

Practical Applications

From a practical standpoint, the present findings suggest that the evaluation of seasonal training structure in amateur futsal players can be effectively conducted through the combined consideration of physical performance data, training load characteristics, and physiological response indicators. In this study, variables such as session rating of perceived exertion (session-RPE) and heart rate variability (HRV) functioned as reflective indicators of athletes' responses to differing training patterns and stress levels between the pre-season and in-season phases, rather than as tools intended to predict or guarantee performance outcomes directly.

Accordingly, coaches and sport scientists working at the university level may use information derived from these variables to support the systematic review and refinement of existing training structures. This approach may help ensure that training load management, training variability, and recovery allocation are better aligned with the practical context of amateur futsal players throughout the competitive season, thereby reducing the risk of undesirable training responses. Specifically, practitioners should carefully manage training load, training monotony, and training strain, particularly during the pre-season phase, to minimize the risk of functional overreaching. Excessive training volume combined with low load variability may impair neuromuscular performance and autonomic regulation, even when the primary objective is to enhance physical fitness. Integrating HRV monitoring alongside subjective load measures such as session-RPE may facilitate the early detection of excessive physiological stress and allow timely adjustments to training programs. In this context, the root mean square of successive differences (RMSSD) represents a practical, non-invasive indicator of recovery status and autonomic regulation that can be readily implemented within amateur futsal environments, supporting evidence-informed decision-making in seasonal training design.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, the use of a one-group repeated-measures design without a control group limits causal inference regarding the effects of seasonal training structure. Nevertheless, this approach was intentionally adopted to reflect the real-world constraints of amateur futsal training environments and to enable appropriate within-subject comparisons across different training phases. Second, the sample consisted exclusively of male amateur university futsal players, which may limit the generalizability of the findings to female athletes or elite futsal populations. However, the specificity of the sample enhances the contextual relevance of the conclusions within the training setting examined. Finally, psychological and perceptual recovery markers were not integrated into the present analysis. Future research should therefore incorporate psychometric assessments alongside physiological indicators, such as heart rate variability, to provide a more comprehensive understanding of the adaptive processes associated with seasonal training structures.

Recommendations

Consistent with the study conclusions, the present findings indicate that adaptations in amateur futsal players are primarily influenced by the overall seasonal training structure rather than by any single training-load variable considered in isolation. Accordingly, the evaluation of training programs should adopt a system-based perspective that accounts for the interactions among training load distribution, recovery allocation, and physiological responses.

From a practical standpoint, the combined monitoring of physical performance, training load characteristics, and heart rate variability (HRV) represents a feasible and applicable framework for reviewing and refining training structures in university-level and amateur futsal contexts. Within this framework, indicators such as session rating of perceived exertion (session-RPE) and HRV should be interpreted as reflective markers of athletes' responses to training stress, rather than as direct predictors of performance outcomes.

From a management perspective, the use of non-invasive and low-cost monitoring tools may support more effective training load management, reduce the risk of maladaptive training responses, and promote continuity of the training process across the competitive season.

Finally, future research should extend monitoring across multiple competitive seasons and include more diverse athlete populations to improve understanding of long-term adaptation patterns. The integration of psychological and recovery-related markers—such as perceived fatigue, sleep quality, and psychological stress—alongside physiological measures is recommended to provide a more comprehensive perspective on adaptation to seasonal training structures. In parallel, future studies should examine the integrated relationships among training load dimensions (volume, intensity, monotony, and strain), changes in physical performance, and HRV in order to develop predictive models for the early detection of short-term overreaching, particularly during the pre-season. Such approaches may further support evidence-based decision-making in training design and recovery management within amateur futsal settings.

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

During the preparation of this work, the author(s) used ChatGPT (OpenAI) in order to assist solely with English language editing and the refinement of academic phrasing. The tool was not used for content generation, data analysis, interpretation of results, or the development of scientific conclusions. After using this tool, the author(s) carefully reviewed, revised, and edited the manuscript as necessary and take full responsibility for the accuracy, scientific integrity, originality, and content of the final publication.

Conflicts of Interest The authors declare no conflicts of interest.

Funding This research was financially supported by Chandrakasem Rajabhat University, Bangkok, Thailand. The funding body had no role in the study design, data collection, data analysis, interpretation of results, or preparation of the manuscript.

Acknowledgments The authors would like to express their sincere gratitude to the futsal players who participated in this study and to the staff of the Sports Science Division, Chandrakasem Rajabhat University, for their assistance and support during data collection.

References

- Addleman, J. S., Lackey, N. S., DeBlauw, J. A., & Hajduczuk, A. G. (2024). Heart rate variability applications in strength and conditioning: A narrative review. *Journal of Functional Morphology and Kinesiology*, 9(2), 93. <https://doi.org/10.3390/jfmk9020093>
- Adlercreutz, H., Härkönen, M., Kuoppasalmi, K., Näveri, H., Huhtaniemi, I., Tikkanen, H., Remes, K., Dessypris, A., & Karvonen, J. (1986). Effect of training on plasma anabolic and catabolic steroid hormones and their response during physical exercise. *International Journal of Sports Medicine*, 7(1), 27–28. <https://doi.org/10.1055/s-2008-1025798>
- Bangsbo, J., Iaia, F. M., & Krstrup, P. (2008). The Yo-Yo intermittent recovery test: A useful tool for evaluation of physical performance in intermittent sports. *Sports Medicine*, 38(1), 37–51. <https://doi.org/10.2165/00007256-200838010-00004>
- Barbero-Álvarez, J. C., Soto, V. M., Barbero-Álvarez, V., & Granda-Vera, J. (2008). Match analysis and heart rate of futsal players during competition. *Journal of Sports Sciences*, 26(1), 63–73. <https://doi.org/10.1080/02640410701287289>
- Bell, L., Ruddock, A., Maden-Wilkinson, T., & Rogerson, D. (2020). Overreaching and overtraining in strength sports and resistance training: A scoping review. *Journal of Sports Sciences*, 38(16), 1897–1912. <https://doi.org/10.1080/02640414.2020.1763077>
- Bellenger, C. R., Miller, D. J., Halson, S. L., Roach, G. D., Sargent, C., & Vincent, G. E. (2021). Monitoring athletic training status through autonomic heart rate regulation: A systematic review and meta-analysis. *European Journal of Applied Physiology*, 121(5), 1297–1311. <https://doi.org/10.1007/s00421-021-04603-2>
- Bourdon, P. C., Cardinale, M., Murray, A., Gastin, P., Kellmann, M., Varley, M. C., & Gabbett, T. J. (2017). Monitoring athlete training loads: Consensus statement. *International Journal of Sports Physiology and Performance*, 12(Suppl. 2), S2-161–S2-170.
- Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle. *Sports Medicine*, 43(5), 313–338. <https://doi.org/10.1007/s40279-013-0029-X>
- Buchheit, M. (2014). Monitoring training status with HR measures: do all roads lead to Rome? *Frontiers in Physiology*, 5, 73. <https://doi.org/10.3389/fphys.2014.00073>
- Buchheit, M., & Simpson, B. M. (2020). Player-tracking technology: Half-full or half-empty glass? *International Journal of Sports Physiology and Performance*, 15(4), 473–485.
- Buchheit, M., & Laursen, P. B. (2021). High-intensity interval training, solutions to the programming puzzle: Part II—Anaerobic energy, neuromuscular load and practical applications. *Sports Medicine*, 51(1), 1–21. <https://doi.org/10.1007/s40279-020-01399-7>
- Callister, R., Callister, R. J., Fleck, S. J., Dudley, G. A., & Kraemer, W. J. (1990). Physiological and performance responses to overtraining in elite judo athletes. *Medicine & Science in Sports & Exercise*, 22(6), 816–824.

- Clemente, F. M., Mendes, B., Nikolaidis, P. T., Calvete, F., Carriço, S., & Owen, A. L. (2017). Internal training load and its longitudinal relationship with seasonal player wellness in elite professional soccer. *Physiology & Behavior*, 179, 262–267. <https://doi.org/10.1016/j.physbeh.2017.06.021>
- Flatt, A. A., Esco, M. R., Allen, J. R., Robinson, J. B., Earley, R. L., Fedewa, M. V., Bragg, A., & Wingo, J. E. (2018). Heart rate variability and training load among National Collegiate Athletic Association Division 1 college football players throughout spring camp. *Journal of Strength & Conditioning Research*, 32(11), 3127–3134. <https://doi.org/10.1519/JSC.0000000000002241>
- Flatt, A. A., & Howells, D. (2019). Effects of varying training load on heart rate variability and running performance among an Olympic rugby sevens team. *Sports Medicine*, 49(6), 1031–1042. <https://doi.org/10.1007/s40279-019-01097-7>
- Foster, C. (1998). Monitoring training in athletes with reference to overtraining syndrome. *Medicine & Science in Sports & Exercise*, 30(7), 1164–1168. <https://doi.org/10.1097/00005768-199807000-00023>
- Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., Doleshal, P., & Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research*, 15(1), 109–115.
- Fry, A. C., Kraemer, W. J., Lynch, J. M., Triplett, N. T., & Koziris, L. P. (1994). Does short-term near-maximal intensity machine resistance training induce overtraining? *Journal of Strength and Conditioning Research*, 8(3), 188–191.
- Fry, A. C., Kraemer, W. J., Stone, M. H., Warren, B. J., Fleck, S. J., Kearney, J. T., & Gordon, S. E. (1991). Overtraining in resistance exercise. *Journal of Applied Sport Science Research*, 5(2), 57–65.
- Hooper, S. L., Mackinnon, L. T., Gordon, R. D., & Bachmann, A. W. (1993). Hormonal responses of elite swimmers to overtraining. *Medicine & Science in Sports & Exercise*, 25(7), 741–747.
- Impellizzeri, F. M., Marcora, S. M., & Coutts, A. J. (2019). Internal and external training load: 15 years on. *International Journal of Sports Physiology and Performance*, 14(2), 270–273.
- Issurin, V. B. (2010). New horizons for the methodology and physiology of training periodization. *Sports Medicine*, 40(3), 189–206. <https://doi.org/10.2165/11319770-000000000-00000>
- Jeukendrup, A. E., Hesselink, M. K. C., Snyder, A. C., Kuipers, H., & Keizer, H. A. (1992). Physiological changes in male competitive cyclists after two weeks of intensified training. *International Journal of Sports Medicine*, 13(7), 534–541. <https://doi.org/10.1055/s-2007-1021304>
- Lehmann, M., Foster, C., Dickhuth, H. H., & Gastmann, U. (1998). Autonomic imbalance hypothesis and overtraining syndrome. *Medicine & Science in Sports & Exercise*, 30(7), 1140–1145.
- Meeusen, R., Duclos, M., Foster, C., Fry, A., Gleeson, M., Nieman, D., Raglin, J., Rietjens, G., Steinacker, J., & Urhausen, A. (2013). Prevention, diagnosis, and treatment of the overtraining syndrome. *European Journal of Sport Science*, 13(1), 1–24. <https://doi.org/10.1080/17461391.2012.730061>
- Milanez, V. F., Pedro, R. E., Moreira, A., Boulosa, D. A., Salle-Neto, F., & Nakamura, F. Y. (2021). The role of aerobic fitness on session rating of perceived exertion and heart rate variability in futsal players. *Journal of Sports Sciences*, 39(11), 1261–1268. <https://doi.org/10.1080/02640414.2020.1862931>
- Nakamura, F. Y., Pereira, L. A., Rabelo, F. N., Flatt, A. A., Esco, M. R., Bertollo, M., & Loturco, I. (2021). Monitoring weekly heart rate variability in futsal players: Associations with training load and performance. *Journal of Strength and Conditioning Research*, 35(5), 1283–1290. <https://doi.org/10.1519/JSC.0000000000002818>
- Plews, D. J., Laursen, P. B., Stanley, J., Kilding, A. E., & Buchheit, M. (2013). Training adaptation and heart rate variability in elite endurance athletes: Opening the door to effective monitoring. *Sports Medicine*, 43(9), 773–781. <https://doi.org/10.1007/s40279-013-0071-8>
- Rave, G., Zouhal, H., Boulosa, D., Doyle-Baker, P. K., Saeidi, A., Ben Abderrahman, A., & Fortrat, J.-O. (2020). Heart rate variability is correlated with perceived physical fitness in elite soccer players. *Journal of Human Kinetics*, 72(1), 141–150. <https://doi.org/10.2478/hukin-2019-0103>
- Schneider, C., Hanakam, F., Wiewelhove, T., Döweling, A., Kellmann, M., Meyer, T., Pfeiffer, M., & Ferrauti, A. (2018). Heart rate monitoring in team sports-A conceptual framework for contextualizing heart rate measures for training and recovery prescription. *Frontiers in Physiology*, 9, 639. <https://doi.org/10.3389/fphys.2018.00639>
- Snyder, A. C., Kuipers, H., Cheng, B., Servais, R., & Fransen, E. (1995). Overtraining following intensified training with normal muscle glycogen. *Medicine & Science in Sports & Exercise*, 27(7), 1063–1070.
- Soares-Caldeira, L. F., de Souza, E. A., de Freitas, V. H., de Moraes, S. M. F., Leicht, A. S., & Nakamura, F. Y. (2014). Effects of additional repeated sprint training during preseason on performance, heart rate variability, and stress symptoms in futsal players: A randomized controlled trial. *Journal of Strength and Conditioning Research*, 28(10), 2815–2826. <https://doi.org/10.1519/JSC.0000000000000461>
- Thorpe, R. T., Atkinson, G., Drust, B., & Gregson, W. (2017). Monitoring fatigue status in elite team-sport athletes: Implications for practice. *International Journal of Sports Physiology and Performance*, 12(Suppl. 2), S2-27–S2-34. <https://doi.org/10.1123/ijspp.2016-0434>
- Urhausen, A., & Kindermann, W. (2002). Diagnosis of overtraining: What tools do we have? *Sports Medicine*, 32(2), 95–102. <https://doi.org/10.2165/00007256-200232020-00002>