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Research article

Comparative Analysis of Adaptive Changes in Immunoendocrine and Physiological Responses to High-Intensity Sprint Interval Training with Progressive and Nonprogressive Loads in Young Wrestlers

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Abstract

The objective of this study was to explore the effects of a 7-week short sprint interval training (SSIT) with differing in programming volume-loads including progressive (P-SSIT) and nonprogressive (NP-SSIT) approaches on the immunoendocrine, physical fitness attributes and physiological parameters in male wrestlers during the pre-season. Thirty young freestyle wrestlers at the collegiate national-level were included in the study and were divided into three groups: P-SSIT (n = 10), NP-SSIT (n = 10), and an active control group (n = 10). The wrestlers engaged in their specific wrestling training three days weekly, while the P-SSIT and NP-SSIT groups underwent a 7-week SSIT, with scheduling in either progressed or nonprogressed volume-based overloads, three times per week. Before and after the intervention, various aspects of physical fitness (such as 20-m sprint, 4×9-m shuttle run, and maximal strength) and physiological parameters (including cardiorespiratory fitness and anaerobic power output), as well as immunoendocrine responses (such as immunoglobulin-A, testosterone, and cortisol) were measured. Following the training intervention, the control group did not show any significant changes in the variable measured; however, both the P-SSIT and NP-SSIT groups experienced significant improvements ($p = 0.001$) in physical fitness attributes and physiological parameters with effect sizes ranging from small to very large, and also more adaptive responses compared with control group ($p < 0.05$). In addition, there were no statistically significant changes observed among the P-SSIT and NP-SSIT groups in terms of immunoendocrine response to training, and physical fitness, as well as physiological parameters ($p > 0.05$). In conclusion, neither the progressed nor nonprogressed approaches of SSIT demonstrated superior effects on adaptations compared to one another. Therefore, it is recommended for strength and conditioning coaches in wrestling to incorporate both P-SSIT and NP-SSIT into their annual training plan, especially during the pre-season phase, to maximize the physical fitness and physiological parameters of their wrestlers while minimizing changes in immunoendocrine responses.

Key words: Athletic development, anaerobic capacity, maximal power, freestyle.

Introduction

Wrestling is known for its explosive and dynamic nature, where athletes engage in rapid and forceful movements while attacking and counterattacking (Chaabene et al., 2017). These intense actions require a high level of energy expenditure for a duration of 6 minutes (2 × 3 minutes) (Farzad et al., 2011). While the anaerobic metabolic pathways are vital for powering these explosive movements, the aerobic system, specifically cardiorespiratory fitness (VO_{2max}), plays a crucial role in sustaining effort throughout the entirety of the match (Bloomfield et al., 1994). Therefore, improving both the aerobic and anaerobic capacities of wrestlers is important for success in a match (Liu and Li, 2023).

High-intensity interval training (HIIT) is presented as a valuable training strategy for inducing meaningful adaptations in both aerobic and anaerobic metabolic pathways (Laursen and Buchheit, 2019). HIIT is typically recommended in various forms such as short intervals, long intervals, repeated sprints, and small-sided games to target the metabolic oxygen, neuromuscular, and anaerobic systems throughout the season (Laursen and Buchheit, 2019). Running-based HIIT is a primary and highly effective training method commonly employed to enhance the cardiorespiratory and metabolic function of players (Boullosa et al., 2022). However, engaging in this training modality needs to high level of motivation and also can lead to the feeling of high physical exertion (Boullosa et al., 2022). To resolve it, incorporating HIIT using short sprints could be recommended to induce such adaptations in the physiological parameters of athletes (Lee et al., 2020). All-out sprint interval training (SIT), which involves intense sprints lasting 30-45 seconds, is a widely recognized and effective training technique that can lead to physiological changes (i.e., cardiac output, and ventilatory thresholds) associated with both aerobic and anaerobic capacity in wrestlers (Farzad et al., 2011; Kolimechkov et al., 2023). However, this type of training requires significant motivation and can lead to feelings of nausea and discomfort due to the demanding physical exertion involved (Boullosa et al., 2022). As a consequence, young athletes may experience reduced physical tolerability, resulting in varying workloads (Lee et al., 2020). Recent research suggests that short sprint interval training (SSIT [3-10s]) with all-out condition can elicit more adaptive responses as the other interval training method, providing a more time-effective workout and increasing enjoyment by lowering the perceived exertion rate (Sheykhlouvand and Gharaat, 2024; Xu et al., 2024). This is due to the fact that the most significant mechanical and biochemical responses (i.e., ATP-PCr utilization) occur at the beginning of sprints (i.e., <10 seconds of exercise) (Laursen and Buchheit, 2019). As a result, SSIT protocols may offer a novel, enjoyable, and efficient strategy for enhancing both aerobic and anaerobic metabolic pathways in young wrestlers (Boullosa et al., 2022).

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To effectively implement a safe and efficient SSIT program, coaches need to consider several factors. These factors include the type of SIT drill (i.e., running or cycling) (Vollaard and Metcalfe, 2017), the intensity of the interval training (i.e., all-out or non-all-out) (Boullosa et al., 2022), and the training surface (i.e., grass or sand) (Cetolin et al., 2021). In addition, the manipulation of various factors related to training loads, such as work bout intensity, duration of the work bout, recovery period intensity, recovery period duration, number of intervals duration, number of interval bout series, between-series recovery duration, between-series recovery intensity and total work performed seems to be of considerable importance in designing SSIT (Laursen and Buchheit, 2019). While there are multiple methods to implement progressive overload, such as increasing exercise intensity or duration (Tschakert et al., 2022), adjusting the number of interval bout series during training can also contribute to the overall training load. For instance, athletes participating in SSIT may start with 3 sets of 10 repetitions in week 1 and progress to 3 sets of 13 repetitions in week 4, gradually increasing the workload by one repetition per week. These increments in the number of interval bout series, from 10 trials to 13 trials, can be considered as a form of "overload". In essence, this indicates that the coach has intensified the training loads from week 1 to week 4, assuming other variables remained constant (Laursen and Buchheit, 2019).

Incorporating a progressive or gradually increase in SSIT loads could be suitable strategy into a training regimen which may cause a gradual increase in stress on the musculotendinous unit, leading to enhanced performance over a period of time (Asadi et al., 2017). Nevertheless, the safety and efficacy of volume-based overload in a sport with a high load of intermittent trials (i.e., wrestling) has not been sufficiently explored in existing literature. Despite previous studies conducted physiological benefits of SIT on wrestlers (Farzad et al., 2011; Kolimechkov et al., 2023), none of them have examined the impact of volume-based overload during the SSIT intervention. This aspect of study design is crucial as progressive overload training is considered an effective method to enhance physiological adaptations (i.e., cardiorespiratory fitness and anaerobic power output) induced by the SSIT program. More research is needed as there is a lack of well-controlled studies on the effects of progressive versus nonprogressive volume-based overload SSIT on the physical fitness and physiological parameters of young wrestlers.

Strength and conditioning coaches usually employ various interval training loads during the preparation phase in order to enhance performance adaptations, leading to athletes potentially undergoing diverse biochemical reactions depending on the volume-loads prescribed in their training regimen (Margonis et al., 2007). Monitoring the immunoendocrine status, including serum or salivary immunoglobulin-A, testosterone, and cortisol levels, is crucial in determining the appropriate training loads to prevent the symptoms associated with overreaching or overtraining (Springham et al., 2022). By achieving a state of stress balance, the risk of maladaptive training can be minimized, thereby reducing the chances of injury and illness (Meeusen et al., 2013). Nevertheless, this specific approach of SSIT effects on optimizing adaptations in wrestlers has not been previously explored. Based on the aforementioned observations, the aim of this research was to investigate the impact of short-term, progressed and nonprogressed volume-based overload SSIT (i.e., gradually increasing the number of interval bout series versus constant the number of interval bout series per week) on various aspects of physical fitness (i.e., 20-m sprint, 4 × 9-m shuttle run, maximal strength) and physiological parameters (i.e., cardiorespiratory fitness, and anaerobic power output), as well as immunoendocrine (i.e., immunoglobulin-A, testosterone, and cortisol) responses in young male wrestlers.

Methods

Participants

This study recruited male freestyle wrestlers from the collegiate level who had participated in national-level competitions at least twice within the past year. To determine the suitable sample size for this research, the G*Power software (Version 3.1.9.2, University of Kiel, Germany) was used. The calculations considered an effect size of 0.8, a power of 0.8, and a p-value of 0.05, which were based on a previous study conducted by Farzad et al. (2011) that investigated the impact of SIT on the physiological parameters of male wrestlers. As a result, a total of 8 subjects were suitable for each group. In order to address the potential dropout of subjects, 10 wrestlers were assigned to each group based on the recent classification for the World Championship by United World Wrestling. Following the initial screening of athletes, thirty male wrestlers (57 kg, n = 3; 61 kg, n = 3, 65 kg, n = 3; 70 kg, n = 3, 74 kg, n = 3; 79 kg, n = 3, 86 kg, n = 3; 92 kg, n = 3, 97 kg, n = 3; 125 kg, n = 3) volunteered to participate in the study. Utilizing a computer-generated random number, the athletes were allocated randomly to one of three groups including progressed (P-SSIT, n = 10), and non-progressed (NP-SSIT, n = 10) volume-based overload SSIT, as well as an active control group (CON, n = 10) representing each weight class (Table 1). The randomization process was executed using R software (version 2.14, Foundation for Statistical Computing). Fulfilling specific conditions was mandatory for the subjects to be included in the study. These conditions involved possessing a background of more than 8 years of wrestling training and competitive experience, engaging in continuous wrestling training for a minimum of 4 years prior to the study, refraining from involvement in any other

Table 1. Subjects characterists (mean ± SD).

Groups	Age (y)	Height (cm)	Body mass (kg)	BMI (kg/m^2)	Body fat (%)	Training Experience (y)
P-SSIT	19.5 ± 0.8	174.6 ± 6.2	79.1 ± 18.6	25.8 ± 4.8	11.8 ± 2.7	9.7 ± 1.2
NP-SSIT	19.8 ± 0.9	174.2 ± 7.4	81.2 ± 20.7	25.6 ± 5.5	12.1 ± 2.8	9.1 ± 1.5
CON	19.9 ± 0.6	173.4 ± 6.6	80.8 ± 19.9	25.5 ± 5.2	11.9 ± 2.1	9.5 ± 1.3

P-SSIT: programming volume-loads including progressive; NP-SSIT: nonprogressive; CON: control.

competitive sports, abstaining from the use of ergogenic aids, and not having any lower or upper-body injuries that would hinder their ability to perform SSIT. Before commencing the study, all athletes received comprehensive information regarding the research procedures, possible risks, and study aims and they gave written informed consent. The study design obtained approval from the Ethics Committee of Wuhan Sports University and followed the ethical principles set forth in the Declaration of Helsinki.

Study design

To identify the most effective approaches to SSIT loads in wrestlers, a longitudinal study design was employed using a randomized controlled trial over a period of 9 weeks between June to August. This design included a pre-test week, followed by 7 weeks of SSIT, and concluded with a post-test week. Before the baseline testing, all subjects underwent a laboratory orientation to familiarize themselves with the testing and training procedures, as well as the study's objectives. During this session, the anthropometric profile of each subject was measured. The athletes were recruited for 2 separate sessions for testing including the measurements of 20-m sprint, 4 × 9-m shuttle run, and lower-body maximal strength on day 1, and physiological variables including Wingate anaerobic power test and incremental exercise test on day 2, respectively. In accordance with previous research on physical performance assessments (Fang and Jiang, 2024), a 20-minute break was allocated between each test. This break served the purpose of facilitating recovery, familiarizing oneself with the test, and conducting warm-up trials for subsequent measurements. Furthermore, a 72-hour period was allocated between the testing sessions to ensure recovery. All assessments were performed in the afternoon, specifically from 4 to 6 P.M. In order to analyze the immunoendocrine changes following the training duration, the fasting blood samples were collected in the morning, prior to the commencement of the training intervention, and following the completion of the training sessions (Gharaat et al., 2020; Barzegar et al., 2021).

Anthropometric measurements

The stadiometer (±0.1 cm, SECA, Germany) was used to conduct the total height measurement, while an electronic scale (±0.1 kg, BEURER, Germany) was utilized to determine the body mass. The percentage of body fat was estimated using the Siri (1961) equation with a 7-site skinfold measurement (chest, midaxilla, abdomen, suprailium, subscapula, triceps, and thigh) and a Lafayette caliper (Skin Fold Caliper, Model 01127 INDIANA). All anthropometric measurements were collected by the same investigator on the subject's right side. The process involved repeated trials until two measurements within 1mm were obtained, and the average of these two measurements was utilized. The calculation of the body mass index (BMI) involved dividing the body mass by the square of the height of the individual, as presented in kg/m^2.

Physical performance measurements

This study utilized the 20-m linear sprint (Bayraktar, 2017), 4 × 9 m shuttle run (Asadi et al., 2017), and maximal strength in leg press exercise (Kraemer and Fry, 1995) to evaluate the physical fitness of wrestlers. The 20-m linear sprint test was carried out on a wooden surface in an indoor setting. Subjects were required to start in a standardized split standing position, with the toe of their preferred foot forward and positioned 0.5 m behind the starting line. The sprint start was automatically activated as the subject crossed the first gate at the 0-m mark, which initiated the timing process. A second gate was placed at the 20-m mark. Running time was accurately measured using photocell gates (± 0.001 seconds, JBL Systems in Oslo, Norway), which were set approximately 0.9 m above the floor, at hip level, to capture trunk movement and reduce false triggers from limbs. Each subject completed three maximal trials, with a 1-minute rest period between trials. The fastest time recorded in seconds from the three trials was selected for analysis. The subject's ability to sprint and change direction was assessed through a 4 × 9-m shuttle run test. To begin the test, the subjects were positioned behind the starting line, awaiting the command to GO. The timing was automatically initiated by employing photo cell timing gates (JBL Systems). Following the completion of the 9-m sprint, the subjects were instructed to change direction using their preferred foot and sprint back to the starting line. Upon successfully finishing the fourth 9-m section, the subjects crossed the finish line, and their time was promptly recorded in seconds using the timing gate system. A 2-minute rest period was given between attempts for each subject to ensure proper recovery. The study involved testing each subject for maximal bilateral concentric one repetition leg-press on a 45° leg press machine (Nebula Fitness, Inc. in Versailles, OH), as per a previously established protocol (Asadi et al., 2017). The leg press evaluations were carried out with subjects seated (with approximately 120° hip flexion, 80° knee flexion, and 10° dorsiflexion) and the weight sliding obliquely at 45°. Upon instruction, subjects executed a fast concentric leg extension from a flexed position (85°) to achieve full extension at 180° against the resistance determined by the weight. In order to adequately prepare for this test, a specific warm-up was conducted. This warm-up involved completing eight to ten repetitions with a light weight, followed by three to five repetitions with a moderate weight, and finally one to three repetitions with a heavy weight. The resistance was incrementally increased until the participants were no longer able to perform a repetition with proper technique and full range of motion. Each participant was allowed up to five maximum attempts, with a five-minute rest period between each attempt. To ensure the safety of the participants, spotters were present throughout the test, providing verbal encouragement and maintaining a secure environment.

Physiological measurements

This study utilized the incremental exercise test, and Wingate anaerobic power test to evaluate the physiological parameters of wrestlers. Specific instructions were given to the subjects to perform a continuous incremental exercise on a treadmill to determine their VO_{2max}. The initial speed of the test was 9 $km.h^{-1}$ and was increased by 1 $km.h^{-1}$ every minute until reaching the maximum speed allowed by the treadmill (16 km.h^{-1}). Subsequently, the incline of the treadmill was increased by 1% every minute until the subjects reached a point of volitional exhaustion. Previous studies have indicated that this protocol, with a 1% increase in treadmill grade per minute, is a reliable method for measuring VO_{2max}. Throughout the tests, expired gas was measured using a Masterscreen metabolic cart (Viasys Healthcare, Jaeger, Würzburg, Germany). The gas analyzers were calibrated following the manufacturer's instructions, using a certified gas mixture with known concentrations. Regarding the two following criteria including (a) the presence of a VO_2 plateau and (b) peak heart rate (HR) greater than 90% of the age-predicted maximum (220-age), the VO_{2max} was considered (Sheykhlouvand et al., 2015; Sheykhlouvand and Forbes, 2017). To evaluate the power performance of the lower body, a 30-second maximal Wingate anaerobic test was performed on a mechanically braked cycle ergometer (model 894E, Monark, Sweden) with the resistance adjusted to 0.075 kg.kg^{-1} of the participant's body mass. The subjects initiated the test by pedaling at maximum speed against the device's inertial resistance, and a personalized load was added subsequently. To ensure subjects maintained their maximum effort throughout the entire 30-second duration, verbal encouragement was consistently provided. Peak power output was determined as the highest power achieved at the 5-second mark, while mean power output represented the average power output throughout the entire test (Liu and Li, 2023).

Immunoendocrine measurements

Following an overnight fast of more than 8 hours, a 10-mL blood sample was obtained from the antecubital vein before and after the training session. The collected sample underwent centrifugation at 3,000 rpm for 15 minutes at 4 °C and was then preserved at -80 °C until additional analysis. Serum testosterone and cortisol levels were assessed utilizing ELISA kits (Monobind, Inc. located in Lake Forest, California 92630, USA). The intra-assay coefficient of variation (CV) was found to be less than 10%. Assessment of serum IgA concentration was conducted using the Hitachi device in conjunction with the available kit (MININEPH TM Human IgA Kit, Birmingham, UK). Selective IgA deficiency was diagnosed if the serum IgA level fell below 50 µL.

Training program

The wrestlers adhered to their regular training schedule of three days per week, specifically on Monday, Wednesday, and Friday, with sessions lasting between 90 to 120 minutes. Additionally, the training groups (i.e., P-SSIT and NP-SSIT) participated in their program for 30 minutes, three times a week on Tuesday, Thursday, and Saturday. Each SSIT session commenced with a 15-minute warm-up (comprising 5 minutes of running, 5 minutes of stretching, and 5 minutes of sprint and ballistic movements) and concluded with a 10-minute cool-down. The training program consisted of 4 sets of SSIT with differing repetitions (i.e., progressed and nonprogressed) of 5-second all-out running with a 1:3 ratio of recovery (i.e., 5 seconds all-out running: 15 seconds self-paced running or walking) between efforts and a 3-minute active rest (i.e., walking and stretching movements) between sets for a duration of 7 weeks (Table 2) (Laursen and Buchheit, 2019; Boullosa et al., 2022). Throughout the training period, a specialist strength and conditioning coach closely monitored the subjects to ensure adherence to the prescribed training programs. According to the guidelines presented by Laursen and Buchhiet (2019), there are several ways available to increase the training load of SSIT. In this study, a progressively incremental approach in number of interval bout series was used for the P-SSIT group. They started with 4 sets of 6 repetitions in week 1 and completed the SSIT program in week 7 with 4 sets of 12 repetitions. This means that the number of interval bout series gradually increased from week 1 to week 7, totaling 756 trials. On the other hand, the NP-SSIT group maintained a constant volume-load, performing 4 sets of 9 repetitions from week 1 to week 7, also totaling 756 trials. Therefore, both groups performed the same number of trials throughout the training period (756 interval bouts), but differed in terms of volume-loads weekly, with one group having a constant volume-load and the other group progressively increasing the number of interval bout series from week 1 to week 7.

Table 2. Weekly sessions of SSIT program.

		P-SSIT	NP-SSIT
	Sets	Repetitions	Repetitions
Week 1	4	6	9
Week 2	4	7	9
Week 3	4	8	9
Week 4	4	9	9
Week 5	4	10	9
Week 6	4	11	9
Week 7	4	12	9
Total number of repetitions		756	756

P-SSIT: programming volume-loads including progressive; NP-SSIT: nonprogressive.

Data analysis

Descriptive statistics were calculated for each variable using mean ± SD. The reliability of measurements was determined using the intraclass correlation coefficient (ICC). The distribution of each variable was assessed with the Shapiro-Wilk test. A 3 × 2 ANOVA was utilized to evaluate the effect of interventions on muscular performance adaptations. Tukey post hoc procedures were conducted when a significant F value was obtained to identify pairwise differences between means. Customized Excel spreadsheets were used to calculate all effect size (ES) statistics. Hedge's g was specifically selected to calculate the ES for all measures, using the pooled standard deviation. The ES statistics were categorized based on their magnitude as follows: less than 0.2 as trivial, 0.2 to 0.59 as small, 0.6 to 1.19 as moderate, 1.2 to 1.99 as large, and 2.0 to 4.0 as very large (Hopkins et al., 2009). Furthermore, the ES is presented together with the 95% confidence interval (CI) for all analyzed measures. The level of significance was determined as $p \leq 0.05$.

Results

Demographics

All performance measurements showed a high level of reliability (ICC) with values ranging from 0.93 to 0.96 and a CV between 3.5% and 7.2%. In this study, each subject demonstrated complete compliance, achieving a flawless 100% rate. Additionally, no injuries were reported in connection with the training and testing interventions used. Prior to the training, no significant differences were observed between the groups. Furthermore, the CON group did not exhibit any significant changes in their variable measures from pre- to post-intervention.

Significant ($p = 0.001$) changes were observed for both the P-SSIT and NP-SSIT groups after seven weeks of training intervention, with ES ranging from small to very large (Table 3 and Table 4). There was a significant group by time interaction ($p < 0.01$) which indicates greater adaptations in physical fitness and physiological parameters for the training groups than the control group. However, in immunoedocrine response to training, no statistically significant differences were observed among groups ($p > 0.05$) (Figure 1). In addition, both the P-SSIT and NP-SSIT groups displayed similar gains in physical fitness attributes and physiological parameters adaptations without statistically significant differences between them as well as the same responses in IgA, testosterone and cortisol levels at post-intervention.

Table 3. Changes in strength and sprint measures from pre- to post-intervention (mean ± SD).

Variables	Pre	Post	Hedge's g (95% CI)	Changes	Significant
		20-m sprint (sec)			
P-SSIT	3.41 ± 0.26	3.24 ± 0.24	-0.65 (-1.55 to 0.25) Moderate	↓	***0.001***
NP-SST	3.45 ± 0.23	3.25 ± 0.19	-0.91 (-1.83 to 0.01) Moderate	↓	***0.007***
CON	3.48 ± 0.18	3.48 ± 0.19		↔	1.000
Post-test comparisons	PSSIT vs. CON		-1.06 (-2.00 to -0.13) Moderate	↓	***0.048***
	NP-SSIT vs. CON		-1.16 (-2.11 to -0.21) Moderate	↓	***0.050***
	P-SSIT vs. NP-SSIT		-0.04 (-0.92 to 0.83) Trivial	↔	1.000
		4x9-m shuttle run sec)			
P-SSIT	9.49 ± 0.50	9.20 ± 0.54	-0.53 (-1.43 to 0.36) Small	↓	***0.002***
NP-SST	9.47 ± 0.51	9.22 ± 0.53	-0.46 (-1.35 to 0.43) Small	↓	***0.001***
CON	9.51 ± 0.50	9.51 ± 0.46		↔	1.000
Post-test comparisons	PSSIT vs. CON		-0.59 (-1.49 to 0.30) Small	↓	***0.001***
	NP-SSIT vs. CON		-0.56 (-1.45 to 0.33) Small	↓	***0.001***
	P-SSIT vs. NP-SSIT		-0.04 (-0.91 to 0.84) Trivial	↔	1.000
		Maximal strength (kg)			
P-SSIT	236.5 ± 66.3	248.5 ± 64.2	0.18 (-0.70 to 1.05) Trivial	↑	***0.001***
NP-SST	233.0 ± 58.8	240.5 ± 54.7	0.13 (-0.75 to 1.00) Trivial	↑	***0.045***
CON	229.0 ± 59.6	230.5 ± 60.3		↔	1.000
Post-test comparisons	PSSIT vs. CON		0.28 (-0.61 to 1.16) Small	↑	***0.007***
	NP-SSIT vs. CON		0.17 (-0.71 to 1.04) Trivial	↑	***0.031***
	P-SSIT vs. NP-SSIT		0.13 (-0.75 to 1.00) Trivial	↔	1.000

P-SSIT: programming volume-loads including progressive; NP-SSIT: nonprogressive; CON: control.

Table 4. Changes in aerobic and anaerobic power from pre- to post-intervention (mean ± SD).

Variables	Pre	Post	Hedge's g (95% CI)	Changes	Significant
		VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)			
P-SSIT	48.86 ± 0.99	51.25 ± 1.07	2.22 (1.11 to 3.33) Very large	↑	***0.001***
NP-SST	48.70 ± 1.23	51.63 ± 0.93	2.57 (1.39 to 3.76) Very large	↑	***0.007***
CON	48.62 ± 1.42	48.52 ± 1.17		↔	1.000
Post-test comparisons	PSSIT vs. CON		2.33 (1.20 to 3.47) Very large	↑	***0.048***
	NP-SSIT vs. CON		2.82 (1.58 to 4.06) Very large	↑	***0.050***
	P-SSIT vs. NP-SSIT		-0.36 (-1.25 to 0.52) Small	↔	1.000
		Peak power output (w)			
P-SSIT	806.9 ± 38.8	879.6 ± 39.1	1.79 (0.75 to 2.82) Large	↑	***0.001***
NP-SST	807.9 ± 59.7	883.6 ± 57.0	1.72 (0.69 to 2.74) Large	↑	***0.001***
CON	805.2 ± 48.3	808.4 ± 50.7		↔	1.000
Post-test comparisons	PSSIT vs. CON		1.51 (0.51 to 2.50) Large	↑	***0.001***
	NP-SSIT vs. CON		1.34 (0.37 to 2.30) Large	↑	***0.001***
	P-SSIT vs. NP-SSIT		-0.14 (-1.02 to 0.74) Trivial	↔	1.000
		Mean power output (w)			
P-SSIT	471.4 ± 24.7	510.5 ± 29.9	1.41 (0.43 to 2.39) Large	↑	***0.001***
NP-SST	472.5 ± 20.4	511.7 ± 19.6	1.88 (0.82 to 2.93) Large	↑	***0.001***
CON	470.6 ± 43.2	471.1 ± 44.7		↔	1.000
Post-test comparisons	PSSIT vs. CON		0.99 (0.06 to 1.92) Moderate	↑	***0.007***
	NP-SSIT vs. CON		1.13 (0.18 to 2.07) Moderate	↑	***0.031***
	P-SSIT vs. NP-SSIT		-0.05 (-0.92 to 0.83) Trivial	↔	1.000

P-SSIT: programming volume-loads including progressive; NP-SSIT: nonprogressive; CON: control.

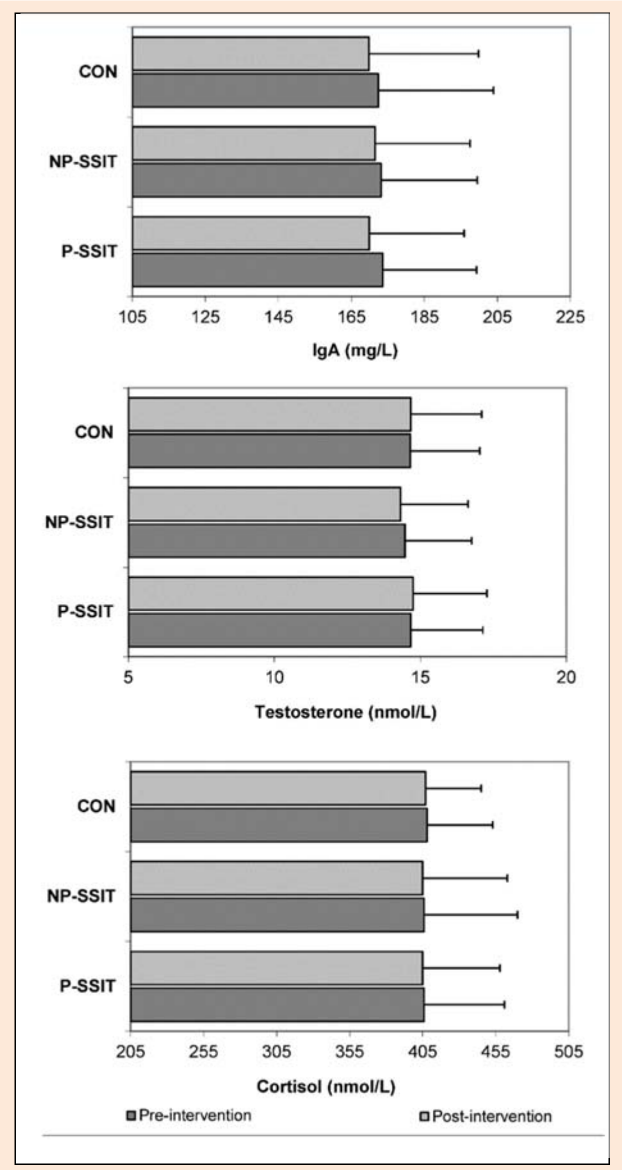

Figure 1. Changes in immunoglobulin-A, testosterone, and cortisol levels from pre- to post-intervention (mean ± SD).

Discussion

Currently, there is a lack of research examining the effects of progressed and nonprogressed volume-based overload SSIT (i.e., gradually increasing the number of interval bout series versus constant the number of interval bout series per week) on physical fitness, physiological parameters, and immunoendocrine responses in freestyle wrestlers during the preparation phase. Therefore, this study aimed to investigate the impact of short-term, progressed and nonprogressed volume-based overload SSIT on various aspects of physical fitness (i.e., 20-m sprint, 4 × 9-m shuttle run, maximal strength) and physiological parameters (i.e., cardiorespiratory fitness, and anaerobic power output), as well as immunoendocrine (i.e., immunoglobulin-A, testosterone, and cortisol) responses in young male wrestlers. The findings revealed that both loading approaches including progressively increases in number of interval bout series (i.e., 1 bout increase weekly) or constant number of interval bout series induced similar meaningful effects in both physical and physiological components of performance following the 7-week intervention. In immunoedocrine response to training, no statistically significant differences among groups were observed. In addition, both the P-SSIT and NP-SSIT groups displayed similar gains in physical fitness attributes and physiological parameters adaptations without statistically significant differences between them as well as the same responses in IgA, testosterone and cortisol levels at post-intervention.

Significant enhancements in the 20-m sprint, 4×9-m shuttle run, and maximal strength were apparent in both the P-SSIT and NP-SSIT groups. This clearly illustrates the beneficial influence of SSIT in improving sprinting speed, change of direction ability, and muscular strength performance after the 7-week intervention. Furthermore, both the P-SSIT and NP-SSIT groups exhibited significant differences when compared to the CON group, indicating that wrestling training alone is insufficient to elicit physical fitness adaptations during the pre-season.

Improving physical fitness attributes (i.e., 20-m sprint, 4 × 9-m shuttle run, and maximal strength) after different forms of SIT have been reported in previous studies (Lee et al., 2020; Clemente et al., 2021; Song et al., 2023). These findings confirm the positive transfer of SIT to meaningful gains in these areas. The underlying mechanisms for these improvements may include enhancements in muscle-tendon system properties, improved muscle coordination, increased firing rate of alpha motor neurons, and overall neuromuscular adaptations resulting from the short-duration training (Dolci et al., 2020). During sprinting speed and change of direction tasks, the leg extensor muscles undergo rapid transitions between eccentric and concentric muscle actions, with minimal ground contact time (Miller et al., 2006). The eccentric to concentric muscle action and reduced ground contact time seen in SSIT may have significant impacts on the 20-m sprint and 4×9-m shuttle run (Dolci et al., 2020). Additionally, the strength gains induced by SSIT could be another factor contributing to improvements in sprinting and change of direction speed. In a study by Seitz et al. (2014), it was shown that increases in lower-body muscular strength can have a positive effect on sprint performance. Therefore, it can be inferred that SSIT, by promoting strength gains, can enhance the performance of wrestlers in sprinting and the 4 × 9-m shuttle run.

An interesting finding from the present study was that both the progressed and nonprogressed volume-based overloads induced similar enhancements in physical fitness attributes after a 7-week training intervention using SSIT. It is important to note that previous studies did not directly compare the effects of progressed and nonprogressed volume-based overloads in SSIT. However, Palma-Muñoz et al. (2021) showed that progressive overload plyometric training is a suitable approach for eliciting greater adaptive responses in physical fitness attributes among basketball players. Therefore, the choice between progressive or nonprogressive volume-based overload in SSIT may differ based on the underlying mechanisms.

During SSIT with all-out conditions, the athletes aim to achieve their maximal efforts in each trial (Arazi et al., 2017). Initiating the P-SSIT intervention with lower repetitions (i.e., 24 trials) compared to NP-SSIT (i.e., 36) at week 1 could induce wrestlers to perform their training program in less time. It is possible that the athlete did not reach their maximum mechanical tensions in the muscle fibers following the lower number of repetitions than NP-SSIT until week 4, resulting in the maximum muscle capacity not being fully utilized (Lacio et al., 2021). Therefore, incorporating the higher number of repetitions during the initial sessions induced by NP-SSIT could produce additional mechanical stress on the muscles, resulting in adaptations in neuromuscular properties.

Gradually increasing the number of repetitions can elevate the stress levels on the muscles, as highlighted in previous literature as the primary mechanism of progressive overload (Asadi et al., 2017; Palma-Muñoz et al., 2021). In the context of SSIT, the athlete's focus is on enhancing running performance throughout the training period and their emphasis is crucial as increasing running speed and distance covered within a set can impose an extra challenge on the athlete (Laursen and Buchheit, 2019). Thus, the rise in muscle mechanical tension due to maintaining the same training load at the start of the training period may coincide with improvements in speed and running performance, suggesting a potential reason for increased overload without the necessity for a gradual rise in the number of trials weekly (Laursen, and Buchheit, 2019). Nevertheless, further research is needed in this area, as this study represents the initial exploration of SSIT from this perspective. Significant improvements in physiological parameters such as VO_{2max}, peak and mean power output were evident in both the P-SSIT and NP-SSIT groups. This serves as a clear demonstration of the positive impact of SSIT on enhancing cardiorespiratory fitness and anaerobic power performance following the 7-week intervention in wrestlers. Additionally, both the P-SSIT and NP-SSIT groups displayed significant differences when compared to the CON group, highlighting that wrestling training alone is inadequate in stimulating physiological changes and does not generate enough physiological stress to bring about such adaptations during the pre-season.

Previously, studies have shown that different forms of SIT can lead to improvements in physiological parameters, specifically VO_{2max}, peak, and mean power output, in wrestlers (Farzad et al., 2011; Liu and Li, 2023). These findings provide further evidence of the positive impact of SIT on these areas. The improvements observed in cardiorespiratory fitness may be attributed to enhancements in two key aspects of aerobic fitness: the central component, which involves the improved delivery of oxygen, and the peripheral component, which signifies the enhanced utilization of oxygen by the active muscles during aerobic activities influenced by SIT; however, these changes were not directly measured and we can only guess and speculate regarding previous studies that assessed these aspects of aerobic fitness adaptations (Sheykhlouvand et al., 2016; Fereshtian et al., 2017; Rasouli Mojez et al., 2021; Sayevand et al., 2022). Additionally, the 7-week SSIT program in wrestlers may lead to improvements in anaerobic power performance through the promotion of neuromuscular adaptations, such as the recruitment of high-threshold motor units, as well as enhancements in metabolic pathways, including increased total creatine content in active muscles and improved buffering capacity of muscles (Sheykhlouvand et al., 2022).

Incremental training loads have been suggested to induce physiological adaptations (Asadi et al., 2017; Andrzejewski et al., 2022). However, this study found that progressed or non-progressed volume-based overload design for SSIT over a 7-week period did not have significant effects than others. It is crucial for physiological changes to occur that there is appropriate metabolic stress, leading to cellular and molecular alterations such as mitochondrial biogenesis (Mesquita et al., 2021). Initiation of the training phase with low repetitions and gradually increasing the number of trials in SSIT did not create the necessary metabolic conditions for significant adaptations. Interestingly, a flat loading pattern (i.e., NP-SSIT) may induce greater metabolic stress in the initial training trials for at least the first 4 weeks. Nevertheless, increasing the number of trials in week 5 for the P-SSIT group allowed athletes to experience similar training loads and achieve similar adaptations in these variables.

Another aspect of SSIT involves encouraging athletes to give their maximal effort (i.e., all-out) in every trial to enhance their running speed and increase the distance covered (Boullosa et al., 2022). This approach adds an extra challenge to the athletes. The consistent elevation of metabolic stress by maintaining training loads during the initial 4 weeks of training may lead to greater adaptations. However, the differences in loads decreased from weeks 5 to 7, resulting in similar physiological adaptations in cardiorespiratory fitness and anaerobic power performance among wrestlers (Farzad et al., 2011). This study is the first to focus on SSIT from this perspective, indicating the need for further research to understand how and when such adaptive responses occur through the use of progressed and non-progressed volume-based overload SSIT.

In the context of immunoendocrine responses to SSIT, it is noteworthy that both training groups demonstrated no changes in testosterone and cortisol levels, as well as IgA following the training intervention. Furthermore, there were no significant differences observed among the groups, indicating that the design of training loads, rest distribution, and scheduling of training for wrestlers during the preparation phase not only had meaningful effects on physical fitness and physiological parameters but also resulted in lower alterations in immunoendocrine responses following the 7-week SSIT intervention.

Based on the findings of the current study, it is evident that both the P-SSIT and NP-SSIT exhibited similar improvements in physical performance, physiological parameters, and immunoendocrine responses following the 7-week training period. This suggests that the total number of interval bout series is more crucial than the method of loading, whether it be progressive or constant. Specifically, starting SSIT with fewer repetitions (e.g., 24 trials in week 1) and gradually increasing the number of trials (e.g., 1 repetition per week) up to higher repetitions (e.g., 48 trials in week 7) did not lead to greater adaptations in neuromuscular and physiological aspects. Conversely, maintaining a consistent number of repetitions during each SSIT session (e.g., 4 sets of 9 repetitions) resulted in similar adaptive responses. Two approaches can be identified regarding these findings. The first approach suggests that a progressive increase in the number of interval bout series during the SSIT period may result in a gradual rise in stress on the musculotendinous unit, leading to neuromuscular and psychological adaptations for the P-SSIT group (Asadi et al., 2017). On the other hand, the second approach indicates that even though the NP-SSIT group trained with constant loads (i.e., 36 trials throughout the training period), improvements in running performance and sprint duration could still lead to overload for wrestlers. One limitation of this study was the lack of data on the distance covered by athletes during SSIT. It is possible that wrestlers in the NP-SSIT groups increased their running distance during 5 seconds all-out intervals leading to induce overloads resulting in adaptions for physical and physiological parameters. However, this remains speculative, and future studies in the field of SSIT should consider calculating the sprint distance covered by athletes using GPS technology.

This study possesses several methodological limitations that necessitate further discussion. Firstly, the study's sample size was relatively small, consisting of only 10 wrestlers. This limited number of participants may have impacted the study's statistical power. However, we conducted a priori power analysis, which indicated that this sample size was sufficient to yield statistically significant results. Secondly, the findings of this study are specific to male wrestlers. Additional research is required to determine whether these findings can be generalized to athletes of different age categories. Lastly, it would have been valuable to incorporate other variables, such as RPE, to measure fatigue, as well as utilize GPS data to assess the distance covered by athletes during SSIT. Future studies should consider including these variables to validate our results. Considering these limitations collectively, we acknowledge that our findings are preliminary, emphasizing the necessity for future research to either challenge or support our outcomes.

Conclusion

The integration of short-duration SSIT into technical-tactical wrestling drills over a period of seven weeks resulted in significant improvements in the physical and physiological performance of athletes during the pre-season phases of the annual training cycle. Significant enhancements in the 20-m sprint, 4 × 9-m shuttle run, maximal strength, VO_{2max}, peak and mean power output were observed following the 7-week intervention. Interestingly, there were no significant changes in the immunoendocrine responses to SSIT. It is important to note that neither the progressed nor nonprogressed approaches of SSIT demonstrated superior effects on adaptations compared to one another. Therefore, it is recommended that strength and conditioning coaches in the field of wrestling incorporate both the P-SSIT and NP-SSIT into their annual training plan, particularly during the pre-session phase, to maximize the physical fitness and physiological parameters of their wrestlers while minimizing alterations in immunoendocrine responses.

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The authors declare no conflicts of interest. The datasets generated and analyzed during the current study are not publicly available, but are available from the corresponding author who was an organizer of the study. The experiments comply with the current laws of the country where they were performed.

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Key points

- The 7-week intervention of SSIT proves to be an effective training method for freestyle wrestlers, as it significantly improves their physical fitness attributes and physiological parameters.
- There was no clear evidence to suggest that either the progressed or non-progressed methods of SSIT had a superior impact on adaptations when compared to each other.
- Maximizing the physical fitness and physiological parameters of wrestlers, while minimizing any alterations in immunoendocrine responses, can be effectively achieved through the utilization of both the P-SSIT and NP-SSIT techniques.

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