Monitoring physiological training load of elite athlete swimmer on specific preparation phase

Monitorización de la carga fisiológica de entrenamiento de un nadador deportista de élite en una fase de preparación específica

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Abstract

Introduction: The trainer's role in designing a plan for altering the training load in the training program, which attempts to push the limits of adaptability while avoiding overtraining, injury, and detraining, helps to ensure the program's success.
Objective: This study examined how monitoring training load during the early specific preparation phase affects the physical condition and body composition of elite swimmers.
Methodology: The research method used was a cohort research design, which is an observational research that focuses on a group of individuals with specific characteristics who are followed over time to evaluate the training load during a special preparation phase in 17d elite swimmers athletes. Training load is assessed using sRPE, body composition is measured using InBody 970, physical condition is measured using VO2max, power, and flexibility, and wearable aircraft (heart rate, distance, and calories). The ANOVA one-way test is the data analysis method.
Results: The results showed that aerobic capacity, arm muscle strength, leg muscles, lower back and hamstring flexibility, shoulder flexibility increased significantly (all $p<0.05$).
Conclusions: This study found that monitoring training load effectively improved physical condition in elite swimmers.

Keywords

Training load; elite athlete; physical condition; swimmer; periodization.

Resumen

Introducción: El papel del entrenador en el diseño de un plan para alterar la carga de entrenamiento en el programa de entrenamiento, que intenta superar los límites de la adaptabilidad evitando al mismo tiempo el sobreentrenamiento, las lesiones y el desentrenamiento, ayuda a garantizar el éxito del programa.
Objetivo: Este estudio examinó cómo el seguimiento de la carga de entrenamiento durante la fase temprana de preparación específica afecta la condición física y la composición corporal de nadadores de élite.
Metodología: El método de investigación utilizado fue un diseño de investigación de cohortes, el cual es una investigación observacional que se enfoca en un grupo de individuos con características específicas a quienes se les da seguimiento en el tiempo para evaluar la carga de entrenamiento durante una fase de preparación especial en atletas nadadores de élite 17d. La carga de entrenamiento se evalúa mediante sRPE, la composición corporal se mide mediante InBody 970, la condición física se mide mediante VO2max, potencia y flexibilidad, y aeronaves portátiles (frecuencia cardíaca, distancia y calorías). La prueba unidireccional ANOVA es el método de análisis de datos.
Resultados: Los resultados mostraron que la capacidad aeróbica, la fuerza de los músculos del brazo, los músculos de las piernas, la flexibilidad de la zona lumbar y de los isquiotibiales y la flexibilidad del hombro aumentaron significativamente (todos $p<0{,}05$).
Conclusiones: Este estudio encontró que monitorear la carga de entrenamiento mejoró efectivamente la condición física en nadadores de élite.

Palabras clave

Carga de entrenamiento; deportista de élite; condición física; nadador; periodización.

Introduction

Periodization of sports is very important to maximize the performance of athletes. Coaches systematically design training programs by focusing on each athlete's training load (TL) and recovery methods, which helps to push the boundaries of training adaptation while minimizing negative effects such as overtraining, injury, and detraining (Helwig et al., 2023). Tracking training load serves as a guide for coaches to create effective training strategies for athletes (Kale et al., 2020). The effectiveness of these training programs correlates with how well the trainer monitors the training load. Therefore, it is crucial to monitor this load, especially in competitive sports settings. Effective monitoring is enhanced by professional coaches, support from sports science, and technological advancements (Pawlik & Mroczek, 2022).

Monitoring training load is a complex process that involves combining various training variables, which are categorized into internal and external loads (Nobari, Kharatzadeh, et al., 2021). External load monitoring relates to metrics such as distance, speed, training volume, power output, and duration, while internal load is assessed through heart rate, biological and psychological stress, and Perceived Activity Level (sRPE) sessions (Veiga et al., 2025). Previous studies have highlighted the importance of monitoring training load, especially in high-performance sports, as overtraining without adequate recovery can lead to overtraining, while inadequate training without progressive overload can lead to detraining (Capdevila et al., 2024). As a result, it is crucial to adjust the training load appropriately to optimize the athlete's performance. Traditionally, training load has been monitored through variables such as strength, speed, repetition, acceleration, and GPS data, which are part of external training load monitoring (Younesi et al., 2021).

Previous studies emphasize monitoring internal training load through metrics such as heart rate, lactic acid, oxygen consumption, and RPE . In addition, monitoring can be facilitated by modern technology such as heart rate monitors. A simpler method for monitoring training load has been proposed, with RPE measurements favored for their validity, reliability, and accessibility. Previous studies have also examined the burden of internal training using lactic acid and heart rate monitoring devices. The study uses internal training load parameters such as sRPE, which combines objective training load metrics with subjective load assessments, providing an index of training load in arbitrary units.

Monitoring training load acts as a daily management tool that leverages feedback from athletes and coaches. This daily surveillance aims to improve physical performance while reducing the risk of injury and other negative effects of training. One approach involves adjusting the training load in a structured training program to align with what is planned. Trainers should be careful in implementing sRPE measurements, as this subjective method assesses the internal burden of structured training and can optimize the training process. (Chen et al., 2024) Therefore, this study seeks to investigate the difference in perceived training load between swimmers who win medals and those who do not, there is a striking research gap in the sports literature regarding the understanding of how the supervision of physiological training load during the initial special preparation phase in the microcycle affects the final fitness level of elite swimmers (Santos-García et al., 2022). Most previous studies have placed more emphasis on evaluating athletes' physical condition at the end of the intensive training phase or in the run-up to competition, while very few have examined the impact of training load monitoring in the early stages of preparation a crucial period for building basic endurance and the necessary muscle strength in the next phase (Versic et al., 2022).

Although training load monitoring techniques have evolved, many studies still focus on the use of standard physiological parameters such as heart rate, RPE, and sRPE without directly linking them to athletes' physical outcomes in the long term (Lago-Fuentes et al., 2020). Existing research has generally not investigated the direct effects of detailed monitoring at the beginning of the microcycle on physiological adaptation, which could affect the optimal final physical condition for elite swimmers (Heishman et al., 2020). In this context, elite swimmers are faced with the great challenge of managing and monitoring training loads to avoid injury or overtraining, which can negatively impact their performance (Espasa-Labrador et al., 2023). This gap points to the need for research that links more thorough physiological monitoring during the initial preparation phase to understand and predict the outcome of the final physical condition achieved in the long term.

The study offers innovation by highlighting the relationship between detailed monitoring of physiological training load in the microcycle during the initial special preparation phase and its impact on the final fitness level of elite swimmers. The focus of this study is not only on short-term training load monitoring, but also how physiological variables collected during specific preparation phases can predict end results related to aerobic endurance, power muscle, and body composition in elite swimmers. Using real-time physiological data through cutting-edge technologies such as wearable devices (e.g., heart rate monitors, GPS, biomechanical sensors), the study delves into how individuals' responses to varying exercise intensities and changes in exercise duration can affect their physiological adaptations. In addition, self-reporting tools such as RPE or session-RPE will be combined with objective physiological data to provide a more comprehensive picture of recovery rates, training balance, and potential overtraining in elite athletes (Wahl et al., 2021).

The study aimed to analyze and track the physiological training load during the micro-cycle of the initial special preparation phase for elite swimmers, assessing its direct impact on the physical condition of athletes. It seeks to provide insight into how training loads that vary from low to high intensity during these early phases affect physiological adaptation. This research is globally significant because it helps in devising data-driven and sustainable training strategies in sports, especially swimming, where international competition is fierce. Achieving peak performance is essential for success on the global stage. By improving understanding of how monitoring the physiological training load during certain phases of preparation affects athletes' physical condition, this study can inform training programs around the world, assisting elite athletes in optimizing their preparation for international competitions such as the Olympics or World Championships.

In addition, the findings of this study could facilitate the creation of more personalized and effective training protocols, allowing trainers and medical personnel around the world to design safer training programs while reducing the risk of injuries that could hinder athletes' success. By improving athletes' physical condition and lowering the likelihood of overtraining, this research can contribute to the long-term sustainability of athletes' careers, which is crucial in elite international sports. Overall, it supports global initiatives to raise training standards in swimming by offering scientific insights that coaches, researchers, and sports professionals can leverage to build more effective evidence-based practices.

Method

Study design

This study used a quantitative descriptive approach with a pre-experimental design to assess and track physiological training load during the initial specific preparatory phase of the microcycle for elite swimmers. The study collect real-time physiological data through wearable devices and other measurement tools, and will examine how these factors affect athletes' overall physical condition. The following are the methods and procedures that will be applied in this research.

Participants

The subjects of the study were elite male swimmers who were undergoing an early special preparatory phase on their microcycles, as many as 17 athletes. Athletes recruited had international or national competitive experience. While the initial inclusion criteria specified an age range of 19–22 years, the final sample consisted of athletes with a mean age of 20.24 ± 0.97 years (Table 2). Participants are selected based on criteria such as training experience and healthy and fit physical status.

Data Collection

Sensor-based wearable technology was being used to track athletes' training sessions, particularly for swimmers (Morais et al., 2022), with devices like the Swimovate PoolMate 2 specifically designed for aquatic environments. This device can monitor various metrics such as heart rate, distance, speed, calories burned, and swimming efficiency. The Session Rating of Perceived Exertion (sRPE) is a subjective measure typically based on the Borg CR-10 scale, where athletes rate their perceived effort during or after workouts on a scale from 0 to 10, reflecting their fatigue or intensity levels. Along with the Borg scale, sRPE also requires the duration of the exercise in minutes, with the sRPE load calculated using the formula sRPE × Training Duration (minutes). Coaches and athletes can easily access the Borg scale in print or via an app for tracking purposes.

Data collection was carried out by assessing aerobic capacity (VO2max) using a multistage fitness test (Campbell et al., 2023) which was carried out by athletes running back and forth between two 20 meter long lines with periodic increases in speed. The explosive strength of leg muscles was gauged through a vertical jump test (Gillen et al., 2020), while upper body explosive power is evaluated with a Medicine Ball Throw (Parrino et al., 2023). Flexibility, which refers to the range of motion in muscles and joints, was tested using a Sit-and-Reach Test for lower back and hamstring flexibility, a Shoulder Flexibility Test with a ruler or measuring tape, and a Back Scratch Test to assess shoulder flexibility by reaching behind the back (Simangunsong et al., 2023; Simoneau, 1998). Body composition analysis includes evaluating percentage of body weight, body mass index, body fat percentage and free fat mass through InBody 970 Bioelectrical Impedance Analysis (BIA) (Branco et al., 2023). Physical conditions (VO2max, leg muscle explosive power, arm muscle explosive power, flexibility) are assessed every month for three months.

Training program

Table 1. Three-month specific preparatory phase training program

Week / Exercise Focus	Types of Exercises	Volume	Intensity	Frequency
1–4 Improved Basic Conditions	a) Aerobics: Interval running, long-distance swimming	60–75 minutes	50–70% VO_2max	4–5 sessions/week
	b) Basic strength exercises: Squats, push-ups, pull-ups, planks	3 sets x 10–15 reps	Light-medium load	3–4 sessions/week
	c) Flexibility: Yoga, dynamic stretching	45-60 minutes	Light	Every day
	d) Core Stability: Plank, side plank	30–60 seconds x 3 sets	Keep	3–4 sessions/week
5–8 Increased Muscle Capacity	a) Aerobics: Mixed style swimming, fartlek running	60–90 minutes	60–80% VO_2max	4–5 sessions/week
	b) Strength training: Deadlift, bench press, shoulder press	3–5 sets x 8–12 reps	Medium-heavy load	3–4 sessions/week
	c)Plyometric: Box jump, squat jump, medicine ball throw	3 sets x 10 reps	Keep	2–3 sessions/week
	d) Flexibility exercises: Static stretching (hamstrings, shoulders, back)	15–20 minutes	Light	Every day
9–12 Specific Physical Specializations	a) Aerobics: Short interval training (HIIT), sprint swimming	45–60 minutes	70–90% VO_2max	3–4 sessions/week
	b) Maximum strength: Squat, bench press, power clean	3–5 sets x 4–6 reps	Heavy loads	3–4 sessions/week
	c) Plyometric: Depth jump, bounding, clap push-up	3–5 sets x 8–10 reps	Tall	2–3 sessions/week
	d) Core Strength: Hanging leg raise, Russian twist	3 sets x 15–20 reps	Keep	3–4 sessions/week
	e) Flexibility and mobility: Foam rolling, PNF stretching	45–60 minutes	Light	Every day

Description: weeks indicate the duration of the training program (1–12 weeks). Training Focus: The main target of each phase (basic condition, muscle capacity, specific). Type of Exercis**e**: Specific activities performed in the program. Volume: The duration or number of targeted reps. Intensity: Difficulty level based on VO_2max, weight, or heart rate zone. Frequency: The number of sessions per week for each type of exercise.

Data analysis

Data analysis was applied using descriptive statistics to describe the mean and standard deviation values of VO_2max, leg muscle explosive power, arm muscle explosive power, lower back and hamstring flexibility, shoulder flexibility, RPE, and sRPE during the microcycle. Normality and homogeneity tests were applied using the Shapiro–Wilk test and Levene test, while the comparative test was applied using the one-way ANOVA test and continued with the Tukey HSD post-hoc test with a significance level of 5%.

Results

The results of the analysis of the characteristics of the research subjects including maximum heart rate, age, height, weight, body mass index, body fat percentage and free fat mass are presented in Table 2. Monitoring of training load was described as in Table 3. The assessment of the level of physical condition of elite swimming athletes are presented in Table 4.

Table 2. Baseline assessment of research subject characteristics

Parameters	N	HIIT (Mean ± SD)
Maximum heart rate (bpm)	17	200.72 ± 4.70
Age (years)	17	20.24 ± 0.97
Weight (kg)	17	76.54 ± 1.48
Height (m)	17	1.79 ± 0.02
Body mass index (kg/m^2)	17	23.97 ± 0.23
Body Fat Percentage (kg)	17	12.00 ± 7.20
Free Fat Mass (%)	17	66.25 ± 3.10

Table 3. Descriptive training load monitoring

Moon	Sunday	Duration/session (minutes)	Sum Voice	RPE installment	Average sRPE (AU)
Month 1	1	120	6	7.10 ± 0.70	852.01 ± 0.27
	2	120	6	8.09 ± 0.20	970.80 ± 0.32
	3	120	6	6.30 ± 0.10	756.03 ± 0.71
	4	120	6	8.02 ± 0.13	962.40 ± 0.38
Month 2	1	120	6	8.08 ± 0.23	969.60 ± 0.92
	2	120	6	8.52 ± 0.31	1022.40 ± 0.28
	3	120	6	6.07 ± 0.24	728.40 ± 0.72
	4	120	6	8.71 ± 0.21	1045.20 ± 0.79
Month 3	1	120	6	8.77 ± 0.81	1052.40 ± 0.39
	2	120	6	9.05 ± 0.18	1086.04 ± 1.20
	3	120	6	7.53 ± 0.29	903.60 ± 0.67
	4	120	6	9.31 ± 0.31	1117.20 ± 0.24

*Description: sRPE (AU) was calculated by multiplying the duration of training by the RPE value for each training session, providing an accurate picture of the physiological training load an athlete receives.

Table 4. Increasing the physical condition level of elite swimming athletes

Parameters	Month 1	Month 2	Month 3	% Increase	P-value
VO_2max (mL/kg/min)	55.10 ± 0.27	57.79 ± 0.19[a]	60.49 ± 0.19[ab]	9.6%	0.001
Leg Muscle Explosive Power (Watts)	2100.06 ± 11.73	2248.77 ± 8.53[a]	2398.76 ± 8.52[ab]	14.3%	0.001
Arm Muscle Explosive Power (Watts)	449.82 ± 2.69	489.83 ± 2.70[a]	529.82 ± 2.69[ab]	17.8%	0.001
Lower Back and Hamstring Flexibility (cm)	32.39 ± 0.41	35.02 ± 0.38[a]	37.80 ± 0.37[ab]	16.6%	0.001
Shoulder Flexibility (cm)	15.21 ± 0.14	17.44 ± 0.19[a]	19.75 ± 0.20[ab]	30.3%	0.001

*Description: [a]Signifikan at month 1 ($p < 0.001$). [b]Signifikan at month 2 ($p < 0.001$). p-value was obtained by one-way ANOVA test and continued by the Tukey HSD post-hoc test.

Discussion

Increased professionalism among athletes in competitive sports is related to an increase in the intensity and volume of training accordingly (Teixeira et al., 2024). Therefore, the success of athletes is greatly influenced by the planning of a detailed training program. The program should be implemented effectively with the help of coaches who devise strategies to adjust training load, so that athletes can push their limits of adaptation while reducing the risk of overtraining, injury, and decreased performance (Arede et al., 2022). Previous research has shown that high training loads without adequate recovery can have negative effects, while ignoring the principle of progressive overload can lead to inadequate adaptation (detraining) (Teixeira et al., 2022). An athlete's achievement is influenced not only by the internal perception of training load (sRPE), but also by the athlete's experience and the total time spent training, which is called flying hours or experience (Costa et al., 2022).

In addition, technical skills, efficiency, psychological state, and recovery strategies of athletes play a significant role in physiological responses (Conte & Kamarauskas, 2022). Observations showed that para-swimmers who did not win medals had a higher average sRPE than medal-winning athletes, which could be linked to better experience and physical fitness in the winners (Temm et al., 2022). As such, trainers need to pay attention not only to the measurement of internal training load (sRPE) but also to various other factors. The research underscores the importance of monitoring technical (biomechanical) skills in athletes, particularly in para-swimming, which involves individuals with unique physical conditions (Nobari, Alves, et al., 2021). Therefore, the internal training cost assessment (sRPE) must also include biomechanical considerations. In addition, previous studies have shown that combining internal load (sRPE) with specific external loads in a training program can improve training outcomes over time compared to just by. relying on internal loads (Tiggemann et al., 2021). As a result, coaches are encouraged to take into account factors beyond internal load monitoring when developing training strategies (Miguel et al., 2021).

Internal measures, such as the use of Session Rating of Perceived Exertion (sRPE), are very useful for monitoring exercise stress in an optimal and individualized way in swimmers (Radzimiński et al., 2020). Previous research has shown that to improve swimming performance, adjustments are needed in physical, physiological, and biomechanical aspects (Matos et al., 2020). Therefore, the effectiveness of training programs in supporting athletes' success depends not only on monitoring the internal training load, but also on assessing the demands of external training (Coppalle et al., 2021). The relationship between training load and performance in sports has been researched for many years. One of the key factors in optimizing performance is the training recipe provided by the coach, physical trainer, or the athlete himself (Clemente et al., 2020).

This process includes different types of exercises to suit the physical quality required, with adjustments to the training load (Ouergui et al., 2020). Training loads are usually differentiated into external loads, which reflect the output of athletes without considering their internal characteristics, and internal loads, which reflect the psychological and physiological pressures felt in response to external demands (Oliveira & Brito, 2023). In summary, while it's important to monitor internal training load (sRPE), it's not the only factor that affects an athlete's success. Training load monitoring, especially internal load (sRPE), is a valuable tool for assessing ongoing training efforts, aiding recovery strategies, and implementing measures to prevent overtraining and reduce the risk of detraining (Rico-González et al., 2021).

The current research on monitoring physiological exercise load during microcycle in the initial special preparation phase for elite swimmers is in line with previous studies that emphasize the importance of physiological exercise load monitoring for athlete performance improvement (Oliveira et al., 2021). Previous research has indicated that the Session Rating of Perceived Exertion (sRPE) method is effective for assessing the internal load felt by athletes during a particular exercise (Claudino et al., 2021). Additionally, several studies have also explored the relationship between exercise load and improved physical fitness indicators, such as VO_2max, muscle explosive power, core strength, and flexibility, all of which contribute to swimmers' performance in competition (Feu et al., 2023).

However, the study offers a more focused contribution by paying attention to the initial specific preparation phase, where the training load can be adjusted gradually to maximize physical adaptation before the competition (Piñar et al., 2022). Unlike previous studies that explored the competition phase or tapering, this study evaluated the effectiveness of using sRPE as a monitoring tool during the microcycle period at the initial special preparation stage (Teixeira et al., 2021). As such, this study not only confirms previous findings, but also enriches the understanding of how optimal training load distribution in the short term can support improved body composition, endurance, and muscle strength in the context of elite swimming (Mandroukas et al., 2023).

The results of this study show that monitoring physiological training load using sRPE during microcycle in the initial special preparation phase can provide a clear picture of the physical adaptation of elite swimmers (Wang & Shan, 2023). Based on the results of measuring physical condition parameters such as VO_2max, muscle explosive power, and flexibility, there was a significant increase from month to month (Paulino et al., 2024). The interpretation of these findings suggests that the systematic and structured use of the sRPE method during the initial specific preparation phase can assist the trainer in regulating the appropriate training intensity and volume to avoid overtraining and support continuous performance improvement (Helwig et al., 2023).

In addition, body composition data showed a decrease in body fat percentage and an increase in fat-free mass, which confirms that the exercise program implemented during the microcycle has succeeded in creating the desired physiological adaptation (Kale et al., 2020). These findings are in line with the purpose of the study, which is to evaluate the effectiveness of physiological exercise load monitoring in improving the physical condition of elite swimmers in the initial special preparation phase (Pawlik & Mroczek, 2022). This improvement in physical indicators confirms that exercise strategies based on sRPE monitoring not only provide benefits in training load management but also in improving energy efficiency, muscle endurance, and overall swimming performance (Younesi et al., 2021). Furthermore, the results of this study support the importance of a data-driven approach in athlete training management, where measurable physiological load monitoring can help athletes reach optimal fitness levels progressively without increasing the risk of injury or excessive fatigue (Chen et al., 2024). Therefore, this finding has significant implications for sports practitioners, especially in the preparation of more effective and measurable training programs for elite swimmers in the preparation phase of competitions (Heishman et al., 2020).

The title of the study regarding the monitoring of training load in elite athletes in the initial special preparation phase of physical condition and body composition has a very important role, both for the global sports community and for the development of knowledge in the field of health and fitness. In a global context, the results of this study can provide better guidance on how to effectively monitor training load in athletes in various sports, especially in the critical early preparation phase. With a deeper understanding of the relationship between training load, physical condition, and body composition, coaches and medical staff can optimize training programs accordingly, minimize the risk of injury, and improve athletes' performance. This research can also make an important contribution to the development of more effective methodologies in monitoring athletes' physical and fitness fitness, which can be widely applied at the international level.

However, there are limitations in this kind of research that need to be noted. One of them is the diversity of individual factors that affect the results of training, such as genetic differences, training experience, and physiological responses of each individual. In addition, access to advanced monitoring technology and the costs required for this study may be limited, limiting the scale and accuracy of the data collected. What's more, the results of this study may be more relevant for elite athletes and less applicable to amateur athletes or those in the early stages of training. These limitations demand further research to expand their understanding and application in a variety of athletic contexts and the wider population.

Conclusions

Monitoring training load in elite athletes during the initial special preparation period of physical condition demonstrates that thorough monitoring of training load was critical to maximizing athlete performance and maintaining a balance of physical condition. In the early special preparation phase, good training load management can help enhance physical condition, such as increased VO_2max, leg muscle explosive power, arm muscle explosive power, lower back and hamstring flexibility, shoulder flexibility, which considerably benefits athletes' performance during competitions. Furthermore, the constant monitoring of training load can help prevent injuries caused by overtraining by ensuring that athletes do not overtrain without adequate recovery time.

These findings also highlight the importance of using appropriate technology for monitoring, such as wearable devices or other instruments that can provide accurate data regarding exercise intensity and volume. However, this research also has limitations in that the research results can be influenced by various factors, including individual variability and differences in research methods. To validate and expand these findings, future research with larger sample sizes and in more diverse settings is needed.

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