UNIVERSITÀ DEGLI STUDI DI PALERMO

Ph.D. Program in Health Promotion and Cognitive Sciences
Dipartimento di Scienze Psicologiche, Pedagogiche, dell'Esercizio Fisico e della Formazione

Rapid Weight Loss in Combat Sports: Multidimensional Impacts on Performance and Health

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Dedicated to my Grandfather Carlo

Always with me

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Abstract

Background: Rapid weight loss (RWL) represents one of the most widespread yet physiologically and psychologically demanding practices in weight-category combat sports. Athletes in disciplines such as judo, wrestling, taekwondo, and mixed martial arts frequently engage in acute weight-cutting strategies involving dehydration, caloric restriction, and intensified training in order to qualify for competition. While these methods are considered part of the competitive culture, mounting evidence suggests that they may compromise cardiovascular function, metabolic stability, neuromuscular performance, and psychological well-being. Within this scientific context, combat sports offer a unique opportunity to investigate how extreme and rapid physiological alterations interact across multiple systems.

Objectives: The overarching objective of this PhD thesis was to develop an integrated understanding of the acute and chronic consequences of RWL, examining its effects on cardiovascular physiology, metabolic responses, muscle damage, postural control, performance indicators, and psychological states. Beyond the contribution of individual articles, the thesis aimed to unify findings from cross-sectional measurements, experimental interventions, biochemical analyses, and narrative or systematic reviews, offering a multidimensional perspective on how weight cutting affects athletes both in the short and long term.

Methods: The research program combined experimental studies on elite and sub-elite combat athletes, longitudinal monitoring, field-based testing, laboratory assessments, biochemical and hormonal profiling, neuromuscular evaluations, stabilometric analyses, and the use of innovative technologies such as EMG, Moxy sensors, and advanced kinematic systems. The work was enriched by international mobility experiences and interdisciplinary collaborations involving nutrition, metabolic health, psychological assessment, and performance sciences.

Results: Across the three years, the main findings reveal that RWL induces consistent alterations in cardiovascular parameters, including increased heart rate, transient reductions in stroke volume, and fluctuations in cardiac biomarkers, suggesting acute myocardial stress during weight cutting. Metabolically, athletes showed dysregulated glucose and lipid profiles, increased oxidative stress, and hormonal shifts resembling early markers of metabolic syndrome, effects detected not only in active athletes but also in former elite combat sport practitioners. Neuromuscular evaluations documented increased muscle

damage (CK, LDH), reductions in explosive power, and impairments in postural control, particularly in tasks requiring fine motor adjustments under fatigue. Psychologically, RWL was associated with increased anxiety, irritability, and perceived fatigue, all of which may negatively influence tactical decisions and performance execution.

Implications: Taken together, these results highlight that RWL is not an isolated physiological stressor but a multisystem perturbation that affects cardiovascular, metabolic, muscular, neuromuscular, and psychological domains simultaneously. The integrative evidence presented in this thesis underscores the need for revised weight-management protocols, education for athletes and coaches, and regulatory reforms to mitigate health risks.

Future Perspectives: Future perspectives include developing sport-specific guidelines for safe weight cutting, exploring individualized monitoring strategies, and implementing longitudinal follow-up programs to assess long-term health outcomes. Ultimately, this work contributes to reconciling performance optimization with athlete safety, promoting a model of competitive excellence that does not compromise long-term well-being.

Overview of Findings

Across the three years of doctoral research, the body of evidence collected through cross-sectional studies, experimental interventions, biochemical analyses, and narrative reviews provides a coherent and multidimensional picture of how rapid weight loss (RWL) and long-term combat sport practice influence cardiovascular physiology, metabolic health, neuromuscular integrity, and overall well-being. The results of the included studies reveal that RWL is not merely an acute competitive strategy but a physiological and metabolic perturbation with both immediate and chronic consequences.

From a metabolic perspective, the study on former elite combat sport athletes demonstrated that individuals exposed to repeated RWL throughout their careers exhibit significantly higher systolic and diastolic blood pressure, altered triglyceride levels, impaired glucose tolerance, and a markedly higher prevalence of metabolic syndrome compared to athletes from non weight category sports. This provides compelling evidence that the health impact of RWL extends beyond the competitive years, predisposing athletes to long-term metabolic dysregulation.

Cardiovascular findings from the echocardiographic study further highlight sport specific cardiac remodeling in elite judokas, demonstrating substantial sex differences in cardiac geometry. Male athletes displayed significantly greater left ventricular mass and mass index than females, confirming the presence of concentric hypertrophy associated with high intensity combat sport training. These structural adaptations integrate with the evidence from the narrative review on cardiovascular responses in judo, which shows that judokas typically present with enhanced cardiac function, improved heart rate variability, optimal blood pressure regulation, and physiological hypertrophy linked to training demands. However, the review also emphasizes the need for careful monitoring due to the high cardiovascular strain induced by judo training and weight reduction practices.

Experimental studies investigating the acute effects of RWL combined with high intensity sport specific training offer further insight into the mechanisms underlying these physiological adaptations. The crossover study in wrestlers demonstrated that a 5 percent RWL protocol amplifies muscle damage responses, with significantly higher increases in markers such as creatine kinase, lactate dehydrogenase, myoglobin, and liver enzymes compared to high intensity training alone. This pattern was mirrored in elite judokas, where

the combination of RWL and high intensity training produced significant elevations in cardiac biomarkers including high sensitivity troponin, CK MB, AST, and LDH, alongside marked increases in heart rate. Notably, these alterations occurred without detectable impairments in left ventricular systolic function, suggesting an acute but reversible cardiac stress response.

Taken together, these findings converge toward several overarching conclusions. First, RWL exerts a consistent cumulative burden on multiple physiological systems, acutely increasing cardiovascular and muscular stress while contributing to chronic metabolic risk later in life. Second, the interaction of high intensity combat sport training with weight cutting practices magnifies biochemical and neuromuscular strain, calling for more regulated and safer approaches to weight management. Third, while combat sports such as judo elicit positive cardiovascular adaptations including enhanced cardiac function, autonomic regulation, and vascular health, the beneficial effects of long-term training must be interpreted in light of the potential risks associated with repeated weight cycling.

Overall, the synthesis of evidence produced across the PhD program supports a unified thesis: RWL represents a multisystem stressor with both immediate performance related implications and long-term health consequences. The results emphasize the importance of developing sport specific guidelines, promoting athlete education, and implementing monitoring strategies that reconcile performance optimization with athlete safety throughout and beyond their competitive careers.

Scientific Context and State of the Art

1. General Framework of the Research

In weight-category combat sports, the contest does not begin when two athletes face each other on the tatami, in the ring, or inside the cage. A crucial part of the battle starts much earlier: it is the struggle with the scale. To be eligible to compete, athletes must meet strict weight limits, often achieved through rapid weight loss (RWL) strategies. These practices, deeply rooted in the culture and competitive logic of combat sports, stem not only from tradition but also from strategic reasons that reward athletes who can temporarily reduce their body mass to compete in lighter categories.

At the root of this behavioural pattern lies a performance-driven anthropometric rationale. Athletes in lower weight classes often present more favourable body proportions, such as longer limbs, a more linear skeletal structure, and advantageous leverage profiles, which can translate into tactical and biomechanical superiority. In grappling-based sports such as judo, Brazilian jiu-jitsu, and wrestling, longer arms improve grip efficiency and leverage during throws or submissions. In striking sports, reach advantage and linearity of movement offer tangible benefits in distance control and tactical dominance.

A second motive is biomechanical. Athletes who compete in lighter divisions frequently display greater movement economy, enhanced speed-to-power ratios, and improved agility, all of which are critical elements for effective attacks, rapid transitions, and defensive reactivity. The physiology of lighter athletes often supports more sustained high-frequency actions with lower metabolic cost.

A third, less visible yet equally relevant factor is cognitive advantage. Competing in a lighter category is often perceived as conferring greater psychological readiness. Athletes report heightened concentration, increased competitive arousal, and a sense of toughness derived from successfully enduring the challenge of weight-cutting. This mental fortification, even if transient, may contribute to the persistence of RWL as a cultural and motivational ritual.

However, not all forms of weight reduction are equal. It is essential to distinguish rapid weight loss, typically occurring within 5 to 7 days through extreme dehydration, severe caloric restriction, and excessive training, from progressive and correctly programmed weight

management strategies based on gradual fat loss, monitored dietary planning, and regular hydration control. While the latter can be safe and even performance-enhancing, RWL imposes severe physiological strain, altering fluid balance, neuromuscular coordination, endocrine function, and cognitive processes. These adaptations do not always vanish once weight is regained during rehydration.

Combat sports therefore represent a natural laboratory for studying the multidimensional consequences of RWL. These disciplines are multifaceted: judo demands explosive power and precise control of the center of gravity; taekwondo requires agility and anaerobic capacity; wrestling and Brazilian jiu-jitsu force athletes to sustain grip strength, technical endurance, and focus under extreme strain; and mixed martial arts combine all these demands in one arena. What unites them is the necessity to excel simultaneously in multiple domains: including strength, endurance, speed, coordination, and postural control. This delicate balance, essential for peak performance, is precisely what RWL threatens to disrupt, exposing the fragility of the human body when subjected to extreme adaptation strategies.

Reducing the prevalence of RWL requires more than simply educating athletes. It demands structural and regulatory solutions, such as adjusting weigh-in timing, implementing hydration testing, introducing multi-stage monitoring of weight trajectories, and involving multidisciplinary teams composed of coaches, sport scientists, nutritionists, and psychologists in long-term weight management. Practical interventions ranging from year-round nutrition periodization to psychological support for stress management and self-regulation represent essential tools to shift the culture of weight-cutting towards safer and more evidence-based practices.

2. Relevance of Combat Sports in High-Level Sport

On the global stage, combat sports occupy a position of prestige. From Olympic tatami mats, where centuries-old traditions such as judo and taekwondo are celebrated, to the dazzling octagons of professional mixed martial arts, millions of spectators' witness displays of refined technique, physical power, and mental resilience. Yet behind the lights, medals, and spectacle lies a less visible reality: athletes constantly reshaping their bodies to fit into rigid weight categories.

The pressure to "make weight" becomes an inseparable part of an athlete's life, dictating training rhythms and conditioning the planning of entire seasons. These rapid fluctuations in body composition, often compressed into just a few days, are virtually unique in sport. Few other athletic contexts demand such rapid and repeated physiological adaptation. This peculiarity makes combat sports a privileged model for studying the combined effects of physical and psychological stress across multiple systems.

Analyzing what happens to these athletes provides not only a clearer understanding of human adaptation mechanisms but also insights with broader implications for health and performance. How does the cardiovascular system respond to abrupt changes in fluids and electrolytes? What happens to metabolism during the constant cycle of restriction and refeeding? And to what extent can the mind preserve clarity, motivation, and decision-making capacity under the strain of dehydration and energy depletion? Combat sports offer invaluable answers to such questions, opening perspectives that extend beyond elite athletics and touch on public health concerns.

3. Focus on Performance, Physiology, and Negative Impacts of RWL

Scientific research over the past decades has consistently shown that rapid weight loss is far from a neutral process. On the contrary, it carries consequences that affect both body and mind, reaching far beyond the mere reduction of body mass.

From a cardiovascular standpoint, RWL often leads to marked variations in heart rate and blood pressure, compromising the efficiency of cardiac response during exertion. Athletes may find themselves with a circulatory system less capable of adaptation precisely when they need maximum responsiveness. Psychologically, the effects are equally striking: heightened anxiety, irritability, premature fatigue, and diminished mental sharpness. Decision-making clarity so crucial in sports where hesitation can mean defeat becomes impaired.

Metabolic processes also undergo profound disruptions. Glucose and lipid profiles fluctuate unpredictably, while hormonal regulation suffers under the strain, creating conditions reminiscent of pre-metabolic syndromes often observed in clinical settings. Muscles, too, signal distress: biomarkers such as creatine kinase (CK) and lactate dehydrogenase (LDH) rise, reflecting tissue damage. At the same time, explosive power the kind needed for sudden attacks or rapid defenses declines, and fatigue perception increases, undermining performance.

Yet most studies have examined these aspects in isolation. What remains missing is an integrated perspective, one that connects cardiovascular changes to metabolic shifts, muscle damage to psychological fluctuations, and shows how these systems interact under the pressure of RWL. It is precisely within this unexplored space that the present research positions itself: to fill the gaps, to provide a unified understanding of phenomena often studied separately, and to offer a a more complete and more realistic picture and more realistic picture of how rapid weight loss impacts athletes in combat sports.

1. Research Motivations

The motivations behind this research can be traced along two intertwined paths one rooted in the pursuit of scientific knowledge, the other in the practical realities of sport and athlete well-being.

On the scientific side, the practice of RWL has long been part of the culture of combat sports such as judo, wrestling, taekwondo, and mixed martial arts. Yet, despite its ubiquity, the scientific understanding of RWL remains fragmented. Most studies stop at the surface, focusing narrowly on body composition changes or short-term performance outcomes. What is missing is a deeper, more integrated perspective capable of connecting the many dimensions involved: the fluctuations of the cardiovascular system, the strain placed upon metabolism, the micro-injuries endured by muscles, the shifts in neuromuscular control, and the psychological toll expressed through anxiety, mood disturbances, and fatigue. Without this broader lens, the complex web of interactions triggered by RWL remains only partially understood. This research seeks to bridge that gap, offering not just isolated findings but a holistic narrative of what truly happens to body and mind when athletes force their weight to drop in a matter of days.

On the practical side, the stakes are equally high. For athletes, coaches, and sports medicine professionals, weight cutting is more than an abstract concept it is a lived experience, often repeated several times a year. Many athletes resort to extreme strategies in the hope of gaining a competitive edge, but the consequences can be severe: compromised performance, heightened risk of injury, and threats to both physical and mental health. Understanding the real impact of RWL can lead to the development of safer, evidence-based guidelines. Such knowledge may help protect muscle tissue from excessive damage, preserve cardiovascular balance, prevent metabolic dysregulation, and reduce the psychological stress that so often accompanies weight cuts. In doing so, this research aims not only to safeguard the well-being of athletes but also to promote performance that is both sustainable and ethically responsible a vision of sport where success is not achieved at the expense of long-term health.

2. Research Questions

At the heart of this work lies a fundamental inquiry: *what truly happens to the body and the mind of an athlete who undergoes rapid weight loss?* This question is not merely technical; it is existential for the countless fighters who confront the ritual of weight cutting before every major competition.

The central objective of this research is to go beyond fragmented observations and to offer a comprehensive picture of the phenomenon. Rather than isolating single variables, the study seeks to weave them together into a coherent narrative, capturing the full extent of how sudden reductions in body mass reverberate across physiological and psychological domains. It will explore how the heart adapts or struggles to adapt when the body is deprived of fluids and energy, whether its rhythm falters under the strain, or whether it maintains stability despite the stress. It will delve into the metabolic shifts that accompany weight reduction, tracing the fluctuations in glucose and lipids, the imbalances in hormones, and the subtle signs of oxidative stress that may foreshadow long-term risks akin to metabolic syndrome.

Equally, the investigation will turn to the muscles, the very engines of combat performance, to uncover whether they remain intact or whether they show clear signs of damage. In this perspective, biomarkers of injury, reductions in explosive strength, and inefficiencies in neuromuscular control become windows into the hidden cost of cutting weight. Yet the story does not end with the body alone. The research also acknowledges the invisible terrain of the mind, where anxiety rises, mood falters, concentration wavers, and fatigue settles in. For fighters, mental resilience is as decisive as physical strength, and the erosion of psychological stability may compromise not only performance but also safety inside the arena.

Ultimately, this study does not intend to treat these dimensions as separate chapters but as interwoven strands of a single fabric. By integrating cardiovascular, metabolic, muscular, and psychological perspectives, it seeks to illuminate the intricate dialogue between body and mind during moments of extreme stress. In doing so, the research aspires to reveal more than isolated findings: it aims to expose the hidden costs of a widespread practice, equipping both the scientific and sporting communities with the knowledge necessary to reconcile performance with health, ambition with responsibility, and the pursuit of victory with the preservation of long-term well-being.

3. Scope of the Thesis

Selected Sport Disciplines

This research focuses specifically on weight-category combat sports, including judo, wrestling, taekwondo, and mixed martial arts. These disciplines have been selected because they not only require athletes to compete within strict weight classes but also share similar physiological demands, such as high-intensity intermittent efforts, explosive movements, and rapid shifts between anaerobic and aerobic metabolism. By examining athletes across multiple combat sports, the study aims to identify common patterns and responses to RWL, providing insights that are broadly applicable rather than limited to a single discipline. Additionally, the weight-related regulations inherent to these sports create conditions in which athletes frequently engage in acute weight-cutting strategies, making them ideal populations for investigating both the physiological and psychological effects of RWL. This cross-disciplinary approach enhances the generalizability of the findings and allows for the development of evidence-based recommendations that can support safer weight management and optimize performance across a wide range of combat sports.

The mentioned sport disciplines have chosen its primary emphasis on weight-category combat sports, specifically disciplines such as judo, wrestling, taekwondo, and mixed martial arts. These sports have been deliberately chosen because they not only require athletes to conform to highly regulated weight classes but also share a set of demanding physiological characteristics. Each of these disciplines obliges competitors to perform under conditions that emphasize repeated bouts of high-intensity intermittent activity, the execution of explosive and technically precise movements, and the ability to transition quickly between anaerobic and aerobic energy systems. The combination of these factors creates a particularly challenging environment for athletes, where physical preparation and weight management are intricately linked to competitive success.

By examining athletes drawn from several different combat sports rather than focusing on a single discipline, this study seeks to uncover patterns that may be consistent across the broader category of weight-regulated combat activities. Such a comparative approach makes it possible to recognize physiological and psychological responses to RWL that are not sport-specific but rather generalizable to a wide population of athletes. Identifying these shared

mechanisms provides valuable insights into how acute weight-cutting practices influence not only immediate performance outcomes but also long-term health and recovery.

Moreover, the strict weight-related regulations imposed by governing bodies in these sports effectively create an environment in which athletes frequently resort to acute weight manipulation strategies in order to qualify for competition. This reality makes combat sport athletes an ideal population for the systematic investigation of both the benefits and risks associated with RWL. The present research therefore addresses not only the physiological consequences of weight-cutting such as dehydration, electrolyte imbalance, and impaired energy availability but also the psychological dimensions, including stress, anxiety, and altered mood states that may accompany these practices.

By adopting this cross-disciplinary and multi-sport perspective, the study significantly enhances the ecological validity and practical relevance of its findings. It allows for the formulation of evidence-based recommendations that extend beyond the boundaries of a single sport, offering a broader framework to support safer and more sustainable weight management practices. Ultimately, the overarching goal is to optimize both health and competitive performance, equipping athletes, coaches, and practitioners with strategies that can reduce the risks of harmful weight-cutting behaviors while still respecting the regulatory and performance demands inherent in modern combat sports.

Part I – First Year of the PhD Program

1.1 Description of the First Year

During the first year of the PhD program, the doctoral candidate had the opportunity to establish numerous collaborations with faculty members and research groups at the University of Palermo, also involving other national and international centers. These interactions represented a crucial element of the training process, providing a stimulating and multidisciplinary context in which the candidate was able to develop advanced scientific, methodological, and analytical skills.

Although the main objective remained the study of combat sports, and specifically the consequences of RWL in athletes, these collaborations enabled the doctoral candidate to participate in cross-disciplinary projects on different yet complementary topics. Such projects included research on nutrition, mindfulness, prevention of eating disorders, epigenetics, postural and neuromuscular assessments, childhood obesity, performance anxiety in team sports, performance and injury prevention in aquatic sports, and kinematic analysis in artistic disciplines such as Dancesport.

Participation in these studies allowed the doctoral candidate to:

1. Apply diverse and complex research methodologies, designing experimental and observational studies, conducting biochemical analyses, physiological and neuromuscular assessments, and employing advanced tools for data collection and analysis.
2. Experiment with innovative technological instruments, including Electromyography (EMG) sensors for muscle activity evaluation, stabilometric platforms for postural control, motion analysis devices, and metabolic monitoring systems, thereby integrating objective and quantitative data into various research projects.
3. Improve skills in international scientific writing and publication by contributing to peer-reviewed articles and systematic reviews, with opportunities to collaborate with senior co-authors, interact with reviewers, and engage with experienced researchers in the field.

4. Integrate multidisciplinary knowledge, developing a comprehensive view of sports research in which physiological, metabolic, psychological, and nutritional aspects intersect, enriching the candidate's scientific approach and enhancing the ability to interpret complex data in real-world applications.
5. Consolidate practical skills both in the laboratory and in the field, from organizing testing sessions to managing technological instruments, as well as processing and interpreting results. This experience enabled the doctoral candidate to acquire an operational proficiency that extends beyond research in combat sports, representing a methodological toolkit applicable across different areas of sport science.

It is important to emphasize that, although these projects were not directly related to the central focus of the thesis, they contributed substantially to the doctoral candidate's scientific training. Engagement in complementary topics made it possible to understand the logic of multidisciplinary research, develop critical skills in reading and interpreting scientific literature, and acquire advanced analytical tools essential for conducting high-quality studies in the field of combat sports.

Furthermore, these collaborations fostered the development of scientific networks, offering opportunities to interact with experienced researchers from various disciplines, participate in seminars, workshops, and lab meetings, and understand the dynamics of scientific cooperation at both national and international levels. This experience provided a solid foundation for addressing the main studies on the multidimensional effects of RWL with rigor and awareness, integrating physiological, metabolic, psychological, and nutritional approaches.

In summary, the first year of the PhD program saw the doctoral candidate engaged in a highly formative and multidisciplinary path, combining participation in research on combat sports with involvement in cross-disciplinary scientific projects. These experiences enabled the development of advanced methodological skills, critical data analysis abilities, mastery of innovative technological tools, and an integrated vision of sports research, representing a fundamental pillar for the continuation of the doctoral thesis.

1.2 Articles Published During the First Year

Review

Fighting the Consequences of the COVID-19 Pandemic: Mindfulness, Exercise, and Nutrition Practices to Reduce Eating Disorders and Promote Sustainability

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Abstract

Over the past two years, the world's population has been tested by the COVID-19 health emergency. This has changed population habits worldwide by encouraging a sedentary lifestyle and overnutrition. Isolation and reduction of social life, for most of the population, was mandatory but it quickly became a new lifestyle. Nowadays, we are encountering the consequences with an increase in nutrition-associated disorders and conditions that cause illnesses in the general population. These disorders include diet excesses that lead to obesity and diet deficiencies and malnutrition, which could rapidly lead to death. These eating disorders are very complex to manage because they often become mental disorders, negatively impacting physical or mental health. This work discusses the benefits associated with the mindfulness–exercise–nutrition (MEN) technique. From a nutritional point of view, it focuses on the effect of a plant-based diet, such as the Mediterranean diet (MD), which has a high tryptophan content that can increase serotonin (the "feel good" hormone) levels. The MEN technique takes a multidisciplinary approach and aims to integrate healthy behaviors into clinical practice using healthy eating, active living, and mindfulness. This method includes controlled physical movements, stretching techniques such as yoga, and aerobic exercise to achieve optimal mental and physical health. This literature review, carried out using the PubMed, ScienceDirect, Scopus, and Google Scholar databases, investigates the

latest research on this topic. The study may be useful for healthcare professionals and clinicians and may help patients become more self-aware, encouraging them to lead a healthier lifestyle, make thoughtful choices, and improve their mental health. The final aim of this study is to promote physiological homeostasis and well-being.

Original article

Evaluation of Posturographic and Neuromuscular Parameters during Upright Stance and Hand Standing: A Comparative Study

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Abstract

Introduction: Bipedal upright postural stance is not the only form of human standing; indeed, an inverted position, a handstand, is required during gymnastics or other sports. This study aimed to understand the differences between the two standing strategies from a postural and neuromuscular perspective. **Methods:** Thirteen skilled gymnasts underwent a stabilometric assessment and an EMG examination in a standard upright bipodalic stance and during a handstand. The EMG examination was performed on the gastrocnemius during upright stance and on the flexor carpi radialis during the handstand. **Results:** Limb weight distribution presented differences between the two vertical stances ($p<0.01$). However, weight distribution between left and right limbs was similar regardless of the task. During the handstand, the weight ratio was prevalently observed on the rear hand for both hands, with a significant difference between the front and rear hand compared to upright stance ($p<0.01$). Normalized EMG amplitude showed significant differences during bipedal standing and hand standing; however, over a 5-second period, the normalized MDF value was similar for both tasks. **Conclusion:** Both standing tasks presented similar postural weight management

patterns when analyzed on the frontal plane but differed on the sagittal plane. Neuromuscular patterns during a 5-second window differ in amplitude but not in the frequency domain.

Review

MiRNAs Expression Modulates Osteogenesis in Response to Exercise and Nutrition

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Abstract

In recent years, many studies have investigated the impact of physical activity and diet on bone health. This review aimed to explore the possible epigenetic mechanisms influencing bone metabolism. Research has highlighted the effects of macro- and micronutrients combined with exercise on gene expression regulation through miRNAs. This review describes how physical activity and nutrition can prevent abnormal epigenetic regulation that could otherwise lead to bone-metabolism-related diseases, the most significant being osteoporosis. Notably, this regulation occurs not only via endogenously produced miRNAs but also through dietary intake. Exogenous miRNAs from animals and plants have been detected in the human transcriptome, suggesting potential cross-kingdom interactions influencing epigenetic regulation of human genes. The key pathways activated by diet and physical activity appear to involve Runt-related transcription factor 2 (RUNX2), whose

expression is modulated by several miRNAs. Among the primary miRNAs involved are exercise-induced miR-21 and miR-21-5p, and diet-induced miR-221-3p and miR-222-3p.

Original article

Biochemical Assessment of Insulin and Vitamin D Levels in Obese Preadolescents after Diet and Physical Activity: A Retrospective Observational Study

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Abstract

Study aim: Childhood obesity is a serious public health problem that has spread over the past 40 years in industrialized countries. This condition can predispose to the onset of several chronic diseases, including hyperlipidemia, which is involved in multiple signaling pathways for bone homeostasis, as well as vitamin D (VitD). There is a communication between adipose tissue and bone, which can regulate each other through feedback mechanisms, including glucose consumption by bone, also regulating insulin levels. This observational study analyzed the effects of training, particularly swimming, combined with a controlled diet on obese adolescents. **Material and methods:** A six-month observational study was conducted involving twenty adolescents aged between 8 and 12 years with diagnosed obesity, according to World Health Organization guidelines. **Results:** Assessments were carried out at the beginning of the intervention (T0) and at the end of treatment (T1). Participants were randomly assigned to either the control group (CG), which followed only the controlled diet, or the experimental group (EG), which combined the controlled diet with planned physical activity. Statistically significant improvements were observed between T0 and T1 in both

groups, particularly for VitD and insulin levels. The improvements were more pronounced in EG (VitD 9.27 vs 25.64; Insulin 29.31 vs 12.66) compared with CG (VitD 8.7 vs 13.7; Insulin 28.45 vs 22.76). **Conclusions:** These results highlight the importance of combined diet and exercise interventions to improve health in adolescents, particularly those with obesity.

Original article

Hormonal and Genetics Influence on Performance Anxiety in Sport Competition

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Abstract

Sports performance anxiety is a behavioral attitude that affects the outcome of athletes and teams. This study investigates the processes that influence competition outcomes, focusing on hormonal and genetic factors. Progesterone plays a key role in reducing anxiety and stress, while high cortisol concentrations are linked to increased anxiety. Salivary alpha-amylase (sAA) has been suggested as a more sensitive marker of acute stress than cortisol. Genetic factors, such as brain-derived neurotrophic factor (BDNF) and striatal dopamine transporter (DAT), also influence anxiety and stress management. Twenty-six female volleyball players (mean ± SD age: 12.07 ± 0.7 years) participated in the study during the follicular and early ovulatory phases of the ovarian cycle. Hormonal and sAA levels were measured before and after a provincial volleyball championship match. Winners showed a significant decrease in salivary cortisol after the match (PRE: 7.7 ng/ml; POST: 4.5 ng/ml), while losers maintained higher post-match levels (PRE: 7.8 ng/ml; POST: 6.6 ng/ml). Winners also had higher sAA secretion than losers (77.21 vs. 62.7) with a post-match increase noted only in winners (p=0.07). SAS-2 psychological test results indicated higher anxiety scores in losers (12.3)

compared to winners (10.5). These findings suggest that salivary cortisol and other hormonal secretions play a key role in performance anxiety, influencing competitive outcomes.

Review

Performance Enhancing Strategies in Sailing Sports: Beyond Training and Nutrition

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Abstract

Purpose: Sailing is a water sport comprising several disciplines distinguished by the type of boat and number of crew. Sailors must constantly adapt to hull movements according to weather conditions. This study aims to provide targeted guidance on training and nutrition for sailing athletes. **Methodological approach:** Effective training requires a synergistic combination of sport-specific exercises and strategies designed to improve overall strength. Various workouts aimed at performance improvement and injury prevention were discussed. **Results:** Findings revealed that, although sailors' training develops strength, endurance, speed, balance, and coordination to cope with postural adaptations, these athletes remain at risk for injuries, primarily affecting the knee and lower back. Sailing involves both aerobic and anaerobic demands, yet explicit guidelines on nutrition, supplementation, and their potential contribution to performance are limited. **Conclusions:** Targeted training programs and personalized nutritional strategies, including timing of macro- and micronutrient intake and specific supplementation, may reduce injury risk and enhance recovery and performance in sailing athletes.

Original article

Kinematic Criteria Determining Swing Movement of World Class Dancesport Athletes

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Abstract

Purpose: The aim of the study was to identify the distinguishing characteristics of the swing movement of the world's top dancesport couples through kinematic variables. **Methods:** The study involved six world-class and six intermediate dance couples. The couples executed three identical series of three natural turns of the figure in a Viennese Waltz, all filmed to music. Six international experts evaluated each trial based on the Absolute Judging System. A triaxial rotational angular velocity measurement (gyroscope) device was placed on the dorsal part of the pelvic girdle and on the posterior part of the thorax of each competitor. **Results:** Analysis of covariance demonstrated that, regardless of sports level, the maximum hip girdle angular rotation velocity in the forward swing movement performed by men was significantly related to the judging score achieved ($F_{1,9} = 11.5$; $p < 0.05$; $\eta^2 = 0.45$). **Conclusions:** The mean squares of the differences of the hip and thoracic spine angular rotation velocity signals were found to be a good criterion for evaluating the swing

movement, which correlates with judges' evaluations. The descriptions of complex rotational movements in this study can be applied in analysis, teaching, and evaluation of dance couples. This is one of the first studies in the literature to detail swing movement in sports dance.

Systematic Review

Effects of Resistance Training on Sleep Quality and Disorders among Individuals Diagnosed with Cancer: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

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Abstract

Background: Sleep disorders are common in cancer patients and may persist years after therapy, leading to various negative consequences. Non-pharmacological strategies such as

exercise interventions are considered to counteract this phenomenon. While aerobic training (AT) has established benefits, evidence on resistance training (RT) remains limited. This systematic review investigates the potential effects of RT on sleep outcomes in cancer survivors. **Methods:** Literature searches were conducted on MEDLINE (PubMed), Web of Science, Scopus, and Cochrane Central Register of Controlled Trials, including only randomized controlled trials (RCTs). Screening was performed using COVIDENCE. Sleep outcomes, assessed via self-reported questionnaires or objective measurements, were extracted from RCTs involving cancer survivors of any age or gender, on or off treatment. Risk of Bias (RoB) was evaluated with the Cochrane RoB 2 tool. Meta-analytic syntheses were conducted on sleep quality and insomnia. **Results:** 21 studies were included. Combined aerobic and resistance exercise programs (COMB) showed promising improvements in sleep quality (-19%) and sleep disturbance (-17.3%). Meta-analysis indicated significant improvements for sleep quality ($d=0.28$, $SE=0.11$, $Z=2.51$, $p<0.01$, 95% CI: 0.07-0.49) and insomnia ($d=0.43$, $SE=0.20$, $Z=2.18$, $p=0.029$, 95% CI: 0.07-0.49). **Conclusion:** RT interventions lasting 60 minutes per session, 2-3 times per week for 12 weeks at 60–80% of one-repetition maximum, can be safely administered to cancer survivors to improve sleep outcomes.

1.3 Progress During the First Year

Although the main objective was the study of combat sports and the effects of RWL on athletes, the doctoral candidate actively participated in cross-disciplinary projects on different yet complementary topics, aimed at strengthening the scientific and methodological foundations necessary to conduct high-level research. Among these, the following can be highlighted:

- **Mindfulness, nutrition, and prevention of eating disorders in the COVID-19 context:** through collaboration with the research group coordinated by Proia and Baldassano, the candidate contributed to a study investigating the influence of mindfulness practices, physical exercise, and nutritional strategies on the prevention of eating disorders and the promotion of sustainable lifestyles. This work emphasized the importance of the mind-body integrated approach to well-being and allowed the candidate to deepen skills in systematic literature review.
- **Postural and neuromuscular assessments:** by participating in a comparative study on upright bipodal posture and handstand in gymnasts, the candidate learned methodologies for collecting and analyzing stabilometric and EMG data, developing abilities in interpreting complex neuromuscular models and advanced techniques of applied posturology in sport.
- **Epigenetics and osteogenesis:** through collaboration on a review addressing epigenetic mechanisms regulated by physical exercise and nutrition, the candidate gained expertise in reading and synthesizing molecular studies and understanding the role of microRNAs in bone health regulation, integrating biological and physiological knowledge with sports activity.
- **Childhood obesity and combined diet-physical activity interventions:** by participating in a retrospective study on obese adolescents, the candidate acquired skills in clinical research methodologies, collection and analysis of anthropometric, biochemical, and metabolic data, consolidating competencies in designing targeted interventions and interpreting outcomes.
- **Performance anxiety and hormonal and genetic factors:** in collaboration with several groups, the candidate contributed to the study of mechanisms influencing performance anxiety in volleyball athletes, integrating psychometric evaluations with hormonal and genetic analyses. This provided insights into the interactions between

stress, physiology, and performance, extending the research perspective beyond combat sports.

- **Performance enhancement strategies in aquatic sports and Dancesport:** the candidate participated in studies on elite sailing athletes and world-class Dancesport couples, contributing to kinematic and kinetic analysis of movements and the integration of biomechanical data with performance and recovery parameters. These experiences strengthened skills in measurement, management, and interpretation of complex data, as well as in designing applied protocols for different sports disciplines.
- **Resistance training and sleep quality in cancer patients:** through collaboration on a systematic review and meta-analysis concerning resistance exercise and sleep in cancer patients, the candidate developed skills in advanced statistical analysis, critical evaluation of randomized clinical trials, and synthesis of results for clinical-sport applications.

These studies, although not directly related to the central thesis topic on combat sports, allowed the doctoral candidate to:

1. Apply diversified research methodologies, including experimental, observational, retrospective studies and systematic reviews;
2. Use advanced technological tools, such as EMG sensors, stabilometric platforms, kinematic analysis systems, and metabolic monitoring devices;
3. Develop critical skills and expertise in scientific writing, contributing to peer-reviewed articles and engaging with senior co-authors and international reviewers;
4. Integrate multidisciplinary knowledge, understanding the interactions between physiology, nutrition, psychology, and biomechanics;
5. Build solid scientific networks, participating in national and international seminars, workshops, and laboratory activities.

In summary, the first year of the PhD program represented a highly multidisciplinary training path, combining participation in specific studies on combat sports with cross-disciplinary projects in nutrition, psychology, epigenetics, biomechanics, and public health. These experiences consolidated the scientific and methodological foundations necessary to rigorously and competently address the main thesis research, equipping the doctoral

candidate with essential tools and knowledge to analyze in an integrated manner the multidimensional effects of RWL in combat sport athletes.

1.4 Scientific Outputs and Rationale of the First-year Program

The first year of the doctoral journey did not simply unfold as a sequence of isolated studies, but rather as a carefully woven fabric of experiences, each thread contributing to the shaping of a broader and more solid scientific identity. The candidate's participation in a wide range of projects from nutrition and mindfulness in the post-pandemic era to biomechanical analysis of movement in elite athletes, from molecular insights on epigenetics to public health perspectives on obesity offered more than mere academic exercises. They represented, instead, the stages of a deliberate apprenticeship, a "scientific gym" in which different muscles of research were trained: the capacity for critical reading, the rigor of methodological design, the dexterity in handling advanced technologies, and the art of transforming data into knowledge ready to be shared with the international community.

From these experiences emerged tangible scientific outputs, including contributions to systematic reviews, meta-analyses, and original studies, many of which reached the stage of publication in peer-reviewed journals. Yet the true value of these results lies not only in their bibliometric weight, but in the intellectual journey they embody. Each project, whether on performance anxiety in volleyball players or sleep quality in cancer patients undergoing resistance training, allowed the candidate to experiment with different methodological lenses and disciplinary languages. In this sense, the year resembled a laboratory of ideas, where physiology conversed with psychology, biomechanics with nutrition, molecular biology with sport performance.

The rationale of such a path is clear: the study of rapid weight loss in combat sports an inherently multidimensional phenomenon cannot be approached with a narrow or fragmented gaze. It demands instead a mind trained to navigate complexity, to recognize the subtle interplay between body and psyche, and to integrate data that range from hormonal markers to postural oscillations, from psychometric scores to metabolic profiles. The first year was therefore conceived as a phase of "cross-training," not unlike the preparation of an athlete who, before excelling in competition, tempers strength, endurance, coordination, and flexibility through a variety of complementary drills.

Thus, what might seem at first sight as a dispersive itinerary reveals itself as a strategic and coherent design. The doctoral candidate emerges not only with publications and conference presentations, but with a sharpened awareness of the interconnections that define human performance and health. The scientific production of the year demonstrates an ability to contribute meaningfully to diverse fields, while the methodological enrichment ensures that the central thesis on RWL will be tackled with the depth, rigor, and integrative vision it requires.

In summary, the first year of the PhD was not merely a preparatory stage, but a true training ground where skills were refined, networks were built, and perspectives were broadened. It was a time of exploration and synthesis, in which the doctoral candidate learned to move with agility between different domains of knowledge, discovering that the strength of scientific inquiry lies precisely in its capacity to weave together fragments into a coherent story. A story that, in the following years, will focus with increasing clarity on the effects of rapid weight loss in combat sports yet will always carry within it the echoes and lessons of this rich and multidisciplinary beginning.

Part II – Second Year of the PhD Program

2.1 Description of the Second Year

In the second year of the PhD program, the doctoral candidate maintained and expanded the multidisciplinary approach initiated during the first year, continuing to establish collaborations with various faculty members and research groups at the University of Palermo, as well as with international institutions, including the University of Novi Sad, the University of Catania, the University of Split, the Free University of Bozen-Bolzano, and the University of Szczecin. The main objective remained the in-depth study of the effects of RWL in combat sports. However, consistent with the educational framework of the PhD program, parallel studies and projects seemingly external to the central theme were also pursued, aimed at developing advanced cross-disciplinary and methodological skills.

Among the main activities of the second year, the following stand out:

- **Optimization of strength training protocols in young females:** the candidate contributed to a comparative study between velocity-based training (VBT) and percentage-based training (PBT), analyzing effects on absolute strength, explosive power, speed, agility, and markers of muscle damage. This experience provided valuable insights into the analysis of neuromuscular parameters, the management of controlled experimental protocols, and the evaluation of performance improvements in complex settings skills directly transferable to the study of combat sport athletes undergoing RWL.
- **High-intensity interventions in patients with multiple sclerosis:** by participating in a HIIT study aimed at improving neuromotor function, bone, and lipid metabolism in MS patients, the candidate refined competencies in designing high-intensity exercise protocols, managing clinical data, and interpreting biomarkers, thereby strengthening the ability to transfer physical and metabolic assessment methodologies across diverse but scientifically rigorous contexts.
- **Bioacoustic correction program in motor science students:** through a randomized controlled trial, the candidate explored the effects of innovative auditory biofeedback interventions on concentration, attention, and cognitive switching ability. Participation in this project enhanced skills in experimental study design, collection

and analysis of neuropsychological data, and statistical evaluation of complex interventions, competencies that are transferable to understanding the psychological factors affecting combat sport athletes.

- **Continuity and synergy with first-year studies:** alongside these projects, the candidate continued to consolidate the methodological skills acquired during the first year, deepening expertise in literature review, advanced statistical analysis, management of technological tools (EMG, stabilometry, motion sensors, metabolic monitoring), and scientific writing. The objective was to integrate multidisciplinary knowledge encompassing physiology, biomechanics, psychology, and nutrition and apply it more directly to studies on combat sports and the effects of RWL.

In this way, even in the second year, the doctoral candidate pursued a parallel and multidisciplinary strategy, seemingly beyond the primary research focus, but instrumental in strengthening the scientific skills required to rigorously address the main studies. Each project provided methodological tools, theoretical knowledge, and analytical capabilities which, once applied to the context of combat sports, enriched experimental design, data interpretation, and the understanding of physiological and psychological phenomena related to RWL and athletic performance.

This multidisciplinary approach and participation in cross-disciplinary projects enabled the doctoral candidate to develop a solid and integrated scientific foundation, combining biological, physiological, psychological, and biomechanical expertise fundamental for successfully advancing the doctoral work and contributing to international literature on combat sports.

2.2 Articles Published During the Second Year

Original article

Optimizing Strength Training Protocols in Young Females: A Comparative Study of Velocity-Based and Percentage-Based Training Programs

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Abstract

The purpose of this study was to compare the effects of velocity-based strength training (VBT) and percentage-based strength training (PBT) on absolute strength, explosive power, speed, and agility, as well as markers of muscle damage after 6 weeks of exercise programs. Thirty young female participants were divided into three groups of 10: VBT, PBT, and a control group. No statistically significant differences were observed between groups across neuromuscular performance tests. Nonetheless, both VBT and PBT groups improved in 1RM squat (Δ% 27.87 and Δ% 8.98, respectively) and 1RM bench press (Δ% 14.47 and Δ% 8.65, respectively), with greater gains in the VBT group. VBT also resulted in notable improvements in SJ height (Δ% 14.32) and CMJ height (Δ% 7.69), while PBT showed improvement only in SJ height (Δ% 6.72).

Original article

High Intensity Interval Training Improves Bone Remodeling, Lipid Profile, and Physical Function in Multiple Sclerosis Patients

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Abstract

Multiple sclerosis (MS) is a demyelinating and neurodegenerative disease caused by an autoimmune chronic inflammatory response, and its etiology is not fully understood. Physical activity plays an essential role in improving quality of life, particularly in neuropathological conditions. This study investigated the effects of high-intensity interval training (HIIT) on bone and lipid metabolism markers and neuromotor abilities in MS patients. Sixteen MS participants were randomly assigned to a control group (CG, 34.88 ± 4.45 yrs) with no

physical activity or an exercise group (EG, 36.20 ± 7.80 yrs) performing HIIT remotely three times a week for 8 weeks. After 8 weeks, physical function improved in the wall squat test (T0 = 27.18 ± 4.21 s; T1 = 41.68 ± 5.38 s, $p \leq 0.01$) and the Time Up and Go test (T0 = 7.65 ± 0.43 s; T1 = 6.34 ± 0.38 s, $p \leq 0.01$). Lipid profile analysis showed decreased total cholesterol (T0 = 187.22 ± 15.73 mg/dl; T1 = 173.44 ± 13.03 mg/dl, $p \leq 0.05$) and LDL cholesterol (T0 = 108 ± 21.08 mg/dl; T1 = 95.02 ± 17.99 mg/dl, $p < 0.05$). Bone formation markers improved, with osteocalcin increasing (T0 = 20.88 ± 4.22 µg/L; T1 = 23.66 ± 6.24 µg/L, $p < 0.05$) and 25-OH Vitamin D levels rising (T0 = 21.11 ± 7.11 µg/L; T1 = 27.66 ± 7.59 µg/L, $p < 0.05$). HIIT positively affected lower limb strength, gait control, bone formation, and lipid management in MS patients.

Original article

Effects of a 14-day Bioacoustic Correction Program on Neuropsychological Parameters in Sports Science Students: A Randomized Controlled Clinical Trial

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This study aimed to determine the influence of a 14-day bioacoustic correction (BAC) program, which in the future may become a solution for individuals experiencing increased psycho-emotional stress, on the properties of attention and concentration of sports science students. The BAC translates EEG activity into auditory feedback, facilitating cognitive self-regulation. The study involved 20 volunteers among sports science students, 10 males, and 10 females, who were randomly allocated into experimental and control groups. A significant group x time interaction was revealed for variables attention stability ($F = 7.36$, $\eta^2p = 0.29$, $p = 0.01$) and mistakes ($F = 15.49$, $\eta^2p = 0.46$, $p = 0.00$) in the Bourdon test, for the concentration ($F = 36.99$, $\eta^2p = 0.67$, $p = 0.00$), switch ability ($F = 17.86$, $\eta^2p = 0.49$, $p = 0.00$), and mistakes ($F = 29.43$, $\eta^2p = 0.62$, $p = 0.00$) in the Landolt test, in favor of the experimental group. There was no statistically significant group x time interaction in the Toulouse-Pieron or Schulte-table tests. Additionally, following the 14-day BAC program, the experimental group demonstrated improvement in almost all parameters of the tests used. This study provides innovative evidence regarding the efficiency of the BAC program in increasing the concentration and attention parameters of students of sports science and physical education. The improvements observed were statistically significant, supporting the potential recommendation of BAC for wider use.

2.3 International Mobility – University of Novi Sad, Serbia

Between the first and the second year of the PhD (September 2023 – January 2024), the doctoral candidate had the opportunity to carry out a research period abroad at the Faculty of Sport and Physical Education, University of Novi Sad, Serbia, under the supervision of Prof. Patrik Drid, where a previous research experience had already been conducted before the PhD. This international mobility represented a crucial stage in the candidate's scientific training, providing a highly specialized environment in applied physiology for combat sports, high-intensity training methodologies, and sport psychology.

During the stay in Novi Sad, the doctoral candidate worked closely with several professors and local researchers, taking part in ongoing multidisciplinary projects and contributing with expertise acquired in Italy. This context made it possible to explore topics complementary to the main focus of the PhD, including:

- **Effects of RWL in combat sport athletes**, with particular attention to Greco-Roman wrestling and judo. In this field, the candidate collaborated on studies aimed at assessing cardiac recovery, muscle strength, and neuromuscular responses following combined protocols of high-intensity training and rapid body weight reduction. These activities enhanced skills in managing complex experimental protocols, collecting and analyzing physiological data, and applying advanced statistical tools for result interpretation.
- **Study of psychological factors in sport**, with particular focus on motivation, competition anxiety, and perceived well-being during matches. The candidate took part in administering and analyzing psychometric tests, thereby deepening the understanding of how psychological parameters influence athletic performance. This experience helped highlight how psychological responses can modulate performance in high-pressure contexts and how they interact with physiological responses such as heart rate, recovery, and perceived fatigue.
- **Acquisition of advanced technical skills**, including the use of motion sensors, stabilometric platforms, electromyography (EMG), and metabolic monitoring systems. The use of these tools enabled the doctoral candidate to gain familiarity with cutting-edge measurement methodologies, essential for accurately evaluating neuromuscular, postural, and metabolic adaptations in athletes, as well as for translating experimental interventions into objective and reproducible data.

The research stay abroad also fostered the development of an international scientific network, involving collaborations with students, PhD candidates, and researchers of various nationalities and disciplines. These interactions stimulated a critical and multidisciplinary approach to research, teaching the candidate how to integrate knowledge from different domains, ranging from high-intensity training to sport psychology, and from biochemistry to applied biomechanics.

This experience had a direct impact on the second year of the PhD, during which the candidate continued to engage in parallel research projects, such as high-intensity interventions in multiple sclerosis patients, bioacoustic correction protocols in students, and optimization of strength training programs in young females. Although not directly linked to combat sports, these studies consolidated methodological, statistical, and experimental expertise, providing useful tools to enhance the design and data interpretation of the main research on the physiological and psychological effects of RWL.

One of the most relevant projects conducted during this period concerned **metabolic syndrome in former combat sport athletes**, with a specific focus on the long-term effects of RWL practices. The study, titled *"Metabolic Syndrome among Former Elite Combat Sports Athletes: The Role of Rapid Weight Loss"*, was carried out in collaboration with the Faculty of Sport and Physical Education in Novi Sad, as well as researchers from the Free University of Bozen-Bolzano and the University of Split.

The project involved a sample of 150 former athletes, half of whom were from combat sports with a history of RWL, while the other half consisted of athletes from disciplines without weight-cutting practices. Key parameters of metabolic syndrome were assessed, including waist circumference, HDL cholesterol, blood pressure, fasting glucose, triglycerides, and oral glucose tolerance tests (OGTT).

The results revealed that former combat sport athletes with a history of RWL showed significantly higher systolic and diastolic blood pressure, increased fasting glucose levels, and a higher prevalence of metabolic syndrome compared to controls (39.5% vs. 16.2%, $p = 0.002$). These findings underscore the importance of monitoring the long-term health consequences of RWL practices and establish a direct link between applied PhD research and broader implications for athletes' metabolic health.

Conducting this study allowed the doctoral candidate to further develop advanced skills in experimental design, multivariate statistical analysis, management of international collaborations, and critical interpretation of clinical and physiological data. Moreover, the experience strengthened the ability to conduct multicenter studies, integrating approaches from physiology, nutrition, biostatistics, and sports medicine, and promoted a multidisciplinary outlook that enriched the main PhD research on RWL in active athletes.

In summary, the stay in Novi Sad and the related international collaborations not only led to the publication of significant studies such as the one on metabolic syndrome in former combat sport athletes but also served as advanced training, consolidating the candidate's profile as an international researcher. By integrating multidisciplinary knowledge, advanced experimental tools, and innovative methodological approaches, this experience provided essential elements to successfully address the complex physiological, metabolic, and psychological issues associated with combat sports and RWL.

2.4 - Metabolic Syndrome among Former Elite Combat Sports Athletes: The Role of Rapid Weight Loss

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Abstract

Background: In terms of the potential influence of rapid weight loss (RWL) on the metabolic health of former combat sports athletes (CSA), the scientific literature is quite scarce. Therefore, the objective of the presented research was to determine the differences in MetS parameters and the prevalence of MetS between former athletes who performed RWL and athletes who did not.

Methods: The sample of the presented study comprised 150 participants, equally divided into two groups: 75 former athletes who had practiced combat sports and 75 ex-athletes of various other sports who did not practice RWL during their careers. The following parameters related to the MetS were evaluated: waist circumference, high-density lipoprotein cholesterol, systolic blood pressure, diastolic blood pressure (BP), fasting glucose, and triglycerides. The oral glucose tolerance test (OGTT) was used to assess the participant's body response to sugar.

Results: The RWL group had significantly higher both systolic ($p<0.001$) and diastolic blood pressure ($p<0.001$) comparison to the group of athletes who did not practice weight reduction during their careers. Additionally, a tendency toward statistically significant differences between groups was recorded in the variable triglycerides ($p = 0.069$). Regarding OGTT, increased values of fasting blood glucose at the final measurement were revealed only in the RWL group ($p = 0.003$). The prevalence of MetS was substantially higher in CSA than in the control group (39.5% vs. 16.2%, $p = 0.002$).

Conclusions: This study suggests that former elite CSA who used RWL during their sports career are susceptible to negative metabolic alterations at the end of their competitive period.

Keywords*: metabolic pathologies, exercise, insulin resistance, obesity, public health, physical activity*

1. Introduction

Lack of exercise and being overweight and obese are the causes of metabolic syndrome (MetS), which is currently assuming almost epidemic proportions (Schmidt-Trucksäss, 2006). Resistance and strength training have a positive influence on insulin resistance, stimulating the uptake of glucose by muscle cells (Schmidt-Trucksäss, 2006). Physical activity is considered very efficient regarding the effects on the metabolic profile of former athletes (Altowerqi, bin Zainuddin, & Hashim, 2020). Physical exercise is also associated with many health-related benefits, reducing the risk of developing various chronic diseases, such as obesity, cardiovascular disease, and type II diabetes mellitus (Kelley & Goodpaster, 2001; Kohl 3rd, 2001; Poddar et al., 2001). There is evidence to suggest that life-long physical activity may be an important factor for MetS prevention in adulthood, demonstrating the significant incidence of MetS among inactive males and females (Yang et al., 2008). Finally, epidemiological studies suggest that former elite athletes have a lower prevalence of cardiovascular disease, diabetes, and hypertension compared to the general population (Kujala et al., 1994; Sarna et al., 1997), emphasizing the importance of physical activity and a healthy lifestyle (Bäckmand et al., 2010; Reifsteck & Gill, 2011).

Rapid weight loss (RWL) is considered a sports practice that can negatively affect the metabolic balance of athletes. Typically, RWL is defined as a 5% reduction in body weight less than one week before competition (Bialowas et al., 2023). Rapid weight loss is often performed to compete in a lower weight category to gain a competitive advantage over rivals and have a greater opportunity to win the competition (Franchini et al., 2012; Roklicer, Rossi, Bianco, Štajer, et al., 2022; Roklicer, Rossi, Bianco, Stajer, et al., 2022; Rossi et al., 2022; Viveiros et al., 2015). Furthermore, the methodologies used for RWL are varied, from gradual dieting, sauna use, and skipping meals, the most dominant ones to reduce weight before competition, up to more extreme methods of RWL, such as the use of laxatives, diuretics, diet pills and vomiting (Drid, Figlioli, et al., 2021). Therefore, alternative methods of sustainable weight loss should be available for athletes (Drid, Figlioli, et al., 2021). The interactive effect of food restriction and fluid deprivation may cause adverse physiological effects on the body (Lakicevic et al., 2021). This stress caused over several years could also lead to permanent adverse metabolic effects for these former athletes (Degoutte et al., 2006).

In the scientific literature, the term MetS is universally used (Samson & Garber, 2014). Specifically, metabolic syndrome has been defined according to the International Diabetes Federation and the American Heart Association/National Heart, Lung, and Blood Institute (Grundy et al., 2005) as a combination of at least 3 or more of the following factors: abdominal obesity (waist circumference (WC) > 102 cm in men); hyperglycaemia (fasting blood glucose (FBG) ≥ 100 mg/dL or current use of insulin or oral hypoglycaemic drugs); hypertriglyceridemia (triglycerides ≥ 150 mg/dL); low HDL cholesterol (HDL < 40 mg/dL in men); high blood pressure (BP) (systolic/diastolic BP ≥ 130/85 mmHg) or regular use of antihypertensive drugs. To define abdominal obesity, we have

adopted the European Cardiovascular Society cut-off point for the European population (Batista & Soares, 2013; Graham et al., 2007).

The United States and many other countries are facing an epidemic of insulin resistance that represents a risk factor for cardiovascular disease. This is occurring in the context of a marked increase in the number of individuals diagnosed with type 2 diabetes mellitus and a dramatic rise in obesity (Mokdad et al., 2001). These MetS trends are likely to continue to increase over time across the global population (Boyle et al., 2001).

Currently, there is a gap in the literature regarding the potential effects of RWL on the metabolic health of former combat sports athletes (CSA). Therefore, the objective of the presented research was to determine the differences in MetS parameters and MetS prevalence between former CSA who implemented RWL during their career and respondents from other sports who did not implement RWL. The authors hypothesized that MetS factors would be more evident in athletes who practiced RWL methods in their careers and that the greater prevalence of MetS would also be recorded in this group.

2. Methods

2.1. Experimental approach to the problem

This cross-sectional study was performed in July 2023 at the Provincial Institute for Sports Medicine and Faculty of Sports and Physical Education, University of Novi Sad, Serbia. During the study, various measurements were conducted, including anthropometric parameters, fasting blood glucose (FBG), lipid profile, and BP. The oral glucose tolerance test (OGTT) was administered by specialized medical personnel (Bartoli et al., 2011). All examinations were performed in the morning, taking an FBG sample, followed by ingestion of 75g (standardized procedure) of glucose dissolved in 250-300 ml of water, in the shortest time possible. In the following hours, the patient was asked to remain seated, without smoking or eating, possibly relaxed (emotional stress could distort the results). Two hours later, a new measurement of basal glycemia was carried out and a comparison was subsequently made between the 2 measurements. Using FBG and 2-hour glucose afterload, a possible impaired glucose tolerance is defined by a 2-hour glucose afterload of 140 to 199 mg/dL or an FBG between 110 and 125 mg/dL.

2.2. Participants

A total of 150 respondents were involved in the presented investigation. Athletes were divided into two groups: RWL group (n = 75, mean age 51.53 ± 11.38 years, mean height 176.87 ± 6.42 cm, and

mean weight 90.43 ± 16.06 kg), which encompassed CSA who competed in judo, jujitsu, karate, kickboxing, taekwondo, boxing and implemented RWL during their careers, and control group (CG) (n = 75, mean age 49.77 ± 15.02 years, mean height 181.64 ± 7.04, cm and mean weight 91.47 ± 14.59 kg) that represented athletes from various sports, such as swimming, soccer, mountain climbing, handball, athletics, rowing, and water polo and did not practice RWL during their carriers. In addition, to be included in the study, participants needed to meet the following eligibility criteria: To be elite male athletes and finish their sports career at least 10 years ago. Athletes from the RWL group also performed weight reduction procedures at least three times a year during their competitive careers. This study was conducted in accordance with the Declaration of Helsinki (Hellmann et al., 2014) and ethical approval was obtained from the ethics committee of the University of Novi Sad, Serbia (Ref. No. 49-10-02-2023-1). All respondents voluntarily participated in this study by signing a written informed consent which was subsequently provided.

2.3. Measurements

Anthropometric measurements included body height, body weight, BMI, and WC. All measurements were conducted by trained researchers using standardized methods. Body height was measured without shoes with a wall-mounted stadium tape measure and a calibrated scale with an accuracy of 0.1 cm, while body weight was measured with a Seca professional scale (maximum recordable weight: 300 kg; resolution: 100 g; Seca, Hamburg, Germany). We calculated body mass index (kg/m²) based on self-reported height (m) and weight (kg) and considered overweight and obesity if BMI was between 25 kg/m² and 29.9 kg/m² and ≥ 30 kg/m², respectively. Additionally, WC was measured by wrapping a flexible tape measure around the bare abdomen, starting at the top of the hip bone at the level of the navel. It was ensured during the circumference measurement that the tape measure was not too tight and that it was straight. Blood samples were taken fasting state of participants in the morning. For glucose, a double measurement was carried out, including evaluation before starting the OGTT test and 2 hours after the end of the test. Each blood sample was collected in special tubes without anticoagulant to obtain serum. The samples were centrifuged at 1300 x g for 15 minutes. Blood pressure was measured with a sphygmomanometer (Riester Diplomat, Jungingen, Germany) from the participant's right arm using a cuff measuring 14.5 × 54.5 cm after at least 5 minutes of rest in a sitting position. Blood pressure was measured twice and a pause of at least 1 minute was taken between measurements. The average of two values was used in the calculations. The data regarding HDL cholesterol and triglycerides were collected in the laboratory following a blood sample from the arm of the participants who had followed a fasting period of at least 12 hours. Then, the values were recorded in the appropriate forms. The International Physical Activity Questionnaire was administered to assess the physical activity performed by each respondent (Craig et al., 2003). Post-career physical activity was calculated in line with the recommendations for adults from the American

College of Sports Medicine and the American Heart Association (Haskell et al., 2007). Specifically, physical activity was considered lower than recommended (lower physical activity recommendation) if less than 30 minutes per day on 5 days per week of moderate-intensity aerobic activity or less than 20 minutes per day on 3 days per week of vigorous-intensity aerobic activity was performed at the end of the career. Conversely, if at least 30 minutes per day for 5 days per week of moderate-intensity aerobic activity or 20 minutes per day for 3 days per week of vigorous-intensity aerobic activity were performed the participant adhered to the physical activity recommendations (Meet physical activity recommendation). A second questionnaire (Sports Medicine Questionnaire) was administered to assess and categorize alcohol and cigarette use. Regarding alcohol consumption, we adopted the World Health Organisation guidelines (Ezzati et al., 2004); classifying subjects as hazardous drinkers, moderate drinkers, or abstainers. In particular, those who have drunk 5 or more standard alcoholic drinks on a single occasion in the last 30 days are considered hazardous drinkers; if they did not drink 5 standard alcoholic drinks on a single occasion in the last 30 days they were considered moderate drinkers, and abstainers if they never had drunk alcohol. Current smoking status was divided into 3 categories, including current smoker, ex-smoker, or never smoker.

2.4. Statistical analysis

All data were analyzed with SPSS (Statistical Package for Social Sciences ver. 24.0, IBM Statistics, Armonk, NY, USA). The normality of the distribution was checked using the Kolmogorov-Smirnov test. In terms of demographic and MetS parameters, the comparison between RWL and CG was performed using the Mann-Whitney test, while the Wilcoxon test examined differences for pre-post glycemia in both groups. The prevalence of overweight/obesity, the presence of MetS, and the differences in lifestyle variables between the analyzed groups were tested with the Chi-squared test. Further, the biserial rank correlation was utilized as a measure of the effects size, and interpreted as trivial (0–0.1), small (0.10–0.30), moderate (0.30–0.50), and large (≥ 0.50) (Kerby, 2014). Data were reported as mean, standard deviation, and 95% confidence interval for MetS variables. For the Chi-squared test, data were presented as percentages. The significance level was set at $p \leq 0.05$.

Table 1. **Risk factors for identifying Metabolic Syndrome.**

Risk factor	Definition
Waist circumferences	Men > 102 cm (>40 in)
Triglycerides	≥ 150 mg/dL
HDL	Men < 40 mg/dL
Fasting blood glucose	≥ 110 mg/dL
Systolic/Diastolic blood pressure	≥ 130/ ≥ 85 mmHg

Note HDL; high-density lipoprotein cholesterol.

3. Results

Demographic and lifestyle parameters of participants are shown in Table 2. No differences between groups were observed regarding athletes' age and body weight. Contrary, statistically significant differences were recorded in the body height (176.87 ± 6.42 cm vs. 181.64 ± 7.05 cm, p = 0.001) and BMI (28.83 ± 4.43 vs. 27.60 ± 3.86, p = 0.04). The RWL group had substantially higher values of BMI relative to the athletes from the CG. There were no statistically significant differences between the analyzed groups in all lifestyle variables, including tobacco, alcohol, and physical activity.

Table 2. Demographic and lifestyle variables of respondents.

Variables	RWL group	Control group	P values
Age (years)	51.53 ± 11.38	49.77 ± 15.02	0.144
Body height (cm)	176.87 ± 6.42	181.64 ± 7.05	0.001***
Body weight (kg)	90.43 ± 16.07	91.47 ± 14.60	0.58
BMI (kg/m²)	28.83 ± 4.43	27.60 ± 3.86	0.04*
Tobacco (%)			0.375
Never smokers	91.9	90.5	
Former smokers	5.4	2.7	
Current smokers	2.7	6.8	
Alcohol (%)			0.283
Abstainers	55.4	44.6	
Moderate drinkers	2.7	6.8	
Hazardous drinkers	41.9	48.6	
Physical activity (%)			0.569
Meet recommendations	27	23	
Lower than recommended	73	77	

*Note: BMI; body mass index - Statistical significance - ***; p<0.001 - *; p<0.05.*

Analyzing the parameters concerning the MetS, statistically significant differences were found for both systolic and diastolic BP (129.89 ± 12.03 mmHg vs 124.59 ± 12.39 mmHg, p = 0.001) and (81.58 ± 11.52 mmHg vs 75. 97 ± 7.67 mmHg, p = 0.001), respectively (Table 3). In addition, a tendency toward statistically significant differences was noted in a triglycerides variable (p = 0.069). However, there were no differences between the RWL group and the CG in parameters such as WC, HDL cholesterol, and FBG.

Table 3. Metabolic Syndrome parameters.

Variables	RWL group	Control group	Mean differences (95% CI)	ES	P value
Waist circumference (cm)	104.78 ± 9.22	104.11 ± 6.94	0.66 (-1.97, 3.30)	0	0.973
Triglycerides (mg/dL)	31.86 ± 17.28	27.54 ± 15.66	4.32 (-1.00, 9.64)	0.17	0.069
HDL cholesterol (mg/dL)	23.22 ± 5.04	23.22 ± 4.68	0 (-1.57, 1.57)	0.02	0.826
GL120 (mg/dL)	112.86 ± 45.54	98.82 ± 29.7	14.04 (1.63, 26.45)	0.14	0.129
Systolic blood pressure (mmHg)	129. 89 ± 12.03	124.59 ± 12.39	5.3 (1.36, 9.24)	0.40	0.001***
Diastolic blood pressure (mmHg)	81.58 ± 11.52	75.97 ± 7.67	5.61 (2.45, 8.77)	0.29	0.001***

Note: ES; Effect size - CI; Confidence interval - GLI20; Glucose after OGTT test (2° measurement) RWL: rapid weight loss

*value; Statistical significance - ***; p<0.001.*

Table 4 depicts the prevalence of overweight/obesity and MetS in both groups. A significant percentage of participants in each group were overweight or obese and no differences between them have been revealed. Nonetheless, the percentage of MetS was considerably higher in the RWL group than in the athletes who did not lose body weight during their career (39.5 % vs. 16.2 %, p = 0.002).

Table 4. Prevalence of Metabolic Syndrome among athletes.

	RWL group	Control group	P value
Overweight/obesity (%)	85.5	77	0.182
With metabolic syndrome (%)	39.5	16.2	0.002**

*Note: RWL – rapid weight loss - P-value; Statistical significance - **; p<0.01*

Figure 1 demonstrates the effects of the implemented intervention in both groups. Following OGTT, it is obvious that in the RWL group, the level of FBG was substantially higher compared to the baseline assessment (100.26 ± 21.6 mg/dL vs 112.86 ± 45.54 mg/dL, p = 0.003). On the other hand, no differences between final and initial measurements were observed in the CG.

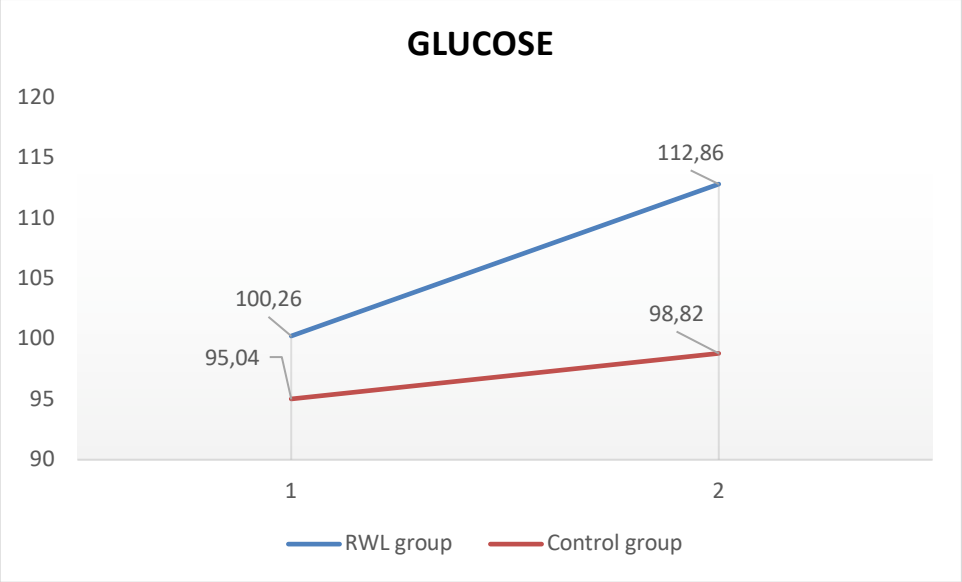

Figure 1. Glucose trend at first and second measurement

Note: *RWL; Rapid weight loss– 1; first glucose measurement – 2; second glucose measurement (after 2 hours.)*

4. Discussions

The objective of the present research was to determine the differences in MetS parameters and the prevalence of MetS between former CSA and respondents who did not perform RWL during their sports careers. Our hypothesis is partially confirmed, since differences were detected between the two groups in 2 out of 5 variables regarding MetS, including systolic and diastolic BP. In addition, a significant trend toward differences was observed for triglycerides ($p = 0.069$). Most importantly, following the OGTT test, a substantial increase in FBG was found only in the RWL group. At last, a higher prevalence of MetS was recorded in the RWL group (39.5 %) than in the group of respondents who did not lose body weight during their careers (16.2 %).

The findings of the presented investigation related to the prevalence of MetS highlight a potential connection between RWL practices and the occurrence of this phenomenon among former CSA. These results are in accordance with previous studies that examined the relationship between RWL and several health variables of CSA (Baranauskas et al., 2022; Figlioli et al., 2021; Lakicevic et al., 2021; Roklicer et al., 2020; Trivic et al., 2023). Namely, the negative health consequences are multiple, such as acute kidney damage (Lakicevic et al., 2021; Trivic et al., 2023), significant muscle damage (Roklicer et al., 2020), and general injury due to training. Moreover, numerous studies defined additional detrimental influences of RWL, such as reduction in bone mineral mass, worsening of muscle performance, body dehydration, increased heart rate, and increased anxiety (Brito, 2012; Degoutte et al., 2006; Malliaropoulos et al., 2018).

Another important aspect of this study is the analysis of OGTT. The results demonstrated substantial differences in FBG levels between the two groups. In particular, the group of athletes who practiced RWL during their careers experienced a significant increase in FBG levels in the second measurement after the OGTT. The results obtained suggest that former CSA who experienced RWL may be at increased risk of impaired glucose metabolism. The presented findings support the idea that RWL may have negative effects on insulin sensitivity and glucose regulation (Talaei et al., 2016). Additionally, it is noteworthy to emphasize that weight reduction negatively influences the level of hormones such as cortisol and testosterone (Artioli et al., 2016; Turocy et al., 2011).

Numerous studies have analyzed the parameters of MetS and their prevalence in former athletes. Several parameters related to the MetS have been examined in literature in former athletes, and the results obtained highlighted lower HDL-cholesterol levels, increased blood pressure, and impaired FBG (Altowerqi, Zainuddin, & Ahmed, 2020). There is convincing evidence that former athletes who have been involved in endurance sports and vigorous training had a lower prevalence of MetS compared to former athletes who competed in sports such as soccer or American football (Altowerqi, bin Zainuddin, & Hashim, 2020). At last, our results are inconsistent with a study in which 33% of 12 former professional footballers had MetS, compared to 50% in the CG (Panayiotoglou et al., 2017). This disagreement could be due to the different nature of the sport.

The practical implications of this study are of paramount importance for both current and former CSA. Athletes currently implementing RWL should be duly informed about the potential long-term risks associated with these practices. Furthermore, coaches, sports organizations, and medical professionals must prioritize the health of athletes by exploring alternative weight management methods to mitigate these risks caused by RWL (Franchini et al., 2012). Moreover, sports nutritionists could have a key role in monitoring the health of athletes and avoiding adverse events (Khodaee et al., 2015). A truly worrying fact is that approximately 60% of judo athletes started performing RWL before competitions at a very early age (i.e. 12-15 years) (Franchini et al., 2012). The health consequences induced by RWL may be more pronounced in athletes who begin to lose weight at a very young age, putting them at greater risk of adverse health-related events in older age (Franchini et al., 2012). This could be one of the reasons that lead to adverse events in former CSA. The effect of nutritional and fluid limitation repeated during their career could lead to negative, sometimes permanent adverse metabolic effects for former CSA that practiced RWL (Lakicevic et al., 2021). In addition, dehydration induced by severe or moderate RWL increases the risk of acute cardiovascular problems (Artioli et al., 2016), which may lead to MetS-related issues.

It is essential to emphasize the importance of maintaining a healthy lifestyle, including regular physical activity and proper nutrition, after retirement from sport. This attitude during the transition from athlete to former athlete can significantly contribute to reducing the risk of MetS and related diseases (He et al., 2014; Lakka & Laaksonen, 2007). Furthermore, additional research is needed to understand in more detail the mechanisms underlying the metabolic alterations associated with RWL.

This could involve analyzing the specific effects of different RWL methodologies and their accumulation over time. Longitudinal studies, which monitor the metabolic health of CSA over an extended period after retirement, represent a key future direction. These studies could provide valuable information on the persistence and evolution of MetS and related conditions over time.

Several limitations are necessary to acknowledge, and they must be considered during the interpretation of the highlighted evidence. Namely, the presented investigation addressed only male athletes. Thus, more studies with the female population are warranted in the future. Moreover, the absence of a group of non-athletes is apparent. Lastly, due to the nature of the study, it was not possible to randomize the participants. In the future, it would be useful to conduct a randomized controlled trial related to the RWL and metabolic health of former CSA.

5. Conclusion

In conclusion, this study showed that former elite CSA, who practiced RWL as part of their competitive period, may be at increased risk of metabolic alterations after their sporting career. Combat sports athletes should also carefully use RWL during their career, or it is recommended to rule it out completely due to the possible negative influence on the athletes' metabolic health. In addition, the improvement of a healthy lifestyle, including regular exercise and an adequate diet, are essential to prevent these negative consequences at the end of a competitive career. Further research is needed to fully and deeply understand the impact of RWL on the metabolic health of former CSA and to develop strategies to mitigate its long-term metabolic consequences.

2.5 - Gender differences in cardiac muscle geometry of elite judo athletes

Authors

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Abstract

Introduction: Changes in cardiac geometry develop after intense and prolonged training. Left ventricular (LV) enlargement, increased wall thickness, and growing mass of the left ventricle occur after strenuous exercise. Combat sport such as judo can lead to concentric left ventricular hypertrophy. Previous studies have found that there are differences in left chamber size and thickness between the sexes, with female athletes having smaller wall diameters and hypertrophy than male athletes.

The research aims to examine heart muscle adaptations and remodeling of cardiac geometry among elite judo athletes and to evaluate differences between males and females.

Materials and Methods: A cross-sectional study included a group of 19 (males n=10, females n=9) professional judokas between 20 and 30 years of age. Demographic and anthropometric data were collected. Cardiac geometry was determined by two-dimensional transthoracic echocardiography.

Results: In terms of left ventricular mass (LVM) and the left ventricular mass index (LVMI) significant differences were found between male and female judokas (233.44 ± 68.75 g vs. 164.11 ± 16.59 g, p = 0.009), and (105.16 ± 24.89 vs. 84.66 ± 15.06, p = 0.044), respectively

Conclusions: A greater enlargement of the heart muscle is observed in male athletes compared to the female group. Left Ventricle enlargement is likely to occur among elite-level judokas.

Keywords**:** cardiac remodeling, judo, left ventricular geometry, gender differences.

1. Introduction

Physiological and pathological remodeling, depending on the growth, exercise, or special situations such as pregnancy in the first case, or as a result of inflammation, ischemia, or various stresses such as biomechanical stress in the second case, refer to geometric alterations in the heart muscle (Wu et al., 2017). Pathological cardiac remodeling is the process of various negative factors leading to structural, functional changes in the left ventricle (LV) in response to internal or external cardiovascular damage or as a result of various pathogenic risk factors, and often anticipates clinical heart failure (HF) (Wu et al., 2017).

The cardiovascular system adapts in response to the hemodynamic stress to which the body is exposed during training. Athletic training leads to LV remodeling and physiological adaptation of heart morphology and function. A pattern of LV geometry is highly dependent on the type of sport, gender, age, comorbidities, and other factors (Kale et al., 2022; Kovacs & Baggish, 2016; La Gerche et al., 2012). These morphological changes depend especially on the type of training and are clinically characterised by changes in size and cardiac shape due to increased load (Mihl et al., 2008).

Distinguishing athletic cardiac remodeling from pathological remodeling, and thus from cardiomyopathy, is important and a frequent medical question. Cardiac magnetic resonance imaging (CMR) plays a crucial role in clinical aid as it can help physicians discriminate a physiological event from a pathological one where electrocardiogram (ECG) and echocardiography alone leave several uncertainties. CMR can more accurately assess cardiac structure and function, as well as thoroughly evaluate the myocardium by detecting crucial changes such as myocardial scarring and/or diffuse fibrosis (Maestrini et al., 2020).

Judo is an intermittent combat sport that requires high levels of intramuscular strength. Training at a competitive level requires full-body engagement and a wide range of both tactical and technical skills to compete at an elite level and it can therefore cause an adaptation of the geometry of the heart over time (Maron & Mitchell, 1994; Porras Alvarez, 2022). There are studies indicating a difference in the increase in relative wall thickness

(RWT) and LV cavity size between genders, i. e. smaller RWT was observed, as well as the size of its cavities in female than in male athletes (Spirito et al., 1994). However, the number of studies and data on gender-specific changes in LV myocardial geometry in combat sports athletes is very limited (Finocchiaro et al., 2017).

Elite judokas regularly implement physically and physiologically demanding training to remain internationally competitive.

Extreme physical exertion requires aerobic and anaerobic energy sources to provide adequate energy during training and competition (Degoutte et al., 2004)._

Previous studies have shown that during intense and strenuous training in judokas, the heart muscle undergoes significant adaptations (Coelho P, 2022; Date et al., 2003). Long-term athletic training is associated with a series of alterations in cardiac structure, function and electrical activity that collectively refer to the broadly defined athlete's heart (Kovacs & Baggish, 2016; Sharma et al., 2002).

However, the clinical profile of the athlete's heart has greatly expanded over the years following the increased accessibility and monitoring of athletes systematically using echocardiography.

Although several studies have evaluated cardiac response to regular exercise training in male athletes, there is limited data on females, who still make up an ever-growing number of elite athletes worldwide. A previous comprehensive study carried out on Italian Olympians revealed that none of the athletes showed absolute RWT greater than the expected upper limits for the general population, and the LV cavity was found to be enlarged in only 8% of athletes (Pelliccia et al., 1996).

The purpose of the present investigation is to examine gender differences in adaptations of cardiac ventricular geometry among elite judo athletes.

2. Material and Methods

We conducted a cross-sectional study at the Vojvodina Cardiovascular Disease Institute (IKVB) in Sremska Kamenica, Serbia, which included a total of 19 respondents divided into two groups. The data was collected by inspecting the electronic records of the respondents through the IKVBV computer system. Written informed consent was obtained from each subject and all procedures were performed and conducted according to the guidelines of the Declaration of Helsinki and approved by both the Institutional Review Board of the Faculty of Sports and Physical Education of the University of Novi Sad, Serbia (Ref. n. 46-06-02/2020-1).

2.1 Participants

The study included 19 elite judokas divided into 2 subgroups, the first group consisted of 10 male athletes (mean age: 25.50 ± 3.17 years), and the second group consisted of 9 female judokas (mean age: 23.56 ± 3.16 years).All judokas included in this study were part of the national team and participated in national and international competitions, achieving numerous victories in major competitions in their sporting careers, such as the Olympic Games, World Championships and World Cups. The subjects started judo between the ages of six and eight; the average duration of judo training experience was 16.55 ± 3.16 years, with a training volume of 20 to 25 hours (20-25) per week. Judoka spent 1.5-2 hours training in the weight room two to three times a week. Participants competed for the senior national team of Serbia in international competitions and scored for IJF ranking, achieving the minimum of one ranking. The subjects were of various categories, from 48 kg up to 78 kg. Four of them reached the Olympic standard (10th, 10th, 16th, and 18th place WRL), while two came close to the Olympic standard and scored 25th. Three of them participated in the Olympics. All participants underwent a standard 12-lead surface ECG recording at rest, with a paper speed of 25 mm/s and a gain of 10 mm/mV. A cardiologist interpreted each ECG to rule out potential abnormalities. The exclusion criteria were: that the judokas were elite level, had been judoing for at least 10 years continuously, and had no particular heart abnormalities so as to compromise the measurement. Measurements were taken in the early morning hours, before taking water or food.

2.2 Body composition

Demographic, anthropometric, and echocardiographic data were analyzed for all subjects.

Analysis of anthropometric characteristics included measurement of body height (H), performed with a Martin anthropometer, with an accuracy of 0.1 cm, performed in a standing position with heels together and toes apart, with hands close to the body. The position of the head during H measurements was horizontal and the values are expressed in centimeters. Body weight (BW) was determined on a medical scale with an accuracy of 0.1 kg.

Body surface area (BSA) was analyzed according to the appropriate formula: BSA (m^2) = (√ (H (cm)) x BW (kg)) / 3600

2.3 Cardiac remodeling assessment

All subjects underwent two-dimensional transthoracic echocardiography using a 2.5 MHz low-frequency probe on a Vivid 9 ultrasound machine manufactured by General Electric's Co. in the echocardiography department of the Cardiology Clinic of the Institute of Cardiovascular Diseases of Vojvodina.

The examination was performed in the supine position, measurements, and calculations of morphological and functional indicators of the left ventricular chamber were performed according to the standards of the American Association for Echocardiography and the European Association for Cardiovascular Imaging (Lang et al., 2015). The following parameters were measured and calculated: LV posterior wall thickness in diastole (PLWd, cm); Interventricular septal thickness in diastole (IVSd, cm); LV wall thickness (RWT, mm) was calculated following the formula: RWT = 2 x PLWd / (end-diastolic volume) LVIDd LVMI was calculated using echocardiographic parameters, according to the following Devereux formula, automatically in the software system:

IMVS = 0.8x (1.04 x [(LVIDd + IVSd + PLWd] x 3 - LVIDd x 3) + 0.6. LVMI was calculated by indexing the patient's body surface area (BSA, m^2).

The geometry of the LV is defined according to the RWT and LVM index. (Figure 1)

• Normal geometry *(type 1 remodeling)*: RWT <0.42 and LVMI ♂ ≤ 115 g/m^2 ♀ ≤ 95 g/m^2.

• Concentric remodeling *(type 2 remodeling)*: RWT ≥ 0.42 and LVMI ♂ ≤ 115 g/m^2 and ♀ ≤ 95 g/m^2.

• Concentric hypertrophy *(type 3 remodeling)*: RWT ≥ 0.42 and LVMI ♂> 115 g/m^2 ♀> 95 g/m^2.

• Eccentric hypertrophy *(type 4 remodeling)*: RWT <0.42 and LVMI ♂> 115 g/m^2 ♀> 95 g/m^2.

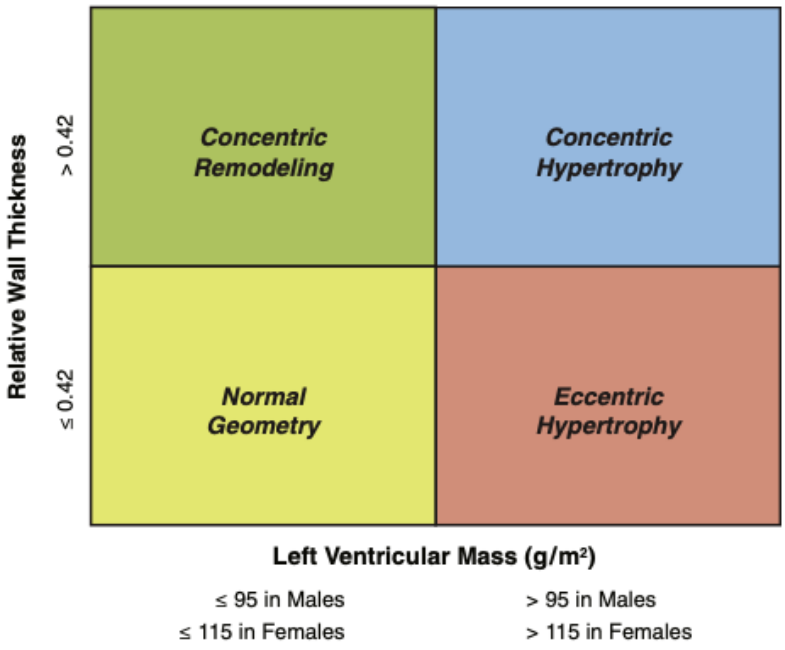


Figure 1. Left ventricular Geometry

2.4 Data analysis

The data obtained were sorted into the Microsoft Office Excel package (version 2019, Microsoft Inc. Italy), while the IBM SPSS (Statistical Package for the Social Sciences, version 20.0. IBM Corp.20, Armonk, NY) was used for the statistical analysis. Data processing included descriptive and inferential statistical methods. Numerical characteristics are presented using means. Depending on the nature of the data, the comparison of numerical characteristic values between the two groups was performed using a t-test for independent samples.

The results are presented in tables and graphs. The level of statistical significance was set at $p < 0.05$.

3. Results

Table 1 presents anthropometric characteristics of the two groups of judokas. . Significantly greater values are evident in males in terms of H, BM and BSA (p=0.000, p=0.005 and p=0.001, respectively).

***Table 1**. Age and anthropometric parameters of judo athletes*

	Males	**Females**	**P value**
	Participants **N = 10** **Average ± SD**	**Participants** **N = 9** **Average ± SD**	
Age (years)	25.50 ±3.17	23.56 ±3.16	0.199
B**H** (cm)	181.90 ±8.17	166.55 ±7.28	**0.000*****
BM (kg)	82.11 ±10.43	63.92 ±13.87	**0.005****
BSA **(m^2)**	2.02 ±0.16	1.70 ±0.18	**0.001****

***Legend**: P-value - statistical significance; ** -p<0.01; *** - p<0.001; SD - Standard Deviation; BH – body height; BM - Body mass; BSA - Body surface area; N - Number of participants.*

Table 2 shows the differences in cardiac remodeling parameters between male and female judo athletes.

Statistically significant values were found in the PLWd between male and female judokas (0.002). Another statistically significant result was the thickness of the IVSd (p = 0.002).

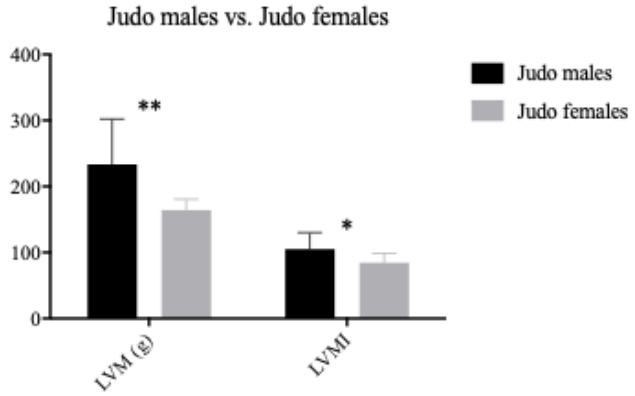
The parameters defining geometry of the LV were evaluated. By comparing the mean values of male and female athletes, the existence of statistical significance was also noticed in LVM (p = 0.009) (Graph 1). Another statistically significant difference was found for LVMI always between male and female athletes (p=0.044) (Graph 1). No statistically significant value for RWT is confirmed in our study (Graph 2).

Table 2. Cardiac geometry parameters of judo athletes

Parameter	**Males** **Average ± SD**	**Females** **Average ± SD**	**P value**
IVSd (cm)	9.84 ±1.06	8.2 ±0.50	**0.002****
PLWd (cm)	9.78 ±0.89	8.47 ±0.63	**0.002****
RWT mm	0.35 ±0.02	0.34 ±0.01	0.167
LVM (g)	233.44 ±68.75	164.11 ±16.59	**0.009****
LVMI	105.16 ±24.89	84.66 ± 15.06	**0.044***

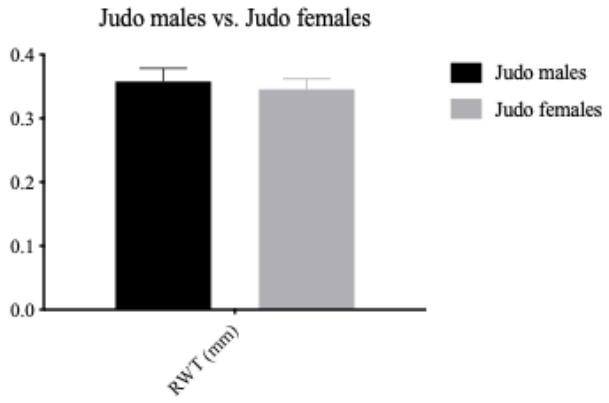
Legend*: IVSd - Thickness of the interventricular septum in diastole; PLWd - Posterior ventricular wall thickness in diastole; RWT - Left ventricular wall thickness; LVM - Left ventricular mass; LVMI - Left Ventricular Mass Index; P-value - statistical significance; ** -p<0.01; * - p<0.05*

Graph 1*. Male judokas vs female judokas - LVM, LVMI.*



Legend*: LVM - Left Ventricular Mass; LVMI - Left Ventricular Mass Index; ** - statistically significant difference between the two groups, p≤0.01; * - statistically significant difference between the two groups p≤0.05*

***Graph 2**. Male judoka vs female judoka - RWT.*



***Legend**: RWT - Thickness relative to the wall of the left ventricle.*

4. Discussion

In our study, significant differences in heart geometry remodeling between male and female judokas were demonstrated. As expected, significantly greater LV changes were observed in male compared to female athletes. The literature has already established that judokas, regardless of gender, have a significantly higher left ventricular posterior wall thickness and greater left ventricular mass than non-athletes of the same gender (Slankamenac et al., 2022), however the cardiac remodeling is complex and depends on various factors (Milovančev et al., 2022). The results obtained are in line with research conducted to date, which indicate that gender is a significant factor that has an important influence on the change of heart geometry in athletes (Chumakova et al., 2021; Utomi et al., 2014). Whyte et al. (Whyte et al., 2000) conducted a survey of judokas, including 17 male and 14 female athletes, and 11 participants in the control group.. The authors reported, significantly higher LV wall thickness values in judokas than in the control group. LV wall thickness was also compared between male and female judokas, whereas significantly higher values were reported in favor of males. The results are related to the results obtained in our work (Whyte et al., 2000).

A study of a total of 1083 combat sports athletes, of which 444 were females, found significantly lower LVM and RWT values than male athletes, which matches our findings (Finocchiaro et al., 2017). Furthermore, our data is inconsistent with previous research from 2021, conducted on a sample of 200 men and 78 women in weightlifting and various martial arts, which showed that female athletes were significantly more likely to have an eccentric type of hypertrophy than men who were more likely to have concentric remodeling of the LV (Chumakova et al., 2021). The adaptations involve the entire cardiovascular system,

particularly in athletes, LV root remodeling can also be expected due to the hemodynamic load caused by intensive training (Pelliccia et al., 2010). Although an increase in LV size has been observed in athletes in the past, as we demonstrated in our study, there are very little data in the literature on this type of remodeling (Pelliccia et al., 2010). Carrdiac muscle adaptation in athletes involves a change in the entire cardiovascular system, a study was performed on the diameter of the left ventricle, whereas a 13% increase was observed in athletes compared to the control group (Iskandar et al., 2015). In a sample of 2317 athletes, including 1300 males and 1017 females, a significant increase in aortic root size was found (Pelliccia et al., 2010).

All these changes in LV geometry occur due to many factors, such as age, race, gender, and type of sport. Additionally, hormones are also assumed to have a major influence on cardiac remodeling in athletes, particularly sex hormones such as testosterone (Tivesten et al., 2006).

It is important to differentiate the athlete's heart and structural heart disease in youth (Maron, 2003). The diagnostic doubt arises when the remodeling adaptations of the athlete's heart mimic some pathological conditions, such as hypertrophic and dilated cardiomyopathies (Sharma et al., 2002). There is currently little evidence regarding cardiac adaptation to resistance training in women, however, one study suggests that elite and highly trained female judokas show significant changes in the morphology of the LV (Milovančev et al., 2022). A cross-sectional report revealed that 24 female weightlifters demonstrated concentric enlargement of the LV (George et al., 1998). Considering that the athlete is often subjected to RWL (Roklicer, Rossi, Bianco, Štajer, et al., 2022; Roklicer, Rossi, Bianco, Stajer, et al., 2022; Rossi et al., 2022) we can also raise a question whether this rapid and sudden weight loss before a competition can influence the athlete's cardiac remodeling? However, there is still no evidence in the literature on this.

The limitation of this study is the number of participants, future studies on the topic with a larger sample of athletes should be carried out.

These results are also associated with the findings of Milovancev et al. (2021) according to which the physiological model of an athlete's cardiac adaptation is complex and varies according to the sport, therefore it must be specified for each sport discipline (Drid, Franchini, et al., 2021). It probably depends on numerous individual parameters such as individual sport type, duration of practice, weekly training volume, athlete's weight category and other variables that influence the physiology of cardiac adaptation. The literature needs further studies to better clarify these complex aspects.

5. Conclusion

Comparison of male versus female heart muscle characteristics, as expected, showed both higher LVM (albeit still in the physiological range) and higher LVMI in males compared to female athletes. Based on the obtained results, we can define that LVM is mildly elevated for males and females, while as regards LVMI, results reported were within the normal range. Physiological cardiac enlargement in elite level judokas is an event that can likely occur but still needs further study and clarification. In fact, males do have larger heart muscle than females.

2.6 - Acute Muscle Damage as a Metabolic Response to Rapid Weight Loss in Wrestlers

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Abstract

Study aim: Dietary and non-dietary weight loss methods are highly prevalent among combat sports athletes (CSA). Most CSA undergo rapid weight loss (RWL) usually a week before the competition to reduce their body mass and thus compete in the lowest weight category possible. The objective of the study was to distinguish the impact of high-intensity sport-specific training (HISST) combined with RWL (phase 1 – P1) on muscle damage markers as well as the effects of HISST alone (phase 2 – P2).
Material and methods: This crossover study was carried out on 12 male wrestlers. It consisted of initial measurement (IM), high-intensity training combined with RWL of 5% (P1), and high-intensity training without RWL (P2). After each phase, muscle damage markers were measured, including myoglobin, aldolase, creatine kinase, aspartate aminotransferase, alanine aminotransferase, and lactate dehydrogenase.
Results: Substantial increase in analyzed biomarkers was evident in both phases (P1 and P2). However, higher levels of almost all biomarkers were obtained in a phase that included RWL compared to the second phase with a greater significance level.

Conclusions: Our study revealed that 5% of RWL combined with HISST impacts the assessed biomarkers to a greater extent than HISST alone, thus providing strong evidence of the influence of RWL on muscular damage in wrestlers. In order to minimize the adverse health-related effects induced by weight reduction, coaches and athletes are encouraged to carefully approach to the weight management methods.

Key words: Weight reduction-Combat sports-High-intensity training-Martial arts-Muscle metabolism

Introduction

Optimizing body composition in various sports can contribute to a competitive advantage (Trexler et al., 2014). Combat sports such as wrestling are highly demanding from the physical, physiological, and metabolic standpoint. Wrestlers achieve an average of 3-4 victories during competition to reach the medal fight. Accordingly, among considerable physical and mental preparation, an athlete must also maintain high energy levels to withstand vigorous bouts on a competition day. Besides strenuous training, wrestlers often undergo rapid weight loss (RWL) procedures to compete in a desired weight class (Roklicer, Rossi, Bianco, Stajer, et al., 2022). Acute body mass reduction is a widely known phenomenon amongst combat sports athletes (CSA). It has been established that most CSA implements some weight-cutting techniques before a competition (Brito et al., 2012). CSA often uses various weight cycling strategies since heavier fighters are considered to have an advantage over lighter fighters (Coswig et al., 2019; Franchini et al., 2012; Matthews et al., 2019; Reale et al., 2016). These strategies are characterized by reducing around 5% of an athlete's body mass within the last week before the competition (Khodaee et al., 2015). The most prevalent RWL methods practiced by CSA are fluid and caloric intake reduction, increased physical activity, plastic suit training, sauna use, heated room training, and prohibited substances such as diuretics and laxatives (Guilherme Giannini Artioli et al., 2010; Brito et al., 2012; Lakicevic et al., 2020; Roklicer, Rossi, Bianco, Stajer, et al., 2022).

Scientific evidence suggests that certain weight-control behaviors are particularly common among wrestlers and might even influence eating disorders (Dale & Landers, 1999). The authors warn of potential negative consequences of RWL, such as lean body mass reduction, dehydration, and depletion of intramuscular glycogen depots, which could reduce performance among competitors in combat sports (Artioli et al., 2016). Additionally, harmful effects of RWL on various body systems have been reported. Namely, it can instigate acute

kidney damage due to intentional dehydration (Lakicevic et al., 2021) and negatively affect psychological well-being and mood (Degoutte et al., 2006; Filaire et al., 2001; Fortes et al., 2018). Furthermore, it is found that Olympic-style wrestlers may suffer nearly twice the injury rate during weight reduction periods compared to regular training (Kim & Park, 2021) and can impact hormone disturbances and restriction of normal growth patterns in younger athletes (Karila et al., 2008).

Muscle damage (MD) is typical in professional and amateur sports, and the causes can differ. It can be provoked by long-term intensive training or metabolic or mechanical factors (Brancaccio et al., 2010). Therefore, highly demanding training and rapid weight reduction ahead of the competition could elicit skeletal MD and increase the risk of damage to other tissues (Torres-Luque et al., 2016). Depending on the cause that preceded the MD, there are indicators by which such changes can be monitored.

We used a set of reliable biochemical markers to gain insight into muscular adaptation to HISST and RWL. In addition to the loss of muscle function and reduced force production, MD is accompanied by an increase in myoglobin (Mb) concentration and creatine kinase (CK) activity in the bloodstream (Clarkson & Hubal, 2002; Peake et al., 2005). Along with the mentioned indicators, enzymes such as aldolase (ALD), aspartate aminotransferase (AST), alanine aminotransferase (ALT), and lactate dehydrogenase (LDH) are also considered plausible markers for assessing muscle tissue adaptation to training (Kim et al., 2007; Mamczur & Dzugaj, 2008).

The literature suggests that intensive exercise can provoke damage to skeletal muscle tissue in athletes (Brancaccio et al., 2010). Bearing that one of the most commonly practiced RWL methods is increased exercise (in terms of volume and intensity), whether the MD occurs due to extensive training or body mass reduction is still quite indefinite. The study aimed to establish the influence of HISST in combination with RWL on MD markers and the impact of HISST without RWL. Namely, the authors hypothesized that weight reduction together with high-intensity training would affect skeletal MD to a greater extent than the same specific training without RWL.

Material and methods

Participants

The sample of respondents consisted of 12 national-level Greco-Roman style wrestlers (average body weight 73.48±4.52 kg, age 24.30±5.10 years, body height 175.22±3.68 cm).

Each participant attended a minimum of 10h of training weekly for the past four years. Only those who had already implemented RWL techniques over the last 2 years were selected for the study. Before starting the experimental treatment, a detailed medical examination was performed to determine the athletes' health condition. The study was conducted in agreement with the declaration of Helsinki. Ethical approval for the study was obtained by the Institutional Review Committee of the University of Novi Sad (Ref. No. 46-06-02/2020-1). All respondents were informed about the requirements of the research and the possibility of withdrawing from the study at any time. Written informed consent for participation in the study was provided by all respondents.

Body composition

Bioelectrical impedance Omron weight scale BF511 (Omron, Japan) was used to measure body composition, including body weight, body mass index (BMI), visceral fat, and muscle and fat mass percentage. Participants were instructed not to have dinner after 9 pm, as well as not to eat in the morning before the measurement. Body height was measured to the nearest 0.1 cm using a Martin anthropometer (GPM, Switzerland).

Experimental design

Following the initial measurement, the experimental treatment took place in two phases to examine the acute effects of RWL on biochemical markers of MD when HISST is performed together with body mass reduction (first phase – P1) and the effects of identical training protocol (HISST) without weight loss (second phase – P2). Body composition and biochemical parameters were determined in all stages (IM, P1, and P2). HISST is a non-standardized test protocol created explicitly for highly-trained competitive wrestlers and composed of performing throws and sprinting (15s) interspersed with low-intensity running (45s), as explained elsewhere (Roklicer, Rossi, Bianco, Štajer, et al., 2022).

In the first experimental phase (P1), the athletes were instructed to reduce 5% of their total body mass in relation to the values obtained at the initial measurement. In this phase, which lasted for 3 days, the athletes attended their regular training sessions and applied self-chosen RWL methods. On the last day of the P1 (3rd day), all the subjects performed the specific training session (HISST) in the morning, followed by the second measurement.

The experimental treatment's second phase (P2) was conducted 7 days after the first phase. In this phase, the influence of a single training session on body composition and biochemical

parameters was examined. Also, the respondents did not reduce their body mass during P2. Body composition assessment and blood sampling were carried out immediately after the training session in the morning, 10 hours following the last meal. Weight measurements and body composition assessments were carried out by three researchers with expertise in the field of combat sports. Blood sampling was done by trained laboratory staff.

During each of the experimental phases (P1 and P2), upon completion of the high-intensity sport-specific training and body composition assessment, blood samples were taken to determine the following biochemical markers: Mb, CK, ALD, AST, ALT, and LDH (Figure 1). Biochemical indicators and markers of muscle damage were determined in the polyclinic with the laboratory "EUROLAB" in Novi Sad, Serbia.

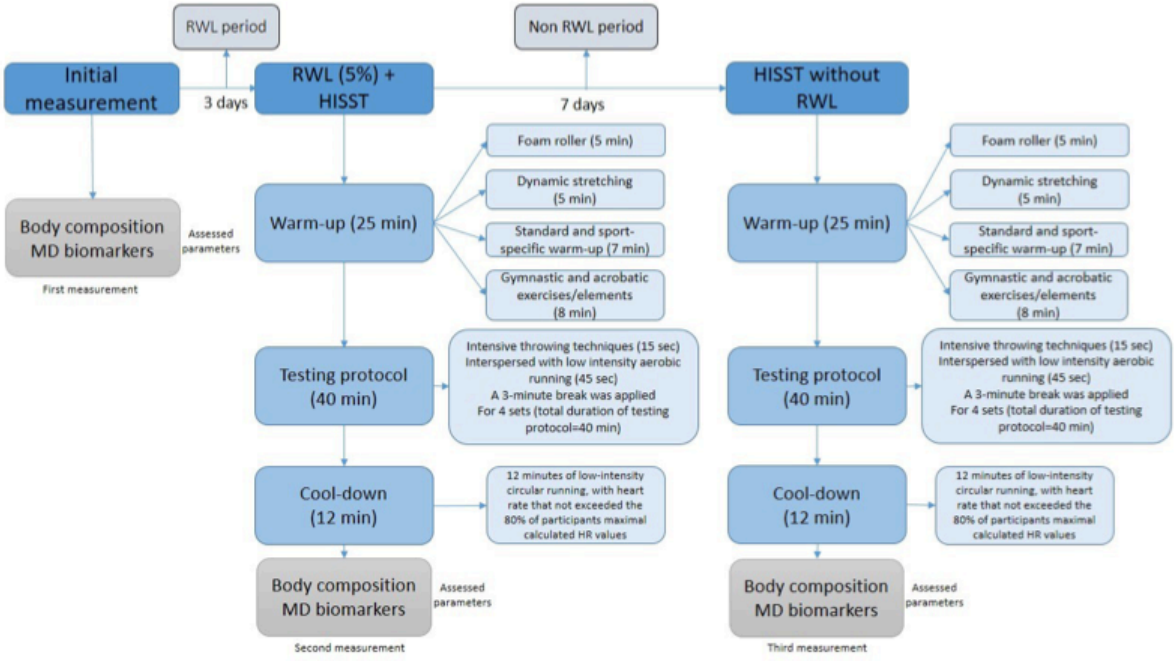

Figure 1. Flow chart of the study design

Blood sampling and analysis of biochemical and hematological parameters

Blood sampling was carried out as follows: During each of the measurements (IM, P1, and P2), blood samples were collected from the anterior cubital vein in the morning between 9 and 10 am, at least ten hours after the last meal (after HISST for the phases P1 and P2).

A venous blood sample of 8 ml was collected in test tubes (BD vacutainer). CK levels were measured using CK-NAC reagent (creatine kinase, activated by N-acetyl cysteine) by utilizing the Dirui apparatus recommended by the International Federation of Clinical

Chemistry (IFCC). Determination of Mb concentration was carried out by the EIA method using the TOSOH diagnostic analyzer (Tosoh, Tokyo, Japan). Fructose-1,6-diphosphate (F-1,6-DP) was used to establish the levels of ALD. The reaction rate of ALD is measured by the subsequent reduction in absorbance at 340 nm due to the conversion of NADH to NAD+, RANDOX reagent.

Statistical analysis

The results are presented as mean values and standard deviations. Statistical analysis was performed with One-Way Repeated Measures ANOVA (Within-Subjects design) and post hoc Bonferroni analysis using the Statistical Package for Social Science - IBM SPSS Statistics for Windows, Version 20.0 (Armonk, NY: IBM Corp. 20.). For all applied tests, the alpha level of statistical significance was determined at $p \leq 0.05$. The sample size for this study was calculated using the power analysis (G-Power 3, Heinrich-Heine-Universität Düsseldorf, Germany) for the primary outcome measures (effect size 0.4, α 0.05, power 0.80).

Results

Body composition

Table 1 depicts the body composition parameters of the athletes during the initial measurement (IM) and the two experimental phases (P1 and P2). All examined parameters changed substantially within both experimental stages. Body mass decreased significantly following a 3-day RWL of 5% coupled with high-intensity specific training ($p \leq 0.001$). Consequently, BMI, fat mass and visceral fat decreased, while muscle mass increased in P1 ($p \leq 0.001$).

Table 1. Body composition of wrestlers at three-time points (n=12)

	IM	P1	P2
Body mass (kg)	73.48±4.52	69.18±3.98***	72.98±4.26‡‡‡
BMI (kg/m^2)	24.08±0.95††	22.72±0.97***	23.85±1.02‡‡‡
Fat mass (%)	16.45±2.41††	12.64±3.12***	14.95±2.44‡‡
Muscle mass (%)	42.55±1.39††	44.59±2.10***	43.46±1.69‡‡
Visceral fat (%)	6.13±1.04†	4.86±1.17***	5.64±1.34‡‡

Legend: Values are presented as arithmetic mean and standard deviation; IM – initial measurement; P1 – RWL and training phase; P2 – training phase only; BMI – body mass index; *** significantly different compared to IM, p≤0.001; ‡‡‡ significantly different compared to P1, p≤0.001; ‡‡ significantly different compared to P1, p<0.01; †† significantly different compared to P2, p<0.01; † significantly different compared to P2, p<0.05.

In P2, the body composition parameters also decreased but with a lower level of significance for BMI, fat mass (p<0.01), and visceral fat (p<0.05), and with an increase in the percentage of muscle mass (p<0.01). Comparing P2 and P1, significantly higher body mass and BMI (p≤0.001) values were recorded, as well as for fat and visceral fat percentage (p<0.01) in favor of the values obtained in P2. At the same time, participants demonstrated lower muscle mass percentage (p<0.01).

Biochemical parameters

Considerable changes in all analyzed MD biomarkers were notable in each experimental phase. Nonetheless, alterations in MD biomarkers were evident to a greater extent in P1 in each parameter except for ALT. The concentration of Mb increased significantly during P1 compared to the values obtained from the initial measurement, with an even higher level of significance (p=0.001) compared to the second phase (p=0.002) (Figure 2). Both in P1 (252.05±123.51 ug/L) and P2 (236.70±162.14 ug/L) Mb concentration exceeded the normal reference range (0.0–73.0 ug/L). Increased ALD activity was observed during P1 and P2 (7.54±2.83, p=0.003 and 7.63±4.21 U/L, p=0.027, respectively) compared to the initial measurement, and the values were at the upper limit of the normal reference range (0.0 – 7.6 U/L) in both phases.

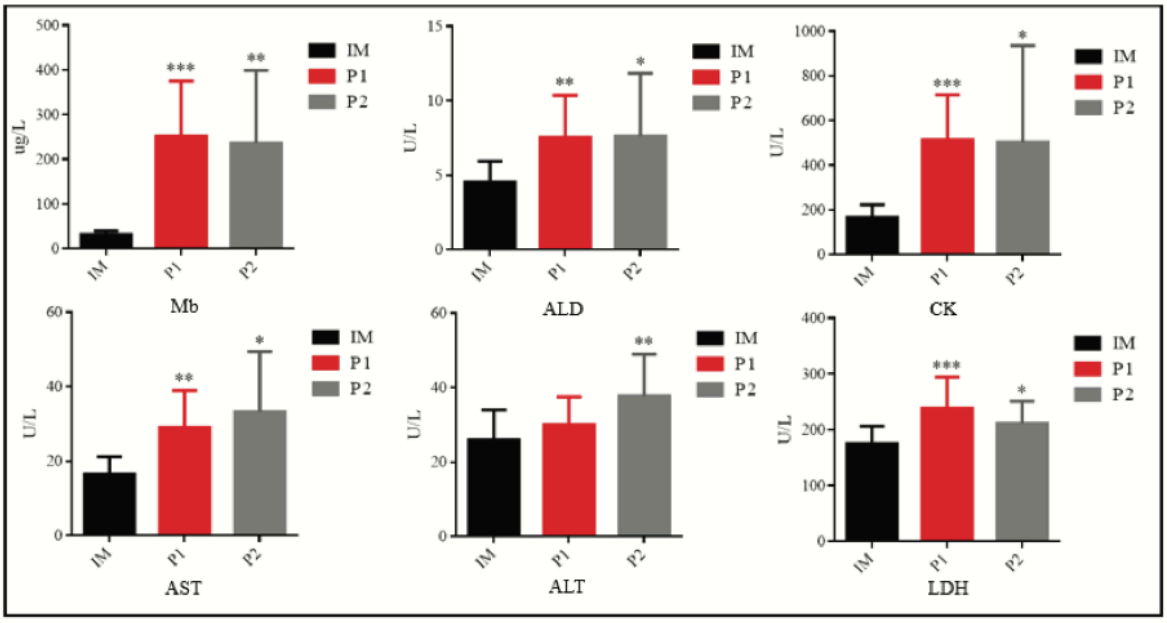

Figure 2. The effects of experimental treatment on biochemical muscle damage markers.

Legend: IM – initial measurement; P1 – RWL and training phase; P2 – training phase only; Mb – Myoglobin; ALD – Aldolase; CK – creatine kinase; AST – aspartate aminotransferase; ALT – alanine aminotransferase; LDH – lactate dehydrogenase; *** significantly different compared to IM, $p \leq 0.001$; ** significantly different compared to IM, $p < 0.01$; * significantly different compared to IM, $p \leq 0.05$

CK activity was significantly increased during P1 ($p=0.000$) and P2 ($p=0.042$), whereas higher values were obtained in P1 (514.22±201.66 U/L) in comparison to P2 (504.11±432.29 U/L). Serum CK values were elevated more than twice the upper limit of the refernce range (26–200 U/L) in each phase. AST values were also increased during the first ($p=0.009$) and second ($p=0.026$) experimental phases. Serum ALT level significantly raised during P2 compared to IM (37.77±11.22 U/L, $p=0.008$). Elevated LDH levels were observed in the experiment's first (238.55±56.00 U/L, $p=0.001$) and second (211.00±40.00 U/L, $p=0.018$) phases, with the values in P1 exceeding the upper limit of the reference range (81–234 U/L). No statistically significant differences were observed between P1 and P2 for all the parameters.

Discussion

This study investigated the influence of HISST combined with an RWL of 5% and the same training without RWL on muscle damage markers. Based on obtained results, HISST with RWL affects remarkably on MD markers in relation to HISST without RWL.

The body composition parameters changed in both P1 and P2, while a higher level of significance was recorded in P1.

Few studies monitored biochemical markers in response to vigorous physical activity in combat sports. A study carried out by Kinaci et al. (Karaman et al., 2021) demonstrated an increase in circulating biomarkers after a single bout in wrestlers. Muscle damage markers (CK, ALT, and AST) increased significantly after a six-minute match ($p<0.01$). Such results are in accordance with our study, as the levels of CK, ALT, and AST ($p\leq0.05$, $p<0.01$, and $p\leq0.05$, respectively) were elevated after P2. Additionally, simulated five-match tournaments caused CK elevation after each bout in elite Greco-Roman style wrestlers following ~6% of weight loss. However, CK values peaked after the last match (Barbas et al., 2011). Comparably, postmatch circulating CK level in freestyle wrestlers raised after a two-day tournament following the same percentage of weight loss (Kraemer et al., 2001). Progressively elevated CK, with the highest values recorded on a second day, might result from the previous 3 bouts completed on the first day of the competition. On the other hand, insignificant CK and LDH increase was reported after a single training session consisting of a 20m shuttle run test in Kyrgyzstan national team Greco-Roman wrestlers (Demirhan et al., 2020). Considering such responses of athletes, the results of the study may imply that highly trained and experienced athletes are well adapted to exercise of high intensities.

The scientific literature which concerns weight management and biochemical markers in wrestlers is rather scarce. Isik et al. (Isik et al., 2018) reported significant muscular damage due to ~5% weight loss in junior freestyle wrestlers, as an increase in ALT, LDH, and CK levels was recorded. Additionally, a similarly designed study demonstrated that dehydration and daily training could provoke a significant increase in serum AST, LDH, and CK levels in wrestlers (Ozkan & Ibrahim, 2016). Athletes reported RWL methods such as fluid and food restriction, together with strenuous exercise and using a sauna to lose weight over 1-7 days. However, the mentioned study does not delineate the extent of fluid and food restriction, which can contribute to biomarker alterations. For instance, it is established that a 3-day RWL of 5% among judokas causes a significant elevation in Mb, CK, and ALD levels (Roklicer et al., 2020), which is highly comparable to the results of our study as judo and wrestling are considered analogous sports. Apart from combat sports, there is an evidence

that RWL negatively affects strength and sport-specific performance in other sports as well (Wilson et al., 2014).

All respondents in our study reduced their body weight by 5% using self-chosen RWL methods by performing intensive specific training in P1, whereas in P2, only the HISST was carried out. It is interesting to highlight that the values of MD markers during the P1 were greater than the P2. Based on the obtained results, it is evident that RWL with HISST can lead to significant muscle damage. It is crucial to emphasize that the values of CK and Mb were elevated over the upper limit of the reference range, which indicates a high degree of muscle function impairment.

Losing weight rapidly is unsustainable from many perspectives, as reducing body mass too quickly could lead to various issues. Undoubtedly, such behaviors lead to metabolic adaptations, further affecting athletes' performance and health. Thus, intentional weight reduction methods among wrestlers attracted the attention of physicians, sports workers, and scientists. Sports scientists have a key role in providing the background knowledge to encourage athletes to avoid or change common weight loss strategies to conserve energy and minimize adverse effects. In order to prevent the practice of manipulating athletes' body mass, one of the recommendations could be to encourage the sporting organizations to bring the official weigh-ins of the competitors closer to the beginning of the competition itself. In that case, athletes would not have enough time to regain body mass drastically, thus achieving a significant weight advantage over their opponents. Second, body weight reduction should be approached gradually by modifying the diet in such a way as to achieve small energy deficits.

Despite the adverse health-related consequences, CSA still undergo voluntary weight cycling procedures. Bearing this in mind, more studies are needed to explore the phenomenon of RWL and modalities to overcome all its adverse outcomes.

This study has some limitations that should be pointed out. The number of subjects participating in this study was limited to twelve male athletes. Moreover, the RWL methods employed by athletes were not reported. Additionally, HISST presents a non-standardized training protocol designed to emulate high-intensity training sessions in wrestlers. Further, serum aminotransferases lack the tissue specificity to allow researchers to differentiate muscle injury from liver injury (Lim, 2020). Although the sample consisted mainly of national-level competitors, it included 3 gold medalists at the Youth U23 National Championship who regularly participated in international competitions. Additionally, selecting highly conducive biochemical markers analyzed to monitor MD throughout the

study could be a strength factor. No studies are available related to the degree of muscle damage caused by exercise-distinctively provoked MD versus RWL and exercise-induced MD in wrestlers.

Conclusion

Particular attention should be paid to the global weight reduction phenomenon in CSA due to potentially harmful health consequences. The results obtained in this study demonstrated that HISST with RWL (5% of body mass) induces an increase in the assessed biomarkers to a greater extent than HISST without RWL. Such a finding corroborates the meaningful influence of body mass reduction strategies on muscular damage in wrestlers. Coaches and athletes must be aware of the harmful metabolic response that weight reduction can cause. Considering that fact, future research in this area would be essential to provide them with safer and more efficient approaches to weight management.

2.7 - Cardiac Biomarkers Alterations in Rapid Weight Loss and High-Intensity Training in Judo Athletes

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Abstract

Background: Studies evaluating alterations in cardiac biomarkers in rapid sport-associated weight loss (RWL) and high-intensity sport-specific training (HISST) are lacking. This pilot study aimed to examine the effects of RWL and HISST on heart rate, blood pressure, cardiac biomarkers, and left ventricular systolic function. Nine elite male judokas participated in the presented survey.

Methods: The athletes underwent a baseline assessment and two testing protocols, the first phase with RWL and HISST and the second phase after 7 days, in which only HISST was performed. Participants underwent electrocardiogram, biomarker, and transthoracic echocardiogram evaluation after each phase.

Results: In the first phase (RWL and HISST), heart rate increased significantly, 58.11 (7.78) versus 79 (9.25), p=0.001; as well as cardiac biomarkers: lactate dehydrogenase isoenzyme 175.33 (31.22) vs. 238.56 (56), p=0.003; aspartate aminotransferase 16.56 (4.61) vs. 29 (9.96), p=0.027; creatine kinase isoenzyme-MB 13 (11.5;24) vs. 29.11 (10.05), p=0.004; and high sensitivity cardiac troponin 10 (0) vs. 14.49 (6.4), p=0.045. In the second phase, only HISST was associated with a significant increase in the alanine aminotransferase isoenzyme, 37.78 (11.22) vs. 26 (8.03), p=0.024, together with creatine kinase 472 (185;654) vs. 166.88 (56.57), p=0.01, compared to the initial measurement.

Conclusions: RWL combined with HISST produced significant alterations in cardiac biomarkers without impairment of left ventricular systolic function.

Keywords: judo, high-sensitivity cardiac troponin, rapid weight loss, high-intensity training, exercise

Introduction

In weight-class sports such as judo**,** rapid weight loss (RWL) is a well-established practice, used by a high proportion of athletes to compete in a lower category and potentially gain a competitive advantage (Guilherme Giannini Artioli et al., 2010; Franchini et al., 2012). Epidemiological studies indicate that more than 60–80% of elite judokas regularly employ RWL strategies in the week leading up to competitions (Guilherme Giannini Artioli et al., 2010; Brito et al., 2012).

Commonly used techniques include caloric and fluid restriction**,** forced dehydration using saunas or plastic suits**,** and prolonged high-intensity training sessions**.** While such strategies can reduce body mass by more than 5% in just a few days, they induce significant physiological alterations, including electrolyte imbalances, decreased plasma volume, increased sympathetic activity, and impaired thermoregulation (Milovancev et al., 2024).

Although the metabolic and muscular consequences of RWL are well documented (Lukic-Sarkanovic et al., 2024), its cardiovascular effects remain incompletely understood, particularly when combined with high-intensity sport-specific training (HISST)**.** Endurance studies have shown that prolonged and intense exercise acutely elevates cardiac biomarkers, such as high-sensitivity cardiac troponin I (hs-TnI), creatine kinase MB isoenzyme (CK-MB), and N-terminal pro B-type natriuretic peptide (NT-proBNP), often without detectable functional cardiac impairment (Shave et al., 2007). However, few studies have examined similar responses in power-based and combat sports, where intermittent, anaerobic, and lactate-producing efforts dominate.

This pilot study aimed to evaluate the combined impact of RWL and HISST on cardiac biomarkers, heart rate, blood pressure, and left ventricular systolic function in a cohort of elite judokas.

Methods

Study Design and Participants

A prospective crossover study was conducted to allow within-subject comparisons, minimizing confounding from individual variability.

Nine elite male judokas participated, with a mean age of 23 years and BMI of 24.1 ± 0.9 kg/m². All had extensive competitive experience and reported habitual RWL practices preceding major competitions.

Experimental Protocol

The study included three phases:

1. Baseline (BL): anthropometric measurements, resting ECG, 2D echocardiography, and blood sampling.
2. Phase 1 (RWL + HISST): athletes reduced 5% of body mass over three days using self-directed RWL strategies (fluid and caloric restriction, sauna, plastic suits). On the final day, a 90-minute HISST session was conducted, including repeated technical throws (Ippon Seoi-Nage) and intermittent high-intensity running.
3. Phase 2 (HISST only): one week later, the same HISST session was performed under normohydrated and normonutritional conditions, without preceding RWL.

Outcomes Measured

Blood samples were analyzed for:

- hs-Troponin I (hs-TnI)
- Total CK and CK-MB
- LDH isoenzyme
- AST and ALT
- NT-proBNP

Left ventricular function was assessed via ejection fraction (EF), global longitudinal strain, and diastolic parameters.

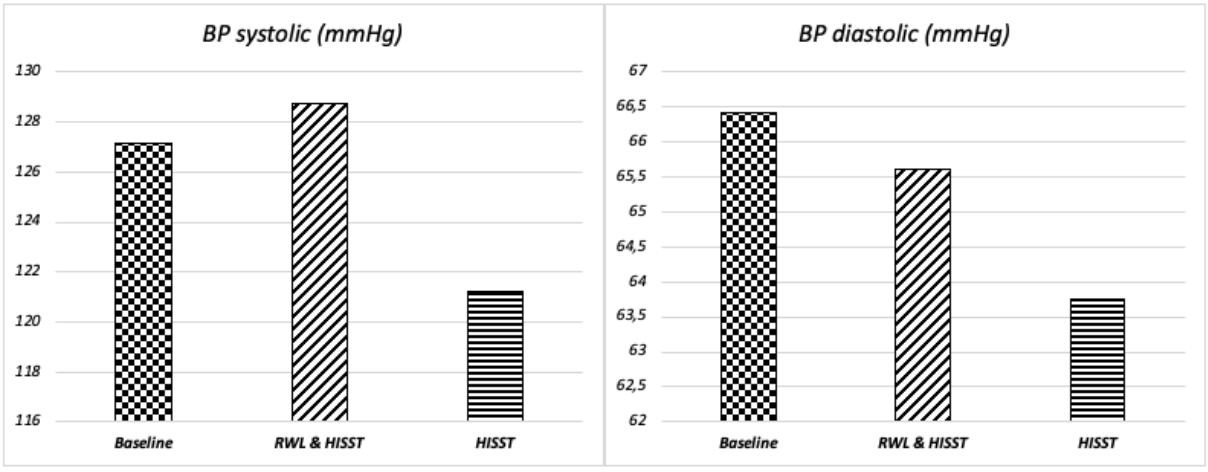
Results

Table 1. Basic athletes' characteristics

Parameters	Mean (SD), Median (Q1;Q3), N (%)
Age (years)	23 (18.5; 23)
Height (cm)	174.43 (3.78)
Weight (kg)	73.37 (4.42)
BMI (kg/m^2)	24.11 (0.96)
BSA (m^2)	1.88 (0.07)
BP systolic (mmHg)	127.14 (14.68)
BP diastolic (mmHg)	66.42 (8.02)
Heart rate (bpm)	58.11 (7.78)
Family history of CVD	2 (22.22%)
Personal previous medical history	2 (22.22%)
Years in training	12.37 (7.09)
Hours spent on training/weekly (h)	12.56 (1.81)

Note: BMI – body mass index, BSA - body surface area, BP - Blood pressure, bpm - beat per minute, CVD - Cardiovascular diseases, Q1 – 25 percentile, Q3 - 75 percentile.

Figure 1. Systolic (A) and diastolic (B) blood pressure during the 3 phases of the study



A B

Note: BP; blood pressure – RWL; rapid weight loss - HISST; high-intensity sport-specific training.

The echocardiographic parameters of judokas are available in Table 2. One athlete exhibited mildly increased interventricular septum and posterolateral wall thickness. The left ventricle showed signs of concentric remodeling in 7 (77.78%) athletes. All judokas had normal systolic and diastolic functions.

Table 2. Echocardiographic characteristics of the examined population

Parameters	**Mean (SD), Median (Q1, Q3)**
LVEDd (mm)	46.67 (1.87)
LVEDd/BSA (mm/m^2)	24.83 (1.25)
LVEDs (mm)	28.22 (1.64)
LVEDs/BSA (mm/m^2)	15.01 (0.89)
IVS (mm)	10 (9.5;10)
PLW (mm)	10 (9.5;10)
RWT (mm)	0.42 (0.33)
LVM (g)	151.26 (18.69)
LVM/BSA (g/m^2)	80.39 (9.34)
EDV (ml)	116 (90.5;117.5)
EDVI (ml/m^2)	57.55 (7.77)
ESV (ml)	33.44 (5.41)
ESVI (ml/m^2)	17.79 (2.92)
SV (ml)	84 (59;87.50)
SVI (ml/m^2)	39.75 (8.09)
EF (%)	64 (60;65)
FS (%)	39.45 (4.02)
LAVs (ml)	52.43 (11.10)
LAVsI (ml/m^2)	27.97 (5.82)
Aortic root (mm)	24.4 (2.60)
Ascending aorta (mm)	27.5 (1.69)
E – wave (m/s)	0.94 (0.10)
A (m/s)	0.53 (0.09)
E/A ratio	1.80 (0.32)
e’ sep (cm/s)	0.12 (0.02)
E/e’sep ratio	7.71 (1.23)
e’ lat (cm/s)	0.13 (0.03)

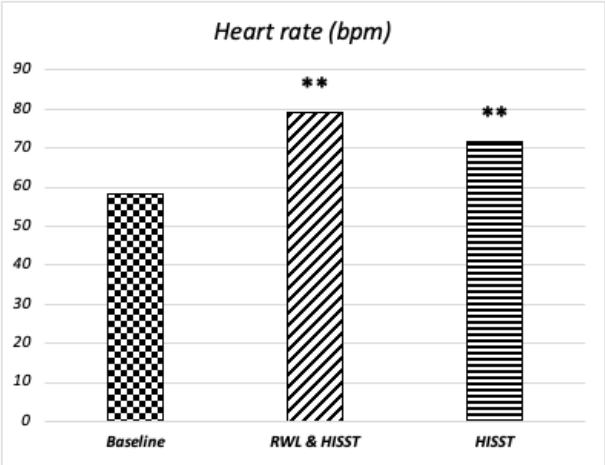
E/e' lat ratio	7.89 (2.46)
e'average (cm/s)	0.12 (0.01)
E/e' average	7.70 (1.22)

Note: A - late atrial contraction, E - early wave, E/A ratio - peak early wave to atrial late wave ratio, e'average - average peak early velocity, E/e' average - early wave to average peak early velocity, E/e' sep - early wave to septal peak early velocity, E/e' lat ratio - early wave to lateral peak early velocity, e' lat - lateral peak early velocity, e' sep - septal peak early velocity, E/e' lat ratio - early wave to lateral peak early velocity, EDV - LV End-diastolic volume, EDVI - LV End-diastolic volume/ body surface area, EF - ejection fraction % ESV - LV End-systolic volume, ESVI - LV End-systolic volume/ body surface area; FS - fraction of shortening %, IVS - inter-ventricular septum, LAVs - left atrium volume at end-systole, LAVsI - left atrium volume index; LV - Left ventricle, LVM - left ventricle mass; LVMI - left ventricle mass index, LVEDd - LV end-diastolic diameter, LVEDd/BSA - LV end-diastolic diameter and body surface area ratio; LVEDs - LV end-systolic diameter, LVEDs/BSA - LV end-systolic diameter and body surface area ratio, p - statistical significance ($p<0.05$), PLW - posterolateral wall, RWT - relative wall thickness, SD - standard deviation, SV - Stroke volume, SVI - stroke volume/body surface area, Q1 - 25 percentile, Q3 - 75 percentile.

Hemodynamic Changes

In the RWL + HISST phase, **heart rate** increased significantly from 58.1 ± 7.8 to 79.0 ± 9.2 bpm ($p=0.001$), indicating heightened sympathetic activation.

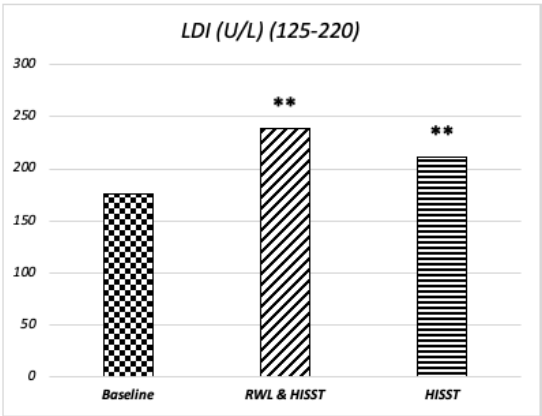
Figure 2. Heart rate in the 3 different phases



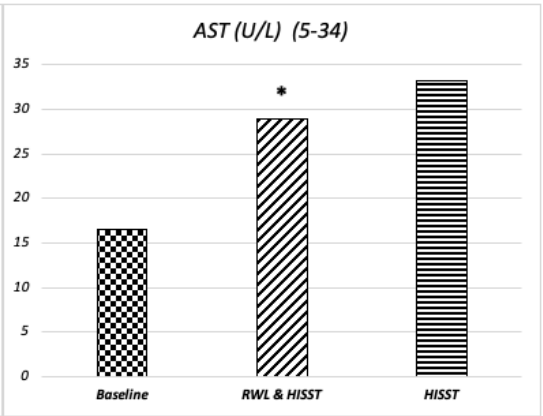
Note: RWL; rapid weight loss - HISST; high-intensity sport-specific training - **; p<0.01

Figure 3. Trend of biomarkers; lactate dehydrogenase isoenzyme (LDI) (A), aspartate aminotransferase (AST) (B), creatine kinase-MB isoenzyme (MBI) (C) and cardiac troponin (hs Troponin I) (D) during the 3 phases carried out.

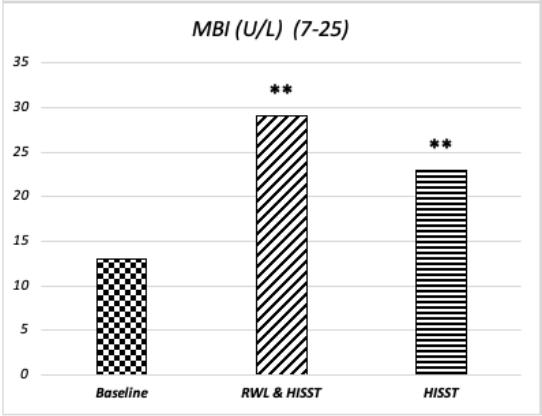
A



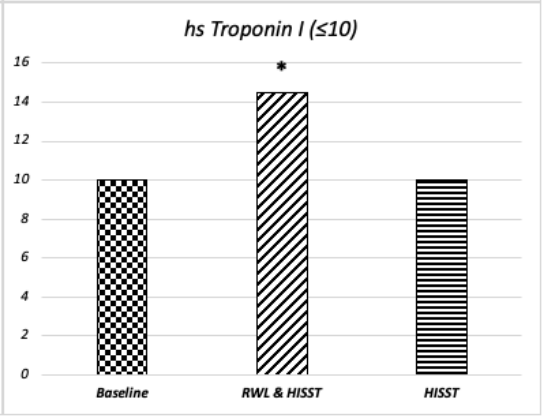
B



C

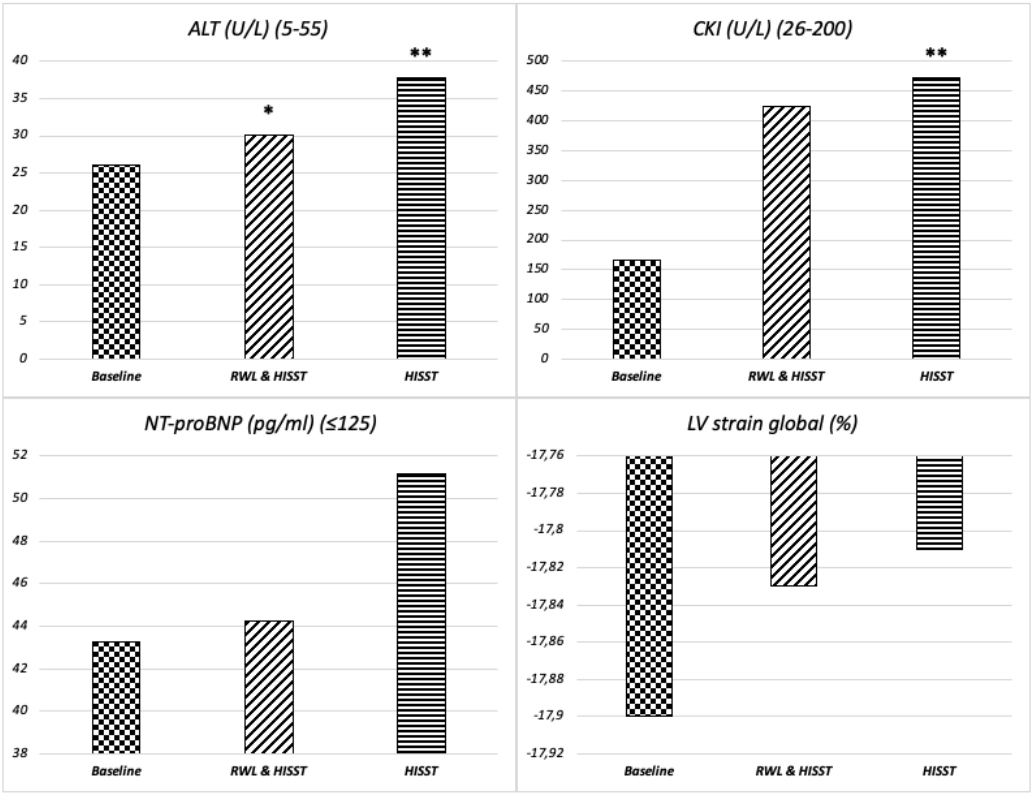


D



Note: RWL; rapid weight loss - HISST; high-intensity sport-specific training - **; p<0.01 - *; p<0.05 – LDI; lactate dehydrogenase isoenzyme - AST; aspartate aminotransferase – MBI; creatine kinase-MB isoenzyme – hs Troponin I; cardiac troponin

A B



C D

Note: RWL; rapid weight loss - HISST; high-intensity sport-specific training - **; p<0.01 - *; p<0.05 – ALT; Alanine aminotransferase isoenzyme – CKI; creatine kinase - NT-proBNP; NT; proB-type natriuretic peptide – LV strain; global LV strain

Cardiac Biomarkers

- LDH isoenzyme: increased from 175.3 ± 31.2 to 238.6 ± 56 U/L (p=0.003).
- AST**:** increased from 16.6 ± 4.6 to 29.0 ± 10 U/L (p=0.027).
- CK-MB**:** increased from 13.0 (11.5–24) to 29.1 ± 10.1 U/L (p=0.004).
- hs-Troponin I: increased from 10 (0) to 14.5 ± 6.4 ng/L (p=0.045), exceeding reference thresholds in over 50% of athletes.

In contrast, the HISST-only phase without RWL resulted in significant increases in ALT (26 ± 8.0 to 37.8 ± 11.2 U/L, p=0.024) and total CK (166.9 ± 56.6 to 472 (185–654) U/L, p=0.01), reflecting primarily skeletal muscle stress.

Left Ventricular Function

Echocardiography revealed preserved systolic and diastolic function in both phases. Most athletes showed concentric remodeling, consistent with chronic adaptation to power-based sport. No acute functional impairment was detected.

Follow-Up

No clinically relevant cardiovascular events were reported during a two-year follow-up.

Discussion

This study demonstrates that the combination of RWL and HISST acutely increases heart rate and cardiac biomarkers in elite judokas, while left ventricular systolic function remains preserved.

Cardiac troponin I, considered the gold standard for detecting myocardial injury (Shave et al., 2010), exceeded reference limits in more than half of participants after RWL + HISST. These transient elevations mirror findings in endurance athletes but are novel in the context of combat sports, where intermittent anaerobic exertion predominates.

Potential mechanisms include:

- Dehydration and electrolyte imbalance from RWL, reducing plasma volume and increasing cardiac preload and afterload (Stanley et al., 2015).
- Sympathetic overactivation, leading to increased heart rate and cardiovascular strain.
- Transient cardiomyocyte membrane permeability, oxidative stress, and metabolic shifts, facilitating troponin and enzyme release (Franklin et al., 2020).

Despite biomarker elevations, echocardiographic indices remained normal, supporting the hypothesis that hs-TnI increases reflect reversible myocardial stress rather than necrosis (Sedaghat-Hamedani et al., 2015; Shave et al., 2010)

These results highlight that RWL previously associated with metabolic and muscular consequences (Guilherme Giannini Artioli et al., 2010; Franchini et al., 2012) also constitutes a significant acute cardiovascular stressor. While no short-term adverse events were observed, repetitive cycles of RWL could have cumulative cardiac effects, warranting longitudinal investigation.

Limitations

- Small sample size (n=9) limits generalizability.
- Non-randomized design and individual variations in RWL strategies.
- Limited blood sampling frequency, preventing precise characterization of biomarker kinetics.

Conclusions

Rapid weight loss (~5%) combined with HISST in elite judokas induces significant increases in cardiac biomarkers (LDH isoenzyme, AST, CK-MB, hs-TnI) without impairing left ventricular systolic function. HISST alone primarily affects skeletal muscle markers. No adverse cardiovascular events were observed over a two-year follow-up. These findings underscore the physiological stress of RWL on the cardiovascular system and the

2.8 Progress During the Second Year

During the second year of the PhD, the candidate consolidated and expanded research on the effects of RWL in combat sports, producing internationally relevant studies that significantly contributed to the scientific literature on the subject. At this stage, the research work did not merely replicate preliminary evidence obtained during the pre-doctoral period and the international mobility at Novi Sad but sought to develop a deeper and more integrated understanding of the physiological, metabolic, and cardiovascular consequences of RWL, combining different methodological approaches and multidimensional assessments. In parallel with complementary studies carried out to strengthen the methodological, physiological, and biochemical foundations required for a robust understanding of the phenomenon, the candidate developed three main studies, which constitute the core of the scientific production of the second year.

The **first study** focused on cardiac geometry adaptations in elite judo athletes, with particular attention to sex-based differences. Using two-dimensional echocardiographic analysis, parameters such as left ventricular mass (LVM) and left ventricular mass index (LVMI) were evaluated. Results showed significantly greater increases in males compared to females, confirming that intensive and prolonged training may induce a more pronounced concentric cardiac remodeling in male athletes. These findings are particularly relevant as they provide a detailed picture of structural heart modifications associated with combat sports, representing a fundamental reference point for evaluating the impact of RWL on cardiovascular function. Moreover, the study enhanced understanding of sex-specific physiological differences, suggesting the need to consider sex and individual characteristics when designing training protocols and weight reduction strategies, in order to optimize performance without compromising cardiovascular health.

The **second study** examined the combined effects of sport-specific high-intensity training (HISST) and RWL on markers of muscle damage in male wrestlers. The biomarkers analyzed including myoglobin, creatine kinase (CK), aldolase, and transaminases showed significant increases under both experimental conditions, but the highest values were observed during the RWL phase. These findings confirm that RWL imposes an additional stress on muscle tissue, potentially increasing the risk of acute or cumulative damage, especially when combined with high-intensity workloads. From a practical perspective, the study provides valuable insights for coaches and strength & conditioning practitioners, highlighting the need

to adopt safer and more controlled weight management strategies that balance the goal of weight-category compliance with the preservation of muscle function and overall athletic performance.

The **third study** investigated the combined effects of RWL and HISST on cardiac biomarkers and left ventricular systolic function in elite male judokas. The results revealed significant increases in heart rate, creatine kinase-MB, lactate dehydrogenase, aspartate aminotransferase, and high-sensitivity cardiac troponin during the RWL phase combined with high-intensity training, whereas high-intensity training without RWL induced more limited and less relevant alterations. Despite the evident rise in cardiovascular stress, no impairments in left ventricular systolic function were detected, suggesting that the athletes' hearts remained capable of maintaining mechanical efficiency even under conditions of substantial physical stress. This study represents an important step forward in understanding the acute effects of RWL on the cardiovascular system, demonstrating that RWL induces significant changes in cardiac biomarkers without causing immediate structural damage.

Collectively, these three studies provided a more comprehensive and detailed overview of the physiological, muscular, and cardiovascular consequences of RWL under high-intensity training conditions, integrating quantitative, biochemical, and functional data. The scientific output of the second year thus consolidated and expanded the methodological and theoretical foundations established during the first year, reinforcing the multidimensional approach adopted by the doctoral candidate. The combination of echocardiographic analyses, muscle and cardiac biomarker assessments, and performance evaluations allowed for a deeper understanding of the interactions between physical stress, weight management strategies, and athlete health. This body of work has paved the way for further developments in integrated research on performance and health in combat sports, providing robust evidence for the design of safer and more sustainable training and weight management protocols, while emphasizing the importance of a personalized approach that accounts for individual differences, sex, and competitive level.

2.9 Scientific Outputs and Rationale of the Second-year Program

The second year of the doctoral journey marked a decisive transition from broad-based exploration to a phase of consolidation and depth. Whereas the first year had functioned as a multidimensional training ground an intellectual cross-training in diverse scientific domains this stage was characterized by a more focused yet equally integrated engagement with the central theme of the thesis: the consequences of rapid weight loss in combat sport athletes. The candidate no longer moved merely across complementary projects but instead began to weave together the various strands of methodology, physiology, biochemistry, and applied sport science into a coherent framework of inquiry.

The scientific production of this year was articulated through three original studies that formed the very backbone of the doctoral research. These works, while distinct in scope and methodology, collectively advanced the understanding of how RWL interacts with the demands of high-intensity training and competition, shaping the athlete's cardiovascular system, muscular function, and overall performance. Importantly, these studies did not remain confined to the laboratory but were projected onto the international scientific stage, positioning the candidate's work within the broader debate on health, performance, and ethics in combat sports.

The first study, centered on cardiac geometry in elite judo athletes, offered a novel contribution by emphasizing sex-based differences. Through the use of advanced echocardiographic techniques, parameters such as left ventricular mass and its indexed values revealed patterns of concentric remodeling that were markedly more pronounced in male judokas than in their female counterparts. This insight, beyond its descriptive value, carried profound implications: it underscored the necessity of tailoring training loads and weight-reduction strategies not only to performance goals but also to the physiological characteristics that distinguish male and female athletes. The study thus enriched the discourse on athlete-centered and sex-sensitive approaches, reminding the scientific and sporting communities that health preservation cannot be detached from individual biological identity.

The second study turned its gaze to the intersection of RWL and high-intensity sport-specific training (HISST) in wrestlers, probing the vulnerability of the muscular system under compounded stress. By measuring biomarkers of muscle damage such as creatine kinase, myoglobin, and transaminases, the research demonstrated how the strain of RWL

significantly amplified the damage induced by demanding training protocols. This finding, alarming in its practical consequences, served as a warning to coaches, trainers, and athletes alike: the pursuit of competitive weight categories through extreme practices may come at the cost of compromised muscular integrity, increasing the likelihood of acute injury and long-term performance decline. In highlighting this trade-off, the study bridged the gap between biochemical evidence and applied sport science, transforming raw data into actionable knowledge for the sporting world.

The third study represented perhaps the most ambitious step, addressing the effects of RWL on cardiac biomarkers and systolic function in elite judokas. Here, the integration of functional and biochemical analyses revealed a striking pattern: while RWL combined with high-intensity training precipitated significant elevations in cardiac stress markers such as CK-MB, LDH, and high-sensitivity troponin, the left ventricular systolic function remained preserved. The heart, though evidently strained, maintained its mechanical efficiency. This paradoxical resilience opened new avenues of interpretation: the cardiovascular system of elite athletes appears capable of withstanding acute episodes of stress without immediate structural damage, but the long-term implications of repeated cycles of RWL remain an open and pressing question. The study thus provided not only reassuring insights but also a call to vigilance, urging the scientific community to consider the cumulative risks of these practices.

Taken together, the three studies formed a coherent and multidimensional narrative. They documented how RWL reverberates across the body: reshaping the heart's structure, taxing the muscles beyond their natural thresholds, and stressing the cardiovascular system in ways that are both subtle and profound. The candidate's methodological arsenal ranging from echocardiographic imaging to biochemical assays demonstrated an ability to bridge disciplines, producing evidence that is both precise in detail and broad in implication.

The rationale of the second-year program emerges clearly from this body of work: to move beyond partial or compartmentalized perspectives and toward an integrated understanding of the athlete as a whole. By situating cardiovascular, muscular, and biochemical findings within the same investigative framework, the research underscored the necessity of a holistic approach to performance science. Just as combat sports themselves demand the harmonious coordination of strength, endurance, balance, and resilience, so too must the scientific study of these athletes embrace the complexity of their physiology and psychology.

In conclusion, the second year of the doctoral program was not only a time of consolidation but also of expansion and international projection. The candidate succeeded in producing studies that carried weight in both the academic and practical domains, providing coaches, physicians, and sport scientists with data of direct relevance to their practice. The scientific outputs testify to a maturing research identity: one capable of navigating between laboratory precision and real-world application, between theoretical depth and ethical concern. This stage has laid the foundation for the final phase of the doctoral work, ensuring that the investigation into RWL will not only enrich the scientific literature but also contribute meaningfully to the health and performance of athletes who live, train, and compete under the pressures of weight categories.

Part III – Third Year of the PhD Program

3.1 Description of the Third Year

Although no new primary studies, during the third year of the PhD program, the candidate continued to consolidate the knowledge acquired in the previous two years, focusing primarily on scientific collaboration and the production of complementary studies aimed at strengthening the theoretical and methodological foundations related to the effects of RWL in combat sports. Although no new primary studies on RWL were carried out during this phase, it represented a crucial moment for the expansion of the scientific network, the sharing of data and expertise with other research groups, and the publication of complementary works that allowed for an in-depth exploration of methodological, physiological, metabolic, and psychological aspects, both in sports and in broader contexts of movement and well-being.

Among the main contributions of the third year are multidisciplinary projects conducted in collaboration with national and international universities, particularly the University of Novi Sad (Serbia) and other European institutions. One such project was a review on the impact of physical activity on occupational stress, which deepened knowledge of the benefits of exercise in daily life and professional contexts, highlighting how movement can positively influence not only individual health but also organizational performance. This study strengthened the candidate's ability to analyze complex phenomena, integrating expertise from sport psychology, exercise science, and physiology.

Other studies conducted during this year investigated the combined effect of foam rolling and static stretching on joint mobility and explosive performance, such as vertical jumping. The 5-week intervention showed significant improvements in ankle dorsiflexion and counter-movement jump performance in participants undergoing the FR-SS combination, compared to static stretching alone. These findings contributed to the definition of effective preparation and injury-prevention protocols in high-intensity sports, integrating practical tools for training and rehabilitation.

Finally, a review on overuse injuries in cyclists provided insights into mechanical, postural, and workload-related risk factors, highlighting how the interaction of training volume, biomechanics, and muscle weakness may predispose athletes to chronic injuries. This work broadened the candidate's perspective on prevention strategies and performance

optimization, with transferable implications for combat sports, where load management and muscle damage prevention are critical.

Overall, the third year was characterized as a phase of scientific and methodological consolidation, during which the candidate strengthened skills in experimental design, the management of multidisciplinary collaborations, and the critical interpretation of results. The scientific production of this year validated and expanded the evidence obtained in the first two years, reinforcing the continuity of the research path and creating a solid and integrated framework of knowledge applicable to performance, health, and injury prevention in combat sports, as well as in broader contexts of movement and physical activity.

3.2 Articles published during the third year

Review

The Effects of Physical Activity on Workplace Stress: A Narrative Review

Carlo Rossi[1]*, Valerio Giustino[1], Antonino Patti[1], Flavia Figlioli[1], Alessandra Amato[2], Domenico Savio Salvatore Vicari[1], Marco Gervasi[3], Alberto Canzone[1], Mirka Lukic-Sarkanovic[4,5], Tatjana Trivic[6], Patrik Drid[6], Patrizia Proia[1], Antonino Bianco[1]

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Abstract

Stress can manifest as a distortion of normal body and mind functioning. Moderate stress may enhance work performance, but excessive stress negatively affects workers' mental and physical health. Sedentary jobs, such as office work, may reduce dynamism but can lead to postural and musculoskeletal issues and increase the risk of metabolic or cardiovascular diseases. Non-sedentary jobs, such as manual labor, may cause workplace injuries due to repetitive movements. Physical activity (PA) can mitigate these adverse effects and improve workers' overall health. This narrative review explores workplace stress in sedentary and non-sedentary occupations and examines the beneficial role of PA in enhancing workers' quality of life and productivity, highlighting that the advantages extend beyond individual health to organizational performance.

Original article

Effects of Foam Rolling and Static Stretching on Ankle Dorsiflexion and Jumping Ability: A Randomized Controlled Trial

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This study aimed to assess the impact of a 5-week intervention that combined foam rolling (FR) and static stretching (SS) on ankle dorsiflexion range of motion (ROM). Furthermore, the study evaluated the influence of the intervention on leaping ability utilizing the counter-movement jump test (CMJ). Random assignment was used to allocate fifty-one amateur sports enthusiasts to either the foam rolling + static stretching (FR-SS) group (n = 22; age: 19.3 ± 6.87 years; height: 171 ± 7.91 cm; weight: 66.7 ± 9.52 kg) or the static stretching (SS) group (n = 29; age: 18.5 ± 4.60 years; height: 171 ± 11.5 cm; weight: 68.3 ± 16 kg). A baseline assessment (T0) and an assessment following the 5-week intervention (T1) were carried out. An inertial sensor was used to quantify the ankle joint ROM, and an optical detecting system was used to measure the CMJ performance. Significant differences were found between T0 and T1 in the FR-SS group. Significant group-by-time interaction effects ($F = 14.44$; $p < 0.001$, $\eta^2p = 0.128$) and between-subject effects ($F = 53.5$; $p < 0.001$, $\eta^2p = 0.353$) were found. Significant enhancements in CMJ performance ($p < 0.01$) were noted after the intervention in the FR-SS group. A similar trend was not observed in the SS group. Our findings suggest that a 5-week intervention combining FR with SS leads to greater improvements on ROM and angular velocity of the ankle joint, and on CMJ performance compared to SS alone. If further research confirms these results, FR and SS could be widely used in sports and rehabilitation.

Review

Frequency of Overuse Injuries and Associated Risk Factors in Competitive Road and Off-Road Cyclists: A Narrative Review

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Competitive road and off-road cyclists often train intensely and participate in numerous races within the same season, reducing rest periods and increasing the risk of overuse injuries. This narrative review aimed to identify the most frequent overuse injuries in competitive cyclists and potential associated risk factors. A literature search was conducted in PubMed, Web of Science, and Google Scholar using terms related to overuse injuries in competitive road and off-road cyclists. Recreational cyclists and triathletes were excluded. The main overuse injuries identified were knee pain, low back pain, and buttock pain. Key risk factors included improper bike fitting, high training volume with low cadence, rapidly increasing training loads, prolonged lumbar flexion, anterior pelvic tilt, weakness of abdominal and lumbar muscles, and abnormal body weight. These findings provide insights for coaches and athletes to prevent overuse injuries in competitive cycling.

Keywords: cycling, overuse injuries, risk factors, road cycling, off-road cycling, injury prevention

3.3 Progress during the third year

Among the studies published, a systematic review on doping in combat sports synthesized the available evidence on prevalence, detection methods, prevention strategies, and overall impacts. Data analysis highlighted a significant spread of doping, with substances such as anabolic agents, diuretics, hormone modulators, and NSAIDs frequently detected, particularly in higher weight categories and among athletes practicing RWL. The study also emphasized how psychological and social factors, such as perceived norms and peer acceptance, influence doping behavior. This review represents the first systematic attempt to analyze the phenomenon of doping in combat contexts, providing useful guidance for developing more targeted anti-doping policies and for designing future studies.

In parallel, a narrative review on cardiovascular physiology in judo explored cardiac system adaptations induced by the high-intensity training typical of this discipline. The study highlighted that judokas develop a physiological increase in left ventricular mass and autonomic regulation characterized by parasympathetic predominance, associated with better stress adaptation and more optimal blood pressure values compared to the general population. The evidence confirms that specific training enhances both aerobic and anaerobic capacity, stimulating vascular and cardiac adaptations functional to performance, while also underlining the importance of continuous monitoring to prevent overtraining or potential long-term negative effects.

Completing this set of complementary studies are research investigations on foam rolling and static stretching for improving mobility and neuromuscular performance, as well as narrative reviews on overuse injuries in endurance sports, which helped to better understand the biomechanical and workload factors responsible for injuries and muscle fatigue, providing insights also useful for prevention in combat sports.

Although these studies were not directly focused on RWL, they enabled the doctoral student to develop a multidimensional and integrated approach, considering the interactions among physiology, psychology, injury prevention, and overall athlete health. The scientific output of the third year thus consolidated and expanded the methodological and theoretical knowledge accumulated during the first two years, providing a solid foundation for further investigations on performance and well-being in combat sports.

3.4 - Cardiovascular Adaptations in Judo: A Narrative Review

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Abstract

Judo is a high-intensity combat sport requiring substantial aerobic and anaerobic capacity. Although research has explored the physiological demands of different sports over the years, few studies have investigated the specific cardiovascular adaptations that occur in judoka. This narrative review examines these adaptations by focusing on cardiac function, heart rate variability (HRV), and hemodynamic responses, with the aim of summarizing the effects of judoka training on cardiovascular health and the relationship with athletic performance. Judo training improves aerobic capacity, with VO_2max values similar to those of team sports athletes. It stimulates physiological hypertrophy of the left ventricle, improving cardiac function. Autonomic regulation shows a parasympathetic predominance, indicating better stress adaptation. Vascular adaptations include increased arterial elasticity and optimal blood pressure management, with judoka exhibiting lower blood pressure values than the general population. In summary, these adaptations promote cardiovascular health and improve athletic performance, although monitoring is essential to prevent overtraining and long-term issues.

Keywords: Aerobic Capacity, Cardiac Function, Cardiac Hypertrophy, Heart Rate Variability, Hemodynamic Responses, Judo, Martial Arts, Combat Sports, Exercise

Introduction

Judo is a combat sport that combines technical skills, strength, endurance, and tactics, characterized by intermittent high-intensity efforts alternating with active or passive recovery phases (Weldon et al., 2024). During a match, athletes must perform explosive movements, such as projections or throws, takedowns, and ground fighting phases (ne-waza), followed by recovery periods that vary according to the rhythm of the fight (Nakatani et al., 2024). This

physiological model imposes a high stress on the cardiovascular system, determining specific adaptations that influence both athletic performance and the athlete's long term health (Di Gioia et al., 2024).

Indeed, judo matches last on average about 5 minutes for men and 4 minutes for women, with possible extensions in the event of a draw. During a fight, athletes alternate short periods of explosive efforts, characterized by attacks and defenses, with periods of active or passive recovery. Studies have shown that the efforts-recovery ratio in judo is about 2:1, with high intensity phases lasting 20-30 seconds, followed by short pauses (Ouergui, Franchini, et al., 2020). Furthermore, the heart rate of judokas during a fight can reach values above of 180 beats per minute (bpm), demonstrating the high cardiovascular effort required (Ouergui, Ardigò, et al., 2020).

The presence of repeated explosive actions with short recoveries in judo determine a significant oxygen consumption and a frequent activation of anaerobic lactic metabolism (Detanico et al., 2016). During a match, the heart rate can reach and maintain between 80% and 95% of the maximum heart rate, with peaks close to 100% in moments of maximum effort (Franchini et al., 2011). This implies a high cardiac and metabolic demand, with adaptations that include increased cardiac output, greater oxygen extraction capacity by the muscles and improvements in tolerance to metabolic stress (Franchini et al., 2014).

Hence, cardiovascular adaptations in combat sports such as judo are of particular interest to the scientific community, as these sports require a unique combination of aerobic and anaerobic capacity (Jakovljevic et al., 2024; Maxwell & Oxborough, 2025).

Furthermore, recovery management is crucial to optimize performance and prevent fatigue, with strategies such as cold water immersion having been shown to be effective in improving post-match recovery (Yadav & Jhajhariya, 2020). These data support the need for targeted training to improve athletes' recovery capacity and endurance, ensuring optimal performance during competition.

1.1 Cardiovascular Adaptations in Judo Training

Judo training induces numerous cardiovascular changes, with some peculiarities due to the intermittent nature of the sport (Buchheit & Laursen, 2013). For example, studies conducted on elite judoka have shown significant increases in maximal oxygen consumption (VO_2max), indicating a measurable improvement in aerobic capacity (Ramos-Campo et al., 2017). A high VO_2max is associated with a better ability to maintain high work intensities and a faster recovery between explosive actions (Tomlin & Wenger, 2001). However, judo-specific

training enhances the ability to tolerate and effectively use lactate as an energy source, delaying fatigue and improving performance during high-intensity efforts (Franchini et al., 2011).

Another key aspect is the improvement of heart rate recovery (HRR), an indicator of the efficiency of the autonomic nervous system in restoring the physiological balance post-exertion. Well-trained judo athletes show a more rapid reduction in heart rate after intense exercise, suggesting enhanced vagal control and more efficient recovery compared to less trained judo athletes or practitioners of lower-intensity intermittent sports (Helms et al., 2015).

Heart rate variability (HRV), another key parameter for assessing cardiovascular health and recovery capacity, is improved in elite judoka compared to amateur practitioners (Buchheit & Laursen, 2013). This implies a greater adaptability of the autonomic nervous system to physical efforts, reducing the risk of overtraining and improving blood pressure regulation (Billman, 2011).

1.2 Health and Performance Implications

Cardiovascular adaptations induced by judo not only improve athletic performance but also have positive effects on general health. Regular practice of high-intensity interval sports has been associated with a reduction in the risk of cardiovascular disease, thanks to improvements in endothelial function, blood pressure regulation, and insulin sensitivity (Helms et al., 2015). Furthermore, high-intensity training such as that of judo stimulates the production of vascular growth factors, improving vasodilation and the ability to transport oxygen to tissues (Querido & Sheel, 2007). Physiological adaptations resulting from judo training contribute to athletes' overall health (Torres-Luque et al., 2016).

However, in addition to the cardiovascular benefits, it is essential to consider the weight management strategies adopted by judokas to fit into the established weight categories for competition (Guilherme G Artioli et al., 2010). Weight management is a crucial aspect of judo training, but it can carry to significant risks if not performed in a controlled manner. Athletes often resort to RWL methods, which include caloric restriction and dehydration (Pocecco et al., 2024). Athletes who undergo to RWL can lead to stress to the cardiovascular system (Guilherme G Artioli et al., 2010; Lukic-Sarkanovic et al., 2024). In fact, RWL can

temporarily reduce plasma volume and increase resting heart rate, which may have negative consequences on performance, long-term cardiovascular function (Reale et al., 2018), and metabolic health (Maksimovic et al., 2024).

A previous study have shown that safer weight management strategies, such as evidence-based weight management programs, can reduce the risks associated with extreme weight loss (Guilherme G Artioli et al., 2010). For these reasons, coaches and trainers should adopt safe and effective weight management strategies, minimizing negative effects on cardiovascular function and optimizing post-competition recovery (Guilherme G Artioli et al., 2010).

Based on these knowledges, the aim of this narrative review is to examine the physiological adaptations induced by judo practice, with a focus on cardiac function, HRV, and hemodynamic responses, to understand how training and competition can influence the cardiovascular system of judo athletes, and to examine the relationship with athletic performance.

This narrative review is divided into subsections. The first section examines the cardiovascular demands and physiological responses to judo training, detailing its impact on aerobic and anaerobic capacity, cardiac function, and vascular health. The second section synthesizes existing studies that evaluate cardiovascular training strategies, assessing their effectiveness in enhancing performance and reducing fatigue in judo athletes.

2. Materials and Methods

To retrieve eligible articles, a manual search was conducted on the following databases: PubMed, Google Scholar, and Web of Science. To identify suitable articles, the following search strategy was adopted: (Cardiovascular effects) AND (judo) OR (combat sports); (Cardiovascular health) AND (judo athletes) OR (judo training). This search was extended using the bibliography within the recruited texts. Articles published in English were considered.

A narrative review approach was chosen to present and explain the current understanding of cardiovascular aspects in judo. Unlike systematic reviews or meta-analyses planned as future steps this format allows for an exploratory discussion, highlighting emerging trends, key findings, and gaps in the literature. By mapping these physiological adaptations, this review

provides valuable insights for coaches, sports scientists, and athletes, guiding evidence-based training strategies to optimize cardiovascular health and performance in judo.

3. Results

The literature review highlighted several significant cardiovascular adaptations in judokas, with positive effects on both performance and health. The studies included indicated improvements in aerobic and anaerobic capacity, heart morphological changes, enhanced autonomic regulation, and improved vascular function and blood pressure.

Table 1 - Indicators of Cardiovascular Response in Judokas

Parameter	Value in Judokas	Comparison with Other Disciplines	Study
VO_2max (ml/kg/min)	50-60	Similar to soccer and basketball players	Franchini et al.
Heart Rate Recovery (HRR)	Faster	Better than less intense intermittent sports	Buchheit et al.
Post-exercise Lactate (mmol/L)	Higher, but cleared faster	Better metabolic acidosis regulation	Bonato et al.
HRV (RMSSD, HF)	Increased	Higher parasympathetic activity vs. sedentary	Morales et al.
Maximum Heart Rate (% HRmax)	80-95%, with peaks at 100%	High cardiovascular response to effort	Franchini et al.
Resting Blood Pressure	Lower than the general population	Similar to endurance sports	Kumagai et al.
Endothelial Function	Improved	Greater nitric oxide production	Bescos Garcia.

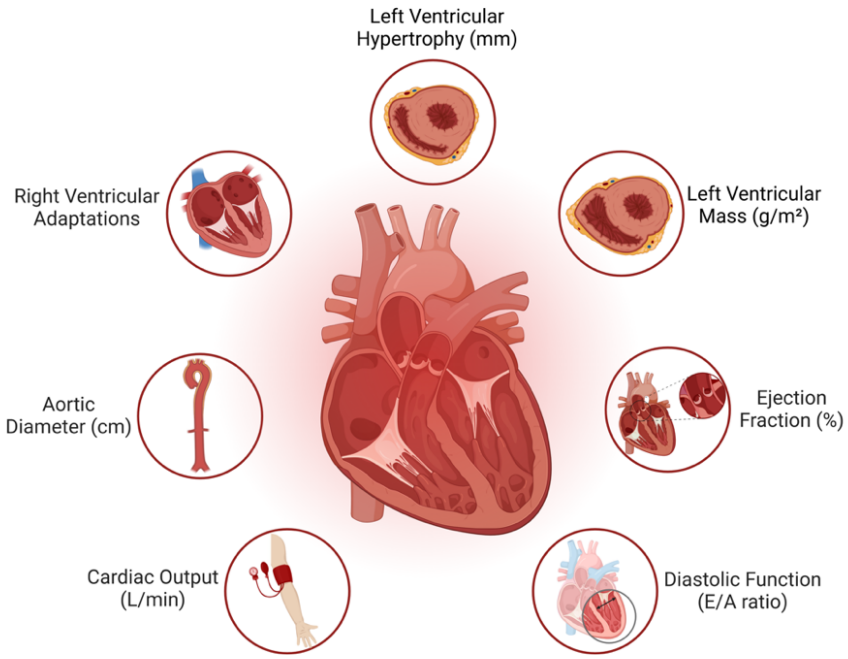
The main indicators of cardiovascular response in judokas are reported in Table 1, and the heart morphological and physiological adaptations in judokas are reported in Table 2 and Figure 1.

VO_2max – Maximal oxygen consumption; HRR – Heart Rate Recovery; HRV – Heart Rate Variability; RMSSD – Root Mean Square of Successive Differences; HF – High Frequency power

Table 2 - Morphological and Physiological Adaptations of the Heart in Judokas

Parameter	Value in Judokas	Comparison with Other Disciplines	Study
Left Ventricular Hypertrophy (mm)	10-14	Similar to endurance athletes	Pelliccia et al.
Left Ventricular Mass (g/m²)	120-140	Comparable to rowing and cycling	Fagard.
Ejection Fraction (%)	55-70	Within normal range for athletes	Pluim et al.
Diastolic Function (E/A ratio)	1.2-1.8	Better filling capacity than sedentary individuals	D'Andrea et al.
Right Ventricular Adaptations	Enhanced	Larger dimensions compared to non-athletes	La Gerche et al.
Aortic Diameter (cm)	3.2-3.8	Adaptive response similar to endurance training	Sharma et al.
Cardiac Output (L/min)	12-20	Greater stroke volume and efficiency to sedentary	Dittrich et al..

Figure 1 - Morphological and Physiological Heart Changes in Judokas



3.1 Aerobic and Anaerobic Capacity

Judo training leads to an increase in both aerobic and anaerobic capacity, enabling athletes to sustain intense and repeated efforts without rapid fatigue.

- **Maximum oxygen consumption (VO_2max):** According to Franchini et al. (2011), elite judokas have mean VO_2max values between 50 and 60 ml/kg/min, values higher than the sedentary population and comparable to those of athletes of team sports such as football or basketball. A higher VO_2max is associated with better oxygen transport and greater resistance to prolonged effort (Franchini et al., 2011).

- **Post-exercise recovery efficiency:** The time required for HRR after exercise is considered an indicator of cardiovascular health. A previous study has shown that judokas have a faster reduction after intense exercise compared to non-athletes, suggesting greater cardiovascular efficiency. This improvement is attributed to increased vagal tone and optimized aerobic recovery capacity (Stanley et al., 2015).

- **Lactate production and disposal:** Well-trained judokas show a greater tolerance to metabolic acidosis, with higher lactate levels but faster clearance times than other athletes (Franchini et al., 2009). This suggests a greater efficiency in the regulation of anaerobic metabolism, essential to sustain repeated explosive efforts (Alioto et al., 2023).

3.2 Heart Morphological Changes

Judo training induces to morphological and physiological adaptations similar to those found in endurance and strength sports.

- **Left ventricular hypertrophy:** Several studies have reported that judokas exhibit an increase in left ventricular mass, a common physiological adaptation in athletes in sports with high cardiovascular demand (Rossi et al., 2024; Slankamenac et al., 2022). This increase in ventricular mass allows for a greater stroke volume, improving the efficiency of oxygen transport during intense physical activity (Tornero-Aguilera et al., 2024).

- **Increased thickness of the interventricular septum:** Although the morphological changes of the heart in judokas are similar to those found in endurance sports, such as cycling or swimming, judokas show an increased thickness of the interventricular

septum, a typical characteristic of power sports (Pelliccia et al., 2023). This reflects the combination of aerobic and anaerobic components typical of judo.

3.3 Autonomic Regulation

The balance between the sympathetic and parasympathetic nervous systems is crucial for recovery and performance in high-intensity sports. Studies indicate that well-trained judokas show a predominance of vagal tone at rest, suggesting better autonomic control.

- **Heart Rate Variability (HRV):** It is known that judokas present significantly higher HRV values than sedentary subjects, with a predominance of parasympathetic activity at rest. This implies a better regulation of the cardiovascular system and a greater capacity to adapt to load variations (Wright et al., 2022).

- **Specific HRV indices:** A previous study reported that in judokas the Root Mean Square of the Successive Differences (RMSSD) and the High Frequency power (HF) indices, indicators of parasympathetic modulation, were higher than in control groups. This suggests a better post-exercise recovery capacity and a reduced predisposition to cardiovascular stress (Rossi et al., 2015).

- **Effect of high-intensity training:** Previous studies have shown that high-intensity interval training (HIIT), often used in judo training programs, improves HRV and cardiovascular efficiency, reducing the risk of overtraining and improving the ability to handle repeated intense efforts (Buchheit & Laursen, 2013).

3.4 Blood Pressure and Vascular Function

Judo training also has positive effects on blood pressure and vascular function, contributing to the prevention of cardiovascular diseases.

- **Reduction of resting blood pressure:** It seems that judokas tend to present lower blood pressure values than the general population, thanks to increased arterial elasticity and reduced peripheral vascular resistance (Dunican, 2017). This adaptation is similar to that observed in endurance athletes and represents a protective factor against hypertension.

- **Acute response to competition:** During a judo match, significant increases in blood pressure and heart rate are observed, with values that can reach 90-100% of maximum heart rate (Cherouveim et al., 2023). However, the return to basal levels occurs rapidly after the fight, suggesting an excellent cardiovascular recovery capacity in well-trained athletes.

- **Improvements in endothelial function:** High intensity training typical of judo stimulates the production of nitric oxide, improving vasodilation and endothelial function (Joyner & Casey, 2015). This contributes to better regulation of blood pressure and an increase in the capacity to transport oxygen to the muscles during exercise.

4. Discussion

This narrative review aimed to examine the physiological adaptations induced by judo practice, with a focus on cardiac function, HRV, and hemodynamic responses, to understand how training and competition can influence the cardiovascular system of judo athletes, and to examine the relationship with athletic performance.

The analysis of cardiovascular adaptations in judo highlights how this sport, characterized by intermittent high-intensity efforts alternating with recovery phases, induces a series of specific physiological changes that optimize athletic performance and improve cardiovascular health. The results of this review confirm that well-trained judoka develop remarkable aerobic and anaerobic capacity, adapted cardiac morphology, enhanced autonomic regulation, improved vascular function, and blood pressure management. However, these changes are not without health implications, requiring a balance between performance and prevention of overtraining or long-term adverse effects.

4.1 Aerobic and Anaerobic Capacity

Improved aerobic and anaerobic capacity is one of the most important adaptations for judoka, who must sustain high-intensity efforts alternating with recovery periods. Research suggests that VO_2max values between 50 and 60 ml/kg/min, such as those observed in judoka, are indicative of a high level of cardiovascular conditioning and endurance (Garbouj et al.,

2016). Although these values are comparable to those observed in other team sports, it is important to emphasize that judo training does not focus only on endurance but also on explosive strategies, such as those needed to execute effective attacks and defenses.

The effects of HIIT on judoka, documented by a previous study, go beyond the simple improvement of aerobic capacity (Calverley et al., 2020; Franchini et al., 2016). Such training also stimulates the ability to manage lactate accumulation, allowing athletes to maintain high performance despite increasing fatigue (Štefanovský et al., 2014). The faster recovery of heart rate post-exertion suggests that judoka have a highly adapted cardiovascular response, which favors a rapid removal of metabolic waste products (Calverley et al., 2020; Franchini et al., 2016; Garbouj et al., 2016). However, the ability to manage metabolic acidosis and lactate management may be variable depending on the intensity and duration of training, as well as the experience of the athlete.

4.2 Heart Morphological Changes

Physiological hypertrophy of the left ventricle, observed in judoka, is a well-known adaptation in many high-intensity and endurance sports (Rossi et al., 2024). The comparability of these changes with those found in endurance sports, such as cycling and running, suggests that judo stimulates a response of the heart that improves the efficiency of blood pumping (Slankamenac et al., 2022). However, unlike purely aerobic sports, judo also requires significant anaerobic and strength work, which could explain the increased thickness of the ventricular walls (Ouergui, Franchini, et al., 2020). This could have direct benefits for the management of explosive efforts and for improving the ability to cope with high-intensity efforts during combat. This type of cardiac hypertrophy appears to be a beneficial adaptation for athletes, but attention must be paid to the risk of cardiovascular overload in the case of excessive training without adequate recovery periods (Franklin et al., 2020). Regular monitoring of cardiovascular health may, therefore, be essential to prevent risks related to hypertension or heart failure in elite judoka.

4.3 Autonomic Regulation

Adaptations in the autonomic regulation of the nervous system are one of the hallmarks of well-trained athletes. In the case of judoka, high parasympathetic activity at rest, indicated by HRV parameters such as RMSSD and HF, suggests a higher ability to handle stress and recover quickly from exertion. These autonomic adaptations are indicative of good

cardiovascular health and a balanced response to load variations during training and competition (Blasco-Lafarga et al., 2013; Campos et al., 2018; Rossi et al., 2015).

The importance of autonomic regulation is particularly evident in judo, where phases of high intensity alternating with periods of active and passive recovery require a rapid transition between states of stress and recovery (Campos et al., 2018). The parasympathetic predominance observed in judoka could not only improve performance but also reduce the risk of cardiovascular disease, contributing to better stress management and the prevention of overtraining (Callister et al., 1990).

4.4 Blood Pressure and Vascular Function

Another positive aspect of cardiovascular adaptations in judo is the improvement of vascular function, which translates into greater arterial elasticity and optimal management of blood pressure. Judokas tend to have lower blood pressure values than the general population, a protective factor that reduces the risk of hypertension and other cardiovascular diseases. However, transient variations in blood pressure and heart rate during combat are normal physiological phenomena, but it is important to monitor them to avoid long-term problems.

Various studies found that the ability to quickly return to baseline post-exercise is a sign of optimal cardiovascular health, but it is important that training is well-balanced to avoid periods of excessive stress on the cardiovascular system (Buchheit & Gindre, 2006; Daanen et al., 2012).

5. Conclusions

Judo, as a high-intensity combat sport, involves a series of cardiovascular adaptations that improve athletes' performance and overall health. The adaptations observed in judoka, including improved aerobic and anaerobic capacity, physiological hypertrophy of the left ventricle, optimal autonomic regulation and improved vascular function, confirm the effectiveness of this sport in inducing positive changes in the cardiovascular system. In particular, the ability to recover quickly after intense stress and the resulting cardiovascular efficiency are indicators of well-balanced training. However, although cardiovascular adaptations are generally favorable, training sessions must be carefully planned to avoid long-term negative effects, such as overtraining or disorders related to excessive intensity. Continuous assessment of athletes' cardiovascular health, combined with a periodized training program, may be the key to optimizing long-term benefits, ensuring high performance and preventing complications.

5.1 Practical Implications and Future Research Directions

The cardiovascular adaptations observed in judo not only improve the performance of athletes but also appear to have positive effects on overall cardiovascular health. However, it is essential to recognize that the intensity of judo training requires careful planning to ensure that the benefits are not offset by potential negative effects (Palumbo et al., 2023). To optimize cardiovascular health while maintaining peak performance, coaches should implement structured periodization, monitor HRV to assess autonomic balance, and ensure adequate recovery strategies. Additionally, safe weight management practices should replace RWL methods to prevent negative cardiovascular consequences (Milovancev et al., 2024; Roklicer, Rossi, Bianco, Stajer, et al., 2022). By integrating these principles, judo training can provide long-term health benefits while reducing the risks associated with excessive training loads.

Future research could focus on evaluating the long-term effects of judo training, considering the relationship between intense sport practice and the prevention or development of cardiovascular diseases. Furthermore, it would be interesting to explore how personalized training strategies, which adequately balance aerobic and anaerobic efforts, can further optimize cardiovascular adaptations, minimizing the risks of overtraining or health problems. Furthermore, it would be optimal to try to perform post-career training to avoid adverse events once the athlete retires from competitive sports.

3.5 - Doping in Combat Sports: A Systematic Review

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Abstract

Purpose: This systematic review synthesizes current research on doping in combat sports, examining prevalence, detection methods, prevention strategies, and overall impact. **Design/methodology/approach:** Of 21 identified articles, six met inclusion criteria. A systematic content analysis was conducted on English-language original research relevant to sport and doping. **Findings:** Doping prevalence is concerning across combat sports, suggesting existing detection and prevention measures may be insufficient. Anabolic agents, diuretics, hormone modulators, and NSAIDs are commonly detected, particularly in heavier weight categories and among athletes engaging in Rapid weight loss (RWL). Psychological and social factors, including social norms and perceived acceptance, influence doping behavior. Beta-agonists were the sixth most frequent cause of adverse analytical findings (AAF) in 2020, while kickboxing had the highest AAF rate among combat sports in 2015. These trends highlight the need for more nuanced regulatory approaches. **Research limitations/implications:** Limited to English-language articles; self-reporting may affect reliability. **Originality/value:** As the first systematic review on doping in combat sports, this study provides key insights for developing anti-doping policies and guiding future research.

Keywords: combat sports, athletes, doping, drug enhancement, exercise, sports integrity

1. Introduction

The use of prohibited substances and methods (Doping) to enhance performance is a significant problem that has plagued different sports, including combat sports (Barnes et al., 2022; Bueno et al., 2022). Various scientific articles (Faiss & Pavot, 2020; Petrou et al., 2022; Sekulic et al., 2017; Vlad et al., 2018) have focused on the fight against doping in sports, addressing the ethical, medical, psychological, and competitive implications . The fight against doping in sports began with tragic events, such as the death of a Danish cyclist in 1960, highlighting the need for a systematic approach to prevent the use of banned substances and protect the health of athletes (Catlin et al., 2008).

The creation of the World Anti-Doping Agency (WADA) in 1999 was a crucial step in the fight against doping, bringing together public authorities and international sports federations to develop more sophisticated detection methods and broaden the range of controlled substances.

Continued progress in the discovery of detection methods for a growing number of doping substances underlines the importance of sustained scientific research, not only to identify athletes who use doping but also to consider the needs of those who may require banned substances for medical reasons (Catlin et al., 2008).

In combat sports, where athletes engage in physically demanding and highly competitive environments, the spectrum of doping poses unique challenges. Combat sports involve unique practices, such as rapid weight loss (RWL), which impose significant physical stress (Artioli et al., 2016; Lukic-Sarkanovic et al., 2024; Maksimovic et al., 2024; Roklicer, Rossi, Bianco, Štajer, et al., 2022). These practices, common in disciplines like boxing and mixed martial arts, also pose distinctive challenges related to doping. A 2016 study stating that RWL methods could be considered doping proposed a proscription of RWL in combat sports as it meets all three World Anti-Doping Agency criteria for a substance or method to be banned from sport (i.e., potential to improve sports performance, potential risk to athletes' health and violation of sporting spirit) (Artioli et al., 2016). The prevalence of doping in combat sports has been documented in various studies, highlighting the need for preventive measures, educational initiatives, and interdisciplinary approaches to effectively address the complexities of doping in this area (Faiss & Pavot, 2020; Vlad et al., 2018). Commonly used drugs in combat sports include anabolic steroids, stimulants, and diuretics, which fall under several pharmacological classes, such as anabolic agents, beta-agonists, and hormone

modulators. The fight against doping involves continuous advances in anti-doping regulations, detection methods, and ethical considerations to maintain fair play and integrity in sports (Vlad et al., 2018). Moreover, Henne (2016), identifies two critical issues in the regulation of combat sports: first, the inherent emphasis on taking physical risks to be competitive, and second, the athletes' willingness to do whatever it takes, including engaging in doping, to achieve success and gain financial and prestige benefits. Anti-doping regulations offer an additional layer of risk that fighters must manage in addition to the dangers associated with doping (Henne, 2016). The prevention of doping in combat sports requires a multifaceted approach that goes beyond testing and enforcement. Educational initiatives aimed at athletes, coaches, and support staff are essential to promoting a culture of clean sport, which can be an additional economic cost in the short term, while if we look at it in the long term, it becomes an investment. Programs that emphasise the ethical, health, and legal consequences of doping can help dissuade people from engaging in these practices (Sekulic et al., 2017). Additionally, creating an environment that supports honest athletes through positive reinforcement and recognition can help reduce the temptation to dope. From an ethical side, the fight against doping raises several important questions. The principle of fair play is at the heart of sport, and doping fundamentally undermines this principle by creating unequal playing conditions. Furthermore, the health risks associated with doping, ranging from cardiovascular problems to hormonal imbalances and psychological effects, pose serious concerns for the well-being of athletes. Policymakers and sports governing bodies must address these ethical challenges while developing regulations that are fair, transparent, and enforceable (Henne, 2016).

There is a significant gap in research concerning the effects of doping among different groups of athletes, highlighting the need for studies that explore the long-term consequences not only on a physical level but also on a psychological and social level to better understand the impact of doping on athletes' health (Marino & Stilo, 2024).

Despite numerous existing recommendations on the treatment of concussions in sports, specific guidance for combat sports is lacking, highlighting the need to develop targeted protocols that address the unique challenges associated with these disciplines (Neidecker et al., 2019).

This systematic review aims to synthesize current research on doping in combat sports, examining the prevalence, detection methods, prevention strategies, and overall impact on sport. With an in-depth analysis of the available literature, this review will provide a comprehensive understanding of the landscape of doping in combat sports and inform future research directions and policy development.

2. Materials and Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards adhered to perform a systematic review and guarantee transparent and thorough reporting (Page et al., 2020). Statement. The current review protocol was registered in the PROSPERO database [Reg. ID CRD42024559690].

2.1 Literature Search Strategy

Three electronic databases were explored for article collection: Web of Science, PubMed, and Scopus. The following string was applied: “Combat sports” AND “athletes” AND “doping” OR “drug enhancement”. Scientific literature from the from inception to July 2024 was considered for this article. The article screening was done in three steps: title reading, abstract reading, and full-text reading. Two reviewers screened the titles and abstract of the record. Notably, investigators were not blinded to the manuscripts, study titles, authors, or associated institutions during the selection process. The screening processes have been summarised via the PRISMA flow diagram shown in the results (figure 1).

2.2. Inclusion and Exclusion Criteria

Only original articles written in English and published in peer-reviewed journals were considered for inclusion in this review. The date limit for the publication period was not set. Review formats of publications have been excluded. Age limitation was not set, and both genders were eligible to be included in the review. The final criterion was that the eligible articles had to be conducted in combat sports and had to include doping within them. Both qualitative and quantitative articles were taken into consideration.

2.3 Data Extraction

Tables (Microsoft Word 2007, Microsoft, Washington, USA) were used to outline important details of the included research, and a narrative description was used to examine the included literature on the subject. Retrieved data was acquired from included articles dealing with doping in combat sports.

2.4. Quality assessment

A Downs and Black checklist was adopted for the current systematic review (Downs & Black, 1998). Furthermore, according to Trac et al., (Trac et al., 2016) the score number 27 was modified, using a modified version of the Downs & Black checklist in which a total score ≥13 (75%) indicates high methodological quality, a score of 11 or 12 (60–74%) indicates moderate quality, and a score ≤ 10 (60%) indicates low quality (Hart et al., 2016; Munn et al., 2010). Two authors separately rated the studies, and the measurement agreement between the raters was evaluated by calculating the interclass correlation coefficient. If there was a disagreement, a third author assisted in the negotiation process to achieve a decision.

3. Results

During the study identification process, 22 studies were selected as studies of potential interest for the review, of which 10 were from WOS, 7 from PubMed, 4 from Scopus, and 1 from other sources. Before the screening phase, 9 duplicate studies were removed, resulting in a total of 13 studies for the screening phase. All 13 studies were reviewed, and nine were excluded at this stage. Subsequently, another 7 were excluded for various reasons; (1) did not involve combat sports, (2) participants were not competitive athletes, and (3) did not involve doping. In the end, 6 studies were included in the review, with 6 study reports included in the final assessment. The average quality of included studies was High (H).

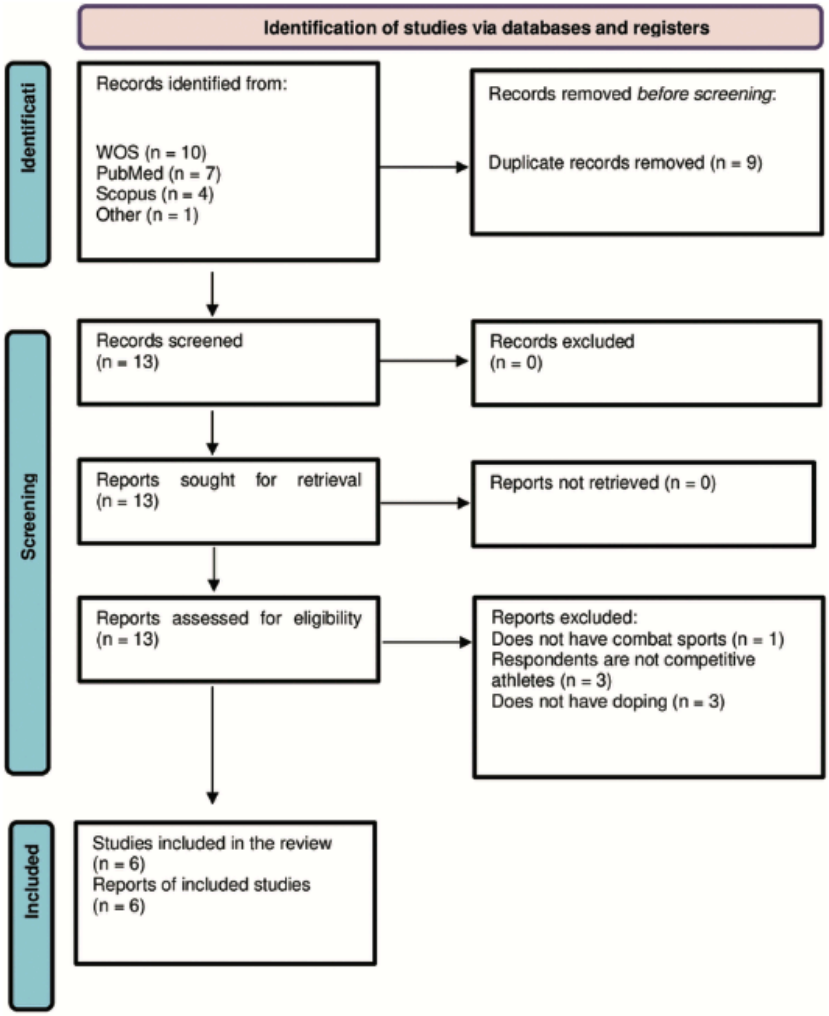

Figure 1. PRISMA flow diagram.

3.1. Sample characteristics

The participants' sample characteristics differed greatly among the six studies that were analyzed for this systematic analysis, indicating a wide range of combat sports disciplines and demographic backgrounds. Sekulic et al., (2017) examined the substance use, diet, and doping practices of 130 kickboxers (92 men and 38 women), with average ages of 21.37 ± 4.83 years for men and 20.31 ± 2.94 years for women (Sekulic et al., 2017). Fares et al., (2020) gathered information on anti-doping rule infractions across various weight classes by analyzing data from 1,070 Ultimate Fighting Championship (UFC) participants, 922 of whom were men and 148 of whom were women (Fares et al., 2021). Petrou et al., (2021) looked at psychological variables impacting doping intentions in 249 mixed martial arts athletes between the ages of 26 and 30 (Petrou et al., 2022). Cheibub et al., (2023) included a small

sample of five female athletes, studying the pharmacokinetics of fenoterol during RWL protocols (Cheibub et al., 2023). Gjelstad et al., (2023) involved a large cohort of 10,418 athletes (7,939 males and 2,479 females) from various sports, focusing on pharmaceutical product use patterns (Gjelstad et al., 2023). Lastly, Henne (2016) considered professional fighters, specifically boxers and MMA athletes, analyzing their reactions to doping allegations and regulatory decisions (Henne, 2016). These diverse samples highlight the varying contexts and challenges of doping across different combat sports.

3.2. Effects of doping on competitive results

Henne, (2016) highlights this complexity, emphasizing the challenges faced by fighters, commissions, and the public (Henne, 2016). This study indicates the frequent disregard of fighters towards commissions and public criticism of commission decisions, while the health problems of fighters are often overlooked during the regulation process (Henne, 2016). This study emphasizes the need for doping regulation that takes into account individual circumstances and athletes' health needs while ensuring the integrity of the sport (Table 1).

The connection between experience in kickboxing and increased likelihood of positive intentions towards doping behavior is emphasized, while better knowledge of nutrition reduces that likelihood. This research also shows a strong association between personal beliefs in the prevalence of doping in kickboxing and potential doping behavior (Sekulic et al., 2017).

3.3. Effects of doping on physiological parameters

A recent 2023 study analyzed drastic weight loss protocols in combat sports, specifically studying fenoterol (Cheibub et al., 2023). The results of this study revealed that athletes who received higher doses of fenoterol had higher excretion peaks than those who received lower doses (Table 1). Additionally, the fenoterol parent compound appeared earlier in urine than its conjugated metabolite, with a sharp peak within the first two to eight hours, followed by a decline. This study highlights the complexity of monitoring and detecting substances in combat sports.

3.4. Effects of doping on psychological parameters

A study explored psychological factors contributing to doping intentions among MMA athletes, emphasizing the complexity of these processes (Petrou et al., 2022). These findings highlight the importance of social norms, self-conscious emotions, and self-regulation in shaping doping intentions, underscoring the need for an interdisciplinary approach to addressing this issue (Table 1).

3.5. Effects of doping on pharmaceutical product use patterns

Patterns of pharmaceutical product use among athletes reveal a significant increase over time. Differences in the use of pharmaceutical products were observed among different sports, indicating the need for tailored approaches to doping regulation in different disciplines (Gjelstad et al., 2023).

A study conducted on UFC athletes indicates significant rates of anti-doping rule violations. Specifically, anabolic agents are often used, particularly in heavier weight categories, necessitating careful regulation and supervision (Fares et al., 2021).

The characteristics of the studies included in the systematic review are visible in Table 1. Analysis of the results of these studies on doping regulation in combat sports highlights the complexity of the issue and the need for a balance between the integrity of the sport and the protection of athletes. Common to all studies is the emphasized importance of an individualized approach to regulation, considering the psycho-social and health needs of athletes, with the imperative of effective monitoring of pharmaceutical substance use to prevent doping and preserve fair play.

Table 1. Results and Outcomes of the Reviewed Studies.

Author	Age	Sample	Methods/treatment	Questionnaire	Parameters	Outcome
Henne., (2016)	N.A.	Professional fighters Box or MMA	Researchers analyzed transcripts of appeal cases before the CSAC and Interview	N.A.	Fighters' Reaction to Doping Allegations	• Open disrespect • Frustration but less confrontation • Often taking a strict position
					Commission's Response to Allegations and Fighters' Arguments	• Sometimes changing decisions under public or fighter pressure • Criticism of the commission's decisions
					Influence of the Public and Media on the Process	• Suspicions of fair treatment of fighters
					Fighters' Health Issues	• Neglecting health problems • Commission's strict stance without taking into account context or individual circumstances

						• Open disrespect • Frustration but less confrontation • Often taking a strict position • Sometimes changing decisions under public or fighter pressure • Criticism of the commission's decisions • Suspicions of fair treatment of fighters • Neglecting health problems • Commission's strict stance without taking into account context or individual circumstances
Sekulic et al., (2017)	21.37±4.83 20.31±2.94	n=130 M=92 F=38	Substance use, nutrition, doping, and ego orientation Questionnaire	QSU KSN KD CTEOSQ	Education, Competitive results, and consumption of dietary supplements Potential doping behavior Opinion on doping Knowledge of nutrition and Sporadic consumption of dietary supplements	
Fares et al., (2020)	N.A.	n=1.070	Search sourcing data from official channels:	N.A.	Weight category	• Heavier categories: More ADRVs • Male fighters: ADRVs increase with

		M= 922 F= 148	USADA & UFC websites to identify fighter information and anti-doping rule violations		Type of ADRV	weight • Most common: Anabolic agents' usage
Petrou et al., (2021)	26-30 years	n=249	A battery of questions derived from WADA's Research Package for Anti-Doping Organisations	Modified Questionnaire	Intentions for doping Past doping use Self-conscious emotions Social norms Self-regulatory efficacy	• Doping intentions: High among MMA athletes • Previous usage: Significant percentage of athletes • Self-consciousness: Varies among athletes regarding doping • Perception of approval: Influences from coaches, teammates, and others • Efficacy: Varying levels in refusing doping offers
Cheibub et al., (2023)	N.A.	F=5	Lima Protocol	N.A.	Concentrations of fenoterol and its sulfonated metabolite	• Fenoterol/Fenoterol sulfate: Detected in treated athletes; not in control

					in urine Excretion profile of fenoterol parent Concentrations of fenoterol parent Time of appearance of a new peak in fenoterol excretion	• Excretion profile: Sharp peak (2-8 hours), followed by decay • Higher doses: Correspond to higher excretion peaks • Weight regain/rehydration: Rapid increase in excretion; variation in peak timing and size
Gjelstad et al., (2023)	20-40 years	n=10.418 M=7.939 F=2.479	DCFs	N.A.	Athlete Level Sport Type Age Group Gender Test Type	• National: Average 1.4 pharmaceuticals per form • Recreational: Average 0.9 pharmaceuticals per form • Speed Skating: Higher pharmaceutical use frequency • Team Sports: Lower pharmaceutical use frequency (varies by sport)

	• Age 20–24: Higher pharmaceutical use frequency • Age 25–29: Higher pharmaceutical use frequency (varies by age group) • Male: Lower pharmaceutical use frequency • Female: Higher pharmaceutical use frequency • During competition: Lower pharmaceutical use frequency • Out of competition: Higher pharmaceutical use frequency

Legend: QSU – the questionnaire on substance use; KSN – the knowledge of sports nutrition questionnaire; KD – the knowledge of doping questionnaire; CTEOSQ – the Croatian version of the task and ego orientation in sport questionnaire; USADA – US Anti-Doping Agency; ADRV – Anti Doping Rule Violation; DCF – Doping control forms; WADA – World anti-doping agency; CSAC – California State Athletic Commission.

The studies on doping across various combat sports reveal a range of performance-enhancing substances and detection complexities. Cheibub et al. (2023) identified fenoterol, a β2-agonist, administered to judo athletes during RWL, with urine tests showing peaks in concentration after administration and rehydration. Fenoterol was administered in doses of 200 μg or 400 μg to elite judo athletes. This highlights the challenges of detecting substances in athletes undergoing extreme weight fluctuation. Similarly, Henne (2015) found anabolic-androgenic steroids (AAS) as the most common substances in combat sports, detected via in-competition urine testing, but procedural issues occasionally complicated test outcomes. The study does not provide precise information about the dosage, frequency, or method of AAS use in these athletes, focusing primarily on the detection process.

In contrast, Petrou et al. (2021) and Sekulic et al. (2017) focused on psychological and social aspects of doping behavior in MMA and kickboxing athletes, respectively, with less emphasis on specific substances or detection methods. Neither study addressed the specific substances used or provided data on the regimen, frequency, or method of doping substance administration, relying instead on self-reported tendencies and attitudes towards doping. Both studies used self-reported questionnaires to assess doping tendencies and attitudes, suggesting a need for more systematic anti-doping education. Meanwhile, Fares et al. (2020) found anabolic agents, hormone modulators, and diuretics as the most common substances among UFC athletes, detected through urine analysis in partnership with USADA, with higher violation rates in heavier weight classes. However, the study does not offer details on the specific regimen or frequency of substance use among these athletes, focusing instead on detection statistics across weight divisions.

Lastly, Gjelstad et al. (2023) analyzed pharmaceutical use among Norwegian athletes, with NSAIDs, analgesics, and anti-asthmatics being the most frequently reported substances. While the study highlights the widespread use of these pharmaceuticals, particularly in endurance sports, it does not provide specific details on the dosage, frequency, or method of administration. Although detection methods were not central to the study, the widespread use

of these pharmaceuticals, especially in endurance sports, reflects their role in managing injuries and respiratory conditions.

All the studies highlight that the specific characteristics of the sport, psychological pressures, and proper education are key factors in combating doping, with additional emphasis on detection challenges and procedural complications in antidoping-processes.

3. Discussion

The goal of this systematic review was to synthesize the current research on doping in combat sports, examining the prevalence, detection methods, prevention strategies, and overall impact of doping on combat sports. Combat sports doping regulation presents a multifaceted challenge that necessitates balancing athlete health and sports integrity.

Comparing the results of our review of doping in combat sports with those of other individual sports, both similarities and significant differences emerge. For example, sports such as cycling, weightlifting and track and field show a prevalence of doping similar to that found in combat sports, with widespread use of anabolic and stimulant agents to enhance physical performance (Barthel et al., 2010; Delbeke, 1996). However, unlike combat sports, where RWL is a critical factor, in other individual sports there is a more marked use of substances to improve endurance or pure strength. For example, in cycling, the use of EPO to increase aerobic capacity has historically been a greater concern (Palmieri et al., 2019). The diversity in the methods and motivations of doping highlights the need for specific regulatory approaches for each sport, considering each discipline's physiological peculiarities and competitive needs.

It is important to note that while sports like cycling have faced challenges with endurance-focused doping, combat sports present unique detection challenges due to the RWL practices that many athletes employ. RWL often leads to the use of diuretics and other banned substances that are harder to detect due to fluctuations in body composition and fluid levels. Detection methods must therefore be tailored specifically to these unique conditions, using more advanced techniques such as hair testing, which can provide a longer detection window

for certain substances, as compared to traditional blood and urine tests (Cadwallader et al., 2010; Roklicer et al., 2020).

In team sports, such as football, rugby and basketball, doping presents different dynamics compared to combat sports. Pressure to improve performance is often shared within the group, and the use of performance-enhancing drugs can be influenced by team dynamics and group culture (Fehske & Lukas, 2020; Graf-Baumann, 2006; Sekulic et al., 2014). While in combat sports the use of doping is often linked to individual performance and exceeding weight categories, in team sports the focus can be on improving the overall endurance and recovery of athletes. For example, the use of anabolic steroids and other substances for muscle recovery has been documented in sports such as rugby and American football (Whitaker & Backhouse, 2017). However, as in combat sports, doping prevention in team sports requires a multifactorial approach that includes education, rigorous supervision and a supportive environment for athletes. Understanding the similarities and differences in doping use between individual and team sports can provide important insights into the development of more effective and targeted anti-doping policies.
The World Anti-Doping Agency has also faced challenges in addressing the specific requirements of combat sports. While WADA has implemented strict regulations regarding the use of diuretics and other performance-enhancing drugs, the inherent pressure on combat sports athletes to lose weight rapidly presents difficulties in effective regulation and monitoring. WADA’s efforts are complicated further by the fact that athletes often hide the use of diuretics in their RWL strategies. The inclusion of hair tests in doping control could be a valuable addition to improve detection accuracy and widen the detection window for substances used during rapid weight changes (Cadwallader et al., 2010; Roklicer et al., 2020).

A study has revealed that the most commonly used medications among Norwegian athletes include analgesics and anti-asthma medications, highlighting the need to monitor the use of these substances both in and out of competition, as they may affect athletes' performance and health (Gjelstad et al., 2023).
The higher prevalence of drug use among athletes at the national level compared to recreational athletes suggests that professional athletes may be more likely to use performance-enhancing drugs, a phenomenon that may require specific prevention interventions for this group of athletes.

The use of anti-asthma medications among athletes exposed to harsh environmental conditions, such as cold and intense training, highlights the importance of considering the specific needs of different sports disciplines when designing measures to prevent doping and athlete health (Gjelstad et al., 2023).

Combat sports doping regulation is a complex issue that demands finding a compromise between protecting players' health and maintaining the sport's integrity. Henne (2016) highlights the challenges of this role by drawing attention to the health problems that fighters frequently ignore and the public's and athletes' frequent disrespect for commission decisions (Henne, 2016). This underlines the urgent need for doping control laws that preserve the integrity of the sport while being considerate of each individual's situation and medical requirements. The World Anti-Doping Code aims to protect athletes' right to participate in doping-free sports and ensure harmonized anti-doping programs (*World Anti-Doping Code 2021 (https://www.wada-ama.org/sites/default/files/resources/files/2021_wada_code.pdf)*). However, resolute action is required to restore fair play throughout the sports industry and provide ethics and fair play education for young athletes (Vlad et al., 2018).

An area that remains under-researched is the frequency of adverse analytical findings (AAFs) in combat sports, which could offer valuable insight into the effectiveness of current detection methods. There is also little detailed information on the specific drugs and substances most commonly used in combat sports, such as anabolic steroids, SARMs, and other agents used for weight management or performance enhancement. Understanding the frequency and types of substances detected in combat sports is essential for developing more targeted prevention strategies (Catlin et al., 2008).

The findings from various studies illuminate different aspects of doping in combat sports: Sekulic et al., (2017) suggest that experience in kickboxing correlates with positive intentions toward doping, whereas better nutritional knowledge can reduce these intentions (Sekulic et al., 2017), indicating the importance of nutrition-focused educational programs to reduce doping behaviors. Cheibub et al., (2023) provide insights into the pharmacokinetics of fenoterol, revealing the complexity of monitoring and detecting doping substances (Cheibub et al., 2023). The study's findings about the excretion patterns of fenoterol underscore the necessity for advanced and precise monitoring techniques to successfully implement anti-doping regulations. According to Gjelstad et al., (2023), athletes' usage of pharmacological

products has increased significantly over time, but with differences between sports (Gjelstad et al., 2023). This emphasizes the need for customized doping policies that consider the unique requirements and dangers connected to every combat sports discipline. Fares et al., (2021) reveal a significant prevalence of anti-doping rule violations among UFC athletes, particularly the use of anabolic agents in heavier weight categories (Fares et al., 2021). To reduce the frequency of doping, strict control and supervision are necessary, particularly in higher-weight classes. Petrou et al., (2022) explored the psychological underpinnings of doping intentions among MMA athletes, highlighting the role of social norms, self-conscious emotions, and self-regulation (Petrou et al., 2022).

Considering that combat sports have particular peculiarities, due to the nature of the study itself, such as RWL techniques (Roklicer, Rossi, Bianco, Štajer, et al., 2022; Roklicer, Rossi, Bianco, Stajer, et al., 2022) there are specific situations that come to be analysed, for example, diuretics are prohibited by WADA (Cadwallader et al., 2010; Roklicer et al., 2020) and are responsible for many cases of doping in combat sports (Halabchi, 2008). In 2005, WADA conducted that there are significant percentages of doping in some combat sports, such as boxing, taekwondo and wrestling (Halabchi, 2008). The literature suggests that RWL techniques should be included as a doping procedure and therefore banned (Artioli et al., 2016). However, this has not yet happened.

These findings suggest that an interdisciplinary approach, incorporating psychological and social dimensions, is essential to address doping behavior effectively. Ultimately, the fight against doping in combat sports requires a multi-faceted approach. The results of a study on the prevalence of neuroenhancement pharmacology (PN) among university students suggest that the search for substances to improve performance, both cognitive and physical, is a significant phenomenon that deserves attention, as it presents parallels with the dynamics of doping in sport. The decrease in PN prevalence in 2021, together with the decrease in cannabis use, indicates that external circumstances, such as the COVID-19 pandemic, may influence students' behaviors regarding substance use, highlighting the need for further studies to understand how these factors may also influence sports doping (Dietz et al., 2022). Despite the observed decrease, the prevalence of PN of approximately 8% in 2021 highlights an important persistent issue that requires the implementation of prevention and awareness strategies, similar to what is needed to address the phenomenon of doping among athletes (Dietz et al., 2022). Doping prevention measures can increase young people's awareness of

health and fitness, highlighting the importance of educational programs that encourage healthy lifestyles and critical use of substances (Pöppel, 2021). Many prevention programs have not led to lasting changes in behavior; therefore, it is crucial to develop personalized approaches that better meet the needs of young athletes, to ensure more effective protection against doping (Pöppel, 2021).

Strengths and limitations

Comprehensive analysis may be both a strength and limitation of the study because it incorporates research from various disciplines such as psychology, pharmacology, and nutrition and offers a multi-faceted understanding of the issue, but at the same time, the included studies vary in their focus, methodology, and scope. Furthermore, another strength is inclusion of numerous combat sports and both men and women, broadening this research to any martial art athlete. Additionally, the search strategy for articles was limited to those written in English. The sincerity of athletes about their experience in doping could have influenced the final results of the research. Given that a small number of studies passed the criteria of our study, further studies are needed to make the results more relevant. Even though we are aware of the mentioned research limitations, the presented results can be valuable as a valid basis for further, compatible research.

4. Conclusions

In conclusion, the regulation of doping in combat sports requires an advanced approach that balances the integrity of the sport with the health and well-being of the athletes. The findings from this systematic review underscore the complexity of doping behaviors and the necessity for tailored, interdisciplinary strategies to effectively combat this issue. Doping in combat sports is influenced by a myriad of factors, including psychological, social, and physiological aspects, which necessitate a multifaceted regulatory approach. Future research and policy development should focus on enhancing education to improve athletes' understanding of the risks and consequences of doping. Implementing comprehensive educational programs and refining monitoring techniques are crucial for accurate detection and prevention. Additionally, addressing the psychological and social factors influencing doping can provide a more effective deterrent. Through creating a comprehensive regulatory framework that

incorporates these elements, the sport can maintain its integrity while ensuring the health and well-being of its athletes.

3.6 International mobility – University of Central Florida, Orlando, Florida, USA

During the final phase of the second year and for most of the third year of the doctoral program, the doctoral student had the opportunity to conduct a research period at the University of Central Florida (UCF, Orlando, USA) (October 2024 – April 2025) in the laboratory of Professor David Fukuda. This experience represented a pivotal moment in the development of the student's scientific and methodological path. This six-month period abroad provided a highly stimulating environment, allowing the consolidation of previously acquired skills, the exploration of new research methodologies, and the initiation of international scientific collaborations.

The main objective of this experience was to more deeply investigate the physiological, metabolic, and cardiovascular consequences of RWL in combat sport athletes, expanding the knowledge developed during the first and second years of the doctoral program. The stay at UCF allowed access to state-of-the-art facilities and laboratories equipped with innovative tools for assessing body composition, muscular and cardiovascular function, and biomarkers of muscle damage. In particular, the use of Bioelectrical Impedance Analysis (BIA) enabled accurate measurements of lean mass, fat mass, and body hydration, providing crucial data to understand the effects of RWL on body composition and metabolic balance in athletes. Simultaneously, sessions of muscle and cardiac ultrasound allowed direct investigation of tissue morphology and cardiac geometry remodeling induced by competitive training, integrating these data with physiological biomarkers collected during experiments.

The research period was characterized by a strong multidisciplinary approach. The doctoral student had the opportunity to interact with various research groups, participate in seminars and workshops, and closely observe innovative experimental protocols. This interaction facilitated the acquisition of advanced skills in protocol design and standardization, collection and management of complex data from multiple sources, and their subsequent statistical analysis. Field experience also allowed the comparison of different methodologies, integrating quantitative and qualitative approaches and developing a more comprehensive understanding of the physiological, metabolic, and psychological phenomena associated with weight-category combat sports.

During this period, the doctoral student worked on studies all in progress, focusing on core topics of the doctoral program, such as the assessment of muscle damage, cardiovascular responses, and changes in body composition following RWL and high-intensity training. Collaboration with UCF laboratories enabled the testing of advanced experimental protocols and the collection of high-quality data, providing a solid foundation for future international scientific publications. Interaction with local researchers and experts in sports physiology, nutrition, and rehabilitation fostered mutual enrichment of skills and paved the way for joint projects and international scientific collaborations, strengthening the doctoral student's academic network and expanding future research opportunities.

A particularly notable aspect of this experience was active involvement in the preparation and submission of two abstracts for high-profile international conferences. The first was prepared for the ACSM Annual Meeting in Atlanta, one of the most important global conferences in exercise science and physiology. The second abstract was submitted to the IEPRS Conference at the UCF Institute of Exercise Physiology and Rehabilitation Science, providing an opportunity for direct interaction with international experts and researchers. Preparing these works required in-depth analysis of preliminary data, contextualization of results within the international scientific literature, and scientific writing according to international standards. These activities allowed the doctoral student to present preliminary findings and receive critical feedback from experts, significantly contributing to the quality and relevance of the research.

During the UCF period, the doctoral student deepened the combined use of BIA, muscle and cardiac ultrasound, and muscle damage biomarker analysis, developing an integrated methodology for studying combat sports. This approach allowed a better understanding of the interactions between high-intensity training, RWL, and physiological adaptations, providing new perspectives for risk prevention and optimization of athlete performance. The experience also fostered personal and professional growth, promoting greater autonomy in protocol design, data management, and scientific writing essential elements for training an internationally competent researcher.

In summary, the period at the University of Central Florida represented a fundamental milestone in the doctoral journey. It allowed the consolidation of methodological skills, hands-on experience with advanced tools and protocols, initiation of international collaborations, and preparation of abstracts for world-class conferences. Furthermore, it

enabled the continuation of ongoing studies in performance, muscle damage, body composition, and cardiovascular function in combat sports, creating a solid foundation for future scientific publications and further research developments. The experience reinforced the doctoral student's multidimensional and integrated approach, confirming the importance of combining theoretical training, practical experimentation, and international networking to effectively address complex issues such as RWL in combat sports.

3.7 Research and Practical Activities at Villa Sarina Medical Center

During the three-year doctoral program, the candidate conducted an extensive portion of research and practical activities at *Villa Sarina* Medical Center in Alcamo, an established center of excellence in osteoarticular, cardiological, and pelvic floor physiotherapy and rehabilitation. The center is located in a late 19th-century villa, set within a park of notable environmental and aesthetic value, providing a unique combination of historical architecture and modern clinical infrastructure. The facility offers a variety of rehabilitative spaces, including a computer-equipped Technogym gym, specialized therapy rooms, and outdoor areas for functional training, enabling both comprehensive patient care and the application of advanced research methodologies.

Within this context, the candidate was integrated into a multidisciplinary team composed of physiotherapists, medical specialists, and healthcare staff, fostering a collaborative environment in which theoretical knowledge and practical expertise were combined to optimize patient outcomes. The candidate's responsibilities involved the design, implementation, and supervision of motor rehabilitation programs, tailored to patients' individual functional needs. These programs encompassed a broad spectrum of interventions, including proprioceptive exercises, muscle strengthening, postural re-education, balance training, and targeted functional mobility exercises. By continuously monitoring patient progress and adapting protocols accordingly, the candidate ensured that interventions were both evidence-based and responsive to each patient's recovery trajectory.

The candidate's work extensively involved the use of rehabilitation technologies and instrumentation, which were fundamental in supporting objective assessment and personalized intervention. Equipment utilized included body composition analyzers, balance boards, proprioceptive platforms, cones, ankle weights, treadmills, stationary bikes, vertical traction devices, and resistance machines such as leg press, chest press, shoulder press, and various core-strengthening apparatuses. The integration of these technologies with direct clinical observation allowed for precise evaluation of motor function, muscle activation, postural control, and patient adherence, providing a robust framework for data-driven decision-making in rehabilitation.

In addition to practical patient care, the candidate contributed to the documentation and analysis of patient outcomes, systematically recording functional metrics, rehabilitation progress, and the response to specific interventions. This process facilitated a detailed understanding of the effects of individualized rehabilitation protocols and allowed for iterative optimization of therapeutic strategies. Furthermore, the candidate actively participated in interdisciplinary discussions and case reviews, providing input on the design of therapeutic pathways and the adaptation of clinical protocols based on observed outcomes and emerging evidence.

This immersive experience significantly enhanced the candidate's research and professional competencies, consolidating skills in clinical assessment, protocol development, and data-driven decision-making. The integration of scientific methodology with practical application fostered a rigorous evidence-based approach, while working within a structured, multidisciplinary environment strengthened critical thinking, time management, problem-solving, and scientific communication skills. Through this engagement, the candidate developed a deep understanding of the interplay between functional rehabilitation, patient-specific adaptations, and technological support, contributing both to personal professional growth and to the advancement of knowledge in physiotherapy and motor rehabilitation.

Overall, the three-year tenure at *Villa Sarina* provided a comprehensive platform for the candidate to bridge research and clinical practice, enabling the acquisition of advanced technical skills, experiential learning in patient-centered care, and the development of a multifaceted perspective on motor rehabilitation that integrates empirical evidence, technological tools, and collaborative expertise. This experience represents a cornerstone of the candidate's doctoral training, reflecting both the depth of practical engagement and the application of rigorous scientific principles in a real-world clinical setting.

3.8 Scientific Outputs and Rationale of the Third-year Program

The third year of the doctoral program represented a moment of synthesis and projection, in which the knowledge, methods, and collaborations developed in the previous years were consolidated and translated into tangible scientific outputs. Unlike the first and second years characterized by the design and implementation of primary studies directly focused on rapid weight loss (RWL) this phase was distinguished by the integration of complementary works, international collaborations, and clinical experiences that expanded both the scope and the depth of the research trajectory.

A pivotal element of this year was the six-month international mobility period at the University of Central Florida (UCF), under the supervision of Professor David Fukuda. This experience allowed the doctoral candidate to deepen the investigation of RWL through advanced methodologies, such as bioelectrical impedance analysis (BIA), muscle and cardiac ultrasound, and biomarker profiling. The possibility of accessing state-of-the-art laboratories and interacting daily with a multidisciplinary community of researchers provided an invaluable platform for methodological refinement and international networking. The preparation of abstracts for the ACSM Annual Meeting in Atlanta and the IEPRS Conference in Orlando represented not only an opportunity to disseminate preliminary findings but also an important exercise in scientific writing, positioning the candidate's research within the global dialogue on sports physiology and combat sports. The rationale behind these outputs lies in the strategic choice to present and validate the research path on high-profile stages, thus ensuring critical feedback from international experts and reinforcing the credibility and visibility of the project.

Parallel to this, the candidate's long-standing involvement at Villa Sarina Medical Center provided a unique opportunity to bridge academic research with clinical practice. The design and supervision of rehabilitation programs, combined with the systematic use of advanced instrumentation such as proprioceptive platforms, resistance machines, and body composition analyzers, enriched the doctoral experience with a strong translational dimension. Here, the rationale was twofold: on one hand, to strengthen practical competencies in patient-centered rehabilitation, and on the other, to develop an evidence-based framework transferable to athletic contexts, particularly in relation to postural control, muscle re-education, and injury prevention. The continuous dialogue with a multidisciplinary

team of physiotherapists and physicians further enhanced the candidate's ability to interpret complex clinical cases and adapt protocols in real time skills that are increasingly indispensable in sports science research.

In terms of scientific production, the third year was marked by a series of complementary studies and reviews that broadened the analytical horizon of the doctoral project. The collaboration with the University of Novi Sad and other European partners led to a comprehensive review on the effects of physical activity on occupational stress, highlighting the systemic role of exercise in enhancing not only physical health but also psychological resilience and organizational performance. This contribution, though not directly focused on combat sports, aligned with the overarching rationale of the doctoral program: to situate RWL and athletic performance within the broader framework of human adaptation to stress, both physical and psychological.

Another significant output was the experimental study on the combined effects of foam rolling and static stretching on mobility and explosive performance. The results, showing improvements in ankle dorsiflexion and vertical jump capacity, provided practical guidelines for warm-up and recovery protocols in high-intensity sports. Similarly, the review on overuse injuries in cyclists shed light on biomechanical and workload-related risk factors, offering preventive insights highly relevant for combat sports, where repetitive load and improper recovery strategies can compromise performance and longevity. Both works, while distinct in discipline, shared a common rationale: to enrich the methodological toolkit available for performance optimization and injury prevention, thereby reinforcing the candidate's capacity to interpret and manage the multidimensional demands of athletic practice.

Collectively, the outputs of the third year illustrate a doctoral trajectory that evolved from specific case studies on RWL to a more integrated and multidisciplinary research vision. The rationale underpinning this evolution was clear: to consolidate methodological rigor, expand the field of application through international and clinical experiences, and translate scientific evidence into practical guidelines for health, performance, and injury prevention. By the end of the third year, the candidate had not only strengthened the theoretical foundations laid in the first two years but also established a solid network of collaborations and a diversified scientific portfolio. This ensured that the research on RWL was embedded within a broader ecosystem of knowledge that spans from elite sport to clinical rehabilitation, from physiological biomarkers to psychological well-being.

In conclusion, the third year represented a crucial milestone in the doctoral journey, where the convergence of international exposure, clinical application, and multidisciplinary collaboration produced a body of scientific outputs that validated the integrated approach adopted throughout the program. The rationale of this phase was not to multiply isolated findings but to create coherence and continuity, weaving together diverse strands of evidence into a robust framework that both advances the scientific understanding of RWL and provides actionable insights for athletes, clinicians, and researchers alike.

Part IV – Future Perspectives

4.1 – Summary of Results, Scientific Implications, and Future Perspectives

The doctoral program represented a highly significant educational and scientific experience, aimed at gaining an integrated and multidimensional understanding of the effects of RWL in weight-category combat sports, with particular attention to the physiological, metabolic, cardiovascular, and psychological consequences for athletes. The entire research path developed through several phases, involving the doctoral student in preliminary studies, original experiments, national and international collaborations, and periods of research abroad, contributing to the consolidation of a rigorous and innovative scientific approach.

From the very beginning of the doctoral program, the research focused on the integrated study of RWL, aiming not only to assess its effects on physical performance but also to investigate cardiovascular, metabolic, and psychological parameters. Studies conducted during the first year established the theoretical and methodological foundations: a systematic review on the role of psychological factors in judo highlighted how anxiety, motivation, emotional states, and perceived effort significantly influence competitive performance. In parallel, experimental studies on Greco-Roman wrestlers and Olympic wrestling athletes provided evidence of RWL's impact on heart rate, recovery, grip strength, and muscle damage, outlining a multidimensional picture of the physiological and psychological effects of rapid weight reduction.

The second year of the doctoral program marked a phase of consolidation and deepening of the research, with the publication of internationally relevant studies focusing on the cardiovascular and muscular consequences of RWL. In particular, three main studies allowed in-depth exploration of:

1. Changes in cardiac geometry in elite judokas, highlighting significant differences between males and females and indicating a more pronounced concentric remodeling in males;
2. The combined impact of sport-specific high-intensity training (HISST) and RWL on muscle damage markers, showing that RWL significantly increases biomarkers of muscle stress compared to training without weight loss;

3. The effects of RWL and HISST on cardiac biomarkers and left ventricular function, demonstrating that although RWL increases cardiovascular stress, left ventricular systolic function remains preserved.

These studies integrated physiological, metabolic, and psychological knowledge, offering a comprehensive view of the risks and management strategies for RWL in combat sports. In parallel, the doctoral student conducted numerous complementary studies aimed at strengthening methodological foundations and exploring additional areas of interest, including general cardiovascular adaptations, muscular performance, postural biomechanics, and overuse injury risk.

The next phase, which involved an international research period at the University of Central Florida (UCF, Orlando, USA), represented a further qualitative leap in scientific training. During approximately six months, between the end of the second year and mid-third year, the doctoral student worked with state-of-the-art laboratories and innovative experimental protocols, employing BIA, muscle and cardiac ultrasound, and muscle damage biomarkers, while exploring the interactions between high-intensity training, RWL, and body composition. The UCF period also enabled the development of international collaborations, observation of specialized laboratories, discussion of advanced experimental protocols, and initiation of ongoing joint studies. During this experience, the doctoral student prepared two abstracts for high-level international conferences: the ACSM Annual Meeting in Atlanta and the IEPRS Conference at the UCF Institute of Exercise Physiology and Rehabilitation Science, allowing preliminary data to be discussed with international experts and receive critical feedback.

The third year of the doctoral program further consolidated the multidisciplinary and integrated research approach. In addition to continuing and completing ongoing studies, the doctoral student collaborated on complementary studies in various areas: analysis of the effects of physical activity on occupational stress, evaluation of muscle recovery techniques (foam rolling and stretching), prevention of overuse injuries in competitive cycling, and investigations on doping and RWL practices in combat sports. These studies helped integrate knowledge on the role of physical preparation and workload management in athlete performance and health, broadening the scientific perspective beyond competitive contexts to include psychophysiological aspects, injury prevention, and training optimization.

Overall, the doctoral research significantly contributed to the international literature on combat sports and RWL, providing a comprehensive and multidimensional view of the effects of rapid weight reduction and high-intensity training strategies. The results have practical relevance for coaches, athletes, and health professionals, suggesting the need for controlled and safe protocols for managing weight and physiological and psychological stress.

From a methodological perspective, the program consolidated advanced skills in experimental design, multimodal data collection, statistical analysis, scientific writing, and international networking, all fundamental for training an independent researcher. The international experience and collaborations established a solid foundation for future joint research projects, enhancing the relevance and impact of the produced results.

In conclusion, the doctoral program allowed the development of an integrated and multidisciplinary approach to research in combat sports, combining physiological, metabolic, cardiological, and psychological expertise, with a constant connection between fundamental research and practical applications. The studies produced, international collaborations, and laboratory experiences enabled a comprehensive understanding of the consequences of RWL and high-intensity training, laying a solid foundation for further scientific developments and the promotion of safe and effective practices in competitive sports. This work represents a significant contribution to understanding the complex phenomena related to performance and athlete health in combat sports, opening the way to new research directions, the development of optimal protocols, and the dissemination of scientific knowledge at an international level.

4.2 General Conclusion

The collective findings presented in this thesis provide a comprehensive and integrated perspective on the physiological, metabolic, and cardiovascular consequences associated with rapid weight loss (RWL) practices in combat sports. Through a combination of experimental evidence, cross-sectional analyses, and broader theoretical reflections on cardiovascular adaptations in judo, this work underscores the complex interplay between high-performance training stimuli and the acute and chronic stressors imposed by aggressive weight management methods.

Overall, the evidence reveals a consistent and multifaceted pattern: while combat sports training promotes beneficial adaptations across several physiological systems, including improved aerobic capacity, favorable cardiac remodeling, and enhanced autonomic regulation, the practice of RWL introduces significant perturbations that compromise both immediate performance outcomes and long-term athlete health. These perturbations span metabolic dysregulation, acute increases in muscle and cardiac biomarkers, alterations in cardiovascular load, and, in the long term, greater susceptibility to conditions such as metabolic syndrome.

From a metabolic standpoint, former elite combat athletes with a history of RWL display a markedly higher prevalence of metabolic syndrome and related cardiometabolic risk factors. These findings suggest that the cumulative burden of repeated weight cycling during an athletic career may predispose athletes to delayed yet clinically relevant health consequences. This phenomenon underscores the need to reconsider the assumption that elite athletes, due to their high fitness levels, are inherently protected from chronic metabolic disorders.

Cardiovascular analyses further reveal that RWL amplifies physiological strain during high-intensity sport-specific training. The acute increases in cardiac biomarkers, such as high-sensitivity troponin and creatine kinase-MB, observed in the combined RWL and HISST condition point toward a transient yet substantial stress imposed on cardiac tissues. Although left ventricular systolic function remains preserved, these biochemical fluctuations raise questions about the long-term implications of repeated bouts of elevated cardiac stress. Echo-based evidence of sex-specific differences in left ventricular geometry among elite judokas further highlights the complexity of cardiovascular adaptations and suggests that male athletes, due to their typically more pronounced hypertrophic response, may experience a different trajectory of cardiovascular remodeling under the dual pressures of high-intensity training and weight reduction.

Neuromuscular and biochemical findings converge to show that RWL exacerbates muscle damage beyond the effects of high-intensity training alone. This amplified response reflects both the metabolic cost of dehydration and caloric restriction and the physiological difficulty of sustaining optimal performance under reduced energy availability. These findings are particularly relevant because muscle damage and impaired recovery may influence technical execution, increase injury risk, and reduce competitive readiness, paradoxically undermining the very performance advantages athletes seek through cutting weight.

Psychophysiological responses, including increased anxiety, decreased perceived energy, and impaired mood regulation, add a further dimension to the overall impact of RWL. Together, these effects indicate that the practice influences not only physiological systems but also the cognitive and emotional domains that are critical for tactical decision-making and competitive composure in combat sports.

Overall, this thesis advances a unified conclusion: RWL is a high-risk practice whose acute and chronic effects can no longer be considered a marginal or unavoidable component of combat sport culture. The evidence demonstrates that while athletes may temporarily benefit from competing in a lower weight category, the physiological costs, particularly when accumulated over years, are substantial and may outweigh the competitive advantages.

In light of these findings, several implications emerge for practice, policy, and future research. Sports federations should consider implementing stricter regulations to limit extreme weight cutting, possibly through competition-day weigh-ins, hydration testing, or longitudinal body composition monitoring. Coaches and support staff should prioritize evidence-based nutritional strategies that emphasize gradual weight management rather than last-minute reductions. Athlete education programs must be strengthened to promote awareness of the long-term consequences associated with repeated RWL cycles.

Future research should aim to refine individualized responses to RWL, investigate long-term cardiac outcomes associated with elevated biomarkers during training, and explore the potential protective role of tailored recovery strategies. Longitudinal designs, larger multi-center cohorts, and advanced physiological monitoring tools will be essential to provide the evidence needed to guide future policy reforms.

In conclusion, this thesis contributes to the growing body of literature that challenges traditional weight-cutting paradigms in combat sports. By highlighting the physiological and metabolic vulnerabilities introduced by RWL, even in highly trained populations, it advocates for a more sustainable and health-oriented approach to weight management. Ensuring that elite athletes can achieve peak performance without compromising their future health is not only a scientific objective but also an ethical responsibility shared by all professionals involved in combat sports.

Part V – Pre-doctoral Experiences and Conference Proceedings

5.1 Conference Proceedings

During the doctoral program, the doctoral student had the opportunity to present preliminary results and ongoing work at numerous scientific events, both nationally and internationally. Notably, two abstracts were prepared for high-profile international conferences: the ACSM Annual Meeting in Atlanta, focused on the physiological effects of RWL and high-intensity training in combat sports, and the IEPRS Conference at the Institute of Exercise Physiology and Rehabilitation Science, University of Central Florida, centered on methodologies for assessing body composition, muscle damage, and cardiovascular adaptations in martial arts athletes.

In addition to these, the doctoral student participated in numerous national conferences, including events organized by SISMES and other scientific societies, sharing complementary studies and updates on ongoing research. Participation in these meetings enabled direct interaction with expert researchers in the field, fostering critical discussion of the results and the initiation of potential future collaborations.

Below are all the abstracts related to the conferences in which the doctoral student took part.

Integration of Science and Sports Practice in Combat Sports / XXII All-Russian Scientific and Practical Conference of Young Researchers, dedicated to Evgeny Mikhailovich Chumakov, February 16, 2023

Abstract Title:

Rapid Weight Loss Affects Mood Alterations in National Level Wrestlers

Authors:

Rossi, C. Manojlovic, M. Sunda, M. Gilic, B.

Abstract: (1)

The implementation of rapid weight loss (RWL) can influence mood states in combat sports athletes. This study aimed to determine the effect of RWL on mood parameters in national-level Greco-Roman wrestlers. Results revealed significant differences in variables representing depression, tension, anger, fatigue, confusion, and vigor. These findings indicate that rapid weight reduction negatively affects mood in wrestlers.

Keywords:

Combat sports, Mood states, Wrestling, Psychology

Abstract Title: (2)

Effects of Rapid Weight Loss on Muscle Damage in Sambo Athletes

Authors:

Roklicer, R. Rossi, C. Maksimovic, N. Bianco, A.Stajer, V. Trivic, T. Drid, P.

Abstract:

This study aimed to examine the effects of rapid weight loss (RWL) on biochemical markers of skeletal muscle damage in sambo athletes. The results highlight the physiological impact of rapid body mass reduction on elite athletes' muscle health, emphasizing potential risks associated with RWL practices.

Keywords:

Sambo athletes, Rapid weight loss, Muscle damage

Stati Generali della Nutrizione Sportiva – 1st National Meeting for Professionals, Rome, March 24–25, 2023

Authors:
Greco Ida, Rossi Carlo, Amato Alessandra, Alioto Anna, Baldassano Sara, Proia Patrizia

Introduction: Non-athletic individuals performing mild physical activity often have excess fat mass, which may not be reflected by BMI. This can reduce metabolism and increase risk of metabolic syndrome. **Methods:** Thirty-eight adults (34.5 ± 15.9 years) engaging in mild "Fitness" activity 2–3 times/week followed a 3-month athlete-style diet. Body composition was assessed using multifrequency BIA (InBody 320) before, during, and after the intervention. **Results:** The protocol significantly reduced weight and fat mass ($p<0.001$) while maintaining or increasing lean mass ($p<0.001$). Basal metabolism and haematochemical parameters also improved, indicating better overall health. **Conclusions:** Athlete-based nutritional protocols applied to non-athletes performing mild activity improve body composition, preserve or increase lean mass, and enhance metabolism. Short-term application appears safe and beneficial for general health.

95rd National Congress of the Italian Society for Experimental Biology (Trieste, 12-15 aprile 2023)

Monitoring Benefits of 6 weeks of a High-Intensity Interval Training Protocol through Polar Unite system in MS Patients: A Pilot Study (1)

Carlo Rossi [1], Patrizia Proia [1], Paolo Ragonese [3], Giuseppe Schiro' [3], Sara Baldassano [2], Sonya Vasto [2], Anna Alioto [1], Alessandra Amato [1]

For many years, patients with multiple sclerosis (MS) have been advised to avoid exercise due to the risk of increased neurological damage [1]. Over the years, the literature has evaluated how physical activity can instead improve physical condition. Is already known that high-intensity interval training (HIIT) could have potentially greater effects on fitness and cognition than moderate continuous exercise [2]. HIIT decreases many MS symptoms and can positively counteract the disease progression even if is performed in a short time compare with continuous training. Patients with MS may have a dysfunction of cardiovascular regulation together with respiratory involvement, which can impair aerobic capacity and thus lead to high fatigue. While aerobic physical activity is known to be beneficial in people with MS, more research is needed to explore the effectiveness of HIIT in people with progressive MS and those with higher levels of disability. This is the start point of our study focused to investigate the effects of a 6-week HIIT workout, three times a week, 30' each session the improvement of cardiovascular function and physical performance and decrease average heart rate. Five subjects with MS (age 39.8 ± 6.3) were enrolled in the study. We analyzed and recorded the training sessions with Polar Vantage V2 Unite, a smartwatch with integrated GPS that allow to evaluation of the differences between the cardiovascular parameters. The results showed a statistically significant decrease, after 6 weeks, of the minimum peak heart rate ($p = 0.043$), which leads to an improvement in diastolic function. Considering that in the literature, subjects with MS often show diastolic dysfunction due to drug intake such as Novantrone ® (Meda Pharma) [3]. Statistically significant increases were also found in calories consumed between the first and last training session ($p=0.038$) suggesting that patients were able to achieve higher work intensity during the training session: higher exercise intensity leads to higher calories expenditure. We can therefore infer that the HIIT protocol, in MS patients, undergoes an improvement in physical performance and training performance. Lack of physical activity tends to increase muscle

weakness and fatigue, as well as perceived fatigue during daily activities and training. Since several studies have already shown that physical training can benefit people with MS, exercise capacity, health-related quality of life, and reduced fatigue, we suggest a HIIT protocol to positively affect cardiovascular functionality, improving diastolic function and decreasing the perception of fatigue.

Hiit Training Improves Functional Movement Tests With A Positive Effect On The Bone Metabolism In Multiple Sclerosis Patients: A Pilot Study (2)

Alessandra Amato[1,2], Sara Baldassano[3], Sonya Vasto[3] , Paolo Ragonese[4], Carlo Rossi[1,2], Anna Alioto[1,2], Stefano Saccomanno[1,2], Giuseppe Schiro'[4], Agata Marchese[3] , Patrizia Proia[1,2]

Multiple sclerosis (MS) is a neurodegenerative disease, chronic in nature, affecting the central nervous system and resulting in large and varied symptomatology[1]. Subjects with this disease have impaired motor function and associated altered bone metabolism, with vitamin D deficiency and consequently risk of osteoporosis[2]. Physical activity could play a key role in improving these aspects. However, to date, it is unclear whether physical activity is as effective in these patients and what exercise would be best suited to reduce the risk of osteoporosis, improve motor function, and contribute to the reduction of chronic fatigue characteristic of the disease[3]. The purpose of our study is to understand whether high-intensity interval training can be effective in improving motor performance and bone metabolism. A first group of 10 subjects diagnosed with MS (EDSS 1.17± 0.56) was recruited for our pilot study. At the beginning of the study (T0) blood sample was collected for each subject in order to analyze bone markers and tests of strength, balance, reaction time, and mobility were administered. In addition, we performed a postural evaluation to investigate anteroposterior and later-lateral oscillations and body weight distribution at the feet. After the initial assessments, the subjects began the 6-week of HIIT (HR between 60% and 80% of HRmax) three times a week, each session lasting about 30 minutes. at the end of the training period (T1), subjects performed all assessments again. Our results showed a better performance after the training period in the lower limb strength tests: 5 times sit to stand (s) (T0:12.54±; T1:10.89±; 0.03) and Wall squat test (s) (T0: 27.19±0.9; T1: 41.68± 1.02; p:0.00); in the lower limb reaction time tests: foot-reaction time test dominant limb (s) (T0: 0.52± 0.01; T1:48.2± 0.02 p:0.05) foot-reaction time test non-dominant limb (s)

(T0:0.55± 0.04; T1: 0.48± 0.02; p:0.03); in the mobility test cervical range of motion with an improvement in the total cervical inclination (°) (T0:81.93± 5.7; T1:99.66±6.6; p:0.01) and in the total cervical rotation (°) (T0:127.96± 8.9; T1:162.53± 5.2;p:0.00) regarding the balance tests an improvement in performance was found only in the time up and go test (s) (T0:7.66± 0.4; T1: 6.34± 0.4; $p < .001$). There were no significant changes in strength and reaction times tests for the upper limbs. As regards bone metabolism, the results show an increase of the bone formation marker Osteocalcin (µg/L) (T0:23.11± 8.24; T1: 25.4± 8.04; p:0.025) and the Vitamin D (µg/L), started below normality values (<30 micrg/L) before the training period, increased after the six weeks (T0:20.44± 6.9; T1:26.44± 2.7; p:0.07). However, this difference does not appear to be statistically significant. No statistically significant differences were found between T0 and T1 for the markers CTX ($p>0.05$) and PTH ($p>0.05$) In conclusion, this training had positive effects on lower limb function by increasing strength, reaction time, and gait stability. In addition, HIIT has an effect on bone metabolism as evidenced by increased markers of bone formation. However further studies with different training times and number of subjects are needed.

2023 MFPRM Congress. BEYOND COVID, Rome, 6th to 8th July 2023

Evaluation Of Taopatch® Effects On Spine Morphology

Background and aims

Spine 3D is a device that allow to monitor the spine from a morphological and functional point of view, through a non-invasive analysis widely used in the medical field. The Taopatch® is an innovative medical nanotechnology that induce beneficial effects on the human body. It is already known that this device can improve and prolong the effect on proprioception, balance, inducing also postural rebalancing. This study aims to examine whether the application of Taopatch® can improve the spinal morphology's change of subjects with spinal dysfunction.

Methods

Twenty healthy subjects with spinal dysfunction, such as hyperlordosis, kyphosis, and scoliosis, were enrolled in the study. The subjects were evaluated by Spine 3D device at the beginning (T0) and after two hours of the application of Taopatch® (T1).

Results

Through comparison of the measurements taken to T0 and T1, a significant change was observed, particularly for some variables such as VertebralDeviationMinus_COR (0.069), TrunkImbalance_VPDM_COR (0.136), and CoronalImbalance_VPDM_COR (0.148).

Conclusions

The application of the Taopatch® would appear to have a positive effect on spinal morphology and rebalance and appears to be a useful tool for long-term support and maintenance of the spinal alignment.

62° Congresso SIB – 7-9 September, Firenze, Polo Didattico Morgagni – Università di Firenze

High-Intensity Interval Training in MS

Alessandra Amato[1], Sara Baldassano[2], Anna Alioto[3], Carlo Rossi[3], Andrea Pagliaro[3], Paolo Ragonese[4], Giuseppe Schirò[4], Giuseppe Salemi[4], Sonya Vasto[2] and Patrizia Proia[3]

Abstract

The aim of our study was to evaluate the possible benefits of a specific type of training (high-intensity interval training, HIIT) in subjects with multiple sclerosis (MS). From a cohort of 130 subjects diagnosed with relapsing-remitting MS, a selected subgroup performed the HIIT protocol. The training program was administered bi-weekly for 12 weeks.

At the end of the study (T1), the results showed changes in lipid profile and bone metabolism. In detail, a significant decrease in total cholesterol ($p=0.02$) and an increase in osteocalcin and vitamin D levels ($p<0.05$) were detected. Regarding neuromotor tests, an improvement in the Wall Squat Test was observed ($p<0.002$).

These findings suggest that HIIT can positively affect metabolic, neuromotor, and bone health parameters in MS patients, supporting its use as an effective intervention to improve physical function and health-related outcomes during the disease period.

Keywords: Multiple Sclerosis, HIIT, neuromotor function, bone metabolism, vitamin D, cholesterol

5th Congress of Polish Biosciences BIO2023 “Different faces of biosciences”
Szczecin, Poland, September 13th–16th, 2023

Hematological and coordination skills evaluations in response to a High-Intensity Interval Training in MS patients

Patrizia Proia[1], Carlo Rossi[1], Anna Alioto[1], Alessandra Amato[2], Andrea Pagliaro[1], Paolo Ragonese[3], Giuseppe Schirò[3], Giuseppe Salemi[3], Sonya Vasto[2] and Sara Baldassano[4]

Abstract

Multiple sclerosis (MS) is a chronic inflammatory demyelinating disease of the central nervous system (CNS) whose etiology is currently not completely understood. It is already known that physical activity plays an essential role in improving quality of life, especially in neuropathological conditions.

The aim of the study was to investigate the possible benefits of high-intensity interval training (HIIT) on haematological parameters and neuromotor abilities in MS patients. From a cohort of 130 subjects diagnosed with MS at the neurology unit of the 'Paolo Giaccone' University Hospital, 16 patients fulfilled the inclusion criteria. Patients were randomly assigned to two groups: a control group that did not perform any physical activity and an experimental group that performed the HIIT protocol. The study was conducted online by a clinical kinesiologist from the Sport Research Unit of the University of Palermo. The training program was administered biweekly for 12 weeks.

The results showed a reduction in Total and LDL-cholesterol levels ($p=0.02$) and an increase in osteocalcin and vitamin D levels ($p<0.05$). Regarding coordination tests, improvements were observed in the Wall Squat Test ($p<0.002$).

Considering the relevance of these preliminary results, further investigations will be necessary, increasing the sample size and exploring additional haematological and coordination outcomes.

Left heart adaptations in Male and Female judo elite athletes (1)

Carlo Rossi[1*], Roberto Roklicer[2,3], Patrik Drid[2], Aleksandra Milovancev[4], Tatjana Trivic[2], Attilio Carraro[3], and Antonino Bianco[1]

Purpose: Cardiac remodeling can occur in two ways: physiological o pathological. Pathological cardiac remodeling is the consequence of adverse factors that lead to structural and functional changes in the left ventricle (LV) in response to internal o external damage [1]. Judo is an intermittent combat sport that requires high levels of intramuscular force. Therefore, our research aims to examine cardiac muscle adaptations and remodeling in elite judo athletes and to evaluate differences between male and female judoka.
Methods: The study included 19 elite judokas divided into two subgroups: the first from 10 male athletes (25.50 ± 3.17) and the second from 9 female judokas (23.56 ± 3.16). All participants underwent surface ECG recording. The following parameters were measured: RWT - Relative wall thickness; LVM - Left ventricular mass; LVMI - Left ventricular mass index. An independent sample t-test was used for values between the two groups. The level of statistical significance was set at $p < 0.05$. Results: In terms of left ventricular mass (LVM) and left ventricular mass index (LVMI), significant differences were found between male and female judokas (233.44 ± 68.75 g vs. 164.11 ± 16.59 g, $p = 0.009$), (105.16 ± 24.89 vs. 84.66 ± 15.06, $p = 0.044$), respectively.
Conclusions: Gender comparison showed higher LVM and LVMI in male athletes than in female athletes. The presence of physiological cardiac enlargement in high- level judokas seems to be a common occurrence. In addition, it can be argued that there is an important influence of gender as a factor.

Cardiac biomarkers alterations in rapid weight loss and high-intensity training in judo athletes (2)

Aleksandra Milovančev[1,2], Aleksandra Ilić[1,2], Tatjana Miljković[1,2], Milovan Petrović[1,2], Anastazija Stojšić Milosavljević[1,2], Roberto Roklicer[3,4], Tatjana Trivic[4], Marko Manojlovic[4], Antonino Bianco[5], Patrik Drid[4*]

Abstract

Objective Studies evaluating cardiac biomarkers alterations in sports-associated rapid weight loss (RWL) and high-intensity-sport-specific training (HISST) are lacking. This pilot study aimed to examine the effects of RWL and HISST on heart rate, blood pressure, cardiac biomarkers, and left ventricular systolic function.

Methods A total of 9 elite male judokas participated in the presented crossover investigation. Athletes underwent baseline assessment and two test protocols, including the first phase with RWL and HISST and the second phase after 7 days, where only HISST was performed. All participants underwent electrocardiogram, biomarkers, and transthoracic echocardiogram assessment after each phase.

Results When baseline parameters were compared to the first phase (RWL and HISST), heart rate significantly increased, 58.11 (7.78) vs. 79 (9.25), p=0.001; as well as cardiac biomarkers: lactate dehydrogenase isoenzyme 175.33 (31.22) vs. 238.56 (56), p=0.003; aspartate aminotransferase 16.56 (4.61) vs. 29 (9.96), p=0.027; creatine kinase-MB isoenzyme 13 (11.5;24) vs. 29.11 (10.05), p=0.004; and high sensitivity cardiac troponin 10 (0) vs. 14.49 (6.4), p=0.045. Second phase, only HISST was associated with significantly increased alanine aminotransferase isoenzyme, 37.78 (11.22) vs. 26 (8.03), p=0.024, along with creatine kinase 472 (185;654) vs. 166.88 (56.57), p=0.01, relative to the initial measurement. Additionally, no significant differences were observed concerning comparisons of baseline values of left ventricular systolic function and the two test protocols.

Conclusion RWL combined with HISST resulted in significant cardiac biomarkers alterations without impairment of left ventricular systolic function. HISST alone caused changes in biomarkers attributed mainly to muscular damage.

Physical activity and diet as a multidisciplinary approach in adolescent obesity (3)

Anna Alioto[1*], Carlo Rossi[1], Simona Capano[1], Alessandra Amato[2], Sara Baldassano[3], Andrea Pagliaro[1], Giulia Lauriello[1], Szymon Kuliś[4], Giuseppe Messina[5], and Patrizia Proia[1]

Purpose: Over the past forty years, many developing countries have witnessed a rapid nutritional transition that has contributed to the spread of one of the most serious public health phenomena, obesity, which mainly affects young adolescents [1]. This condition may predispose to the development of several chronic diseases, such as hyperlipidaemia, which is involved in multiple signalling pathways for bone homeostasis, as well as vitamin D (VitD) [2]. There is communication between adipose tissue and bone, which can regulate each other through feedback mechanisms, including glucose uptake by bone, also regulating insulin levels. In our study, we aimed to investigate the effects of a combined swimming programme and structured nutritional therapy in obese adolescents.

Methods: We observed potential changes in body composition and bone metabolism markers in obese adolescents dictated by the application of a physical activity and nutrition programme during a 6-months period. For this purpose, 21 obese subjects aged between 8 and 12 years (height CG 143 ± 7.89 cm vs. EG 142 ± 13.2 cm) were recruited according to the parameters specified by the World Health Organisation (WHO) for determining BMI. Investigations of body compartment changes were performed using the Akern Bioelectrical Impedance Analysis (BIA) 101 device (AKERN SRL, RJL Systems, Detroit, USA). Participants were followed up before, during and at the end of the intervention period by nutrition professionals specialised in childhood obesity at a frequency of 45 days.

Results: Initially (T0), our statistical investigations showed no significant differences between EG and CG. However, after 6 months (T3) of the intervention, based on the modification of the dietary plan, boosted with Vit D supplementation, statistically significant results emerged both within the same group and between both groups, compared to the initial period. Specifically, about FM, Vit D and insulin levels. But although, the intervention determined changes in both these were more pronounced in the EG, which additionally had swimming sessions (FM 21.55 kg vs 15.06 kg, $p < .001$; Vit D 9. 27 ng/ml vs 25.64 ng/ml, $p < .001$; Insulin 29.31 IU vs 12.66 IU, $p < .001$) compared to the CG (FM 20.66 kg vs 18.09 kg, $p < 0.01$; Vit D 8.70 ng/ml vs 13.70, $p < .001$; Insulin 28.45 IU vs 22.76 IU, $p < .001$).

Conclusions: In conclusion, this study confirms the importance of diet and exercise in improving the health of adolescents, particularly those with obesity. However, it is still necessary to recognize the need to intervene at several levels in the fight against paediatric obesity involving the family network, the school and doctors and health professionals in

general, there is still a field to explore, especially that which concerns sport, individual and group, and dietary supplementation [3].

INTEGRATION OF SCIENCE AND SPORT PRACTICE IN MARTIAL ARTS
Proceedings of the XXIII International Scientific and Practical Conference of Young Scientists, dedicated to the memory of Honored Master of Sports of the USSR, Honored Coach of the USSR, Professor
Evgeny Mikhailovich Chumakov
(February 16, 2024)

Effects of Rapid Weight Loss on the Health of Athletes: A Brief Review

Rossi C., Manojlovic M., Roklicer R., Trivic T., Bianco A., and Drid P.

Annotation: This abstract shows the importance of examining the impact of rapid weight loss (RWL) on physical, mental, and metabolic health, considering contemporary social pressures and aesthetic expectations. Through a brief scientific review, the document explores physiological, psychological, and metabolic alterations associated with RWL. In conclusion, it advocates for an integrated approach to inform personal decisions and guide medical practices, emphasizing the significance of public education on sustainable weight management and the promotion of a healthy lifestyle.

Keywords: *rapid weight loss; combat sports; physiology, metabolic events, exercise*

6th International Scientific
Conference on Exercise and Quality of Life
Novi Sad, Serbia. 11-13 April 2024

Rapid Weight Loss and its Impact on Skeletal and Cardiac Muscle Biochemical Markers in Wrestlers: Implications for Combat Sports (1)

Rossi Carlo[1*], Roklicer Roberto[2], Manojlovic Marko[2], Trivic Tatjana[2], Drid Patrik[2], and Bianco Antonino[1]

Background: Restrictive diets, forced fasting and voluntary reduction of body mass have attracted the attention of scientists, health professionals and athletes. Reducing weight too quickly is unsustainable and can lead to numerous complications. Short-term body weight regulation is prevalent in combat sports, where rapid weight loss (RWL) methods are employed by athletes in the week leading up to competition, resulting in an average loss of 5% of body weight. This study aimed to examine the effects of rapid weight reduction on changes in biochemical markers of skeletal and cardiac muscle in wrestlers.

Materials and Methods: The study involved an initial measurement (IM) and two experimental phases. The experimental treatment, following the initial measurement, occurred in two phases to investigate the acute effects of weight reduction on biochemical markers when 5% of body weight was reduced in conjunction with sport-specific training (Phase 1 - P1) compared to changes caused solely by high-intensity sport-specific training without weight reduction (Phase 2 - P2).

Results: The application of rapid weight loss together with specific high-intensity training caused statistically significant changes in the markers examined. However, when only high-intensity sport-specific training was applied, a change in the activity of the tested markers was still observed, although less than when combined with RWL.

Conclusion: For the well-being and safety of athletes, it is advisable to consider interventions such as introducing modifications to competition rules in combat sports, categorized by weight classes. This would contribute to addressing the potential risks

associated with rapid weight loss strategies in the context of combat sports, emphasizing the need for a balanced approach to athlete health and performance.

A comparative study on optimizing strength training protocols in young females: Velocity-based vs. percentage-based programs (2)

Marko Manojlović[1], Isidora Vasiljević[1], Carlo Rossi[2], Tatjana Trivić[1], Antonino Bianco[2]
[1]Faculty of Sport and Physical Education, University of Novi Sad, Novi Sad, Serbia; [2]Sport and Exercise Sciences Research Unit, University of Palermo, Palermo, Italy

Background

The purpose of this study was to compare the effects of velocity-based strength training (VBT) and percentage-based strength training (PBT) on absolute strength, explosive power, speed, and agility, as well as markers of muscle damage after 6 weeks of exercise programs and a total of 12 training sessions.

Materials and methods

The study included 30 subjects divided into three groups of 10 respondents: VBT, PBT, and control. Before and after the experimental treatment, the subjects performed various neuromuscular tests, including one-repetition maximum (1RM) squat exercise and 1RM bench press for absolute strength, squat jump (SJ) and countermovement jump (CMJ) for explosive strength, 5-meter and 20-meter run tests for speed, as well as 505L and 505D tests for agility. Creatine kinase and creatine kinase isoenzyme were analyzed as markers of muscle damage before and after the first training session and 24 hours after the last training session.

Results

All implemented neuromuscular performance tests revealed no statistically significant differences between groups. Furthermore, no significant differences were found between the groups regarding the examined markers of muscle damage across all phases. The velocity-based and percentage-based strength training groups showed significant improvement in 1RM squat exercise and 1RM bench press, but a greater enhancement was observed in the VBT group. Furthermore, VBT induced substantial changes in SJ and CMJ height, while PBT only improved in the SJ test. In the control group, no differences between baseline and follow-up measurements were observed in all tests.

Conclusions

Although no difference was found between groups, VBT induced greater absolute strength and explosiveness improvements than traditional training and can be considered more effective.

The Role of Rapid Weight Loss in Metabolic Syndrome Among Former Elite Combat Sports Athletes (1)

Patrik Drid[1], Nemanja Maksimovic[2], Ognjen Cvjeticanin[1], Carlo Rossi[2], Marko Manojlovic[1], Roberto Roklicer[3], Antonino Bianco[2], Attilio Carraro[3], Damir Sekulic[4], Aleksandra Milovancev[5], Tatjana Trivic[1]

Background/Purpose
Rapid weight loss (RWL), a common strategy in combat sports, is often employed to compete in specific weight categories, providing a competitive advantage. However, associated dietary restriction and dehydration practices may lead to adverse metabolic effects, potentially culminating in metabolic syndrome (MetS) post-sporting career. This research aims to identify disparities in MetS parameters and prevalence between former athletes who underwent RWL and those who did not.

Methods
The study involved 150 participants, evenly split into two groups: 75 former combat sports athletes who engaged in RWL and 75 former athletes from sports where RWL was not practiced. MetS-related parameters were assessed, including waist circumference, HDL cholesterol, systolic and diastolic blood pressure (BP), fasting glucose, and triglycerides.

Results
A statistically significant difference in MetS prevalence was observed between the two groups (39.5% vs. 16.2%). Additionally, significant variations in systolic and diastolic BP ($p=0.001$) were identified, along with a notable trend in triglycerides ($p=0.069$).

Conclusions
Former elite martial arts athletes who incorporated RWL during their competitive phase may face an increased risk of metabolic alterations after their sporting career.

Subjects With MS Improve Physical Performance, Bone Health, And Lipid Management Following High-intensity Interval Training (2)

Alessandra Amato[1], Sara Baldassano[2], Carlo Rossi[2], Anna Alioto[2], Andrea Pagliaro[2], Giuseppe Musumeci[1], Patrizia Proia[2]

Background/Purpose

Physical activity plays a crucial role in quality of life and motor skill management, even in subjects with neuropathological conditions. Multiple sclerosis (MS) is a neurodegenerative disease causing demyelination due to autoimmune dysfunction, resulting in motor symptoms and altered bone turnover. The study aimed to investigate the effects of high-intensity interval training (HIIT) on physical performance, bone health, and lipid metabolism in MS patients.

Methods

From 130 recruited participants, 16 subjects with MS met inclusion criteria and were analyzed. Participants were randomized into a Control Group (CG, 34.88 ± 4.45 yrs) and an Exercise Group (EG, 36.20 ± 7.80 yrs), performing no exercise or a HIIT protocol three times a week for 8 weeks, respectively. Assessments at baseline (T0) and post-training (T1) included bioimpedance analysis, coordination tests, and bone/lipid marker analysis.

Results

After training, the wall squat (s) (T0=27.18±4.21; T1=41.68±5.38, $p \leq 0.01$) and Time Up and Go test (s) (T0=7.65±0.43; T1=6.34±0.38, $p \leq 0.01$) performances improved. Lipid markers showed LDL-cholesterol reduction (T0=108±21.08; T1=95.02±17.99, $p<0.05$). Osteocalcin levels (T0=20.88±4.22; T1=23.66±6.24, $p<0.05$) and 25-OH Vitamin D (T0=21.11±7.11; T1=27.66±7.59, $p<0.05$) increased.

Conclusions

HIIT improved lower limb strength, gait control, bone formation, and lipid management in multiple sclerosis patients.

Kinematic Differences of the Kicking Leg in Roundhouse Kicks at Different Heights and Distances in Ju-jitsu Athletes (1)

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Background/Purpose

Roundhouse kick is a common technical gesture in several martial arts, frequently used in competition to target different parts of the opponent's body. This study aimed to analyze kinematic differences in roundhouse kicks at various heights and distances, focusing on the range of motion (RoM) of the hips, knees, and ankles in Ju-jitsu athletes.

Methods

Sixteen Ju-jitsu athletes (10 males, 6 females) performed a standardized 10-minute warm-up followed by roundhouse kicks at three distances (short, medium, long) aimed at three heights (high, medium, low), determined relative to each participant's anthropometry (chin, abdomen, knees). Distances were calculated based on trochanter–malleolus length. Seven inertial sensors (Moover Gait, Sensor Medica, Italy) were placed on the pelvis (n=1), thighs (n=2), ankles (n=2), and dorsum of the foot (n=2) to record kinematic data.

Results

Hip flexion-extension RoM varied significantly across kick heights ($p<.001$) and distances ($p=0.011$), with post-hoc analyses showing reductions between short and long distances ($p=0.005$) and high versus low kicks ($p<.001$). Hip abduction-adduction RoM decreased between high–medium and medium–low kicks ($p<.001$). Knee flexion-extension RoM also showed significant differences by height ($p<.001$) and distance ($p<.001$). No significant differences were found in ankle RoM.

Conclusions

Kick height and distance significantly affect hip and knee RoM in Ju-jitsu athletes,

highlighting the importance of tailored training to optimize performance and minimize injury risk.

Segmental Bioelectrical Impedance Reveals Muscle Damage Markers Following Eccentric Calf Training

Authors: Carlo Rossi[1], Ecaterina Vasenina[2], Jack Livingston[2], Kworweinski Lafontant[2], Jeffrey R. Stout[2], and David H. Fukuda[2]

Background

Segmental bioelectrical impedance analysis (BIA) assesses muscle and fluid changes through parameters such as phase angle (PhA), resistance (R), and reactance (Xc). This study aimed to examine localized BIA changes following eccentric training in the plantar flexors, providing insights into recovery and muscle damage processes.

Methods:

Twenty male participants (82.6±16kg; 177±8.7cm; 23.8±3.45yrs) performed unilateral eccentric plantar flexor training. The protocol included four sets of 50 repetitions with a 40% body mass weighted vest, followed by a set to failure. One leg was trained (intervention), while the other served as a control. BIA parameters, including intracellular water (ICW), extracellular water (ECW), R, Xc, and PhA (50kHz), were measured pre-, immediately post-, and 24-, 48-, and 72-hours post-exercise. A two-way repeated measures ANOVA (leg×time) was used to evaluate differences.

Results:

Significant leg×time interactions were observed for all parameters ($p<0.05$). In the trained leg, ECW decreased ($p<0.001$; ↓0.250±0.021L), while R ($p<0.001$; ↑13.873±1.69Ω) and Xc ($p<0.001$; ↑3.035±0.387Ω) increased immediately post-exercise. PhA showed acute increases post-exercise ($p<0.001$; ↑0.31±0.04°), a reduction at 24 hours ($p<0.001$; ↓0.31±0.04°), and partial recovery at 48 hours ($p=0.022$; ↑0.22±0.07°). ICW decreased at all time points ($p<0.05$; range: ↓0.267 to ↓0.169L). Control leg changes were limited to immediate post-exercise for ICW ($p=0.001$; ↓0.133±0.021L), ECW ($p=0.001$; ↓0.121±0.020L), R ($p=0.001$; ↑6.966±1.33Ω), Xc ($p=0.002$; ↑1.385±0.302Ω), and PhA ($p=0.048$; ↑0.11±0.03°).

Conclusions:

Segmental BIA parameters detected acute and delayed changes in fluid balance and muscle status following eccentric training. These findings underscore the potential of segmental BIA

to monitor muscle recovery and damage, with implications for optimizing training and rehabilitation strategies.

ACSM's 72nd Annual Meeting will be held in Atlanta, GA.May 27 – 30, 2025

Eccentric Calf Training Alters Segmental Bioelectrical Parameters Indicative of Muscle Damage

Carlo Rossi[1], Ecaterina Vasenina[2], Jack Livingston[2], Kworweinski Lafontant[2], Jeffrey Stout[2], David Fukuda, FACSM[2]

Background/Purpose

Segmental bioelectrical impedance analysis (BIA) can assess cellular health through phase angle (PhA), resistance (R), and reactance (Xc), providing insight into localized muscle and fluid balance changes during exercise recovery. This study aimed to evaluate segmental BIA parameters after eccentric calf training.

Methods

Twenty male participants (82.6±16 kg; 177±8.7 cm; 23.8±3.45 yrs) performed unilateral eccentric plantar flexor training: four sets of 50 repetitions with 60 s rest between sets, wearing a weighted vest (40% body mass), followed by a fifth set to failure. One leg was randomly assigned to intervention, the other served as control. Segmental BIA parameters—including intracellular water (ICW), extracellular water (ECW), R, Xc, and PhA at 50 kHz—were recorded pre-exercise, immediately post, and at 24, 48, and 72 hours post-training. Two-way (leg×time) repeated measures ANOVA was applied.

Results

Significant leg×time interactions were observed for all BIA parameters ($p<0.050$). In the intervention leg, ECW decreased ($p<0.001$), R and Xc increased ($p<0.001$), and PhA showed significant changes immediately, 24 h, and 48 h post-exercise. ICW in the intervention leg showed significant differences at all time points ($p<0.050$). The control leg exhibited acute changes immediately post-exercise, likely due to strength testing.

Conclusions

Segmental BIA parameters change significantly in muscles subjected to eccentric training,

following distinct temporal patterns, potentially reflecting primary and secondary phases of muscle damage.

5.2 Published Articles before PhD Period

Systematic Review

The role of psychological factors in judo: A systematic review

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Abstract

Background: Psychological parameters are relevant in the practice of judo. Previous studies have shown that parameters such as anxiety or motivation can have a negative or positive impact on the athlete's performance and general well-being, depending on the athlete's perception. This systematic review aimed to summarize the studies examining the influence of various psychological parameters on well-being and performance in judo athletes. Methods: We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. We searched the Web of Science database for studies that investigated the role of these parameters in elite athletes. Of the 286 articles initially identified, 17 met our eligibility criteria and were included in the review. In total, data from 721 judo athletes were analyzed. Results: The studies included demonstrated the impact of various psychological parameters during high-level performance, and how these parameters can influence the outcome of competition. Increased feelings of tension, anger, anxiety, or nervousness were significantly associated with defeat, while decreased negative emotions and increased motivation were observed among athletes achieving better performance. Conclusions: Considering that an athlete's psychological state can affect performance, it is important to monitor and train these factors. Further research under standardized conditions is needed to better understand the effects of psychological parameters on judo athletes.

Original Article

Rapid weight loss coupled with sport-specific training impairs heart rate recovery in Greco-Roman wrestlers

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Abstract

Wrestling is a sport that can be classified with the use of alternating aerobic-anaerobic metabolism with moderate but high impact energy expenditure. It is considered one of the sports where muscle strength is predominant. The implementation of different perspectives of action, such as pulling, pushing, and lifting, during the struggle activities causes various physiological requirements. Heart rate recovery (HRR) is the difference between heart rate during exercise and a certain amount of time after the start of recovery. PURPOSE: The goal of this study was to determine the difference in HRR between two different cases: sport-specific high-intensity training combined with rapid weight loss (RWL) and sport-specific training only. METHODS: Ten national level wrestlers (mean age 22.44 ± 4.53 years; mean body weight 73.36 ± 4.42 kg; mean body height 174.43 ± 3.78 cm) were included in this study. All participants underwent sport-specific high-intensity training (HISST) along with RWL procedures, for the first measurement. For the second measurement, an identical training session was performed with no RWL included. The high intensity sport specific training consisted of four sets of shoulder throws with work to rest ratio: 15:45 s and each set lasting 10 minutes with a 3-minute break in between. Heart rate recovery was measured in three time points: first, second and third minute after each set of throws. RESULTS: We found a statistically significant difference for the values obtained after the first and second minutes of recovery in the second set for both cases ($p = 0.034$ and $p = 0.037$, respectively) with higher values observed when RWL was included. CONCLUSION: It can be concluded that there is undoubtedly a difference in HRR during training and RWL compared to HISST

alone. Additionally, sport-specific training along with RWL could compromise the aerobic component of recovery.

Original Article

Prevalence of rapid weight loss in Olympic style wrestlers

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Abstract

The methodology applied for rapid weight loss (RWL) among elite wrestlers is quite unexplored. Therefore, the aim of this study was to analyze the prevalence of sources of influence and methods used for RWL and to determine the differences between wrestling styles. A total of 229 wrestlers who competed at the World Championship held in Belgrade, Serbia, participated in this research. All respondents completed a questionnaire designed to evaluate RWL patterns in combat athletes. Participants were classified according to wrestling style: Greco-Roman, freestyle, and women's wrestling. Sixty-nine percent of wrestlers had previously lost weight to compete. Most respondents reported starting to lose weight approximately 7 days before competition. On average, athletes reduced 4.17 ± 2.23 kg to reach the target weight. The wrestling coach was identified as the most influential person in shaping RWL strategies, whereas nutritionists and physicians had the least impact on the weight-cutting process. Regarding the methods applied, significant differences between the three styles were observed for the following variables: training in a heated room, restricting fluid ingestion, training in plastic suits, gradual dieting, increased exercise, diet pills, and sauna use. The most frequently reported techniques across all wrestling styles were increased exercise, gradual dieting, training in a heated room, and sauna. Conversely, the least implemented methods included diet pills, diuretics, laxatives, and self-induced vomiting. The results suggest that the majority of wrestlers engage in RWL despite its harmful health consequences. Therefore, increased education of wrestling coaches is necessary to control and mitigate the negative impact of these practices.

Original Article

The Effect of Rapid Weight Loss on the Handgrip Strength of National-Level Wrestlers

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Abstract

The effects of rapid weight loss (RWL) in combat sport athletes is an area that is not yet fully understood. Therefore, the goal of this study was to determine the impact of RWL on handgrip strength (HGS) in Greco-Roman wrestlers. This cross-over study included 10 athletes who were examined for HGS at three time points for each hand. The first measurement – baseline (BL) – was performed before weight reduction. The second measurement – phase 1 (P1) – was taken after High-Intensity Sports Specific Training (HISST) combined with RWL. In this phase, participants were required to lose 5% of their body mass within 3 days, after which HISST was conducted on day 3. The third measurement – phase 2 (P2) – was performed seven days after P1, which included HISST without RWL. When comparing the HGS values, a significant difference was observed only for the left hand between P1 and P2, indicating that grip strength was significantly stronger after RWL combined with HISST. This research is of potential importance to combat sports coaches and athletes, as it evaluates the effect of RWL on performance parameters. The results could help optimize wrestlers' weight-reduction strategies while maintaining performance.

5.3 Preview and Pre-doctoral Experiences

Before starting the PhD program, the doctoral candidate had the opportunity to enrich their scientific background through six months abroad at the Faculty of Sport and Physical Education, University of Novi Sad, Serbia, within the Erasmus program. During this period, the candidate conducted four experimental and applied studies, developing advanced skills in experimental design, data collection, statistical analysis, and interpretation of results, thereby consolidating the methodological foundations necessary to address complex studies in the fields of sport and metabolism.

This international experience allowed the doctoral candidate to engage with different methodologies, multicenter approaches, and advanced assessment tools in physiology, motor neuroscience, metabolism, and sports medicine. The activities carried out represented a crucial moment of multidisciplinary training, providing the opportunity to integrate theoretical and practical knowledge, develop critical scientific analysis skills, and strengthen abilities in managing international collaborations.

The time spent in Novi Sad under the supervision of Professor Patrik Drid therefore represented a crucial step, preparing the doctoral candidate to embark on the PhD journey with a solid methodological and experimental background. The skills acquired during these six months made it possible to approach subsequent studies on combat sports with greater awareness and rigor, particularly regarding the impact of RWL on performance, physiology, metabolism, and psychological aspects, thus providing an ideal continuum between pre-doctoral training and advanced research.

The first study, a systematic review on the role of psychological factors in judo, highlighted how anxiety, motivation, emotional states, and perceived exertion can significantly influence athletes' performance and well-being. The analysis, conducted on data from 721 high-level judoka, showed that elevated levels of tension, nervousness, or anger were associated with poorer competition outcomes, while higher motivation and reduced negative emotions were correlated with better performances. This work provided an updated overview of the influence of psychological factors in combat sports and emphasized the importance of monitoring and training these aspects in competitive preparation.

The second study investigated the impact of combining high-intensity sport-specific training and RWL on cardiovascular parameters in Greco-Roman wrestlers. The results showed that RWL impaired heart rate recovery (HRR) during the first minutes post-training, suggesting a negative effect on the aerobic component of performance. This study highlighted how RWL, if not properly managed, can directly affect an athlete's ability to recover between high-intensity efforts.

The third study analyzed the prevalence of RWL practices among Olympic wrestlers, showing that 69% of participants underwent weight reductions before competition, with an average loss of about 4 kg in the seven days preceding the event. The research also revealed the predominant role of coaches in determining RWL strategies, while nutritionists and physicians played only a marginal role. This work provided a detailed picture of current practices, highlighting potential health risks and the need for greater education of the professionals involved in athlete preparation.

The fourth study assessed the effect of RWL on handgrip strength in Greco-Roman wrestlers. The results demonstrated that the combination of specific training and RWL can alter certain performance capacities, with significant differences observed between measurements taken before and after RWL. These findings have important practical implications for optimizing weight reduction strategies and managing performance in combat sports.

Taken together, these studies outlined an initial framework of the multidimensional effects of RWL, highlighting its simultaneous impact on physiological, metabolic, muscular, and psychological parameters. The research conducted so far has therefore laid the groundwork for an integrated approach aimed at understanding not only athletic performance but also athletes' short- and long-term health.

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