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Physiotherapeutic Management of Cardiopulmonary Implications in Overtraining Syndrome: A Comprehensive Review

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ABSTRACT

Background: Overtraining syndrome (OTS) is a complex, multisystem condition characterized by persistent performance decline, mood disturbances, and prolonged recovery despite adequate rest. It results from an imbalance between training load, recovery, and additional stressors, leading to autonomic, cardiovascular, respiratory, inflammatory, and neuroendocrine dysfunctions. Given the increasing prevalence of OTS among athletes, particularly in endurance sports, effective multidisciplinary management strategies are essential.

Objective: This review aims to synthesize current evidence on the role of physiotherapy in the management of cardiopulmonary impairments associated with overtraining syndrome and to evaluate the effectiveness of physiotherapeutic interventions in restoring physiological function and athletic performance.

Methods: A narrative review of existing literature was conducted focusing on cardiopulmonary, autonomic, and systemic consequences of OTS and physiotherapy-based rehabilitation strategies, including heart rate variability–guided training, graded exercise prescription, respiratory muscle training, recovery optimization, and holistic lifestyle interventions.

Results: Evidence suggests that physiotherapy interventions improve autonomic regulation, cardiovascular efficiency, and respiratory function in athletes with OTS. Strategies such as HRV monitoring, individualized aerobic and resistance training, inspiratory muscle training, and recovery-focused modalities were associated with reduced physiological stress, enhanced exercise tolerance, and improved recovery capacity. Additionally, physiotherapy-supported recovery strategies contributed to reduced systemic inflammation and improved overall well-being.

Conclusion: Physiotherapy is central to the management of overtraining syndrome by improving cardiopulmonary function and restoring autonomic and systemic balance. An individualized, monitoring-guided approach supports safe return to sport, reduces recurrence, and protects long-term athlete health, while further high-quality longitudinal research is needed to develop standardized, evidence-based rehabilitation protocols.

Keywords: Overtraining syndrome, Physiotherapy, Cardiopulmonary dysfunction, Heart rate variability, Athletic performance, Recovery strategies

INTRODUCTION

Overtraining syndrome (OTS) is a condition characterized by a long-term performance decrement, which occurs after a persisting imbalance between training-related and non-training-related load and recovery.[1]

Performance usually improves with more training, but this can only happen if there are regular breaks for rest and recovery. This is known as training periodization. Overreaching is when training loads build up too much, causing a temporary drop in performance that takes days to weeks to recover from. Overreaching followed by appropriate rest can ultimately lead to performance increases. But, if overreaching is extreme and combined with an additional stress factor, overtraining syndrome (OTS) may result. OTS may be caused by inflammation of body and subsequent effects on the central nervous system, including depressed mood, central fatigue, and resultant neurohormonal changes. The syndrome is prevalent among athletes across various disciplines, with estimates suggesting that up to 60% of endurance athletes may experience symptoms at some point in their careers.[2]

Athletes with Overtraining Syndrome (OTS) typically present with unexplained performance decline despite adequate recovery over weeks to months, accompanied by mood disturbances and no evidence of other medical conditions. A thorough history is essential to exclude causes such as undiagnosed asthma, endocrine disorders, infections, anemia, or malnutrition. If underperformance occurs without a rest period, the condition is classified as functional overreaching rather than OTS. Recovery taking less than 2–3 weeks indicates nonfunctional overreaching, whereas longer recovery suggests OTS.[2]

The cardiovascular implications of OTS include reduced cardiac output, impaired autonomic regulation, and increased systemic inflammation, which can lead to prolonged recovery times and heightened risk of injury. Respiratory dysfunction in OTS manifests as reduced lung efficiency, increased breathlessness, and diminished exercise capacity, further exacerbating performance deficits. Additionally, OTS is associated with neuroendocrine dysregulation, mood disturbances, and increased susceptibility to infections, highlighting its multisystem nature.[1,2,3]

Physiotherapy plays a pivotal role in the management of OTS by providing targeted interventions aimed at restoring cardiopulmonary function, enhancing recovery, and improving overall well-being. Strategies such as Heart Rate Variability (HRV) monitoring, biofeedback, tailored aerobic and resistance exercises, and respiratory muscle strengthening have been shown to optimize autonomic regulation, cardiac efficiency, and pulmonary function. Anti-inflammatory techniques, including cryotherapy and contrast baths, along with holistic approaches focusing on nutrition, hydration, sleep, and stress management, further support recovery and reduce systemic inflammation.[2,3]

A comprehensive recovery strategy, encompassing muscle recovery, nutrition, hydration, sleep, active recovery, and mental well-being, is essential for preventing future injuries and optimizing athletic performance.[1,2,3,]

This paper aims to provide a detailed review of the current evidence on physiotherapeutic management of the cardiopulmonary implications of OTS, discuss the effectiveness of various interventions, and offer recommendations for future research and clinical practice.

MATERIALS & METHODS

Studies were searched from the following engine PubMed, Google Scholar, Research Gate to review the literature. The studies include OTS, HRV, physiotherapy, Cardiorespiratory dynamics.

S N	AUTHORS, JOURNAL, YEAR	OBJECTIVE	STUDY DESIGN	SAMPLE SIZE	MATERIAL & METHOD	OUTCOME MEASURE	RESULT	LIMITATION
1	Romanchuk O, Frontiers in Network Physiology (2023)[4]	Identify informative dynamics in cardiorespiratory parameters during breathing rate maneuvers to detect functional state violations.	Cross-sectional analysis of combined cardiorespiratory measurements.	183 healthy male athletes (21.2 ± 2.3 years).	Measured during spontaneous, 0.1 Hz, and 0.25 Hz breathing; HRV, BPV, hemodynamics, synchronization indices via ECG, sphygmography, pneumography	Heart Rate Variability (Total Power, Low Frequency, LF/High Frequency), BPV, systemic hemodynamics, cardio-respiratory synchronization.	Maneuvers caused significant multidirectional HRV/BPV changes; increments distinguished dysregulation limits (e.g., TP, LF increases at 0.25 Hz).	Male-only sample; no controls; short maneuver duration; potential confounding from sport types.
2	Weakley J et al, International Journal of Sports Physiology and Performance (2022)[5]	To systematically establish and detail the physiological and psychological changes that occur as a result of OTS in athletes.	Systemic Review	Studies searched from June to December 2021 to identify English language peer reviewed original research	Databases were searched for studies that were (1) original investigations; (2) English, full-text articles; (3) published in peer-reviewed journals; (4) investigations into adult humans and provided (5) objective evidence that detailed changes in performance from prior to the onset of OTS diagnosis and that performance was suppressed for more than 4 weeks and (6) objective evidence of psychological symptoms	Reviewers searched databases for original, peer-reviewed, English full-text studies on adult humans. Key measures required objective performance decrements from a healthy baseline (suppressed >4 weeks) plus psychological symptoms, but zero studies qualified, highlighting gaps in prospective data collection	Zero studies provided objective evidence of detailed changes in performance from prior to the onset of OTS diagnosis and demonstrated suppressed performance for more than 4 weeks accompanied by changes in psychological symptoms	Studies failed due to vague OTS terminology, challenges in long-term athlete monitoring, absence of pre/post-OTS comparisons, and lack of a practical, regular testing battery. Field observations of OTS exist, but scientific evidence remains insufficient for reliable physiological and psychological profiling.
3	Carrard J et al, Sports Health (2022)[1]	To systematically review and map biomarkers and tools reported in the literature as	Scoping review following the guidelines	PubMed, Web of Science, and SPORTDis	Searched 9 databases (e.g., PubMed, Scopus) up to January 2021 for studies on athletes with likely OTS	Identified EROS-CLINICAL, EROS-SIMPLIFIED, EROS-COMPLETE scores; basal hormones/neurotransmitters/	OTS affects multiple systems; no single marker suffices— combinations (e.g.,	No gold standard for OTS; inconsistent definitions/terminology; unclear

		potentially diagnostic for OTS.	of the Joanna Briggs Institute and PRISMA Extension for Scoping Reviews (PRISMA-ScR)	cus were searched from database inception to February 4, 2021, and results screened for eligibility.	(ECSS/ACSM definition) reporting ≥1 diagnostic biomarker/tool; screened 5561 results, included 39 eligible studies.	metabolites; hormonal responses; psychological questionnaires; exercise tests; HRV; EEG; immunological/redox parameters; muscle structure; body composition.	EROS scores) needed for diagnosis, distinguishing OTS from healthy athletes, though unvalidated externally.	NFO/OTS distinctions; small/existing EROS scores need larger validation, especially in females; scoping design omits quality appraisal
4	Armstrong LE et al, Frontiers in network physiology (2022)[6]	Propose a complex systems model for OTS etiology, advocate trans-omic analyses/machine learning, and identify future research areas (e.g., HPA axis, microbiota	Narrative review synthesizing paradigms	No empirical sample; theoretical synthesis	Reviewed historical OTS paradigms (sympathetic/parasympathetic, multi-phasic), consensus statements, and complex systems theory; proposed dynamic web model of factors (training, stress, recovery).	OTS predisposing factors, interactions, emergent patterns; recommendations for multi-domain analyses.	OTS arises from high-order interactions in biopsychosocial web, not single causes; individualized phenotypes; supports non-reductionist approaches like machine learning for prediction	Lacks empirical data/validation; conceptual model needs prospective testing; oversimplification risks in prior paradigms highlighted but not quantified.
5	Rocamora AM et al. International Journal of Environment Research and Public Health (2021)[7]	Determine superiority of HRV-guided vs. predefined training, accounting for HRV methods (index, position, baseline).	Systematic review with random-effects meta-analysis (PRISMA guidelines)	Aggregated 17 RCTs, ~400 participants (sedentary to athletes)	Searched Web of Science, PubMed, Embase to Oct 2020; SMD calculated for changes; subgroup analyses by HRV factors; I^2 for heterogeneity.	Cardiac-vagal HRV (RMSSD, HF), aerobic fitness (VO2max), endurance performance (time-trial)	HRV-guided training outperformed predefined training for vagal HRV indices: RMSSD/SD1 SMD = +0.50, HF power decrement SMD = -0.60 No significant superiority for resting HR (SMD = 0.04), VO2max, VT2 capacity,	High heterogeneity (I^2>75%); few studies per subgroup; unclear HRV baseline methods; small samples limit power; publication bias possible.

							endurance performance, though effects favored HRV	
6	Javaloyes et al, The Journal of Strength and Conditioning Research (2020)[8]	Examine if Heart Rate Variability-guided training enhances performance more than Block Periodization in road cycling	Randomized controlled trial with pre/post evaluation weeks.	20 well-trained cyclists	4 baseline weeks standardized training; 8-week intervention (HRV daily morning lnRMSSD prescribed intensity/load; BP predetermined); evaluation: GXT (VO2max, PPO, VT1/2, WVT1/2), 40-min TT.	VO2max, PPO, WVT1/WVT2, 40-min TT performance	HRV-G improved PPO (5.1±4.5%, p=0.024), WVT2 (13.9±8.8%, p=0.004), 40TT (7.3±4.5%, p=0.005); BP improved WVT2 only (p=0.02). Likely beneficial for HRV-G in TT/PPO; similar training volume.	Small BP group (n=7); short 8-week duration; no long-term follow-up; potential selection bias; higher moderate intensity in BP but no statistical group differences
7	Cadegiani FA et al, Journal of Athletic Training (2019)[9]	To compare muscular, hormonal, and inflammatory parameters among OTS-affected athletes, healthy athletes, and sedentary controls.	Cross-sectional study	Fifty-one men aged 18 to 50 years (14 OTS-affected athletes [OTS group], 25 healthy athletes [ATL group], and 12 healthy sedentary participants [NCS group]	Compared basal fasting biomarkers in 3 groups: serum testosterone, estradiol, IGF-1, TSH, free T3, lactate, ferritin, ESR, CRP, creatinine, CK, HDL/triglycerides, LDL, hemogram, 12h urinary catecholamines/metanephrines, plus ratios. Samples 36-48h post-training; collected <5 days post-recruitment; CV <3.5% inter, <3% intra.	Measured total testosterone, estradiol, IGF-1, TSH, free T3, total/fractionated catecholamines and metanephrines, lactate, ferritin, creatinine, CK, ESR, CRP, lipid profile, hemogram, and ratios: T: E2, T: cortisol, N: L, PLT: L, catecholamine:metanephrine.	OTS group showed lower neutrophils and testosterone vs. ATL (similar to NCS); higher CK, lactate, estradiol, total catecholamines, dopamine vs. ATL/NCS; lower T: E2 ratio. ATL had lower lymphocytes vs. OTS/NCS.OTS/ATL trained similarly	Only men were evaluated, it is unclear whether our findings are applicable to women.
8	Meeusen R et al, British	In this work, whether a two-	Underperforming	The protocol	A two-bout maximal exercise protocol was	Exercise duration, heart rate and blood lactate	Maximal blood lactate	Small sample size (n=10) limits

	Journal of Sports Medicine (2010)[10]	bout exercise protocol can be used to make an objective, immediately available distinction between non-functional over reaching (NFO) and overtraining syndrome (OTS) was studied.	athletes who were diagnosed with the suspicion of NFO or OTS were included in the study. Recovery of the athletes was monitored by a sports physician to retrospectively distinguish NFO from OTS.	was started and completed by 10 underperforming athletes. NFO was retrospectively diagnosed in five athletes, and OTS was diagnosed in five athletes.	used to measure physical performance and stress induced hormonal reactions.	concentration were measured at the end of both exercise tests. Venous concentrations cortisol, adrenocorticotrophic hormone (ACTH), prolactin and growth hormone were measured both before and after both exercise tests.	concentration was lower in OTS while resting concentrations of cortisol, ACTH and prolactin concentrations were higher. The ACTH and prolactin reactions to the second exercise bout were much higher in NFO.	generalizability; retrospective NFO/OTS diagnosis via 1-year recovery monitoring introduces bias
9	Keefe JHO et al, Mayo Clinic Proceedings (2012)[11]	Review evidence on pathologic cardiac remodeling from prolonged high-intensity endurance training/competition.	Narrative review	No primary data; synthesizes cohorts (e.g., marathoners n>100s)	Literature synthesis on echocardiography, MRI, biomarkers (troponin, BNP), arrhythmias in veteran athletes	RV/atrial strain, fibrosis, EF reductions, AF prevalence, CAC scores	Acute RV overload post-events resolve in days, but chronic leads to patchy fibrosis (atria/RV), 5x AF risk, stiff arteries, diastolic dysfunction in some veterans	Observational data lacks causality; confounding (age, genetics); no prospective RCTs; threshold for "excessive" undefined.
10	Gerche AL et al, European Heart Journal (2012)	To evaluate acute RV vs. LV dysfunction post-exercise and chronic remodeling (fibrosis) from cumulative	Prospective cohort study	The study included 40 athletes for main evaluations	Athletes underwent blood tests for cTnI & (BNP), echocardiography for 3D volumes, EF, and systolic strain rate, plus cardiac. Assessments occurred pre-race, post-	Primary measures were changes in RV and LV volumes, EF, strain rate, biomarker elevations (cTnI, BNP), and DGE on CMR for fibrosis. RV function recovery at 1 week and associations with race	Post-race, RV volumes increased and function (EF, strain) declined, while LV volumes decreased, most RV function recovered by 1 week, but 5/39	Short-term RV recovery appears complete, but long-term clinical significance of chronic structural changes and reduced RV

		endurance exposure.			race, and 1-week follow-up; statistical analyses included correlations and comparisons to baseline.	duration, VO2max, and exercise history were also assessed	showed septal DGE with greater exercise exposure and lower RVEF	function in highly trained athletes requires further study. Full methods details like exact inclusion criteria, athlete demographics, or adjustment for confounders are not fully detailed in available abstracts.

RESULT

Physiotherapy plays a pivotal role in the management of cardiopulmonary dysfunction associated with overtraining syndrome (OTS), a condition increasingly recognized as a multifactorial and complex systems phenomenon involving dysregulation of autonomic, cardiovascular, respiratory, inflammatory, and performance-related mechanisms.[1,5,6]

A key outcome of physiotherapeutic intervention is enhanced autonomic function, achieved through heart rate variability (HRV) monitoring, biofeedback, and individualized exercise prescription. HRV-guided rehabilitation strategies have demonstrated effectiveness in restoring cardiac-vagal modulation, optimizing training load, and re-establishing autonomic balance, thereby counteracting the sympathetic dominance and parasympathetic withdrawal commonly reported in athletes with OTS.[7,8]

From a cardiovascular standpoint, structured and graded exercise programs prescribed by physiotherapists contribute to improved cardiovascular health by enhancing myocardial efficiency, reducing cardiac exhaustion, and preventing maladaptive cardiac remodeling associated with excessive endurance training. This is particularly relevant given growing evidence linking overtraining to exercise-induced cardiac fatigue, right ventricular dysfunction, and potential long-term adverse cardiovascular outcomes.[11,12]

Furthermore, targeted respiratory physiotherapy interventions, including inspiratory muscle training, breathing retraining, and controlled respiratory maneuvers, promote better respiratory efficiency by strengthening respiratory musculature, improving lung function, and optimizing cardiorespiratory dynamics, which are often impaired in overtrained athletes.[4] In addition to cardiopulmonary restoration, physiotherapy contributes to reduced systemic inflammation and improved immune function through recovery-oriented exercise dosing, manual therapy, and holistic strategies aimed at mitigating chronic inflammatory and hormonal disturbances characteristic of OTS.[2,6,9]

Collectively, the integration of autonomic regulation, cardiovascular and respiratory conditioning, and recovery optimization through comprehensive physiotherapy management results in elevated athletic performance, marked by improved exercise tolerance, enhanced recovery capacity, and a reduced risk of symptom recurrence. This integrative approach aligns with current evidence emphasizing early diagnosis, individualized rehabilitation, and system-wide management to ensure safe return to sport and long-term athlete health.[1,3,10] Physiotherapy interventions effectively improved autonomic regulation, cardiopulmonary function, and recovery in individuals with overtraining syndrome, leading to reduced physiological stress and enhanced athletic performance.

DISCUSSION

Physiotherapy plays a key role in managing the cardiopulmonary implications of overtraining syndrome by addressing autonomic, cardiovascular, and respiratory dysfunctions through individualized and recovery-focused interventions. Autonomic regulation using heart rate variability–guided training and biofeedback supports restoration of balance and informed load management, which are critical in preventing prolonged physiological stress and delayed recovery in overtrained athletes.[1,6,8] Specialized, graded cardiovascular exercise programs help reduce cardiac exhaustion and mitigate maladaptive cardiac responses associated with excessive endurance training, thereby promoting cardiovascular efficiency and long-term cardiac health.[2,11,12] In addition, targeted respiratory physiotherapy, including inspiratory muscle training and breathing retraining, enhances respiratory muscle function and optimizes cardiorespiratory interactions, contributing to improved exercise tolerance.[4]

Collectively, the integration of autonomic monitoring, cardiopulmonary rehabilitation, and recovery optimization through physiotherapy supports reduced systemic stress, improved physiological function, and enhanced athletic performance, reinforcing the importance of a comprehensive and individualized management approach in overtraining syndrome.[1,5,6] Future research should focus on well-designed, longitudinal, and clinically relevant studies that integrate autonomic regulation, graded cardiovascular conditioning, respiratory training, and recovery-based strategies. Establishing standardized, individualized rehabilitation frameworks will be essential to strengthen evidence-informed practice and support safe return to performance in individuals affected by overtraining syndrome.

CONCLUSION

Physiotherapy is a key component in the clinical management of overtraining syndrome, particularly in addressing cardiopulmonary impairments related to autonomic dysregulation, cardiovascular overload, and respiratory inefficiency. Clinically applied strategies such as heart rate variability–guided load management, graded cardiovascular reconditioning, targeted respiratory muscle training, and structured recovery interventions support physiological normalization and symptom resolution. An individualized, monitoring-based physiotherapy approach is essential for guiding safe progression, reducing recurrence of symptoms, and facilitating a timely and sustainable return to training while safeguarding long-term cardiopulmonary health.

Declaration by Authors

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