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Integrated protocol for isokinetic and biomechanical assessment in muscle recovery for high-performance athletes.

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Integrated protocol for isokinetic and biomechanical evaluation in muscle recovery of high-performance athletes

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Summary

Muscle recovery in high-performance sports requires diagnostic precision combined with...
Interventions guided by quantitative data. This article presents a proposed protocol.
clinical practice, developed over nearly two decades of specialized experience, which integrates
Isokinetic dynamometry and functional biomechanical analysis to identify asymmetries and deficits in
Torque. A multidisciplinary approach, grounded in exercise physiology and monitoring.
Continuous systemic treatment aims to reduce the incidence of relapses and optimize the return to sport. It is proposed...
that sports clearance be based on objective quantitative criteria, individualized progression.
Based on updated scientific goals and foundations. The prospective multicenter validation of this protocol.
This constitutes the subsequent stage of the investigation.

Keywords: Sports Rehabilitation; Biomechanics; Isokinetic Dynamometry; Muscle Recovery; Orthopedic Physiotherapy.

Abstract

Muscle recovery in high-performance sports requires diagnostic precision combined with
interventions guided by quantitative data. This article presents a clinical protocol proposal developed
over nearly two decades of specialized practice that integrates isokinetic dynamometry and functional
biomechanical analysis to identify hidden asymmetries and specific torque deficits. The
multidisciplinary approach, grounded in exercise physiology and continuous systemic monitoring,
aims to reduce the incidence of recurrence and optimize return to sport. It is proposed that sports
clearance be based on objective quantitative criteria, individualized goal-driven progression, and up-
to-date scientific evidence. Prospective multicenter validation of this protocol constitutes the next
step in the investigation.

Keywords: Sports Rehabilitation; Biomechanics; Isokinetic Dynamometry; Muscle Recovery; Orthopedic Physiotherapy.

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Introduction

The incidence of musculoskeletal injuries among elite athletes represents a complex challenge for sports health teams. The clinical management of these occurrences often determines the The success or decline of a competitive season requires swift and well-founded interventions. In evidence. Historically, traditional therapeutic models were limited to pain relief. and to basic tissue healing, neglecting underlying structural dysfunctions. Bahr and Krosshaug (2005) already warned of the need to understand the multifactorial mechanisms of injuries, emphasizing that the absence of pain rarely equates to full functional readiness.

With the maturation of the Human Movement Sciences, it has been demonstrated that imbalances Subtle force and kinematic changes remain latent when not measured by adequate technological instrumentation. This diagnostic gap accounts for the high rates of Recurrence observed in both explosive and physical contact modalities. Paton et al. (2023), in the Consensus The London International Committee on muscle injuries reaffirmed that assessment through testing... Isolated manuals fail to detect critical biomechanical asymmetries, making the adoption of alternative methods imperative. of instrumented assessments.

To address this methodological limitation, this article describes an integrated protocol that... It combines computerized isokinetic assessment, functional biomechanical rehabilitation, and... Continuous physiological monitoring. The central objective is to present the scientific guidelines for this. The proposal demonstrates, with support from recent research and the author's scientific output, that the proposal is supported by recent research and the author's scientific output. (Gomes Júnior et al., 2024), how data quantification can make muscle recovery a A predictable, measurable, and safe process.

This is a report of a systematized clinical experience, based on scientific literature. international. It is recognized that formal validation of the protocol through randomized studies Controlled studies represent a current limitation and a future research agenda.

1. Cellular Physiology of Muscle Tissue Injury and Repair

Understanding the microscopic and macroscopic mechanisms of striated muscle tissue Skeletal muscle formation forms the basis for any excellent therapeutic intervention. A rupture of myofibrils trigger an inflammatory cascade coordinated by chemical mediators essential to biological signaling. Järvinen et al. (2005) demonstrated that the initial phagocytic process is necessary for the removal of necrotic tissue and for the activation of myogenic satellite cells. Careful management of the acute inflammatory response determines the structural integrity of the tissue. repaired. Interventions that completely block the cyclooxygenase pathway can result in

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Mechanically fragile and disorganized repair tissue (Mackey et al., 2011). On the other hand, the Excessive accumulation of inflammatory exudate causes local ischemia and delays cell proliferation. fibroblasts. The balance between these poles guides therapeutic modulation in the early stages of treatment.

The scar tissue resulting from the remodeling phase exhibits viscoelastic properties. distinct from those of the original fiber, with less elasticity and greater susceptibility to breakage when prematurely subjected to maximum stress. Therefore, motor intervention should promote Progressive alignment of collagen fibers through gradual therapeutic mechanical stress. respecting the biological timing of each stage of healing.

2. Isokinetic Dynamometry as a Diagnostic and Prognostic Tool

Computerized isokinetic evaluation has transformed our understanding of generation capacity. human strength in specialized rehabilitation centers. The equipment allows for the measurement of maximum peak torque at various predetermined angular velocities, with resistance accommodative structure that ensures joint integrity under maximum stress (Dvir, 2004).
In clinical practice, isokinetic technology replaces the subjectivity of conventional manual tests. through precise kinetic graphs, detailing the contractile behavior of the muscle at each degree of range of motion. This level of detail reveals specific deficits that would go unnoticed in purely observational assessments.
One of the primary indicators is the strength ratio between the agonist and antagonist muscles. Imbalances in this proportion, particularly in the hamstring/quadriceps ratio, constitute Predictive factors for muscle ruptures during sprints and sudden decelerations (Undheim et al., 2015). Bilateral asymmetry, in turn, is compared to the healthy contralateral limb: deficits Difficulties exceeding 10% represent an unacceptable biomechanical risk for sports clearance, according to... consensus from the literature and accumulated clinical experience in the described protocol.
The generated reports guide decision-making with transparency and allow the athlete themselves to... Visualize your shortcomings, which promotes adherence to the recovery program.

3. Advanced Biomechanical Analysis of Kinetic and Kinematic Patterns

Compromised muscle in one group affects the entire interconnected kinetic chain.
The central nervous system rapidly develops compensatory adaptations to avoid stimulation of nociceptors and preservation of locomotion. These adaptive patterns, however, alter They negatively affect joint kinematics and overload previously healthy adjacent structures.

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Biomechanical mapping is an indispensable tool for the early detection of these compensations. The protocol uses two-dimensional biophotogrammetry and high-rate video recording. charts for the analysis of athletic movement, with special attention to lumbopelvic stability and to Dynamic valgus alignment of the knees during landing.

Studies by the author himself (Gomes Júnior et al., 2024) have shown that Impingement Syndrome The femoroacetabular joint imposes severe kinematic restrictions, altering the efficiency of displacements and generating compensatory torsional forces, frequently culminating in recurrent injuries in pelvic complex. The integrity of the plantar arch and the mobility of the talocrural joint are also important. They directly modulate the recruitment of proximal stabilizers.

The reconditioning of neuromotor control acts in the progressive deconstruction of these patterns. injury. The athlete is trained to recruit the appropriate motor units in chronological sequence. correct, restoring inter- and intramuscular coordination and reducing the risk of joint wear. premature.

4. Multidisciplinary Systemic Integration in High Performance

The recovery of an athlete subjected to extreme demands cannot be conducted under a fragmented clinical perspective. The integration between orthopedic physiotherapy and knowledge in Clinical nursing broadens the scope of analysis and provides a relevant therapeutic advantage to... to treat the organism as an integrated biological system.

Monitoring of basal metabolic status should precede the start of any session. Intensive rehabilitation. Detection of central nervous system fatigue or infectious processes. Subclinical conditions significantly reduce the ability to adapt to regenerative training. (Gabbett, 2016). Monitoring vital signs and heart rate variability (HRV) and the scales of perceived exertion guide the magnitude of the daily workload.

Therapeutic modulation of the inflammatory process through biophysical resources, including Photobiomodulation and compression therapy require in-depth knowledge of windows. therapeutics and dosimetry, with the aim of maximizing mitochondrial respiration without inducing stress. additional oxidative.

Health education is an essential pillar of the therapeutic relationship. The athlete receives guidance. based on the restorative role of deep sleep phases and the importance of management of stress outside the clinic (Bourdon et al., 2017). Strict control of these extrinsic factors It enhances the results of isokinetic training and keeps the body in an environment... biochemical factors that favor protein synthesis.

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5. Exercise Prescription Based on Objective Metrics

The design of a contemporary kinesiotherapy program requires abandoning empiricism in
For the sake of quantitative precision. Based on isokinetic reports, the therapeutic prescription is
targeted at the joint angles where the equipment identified the greatest deficits.
muscular.

In the initial stages, isometric exercise provides safe neural reactivation, endogenous analgesia, and
Recruitment of motor units without mechanical friction at the edges of the lesion. Progression to
Concentric contractions to restore trophism and basic contractile capacity and, subsequently,
for moderate to high intensity eccentric training, central body braking mechanism and
absorption of kinetic energy in sports movements. Van Dyk et al. (2016) demonstrated that the gain
Eccentric force training substantially reduces the incidence of muscle strains, a finding
corroborated by a systematic review by Rudisill et al. (2023).

The weekly training volume is adjusted in accordance with the acute:chronic load ratio of the
athlete, a tool whose predictive value has been reaffirmed in recent reviews (Matas-Bustos et al.,
2025; Bourne et al., 2018). Progression between phases is based exclusively on the achievement of goals.
biomotor and objective strength indices are considered, not the chronological time of absence. A
Pre-session isometric hand dynamometry allows for daily monitoring of fatigue.
Neuromuscular: drops greater than 10% indicate the need for immediate volume reduction.
programmed.

6. Dynamic Functional Testing and Neuromuscular Reconditioning

The maximum force in an open kinetic chain, measured on an isokinetic dynamometer, does not, by itself,
ensures motor competence in a competitive environment. Neuromuscular reconditioning has
with the goal of integrating the recovered contractile capacity into multiplanar movement patterns and
unstable, transferring adaptations from the clinic to the field (Wilk et al., 2024).

The Modified Star Excursion Balance Test (mSEBT) is used as an assessment tool.
Validated functional assessment, revealing deficiencies in dynamic postural control not detectable by
Static equipment (Plisky et al., 2009; Gomes Júnior et al., 2024). Proprioceptive training
through non-anticipatory external disturbances it re-educates the muscle spindles and tendinous organs of
Golgi, reducing the latency of the joint stabilizing response.

Plyometric exercises are introduced in the final stages to restore the efficiency of the cycle.
Muscle lengthening and shortening. The periodization of plyometric training follows specific criteria.
Strict measures are in place to prevent inflammatory overload in newly remodeled connective tissue structures.

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Final reconditioning simulates the specific kinetic demands of the tactical position and the sport.
The athlete's sporting development, ensuring the transfer of neuromuscular skills to the real-world context.
of the game.

7. Quantitative Criteria for Returning to Sport

The decision to clear an athlete for a return to competition is the moment of greatest responsibility.
Clinical practice in this protocol. Discharges based solely on the absence of symptoms are considered.
insufficient. The adopted criteria flow is cumulative: all the following parameters must be
completed before release.
The first criterion requires, at a minimum, the recovery of 90% of the peak isokinetic torque in relation to the
contralateral limb, the Limb Symmetry Index (LSI). Simultaneously, the ratio
The agonist/antagonist combination must conform to the normative references for the modality. The tests
For functional exercises, the triple crossover jump and the mSEBT must exhibit symmetry greater than 90% (Blanch &
(Gabbett, 2016). Finally, the absence of kinesiophobia and the athlete's psychological readiness are evaluated.
through validated scales and direct observation during competitive intensity simulations
(Ardern et al., 2013).
The release is formalized through a detailed technical report, containing infographics of
evolution, biomechanical asymmetry data and isokinetic results, and is forwarded to the entire
technical committee. Discharge ceases to be a clinical estimate and becomes the measurable outcome of
a structured process.

8. Longitudinal Monitoring and Relapse Prevention

The conclusion of the intensive rehabilitation period marks the beginning of an ongoing maintenance protocol.
Preventive structural monitoring. Longitudinal follow-up is considered an integral part of the protocol.
not an optional feature (Mendiguchia et al., 2017).
Quarterly isokinetic and biomechanical reassessments track the maintenance of torque patterns.
established. The density of the sporting calendar imposes cumulative microtraumas that can
compromising the strength reserves built up during rehabilitation. These reassessments function as
An early warning system, identifying silent declines before clinical breakdown.
Microcycles of preventive eccentric exercises and lumbopelvic stabilization are integrated into
pre-training warm-up for the athlete. The knowledge acquired during treatment enables the
The athlete performs their own maintenance routine independently. The flow of information

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Communication between the physiotherapist and the club's medical department allows for immediate adjustments to the training load.
work when experiencing signs of fatigue or decreased strength.

Table 1 – Summary of the Integrated Phased Protocol

Phase	Period	Instruments	Criteria of Progression	Main Objective
Acute	Days 1–7	Isometric dynamometry, vital sign monitoring, VFC	Absence of acute edema; pain ÿ 3/10 (EVE)	Inflammatory control and safe neural reactivation.
Subacute	Weeks 2–4	Isokinetic evaluation, biophotogrammetry 2D	ISM ÿ 70%; agonist/antagonist ratio within normative limits	Restoration of basic trophism and contractile capacity.
Functional	Weeks 4 8	mSEBT, jump tests, daily hand dynamometry	ISM ÿ 85%; symmetrical mSEBT ÿ 90%	Neuromuscular reconditioning and progressive plyometrics
Return to Sport	Weeks 8 12+	Full isokinetic battery, psychological readiness scale, specific sports simulation.	ISM ÿ 90%; triple hop ÿ 90%; absence of kinesiophobia	Safe release with detailed technical report.

ISM = Limb Symmetry Index; mSEBT = Modified Star Excursion Balance Test; HRV = Heart Rate Variability.

Limitations and Research Agenda

This protocol is based on systematized clinical experience and supported by the literature.
It is scientific, but it does not present primary data from a controlled clinical trial. That is
Its main methodological limitation. The absence of a control group and randomization prevents...
to causally assess the comparative effectiveness of the protocol.
As a future research agenda, it is proposed: (1) a prospective multicenter study with athletes of
different modalities; (2) analysis of the predictive validity of quantitative discharge criteria for
different populations; and (3) development of a longitudinal monitoring platform with
Integration of isokinetic, biomechanical, and training load data.

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Conclusion

The integration between computerized isokinetic assessment and functional biomechanical rehabilitation.
It raises the level of rigor in sports physiotherapy care. Replacing empiricism with objective metrics,
From diagnosis to sports clearance, it reduces the risk of relapse and provides a clinical basis.
every therapeutic decision.
A systemic view of the athlete, which incorporates metabolic monitoring, psychoeducation and
Longitudinal follow-up broadens the scope of intervention beyond the affected joint.
A successful return to sport is the outcome of a structured, biological process.
grounded in facts and customizable through quantifiable goals.
The standardization and prospective validation of this model represent the desired contribution to the
Advances in Sports Health Sciences, with the potential to reduce human and economic costs.
associated with musculoskeletal injuries in high-performance sports.

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