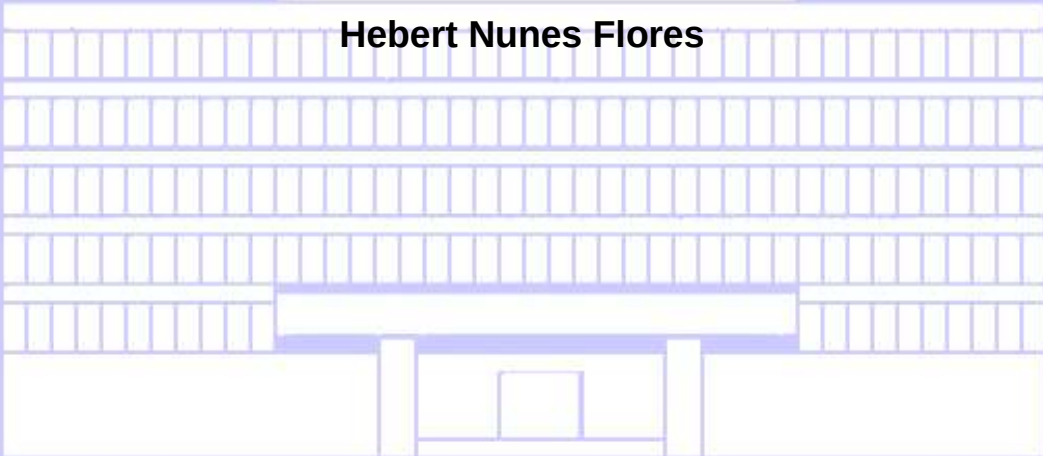


**UNIVERSIDADE FEDERAL DE CIÊNCIAS DA SAÚDE DE
PORTO ALEGRE
CURSO DE FISIOTERAPIA**



Hebert Nunes Flores

**Post-match muscle pain code: a
novel approach for screening the
risk of muscle injuries in football.**

**Universidade Federal de Ciências da Saúde
de Porto Alegre**

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Post-match muscle pain code: a novel approach for screening the risk of muscle injuries in football.

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Ao meu herói, que já não está mais entre nós, mas tenho certeza que de onde ele estiver certamente está feliz com mais essa conquista do seu “bicho véio”.

Te amo para sempre vô. Saudades.

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Gratidão.

RESUMO

Objetivo: Verificar a associação entre uma abordagem de dor muscular pós-partida, o *Muscle Pain Code* (MPC), com lesões musculares no futebol profissional masculino.

Design: Estudo de coorte retrospectivo com duração de quatro temporadas.

Contexto: Clube profissional de futebol de nível nacional.

Participantes: 80 jogadores.

Metodologia: O MPC classifica a dor em 4 códigos de acordo com a extensão da área dolorosa (0 – 3). Os escores individuais de dor foram coletados no segundo dia pós-partida e os jogadores eram monitorados quanto à ocorrência de lesões musculares por até cinco dias nas semanas com duas partidas

Resultados: Jogadores foram monitorado em ~21 pós-jogos, totalizando 1.656 follow-ups. Sessenta e dois jogadores sofreram 229 lesões. Em 98% dos follow-ups sem lesão muscular, o escore do MPC foi “0” ou “1”. Contrariamente, os casos de lesão foram precedidos em 63% e 78% por escores “2” e “3”, respectivamente. Houve um significativo aumento na probabilidade de predizer lesões musculares com o aumento dos escores (OR= 9.5).

Conclusão: Jogadores com escores 2 ou 3 no MPC possuem maior risco de lesões musculares no jogo subsequente. O MPC é uma ferramenta nova, factível e válida para identificar o risco de lesão muscular em jogadores profissionais de futebol.

Palavras-chave: Lesões musculares, escala de dor, futebol.

ABSTRACT

Objective: To investigate the association of a novel approach to assess post-match muscle pain, the Muscle Pain Code (MPC), with subsequent muscle injury.

Design: Four-season retrospective cohort study.

Settings: Professional football club competing in the highest national leagues.

Participants: Eighty players.

Main outcome measures: The MPC classifies pain in four codes according to the extension of the painful area (0 – 3). Individual pain codes were collected on the second post-match day, and players were followed for muscle injuries over the next five days in weeks with two matches.

Results: Players were followed by ~21 weeks, totaling 1656 follow-ups. Sixty-two players sustained 229 muscle injuries. 98% of the uninjured follow-ups were preceded by an MPC coded as 0 or 1. Conversely, 63% and 78% of follow-ups in which injuries occurred were preceded by codes 2 and 3, respectively. An increase in the predictability of muscle injuries was observed in follow-ups with increased MPC coded codes (OR = 9.5).

Conclusions: Players with post-match MPC coded as 2 or 3 have a higher risk of muscle injury in the subsequent days. MPC is a novel, feasible and valid approach to predicting muscle injury risk in professional soccer players.

Key words: Muscle strain, injury prevention, pain scale, soccer.

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LISTA DE ABREVIATURAS E SIGLAS

Confidence Intervals – CI

Delayed Onset Muscle Soreness – DOMS

Muscle Pain Code – MPC

Numeric Rating Scale – NRS

Odds Ratio – OR

Visual Analogue Scale – VAS

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Post-match muscle pain code: a novel approach for screening the risk of muscle injuries in football.

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1. Introduction

The overall incidence of injuries in professional male football (soccer) players is 8.1 injuries/1,000 hours (López-Valenciano et al., 2020). Muscle injuries are the most incident, accounting for 44-47% of all injuries (Bengtsson, Ortega Gallo, Ekstrand, 2021), and play a negative role in teams' performance (Häggglund et al., 2013) and clubs' finances (Eliakim, Morgulev, Lidor, Meckel, 2020). Consequently, muscle injury prevention is a major concern of the football medicine community. Elite clubs traditionally invest in screening testing batteries at preseason to identify those players with a high risk of injury (Meurer, Silva, Baroni, 2017; McCall et al., 2014). However, considering the complexity of sports injuries (Bittencourt et al., 2016) and the non-linear dynamic behavior of athletes and their risk factors for injuries along the season (Stern, Hegedus, Lai, 2020), preseason data has poor predictive value for in-season injuries (Opar et al., 2021). Therefore, incorporating continuous athlete monitoring to identify when players are most susceptible to injury seems recommendable for injury prevention. (Baroni, Costa, 2021).

Wollin, Thorborg, Drew and Pizzari (2020) implemented a secondary prevention strategy with hamstring maximum strength monitoring on the second post-match day and found a reduction in hamstring strain injury rate in under-17 football players. However, professional football clubs can play up to 80 matches per season, sometimes with three matches in a single week. In each match, players perform several high-intensity activities such as sprints, high-speed running, accelerations and decelerations, cuttings, jumping and changing of direction (Aquino et al., 2021) that may prompt transient fatigue during match-play and exacerbate post-match residual fatigue (Silva et al., 2018). It is also necessary to account for the physical burden caused by training sessions, as well as the mental stress caused by travel and all kind of pressures related to high-performance sport. As a consequence, monitoring the players' status through physical performance assessments, such as maximum strength testing, is challenging due to the teams' routine. Therefore, in order to achieve greater ecological value within the 'real world' of professional football, monitoring players over the season requires time-effective tools that generate the least possible physical burden on athletes.

Pain may be defined as an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage (IASP, 2021). Pain perception is typically measured by ordinal scales based on the

intensity of the painful symptom, such as the visual analogue scale (VAS) or the numeric rating scale (NRS) from 0 to 10 (Chiarotto et al., 2019). A range of pain intensity scales has been widely used for decades (Jensen, Karoly, Braver, 1986). Such scales have been applied to assess the exercise-related pain, derived from fatigue and muscle damage (usually referred to as delayed onset muscle soreness - DOMS) (Clarkson, Hubal, 2002); thus acting as an indirect marker of the athletes' post-exercise recovery status (Scherr et al., 2013). Concurrently, scales have been applied in the initial assessment of athletes with a suspected muscle injury, as well as repeated along the rehabilitation program to help clinicians in decision-making regarding the progression of treatment and return to sport (Medeiros, Aimi, Vaz, Baroni, 2020; Mendiguchia et al., 2017).

The Munich consensus statement (Mueller-Wohlfahrt et al., 2013) classified exercise-related muscle pain as 'type 1' (*overexertion-related muscle disorder*), while functional and structural injuries were classified as 'type 2' (*neuromuscular muscle disorder*) and 'type 3' (*partial muscle tear*), respectively. It is noteworthy that disorders and injuries might generate the same level of pain on an intensity scale, thus VAS or NRS scores in isolation are not able to distinguish injured athletes from merely fatigued ones. Conversely, the extension of the painful area is different in such conditions: athletes affected by exercise-related pain (i.e., type 1) usually experience a generalized discomfort in the exercised muscle groups, while those with functional or structural muscle injuries (i.e., types 2 and 3) usually report a specific site or zone of muscle pain (Mueller-Wohlfahrt et al., 2013). However, to the best of our knowledge, a method to classify muscle pain according to the extension of the painful area is lacking in the literature.

The current study proposed a novel approach for muscle pain classification: the Muscle Pain Code (MPC). The fundamental idea was to provide a quick and easy-to-use measurement tool that would allow inferring the most probable type of involvement responsible for post-match muscle pain. The MPC classifies muscle pain into 4 codes: "no pain" (code 0), "general muscle pain" (code 1), "regional pain in a muscle" (code 2) and "pain in a specific site of the muscle" (code 3). In theory, code 1 would be an indication of an overexertion-related muscle disorder (type 1), while codes 2 and 3 would be an indication of functional or structural muscle injury (types 2 or 3) (Mueller-Wohlfahrt et al., 2013). Finally, this study aimed to investigate the association of MPC

at the post-match second day with subsequent muscle injury risk in a cohort of professional football players.

2. Methods

2.1 Overview

In this observational retrospective cohort study, professional male football players were monitored throughout four seasons (2016 to 2019) to investigate the association between the post-match Muscle Pain Code (MPC) and subsequent muscle injury.

As part of the weekly clinical and physiological evaluation routine for muscle injury, MPC scores were collected on the second day after the index matches, before returning to the training routine. Players who entered the club during the study were informed and familiarized before having their data included in the analysis. Follow-up for the occurrence and recording of muscle injuries related to MPC continued for the next 5 days (Figure 1). Pre-season data was not included in the study.

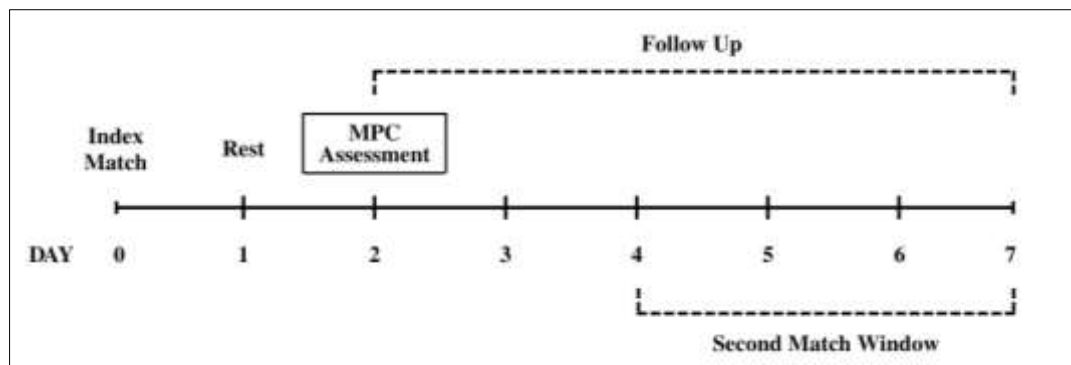


Figure 1. Flowchart of the study.

2.2 Participants

All players from a Brazilian male professional football team were considered for eligibility. The team competed in the Brazilian Championship A Series (top national league) in the first season and the B Series in the next three seasons. The number of players that met the inclusion criteria over the study determined the convenience sample size. Participants were informed of the benefits and risks of the investigation before

signing an informed consent to participate in the study. The study was approved by the Ethics Committee on Human Research of the XX (# 2.390.889).

To be included in the study the players should: 1) have gone through a general health assessment routine conducted by medical staff and be cleared to compete; 2) have the physical capabilities needed to face the football training and matches demands, defined by the club strength and conditioning staff; 3) have been monitored after playing at least five matches in the club, as a cut-off to avoid biased data and 4) have played at least 45 minutes in both index and follow-up matches of the week. Only weeks in which index and follow-up matches were interspersed by four to seven days were included in the analysis (i.e. congested periods, considered as 3 football matches per week, were not included). Goalkeepers and preseason data were not included in the study.

2.3 Injury Follow-up

In this present study, the non-contact muscle injury was defined as any physical complaint sustained by a player preventing his participation in training sessions or matches (Fuller et al., 2006). An index match was defined as the first match in a week a player finished without injury. The follow-up period lasted until the second match (follow-up match). Depending on whether a muscle injury occurred or not during the follow-up by each player, it would be considered an injury case or a non-injury case follow-up, respectively. A follow-up match finished without injuries was considered an index match for the next 7 days and so on.

2.4 Muscle Pain Code Assessment (MPC)

A categorical 4-point pain scale named Muscle Pain Code (MPC) was designed by authors to players report their post-match perception of the extension of the painful area in (Figure 2): “no pain” (coded as 0), “general muscle pain” (coded as 1), “regional pain in a muscle” (coded as 2) and “pain in a specific site of the muscle” (coded as 3).



Figure 2. Illustrative diagram of the 4 categories covered by the Muscle Pain Code (MPC).

The MPC was applied by the team's physiologist, and players who coded 0 on the scale were allowed to immediately participate in the team's planned training sessions and games. Players coding 1 on MPC participated in the scheduled training sessions after attending post-match recovery strategies (e.g., massage). When players coded 2 or 3 on MPC, the physiotherapist guided a clinical evaluation consisting of palpation of the muscles, passive and active range of motion, functional performance, and physical complaint. If a muscle injury was suspected, the team physician conducted an in-depth assessment, deciding whether ultrasound (Woodhouse, McNally, 2011) or magnetic resonance images (Stoller, 2007) were necessary for the diagnostic. When a muscle injury was confirmed, the player was referred for treatment by the club's physiotherapy department. Confirmation of a suspected injury that occurred in the index match caused the interruption of the follow-up and its exclusion from the analysis.

2.5 Statistical Analyses

Descriptive statistics were used to summarize participants' characteristics. Means, standard deviations and confidence intervals were computed for continuous variables and frequency distributions were generated for categorical variables. Data were analyzed in three stages. First, the association between pain extent and muscle injury through univariate logistic regression analysis was investigated. Then, a logistic regression model was used to analyze the effect of pain and its interaction with muscle injuries. The model used an unstructured working correlation. Associations were expressed as OR with 95% confidence intervals (CI). A $p < 0.05$ was considered significant. Analysis was performed using an Excel Spreadsheet available at

<https://www.pedro.org.au/english/downloads/confidence-interval-calculator/>. and IBM SPSS Statistics (version 22, Armonk, NY).

3. Results

Participants' mean (SD) characteristics were: 24.9 (4.1) years old, 79.0 (6.0) kg and 180 (5.5) cm in height. During the 4-season period, the team played a total of 273 matches (mean of ~68 per season) resulting in 1,656 eligible follow-ups that were included in this study. MPC was associated with muscle injury with a significant prediction likelihood ($b=2.2478$, $SE=0.1286$, $OR=9.4669$, 95% CI (7.35-12.18), $p<0.001$). (Figure 3).

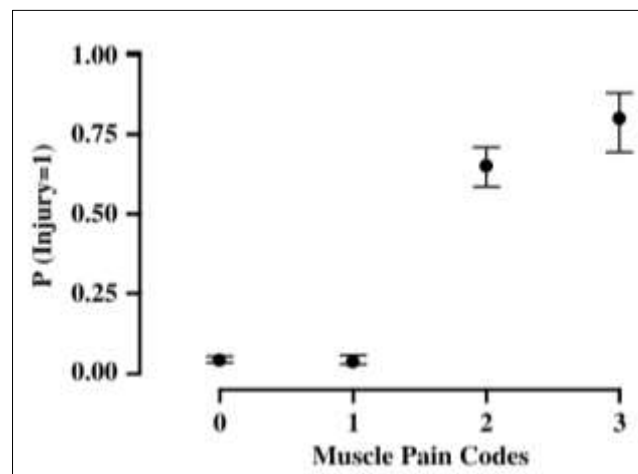


Figure 3. Association between pain codes and injury (0 = not injured; 1 = injured).

Of the 80 players included in the study, 62 (77.5%) had at least one muscle injury confirmed. All injuries occurred in official matches. On average, injuries were identified in 14% of follow-ups. Overall, the included athletes suffered 229 muscle injuries during the study (Table 1). The most prevalent muscle injuries were in the hamstrings with 123 cases (54%, in 56% of athletes). Of all injury cases reported, 88% were preceded by MPC codes 2 and 3 (Table 2). Players reporting code 0 stayed uninjured in 942 follow-ups, which represents 66% of the uninjured cases. The classification into no pain (code 0), general pain (code 1), regional pain in a muscle (code 2) and pain in a specific site of the muscle (code 3) generated an incremental increase in Odds Ratio (OR).

Table 1. Location of muscle injuries sustained in the follow-up periods.

Muscle Injured	Primary	Re-injury	% of Players
Hamstring (123)	45 (37%)	78 (63%)	56%
Adductor (49)	34 (69%)	15 (31%)	43%
Triceps Suræ (43)	28 (65%)	15 (35%)	35%
Quadriceps (11)	8 (73%)	3 (27%)	10%
Psoas (3)	3 (100%)	0 (0%)	4%
Total	52%	48%	77%

Table 2. Odds ratio (95% Confidence Interval) of different pain levels (codes 1 to 3) in relation to no pain (code 0) for subsequent muscle injuries.

Pain	Data		OR (95%CI)
	Uninjured	Injured	
0	942 (98%)	21 (2%)	-
1	383 (98%)	6 (2%)	0.78 (0.33 – 1.84)
2	85 (37%)	143 (63%)	73.04 (44.28 – 120.47)
3	17 (22%)	59 (78%)	151.12 (76.20 – 299.67)

4. Discussion

In this study, we investigated the association between a novel approach to assess post-match muscle pain, the Muscle Pain Code (MPC), with subsequent muscle injury occurrence in a cohort of professional football players. To the best of our knowledge, this is the first study aiming for the classification of pain based on its extension and muscle region affected that has been followed up for the incidence of muscle injury. Lined up with our hypothesis, our findings show that post-match focal pain leads to a higher likelihood of sustaining a muscle injury in the subsequent days than a spreading pain.

Throughout the present study, there were muscle injuries in 14% of all follow-ups. The hamstring, adductors, gastrocnemius, and quadriceps were the most prevalent muscles injured over the four seasons, making our results in agreement with football epidemiological studies (López-Valenciano et al., 2020; Ekstrand, Häggglund, Waldén, 2011). Hamstring muscle alone represented more than half of all muscle injuries reported, seeming a significantly higher than the 37% presented by Ekstrand et al (2011). The average of ~57 injuries per season during the four seasons, also suggests an elevated number of injuries in a single club, even if considered congested periods (Bengtsson, Ekstrand, Häggglund, 2013). Although concerning, this inflated incidence may be partially explained by the definition of injury used in the study, based on the absence of a player from training and/or match due to muscular complaints (Fuller et al., 2006). Also, the increasing number of high-speed running and sprints during football matches in the recent years, which are the most common mechanism of this muscle injury (Danielsson et al., 2020) may play a role in the number of muscle injuries found (Nobari et al., 2021).

High-intensity football tasks, such as sprinting, require a peak of myoelectric activation and eccentric force in an elongated position (Kakehata, Goto, Iso, Kanosue, 2021), which repeatedly performed in a match can result in both micro ruptures or fiber ruptures resulting in muscle damage which potentially causes a different perception of the unpleasant sensorial in the muscles (Silva et al., 2018). Although muscle damage is commonly assessed by the Visual Analogue Scale (VAS), this tool based on pain intensity does not seem to be accurate to differentiate the level of muscle damage to be used as a predictor of subsequent risk of muscle injuries. Differently, the development of the MPC relied on the Munich consensus statement (Mueller-Wohlfahrt et al., 2013). The assumption that supports this nominal scale is to differentiate delayed onset muscle soreness from microstructures of the musculature from minimal fibers ruptures that would represent a risk of future injury if no recovery was given to the player. The predictive value found for this pain coding strategy was very impressive, with OR=73 and OR=151 for codes 2 and 3, respectively. This value is much higher than other factors described as predictive of injuries in football, such as agonistic/antagonistic isokinetic strength (Delextrat, Gregory & Cohen, 2010), flexibility (Warren, Lowe, Armstrong, 1999), and muscle architecture (Cuthbert et al., 2020). One possibility to explain why the MPC presented such high predictive values compared to these other

variables is because pain assessment was weekly updated, while those are single assessments, usually conducted in the pre-season.

Recently, Delaval et al. (2022) published the only investigation that we are on the association between post-match pain and non-contact injuries in football players. The authors conducted a slightly different follow-up protocol than ours, assessing pain through Hooper scale and a perceived recovery status scale (varying from 0 - “Very Poorly Recovered” to 10 – “Very Well Recovered”) each between-matches days during weeks with two games along a 2-season cohort study, totalizing 38 matches. Like us, they also reported 1) a higher incidence of hamstring injuries (35% of non-contact injuries; ~47% of all muscle injuries), and 2) pain (and also fatigue) were predictors of non-contact injuries. These results suggest that continuously monitoring pain is a cheap, quick, and easy-to-apply strategy to identify football players at increased risk of injury.

Some limitations of this study should be acknowledged. First, our study analyzes the injury/games played, not injury/hours played as commonly described in the literature (Bengtsson et al., 2021; Ekstrand et al., 2021; López-Valenciano et al., 2020). Second, match demands data (i.e. internal and external workload measures) and post-match individual behavior (e.g. sleep quantity and quality, diet, hydration, recovery measures), as potential confounders, would allow a better understanding of players' responses over the weeks. At last, by adopting the definition of non-contact muscle injury as any physical complaint sustained by a player preventing his participation in training sessions or matches, as described by Fuller et al. (2006), we did not distinguish pain limitations or diagnosed events into injury definition. In the context of a calendar full of competitions and matches, clubs are generally conservative in the definition of injury for the preservation of the players' health, with the intention of not aggravating an injury and, consequently, avoiding competitive losses for the team (Hägglund et al., 2013) and financial losses for the club (Eliakim et al., 2020).

In conclusion, MPC emerges as an interesting alternative due to its feasibility and validity in predicting muscle injury in the ‘real world’ of professional football. This free scale allows a quick data acquisition, requiring no more than one staff member to apply it to players. This scale can be used by football teams as a strategy to mitigate the risk of muscle injuries. Further randomized clinical trials are encouraged to verify the

effectiveness of MPC as a decision-making criterion in the incidence of muscle injuries in football players.

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Anexos

Anexo A – Guide for Authors

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