Title: Faster and slower post-training recovery in futsal: multifactorial classification of recovery profiles.

Running head: Classification of recovery profiles in futsal

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Authors: Carolina F. Wilke[1, 2], Felipe Augusto P. Fernandes[3], Flávio Vinícius C. Martins[3], Anísio M. Lacerda[3], Fabio Y. Nakamura [4, 5], Samuel P. Wanner[1], Rob Duffield[2]

[1] Exercise Physiology Laboratory, School of Physical Education, Physiotherapy and Occupational Therapy, Universidade Federal de Minas Gerais, Belo Horizonte (MG), Brazil
[2] Sport & Exercise Discipline Group, Faculty of Health, University of Technology Sydney, Sydney (NSW), Australia
[3] Laboratory of Optimization and Metaheuristic Algorithms, Computer Department, Centro Federal de Educação Tecnológica de Minas Gerais (CEFET), Belo Horizonte (MG), Brazil
[4] The College of Healthcare Sciences, James Cook University, Queensland, Australia
[5] Department of Medicine and Aging Sciences, "G. d'Annunzio" University of Chieti-Pescara, Italy

Corresponding Author:
Carolina Franco Wilke

Institution: Exercise Physiology Laboratory, School of Physical Education, Physiotherapy and Occupational Therapy, Universidade Federal de Minas Gerais, Belo Horizonte (MG), Brazil.

Mail address: 6627, Av. Pres. Antônio Carlos, Campus - Pampulha - Belo Horizonte. 31270-901

Telephone: +55 (31) 3409-2350

E-mail: carol_wilke@hotmail.com

ABSTRACT

Purpose: To investigate the classification of faster vs slower recovery profiles in elite futsal players and factors that distinguish between them. **Methods:** Twenty-two male futsal players were evaluated for the time-course of post-training recovery in countermovement jump (CMJ), 10m sprint, creatine kinase concentration (CK), total quality recovery (TQR) and Brunel Mood Scale (fatigue and vigor) before, post, 3, 24 and 48h after a high-intensity training session. Hierarchical cluster analysis was used to allocate players into different recovery profiles using the area under the curve of the percentage differences from baseline of each variable. One-way ANOVAs and effect sizes (ES) were used to compare the time-course of each variable and players' characteristics between clusters. **Results:** Three clusters were identified and labelled as faster (FR; n=6), slower physiological (SL_{phy}; n=7) and slower perceptual recovery (SL_{perc}; n=6), respectively. FR presented lower (better) AUC in 10m sprint than SL_{phy} (p=0.001) and SL_{perc} (p=0.008). FR also showed higher (better) AUC in TQR compared to both SL_{phy} (p=0.018) and SL_{perc} (p=0.026). SL_{perc} showed higher (better) AUC in CMJ than SL_{phy} (p=0.014), though presented higher (worse) fatigue AUC compared to SL_{phy} (p=0.014) and FR (p=0.008). AUC of CK was higher (worse) in SL_{phy} compared to FR (p=0.001) and SL_{perc} ($p<0.001$). SL_{phy} was younger than SL_{perc} (p=0.027), whereas FR were faster 10m sprinters than SL_{phy} (p=0.003) and SL_{perc} (p=0.013) and tended to have a lower VO_{2max} (ES=1.??). **Conclusions:** Differing post-training recovery profiles exist in futsal players, possibly influenced by their physical abilities and age/experience.

Keywords: Cluster analysis, classification analysis, team sport, performance.

Introduction

Post-exercise recovery is a complex process involving the return of performance, physiological or perceptual perturbations to near pre-exercise values[1]. This concept is made opaque by the multi-factorial nature and varying timelines of different parameters[2]. For example, a recent meta-analysis on post-match recovery in soccer concluded that while sprint, hormonal and skill/technical parameters are restored within 72 h, muscle damage, countermovement jump (CMJ) and perceived well-being take longer[3]. However, high inter-individual variability of the recovery timeline exists (i.e. faster and slower recovery); often influenced by a variety of external (i.e. training/match loads, sleep and nutrition) and internal factors (i.e. aerobic and intermittent-sprint capacities[4-6]), creating further challenges to interpret recovery. Thus, the ability to identify faster or slower multifactorial recovery profiles may aid the prescription of recovery strategies.

It is often recommended that recovery time, appropriate recovery strategies and training load should be prescribed individually[1, 7]. Albeit optimal, this invokes a challenge to coaching staff given the diverse player requirements alongside restricted facilities and staff availability. In this context, identifying faster and slower recovery athletes may allow practitioners to focus on smaller groups based on predominant characteristics[8]. Such an approach is akin to strategies in health research, where identifying certain patterns in multifaceted conditions (e.g. disease diagnosis) assists professionals in selecting the most effective intervention[9, 10]. Similar methods in sport has precedent; whereby the application of a statistical classification tool to 8 screening tests classified 28 professional rugby union players into 4 injury risk profiles[11]. This information was used as a basis for developing preventative programs targeting players' respective needs. Accordingly, it seems reasonable to suggest that identifying athletes' recovery profiles could provide means for more accurate management of recovery time, interventions and training loads.

Futsal features a relatively short post-match recovery time compared to other team sports[4, 7]. Previous studies report restoration of physical performance within 24 h post-match, whereas perceptual markers take longer[12, 13]. However, these characteristics occur within the context of highly congested tournaments (i.e. up to 5 games in 7 days[14]; and ≈10 training sessions per microcycle[15]). Within such congested schedules, individuals respond and cope differently with physiological and perceived fatigue, though adequate recovery is a common requirement for subsequent performance. Hence, futsal constitutes an appropriate test-bed to investigate faster and slower recovery profiles. Therefore, the aim of this study was to investigate whether elite futsal players can be classified into different recovery profiles (i.e. faster vs slower) based on multiparameter post-training evaluation. A secondary aim was to compare player characteristics between recovery groups that differentiates post-training timeline characteristics.

Methods

Subjects

Twenty-two male field futsal players participated in this study (age: 21.5 ± 5.2 years, weight: 69.6 ± 7.0 kg, height: 174.1 ± 5.6 cm). They were members of either the professional (PROF) or under-20 (U20) squad of the same first division Brazilian team. Players provided written informed consent after explanation of all procedures and were cleared by the team's medical physician to participate in the study. The study was approved by the University Research Ethics Committee (50166015.9.0000.5149).

Design

At the start of the 2016 pre-season, an observational design was implemented, with players undertaking anthropometric and maximal aerobic capacity (VO_2max) assessments. After 1 (PROF) and 2 (U20) weeks of training, they underwent a high-intensity technical-tactical training session representative of a typical major training session to provide a fatiguing stimulus. Perceptual, physiological and performance assessments were completed before, immediately and 3, 24 and 48 h post-session to evaluate the time course of recovery. In the 48h preceding and prior to all experimental sessions, players were instructed to maintain their habitual diet and refrain from alcohol, caffeine and high-intensity exercise.

Methodology

Participant description

At the beginning of the season, stature and body mass (in training shorts and shirt) were measured. VO_2max, maximal heart rate (HRmax) and ventilatory threshold (VT) were then determined during a maximal incremental test. Participants ran on a treadmill (HPX 380, Total Health®, Brazil) with fixed 1% inclination, initial speed of 6 $km \cdot h^{-1}$ and continuous increments of 1.0 $km \cdot h^{-1}$ every minute, until volitional exhaustion. VO_2 (K4b^2; Cosmed®, Italy) and HR (RS801, Polar®, Finland) were continuously measured and recorded every minute. A 10-point scale[16] was used to assess their rating of perceived exertion (RPE) at the end of each stage. The exercise was ceased when at least one of the following criteria was observed: the volunteer 1) requested the interruption of the test; 2) failed to maintain the stipulated speed; 3) rated 10 on the RPE scale; 4) showed any signs of dizziness, mental confusion, pallor, cyanosis or nausea. The spirometer was calibrated before each test according to the manufacturer's instructions. VO_2max and HRmax were considered the highest values measured during the test.

Training session

A 70 min high-intensity technical-tactical training session was performed in the morning on a 38 m x 20 m indoor futsal court. The session was developed and conducted by each squad's coach to ensure ecological validity with a highly-fatiguing training session. Although sessions were not explicitly standardized, coaches were instructed to be 70-min in duration of high-intensity via full-court, drill-based sessions. Accordingly, both contained only futsal-specific activities (i.e. small-sided games and game simulations) performed on a full court, with varying technical-tactical instructions.

Before the beginning of the session, a 15-min warm up consisting of different running speeds, sprints, changes of direction, and futsal specific activity was conducted by the strength and conditioning coach. During the session, players were equipped with a heart rate receiver (Polar®, Finland) and a Global Positioning System device coupled with a triaxial accelerometer (SPI ProX2, GPSports Systems®, Australia). The device had a sampling frequency of 100 Hz and was used in the indoor mode, whereby only the accelerometer and HR data were recorded. Units were positioned between the athletes' shoulder blades in a customised designed vest. Player Load was used as a measure of external training load[17]. Internal load was quantified using HR and RPE. Mean HR was calculated relative to the players' maximal HR in the incremental test (%HRmax), and the training impulse (TRIMP) according to Edwards[18]. RPE was analysed as an indication of training intensity using the individual absolute values and as an index of overall training load (session RPE; sRPE) as a product of RPE by the session duration[16].

Recovery timeline characterization

Players arrived 60 min prior to the session for pre-training assessments, starting with 1) hydration status by urine specific gravity (USG) using a portable refractometer (Uridens Inlab, São Paulo, Brazil). This was followed by 2) creatine kinase (CK) concentration from capillary blood samples collected from the fingerprint (Reflotron, Roche®, Switzerland; with intra-assay coefficient of variation of <3%[19]). In turn, 3) players answer a customized wellness questionnaire that included i) sleep hours and quality (1 = very bad and 5 = very good), ii) the total quality recovery scale, ranging from 6 (worse than very, very poor recovery) to 20 (better than very, very good recovery) (TQR [20]), and iii) a Portuguese version of the Brunel Mood Scale (BRUMS[21]), whereby vigor and fatigue constructs consist of the sum of four items scored from 0 (nothing) to 4 (extremely).

Following the warm-up, participants performed a countermovement jump (CMJ) and 20m sprint test with a 180º change of direction at 10m. The CMJ was performed on a force platform (Ergo System®, Globus, Italy) with a squat until reaching approximately 90º of knee and hip flexion, followed by fast knee and hip extension, keeping the hands in the waist. The mean value of four jumps separated by 15s was used for analysis. For the sprint test, photoelectric cells (Multisprint, Hidrofit®, Brazil) were positioned at the start and finish lines and at 10m mark to assess time to complete 10 and 20m. Due to technological malfunction, only the first 10m times were used for analysis and this test is referenced as 10m sprint. Once the training session was completed, CMJ, sprint and CK concentration were repeated, and approximately 15min later players answered to BRUMS and RPE. All procedures performed before the session were then repeated 3, 24 and 48 h after training to assess the time course of recovery for each variable. Due to restriction on the days of testing in the training facilities, the 24 h post-training physical tests and CK concentration assessment were not performed by the PROF team (n=9), though both wellness and BRUMS questionnaires were still recorded. Players were familiarized with testing procedures in the days preceding the experimental session.

Statistical analysis

Firstly, to determine the profile of recovery for each marker, the percentage difference between pre-training and each post-session time point was determined. These values were then transformed to a z-score and used to calculate the area under the curve (AUC) of the entire 48 h post-training timeline for each variable via the trapezoidal method as a representation of post-training recovery kinetics.

Then, using AUC of the 6 recovery parameters, an agglomerative hierarchical cluster analysis based on Euclidian distance and average linkage criteria was performed (Python 2.7, Python Software Foundation, https://www.python.org/). Briefly, each subject's data for each measure is plotted in a multi-dimensional plan and the Euclidian distance between subjects is calculated. The lower the distance between two subjects, the more similarities they share, which further enables their classification into groups (clusters). The threshold difference of 115 was used to optimise clustering based initially on dendogram differentiation, and then by theoretical and meaningfulness of the resulted grouping.

Finally, to investigate the differences and characteristics between the identified clusters, the AUC and the % change from baseline of each variable at each time point were compared. Normality of distribution and homogeneity of variance assumptions were checked using the Shapiro-Wilk and Levene's tests, respectively. Normally distributed data were compared using a one-way analysis of variance, followed by the Tukey's post hoc test when applicable. Non-normally distributed data were compared using Kruskal Wallis, followed by pairwise comparisons when applicable (SPSS® software, version 22). Cohen's d effect sizes (ES) were also calculated for each pairwise comparison[22]. The magnitudes of the ES were qualitatively interpreted using the following thresholds: < 0.2, trivial; 0.2–0.6, small; 0.6–1.2, moderate; 1.2–2.0, large; 2.0–4.0, very large and; > 4.0, nearly perfect [22].

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Results

Cluster analysis resulted in the classification of players into 3 respective groups (Figure 1A). Cluster 1 consisted of 6 U20 players, cluster 2 included 7 players (4 U20 and 3 PROF), and 6 players were grouped in cluster 3 (2 U20 and 4 PROF). However, 3 athletes were not included in any group due to the average linkage distance threshold (1 U20 and 2 PROF).

As context to the recovery profiles, both external and internal training loads were not significantly different (p>0.05) between the 3 groups (Table 1); however, small - moderate effect sizes were evident for PL and TRIMP between clusters 2 and 3 (ES = -0.95, CI = [-2.10- 0.21] and -1.07 [-2.22- 0.09], respectively); as well as for % HRmax between clusters 1 and 2 (-0.86 [-2.10- 0.37]).

* Table 1 about here *

Figure 1B presents the AUC for each recovery variable of the respective clusters. Of note, lower AUC for 10m sprint, CK and Fatigue; and higher AUC for CMJ, TQR and Vigor represents a better post-session response and/or a shorter time to return to baseline. For ease of interpretation, clusters with the best or worse AUC in each variable will be reported to contrast with other clusters. Cluster 3 showed significantly higher (better) AUC in CMJ than cluster 1 (p=0.014; ES=1.63, CI = [0.65- 2.60]). For 10m sprint performance, AUC of cluster 2 was significantly lower (better) than clusters 1 (p=0.001; -1.82 [-2.79- -0.86]) and 3 (p=0.008; -2.59 [-3.54- -164]). A significantly higher (worse) AUC of CK was evident in cluster 1 compared to clusters 2 and 3 (p=0.001; 2.26 [1.33- 3.20] and p<0.001; 3.46 [2.49- 4.43], respectively). Cluster 2 showed higher (better) AUC in TQR compared to both cluster 1 (p=0.018; 1.43 [0.49- 2.36]) and cluster 3 (p=0.026; 1.55 [0.63- 2.46]). Similarly, AUC for vigor scores in cluster 2 was significantly higher (better) than cluster 3 (p=0.003; 2.07 [1.15- 2.99]). Regarding fatigue, cluster 3 presented significantly higher (worse) AUC compared to cluster 1 (p=0.014; 1.50 [0.53- 2.47]) and cluster 2 (p=0.008; 1.69 [0.72- 2.66]). Collectively, based on the most prominent characteristics of recovery depicted by each cluster, we classified them as follows:

Cluster 1 = slower physiological recovery group (SL_{phy})
Cluster 2 = faster recovery group (FR)
Cluster 3 = slower perceptual recovery group (SL_{perc}).

* Figure 1 about here *

Subsequently, to test the appropriateness of the above cluster descriptors, the mean percentage changes relative to baseline in each parameter over the 48 h post-training recovery were compared (Figure 2). Immediately post-session, changes in physical performance (CMJ and 10m sprint) and CK were not significantly different between the 3 clusters (CMJ: p=0.467; 10m sprint: p=0.692; CK: p=0.447; ES ranging from -0.60 [-1.60- 0.41] to 0.71 [-0.20- 1.62]). However, CK concentration presented a significantly higher increase in SL_{phy} at 3 h post-session compared to FR (p=0.027; 1.27 [0.28- 2.26]) and SL_{perc} (p=0.022; 1.35 [0.37- 2.34]), as well as higher changes 48 h after training than SL_{perc} (p=0.005; 2.61 [1.62- 3.60]). The % change in 10m sprint performance of FR participants was significantly lower (better) compared to SL_{phy} at 3 h (p<0.001; -2.81 [-3.74- -1.88]) and 48 h (p=0.007; -1.85 [-2.79- -0.91]); as well as lower than SL_{perc} players 3 h (p=0.002; -2.07 [3.01- -1.13]). Contrastingly, 3 h after training the changes in CMJ were significantly better in the SL_{perc} group compared to FR (p=0.013; 1.59 [0.63- 2.55]) and SL_{phy} (p=0.001; 2.16 [1.19- 3.13]), whereas differences were not significant at 48 h.

In respect to perceptual responses, no significant differences amongst clusters were evident in the change in TQR 3h post-session (p=0.246). However, its subsequent increase was significantly higher in FR compared to SL_{per} at 24h (p=0.041; 1.12 [0.19- 2.05]) and compared to SL_{phy} at 48h post-session (p=0.027; 1.37 [0.40- 2.34]). Similarly, the decrease in vigor immediately (p=0.218) and 3h after the session (p=0.245) were not significantly different between clusters. However, changes were significantly higher in FR compared to SL_{perc} at both 24h (p=0.011; 1.88 [0.96 to 2.80]) and 48h after training (p=0.012; 2.07 [1.16-2.98]). Fatigue scores were only different 24h post-session, when the SL_{perc} group presented higher changes from baseline compared to SL_{phy} (p=0.011; 1.88 [0.89 to 2.87]).

* Figure 2 about here *

When comparing participant characteristics between the 3 clusters (Table 3), anthropometric measures were not significantly different (p>0.05), though SL_{perc} players were younger than SL_{phy} (p=0.027; -1.04 [-2.03- -0.05]) and moderate effect sizes were evident compared to FR (p=1.000; -0.55 [-1.52- 0.42]) clusters. Regarding physical performance, SL_{phy} and SL_{perc} players were significantly faster in the 10m sprint compared to FR (p=0.003; -1.99 [-2.96- -1.02] and p=0.013; -1.89 [-2.84- 0.93], respectively). Although no significant difference was evident for VO_{2max} (p=0.128), there was a moderate - large effect for higher values in FR in comparison to SL_{phy} (1.13 [0.15- 2.11]) and for SL_{perc} in comparison to SL_{phy} (0.70 [-0.33- 1.73]).

From baseline measures, only vigor scores were significantly higher in SL_{phy} than in FR participants (p=0.041, 1.16 [0.23- 2.10]). Moderate effect sizes were found for TQR (-1.16 and -0.88), vigor (-1.59 and -1.05) and sleep quality (-0.83 and 1.14) when comparing FR to both SL_{phy} and SL_{perc}, respectively. In addition, effect sizes were moderate for tension (-0.81 and -0.84) and depression (-0.98 and -0.63) when comparing SL_{perc} to FR and SL_{phy}, respectively.

* Table 2 about here *

Discussion

This study investigated the identification of faster and slower post-training recovery profiles in elite futsal players, and the distinguishing characteristics between respective groups. The cluster analysis differentiated 3 groups based on 6 recovery parameters (cluster 1 = SL_{phy}; cluster 2 = FR; cluster 3 = SL_{perc}). FR players demonstrated better post-training recovery in 4 of the 6 measures (10m sprint, TQR, vigor, fatigue), showed slower sprint performance and moderate effects for increased VO_{2max}. SL_{phy} players showed poorer sprint performance and higher CK concentrations, despite a tendency to report better perceived recovery (TQR, vigor and fatigue). Conversely, SL_{perc} players were older than SL_{phy}, and reported poorer mood states (vigor and fatigue) despite no overt decrement in any physical performance. Consequently, a multi-parameter classification of recovery state may be possible to differentiate recovery characteristics and guide training and recovery practices.

Given the technical-tactical nature of the session replicating ecologically valid high-intensity training routines, training load was not precisely standardized for all players. However, despite better pre-training TQR of FR players, no differences in training load parameters PL, %HRmax and RPE were between clusters (Table 1). Aligned with these results, comparisons of post-session CMJ, 10m sprint and CK changes from baseline were not significantly different between clusters, supporting previously reported association between training loads and physical performance after a soccer match[23]. Therefore, it is reasonable to infer that factors aside from training loads would explain the distinct recovery profiles.

Discussing the respective groups in isolation, FR demonstrated faster recovery in 10m sprint, TQR, vigor and fatigue than the other groups. We propose this represents a "preferred" recovery profile given reduced extent of post-training fatigue or faster return to pre-testing is considered optimal[1, 4]. Additionally, the aligned response of objective and subjective parameters agrees with integrative models of fatigue[24], supporting recent perspectives of the mechanisms underpinning recovery[2]. Interestingly, defining characteristics of this FR cluster were the slowest 10m time compared to the other clusters and a tendency (moderate ES) towards higher VO_{2max} compared to the other two clusters. Such a finding aligns with previous research reporting that players with higher YoYo performance showed faster post-match recovery following a rugby league match than their counterparts with lower performance[4]. Accordingly, the profile of futsal players who may be considered to have better "recovery capability" may relate to higher aerobic fitness. However, the tendency towards lower $\%HR_{max}$ during the session for FR players compared to SL_{phy} groups raises the question of whether physical capacity or training load may best explain the difference in recovery profile .

SL_{phy} players exhibited the worst AUC for CMJ and CK, based on a decrease in CMJ 3h post-session and the sustained increase in CK up to 48h. This profile represents higher peaks in muscle damage and reduced power during the 48h post-training, which could risk optimal performance at ensuing training/competition sessions during congested schedules, and represent the most important group to intervene to aid recovery[1]. Notably, SL_{phy} presented faster 10m sprint time before training, as well as a tendency (moderate ES) towards lower VO_{2max} than FR. In this case, it is not unexpected that high power athletes with higher proportion of fast-twist muscle fibers may experience greater decrease in power performance and longer time for muscle damage repair[25, 26]. Albeit speculative, this rationale also aligns with the greater decreases in speed previously observed in faster futsal players after a preseason[27]. Accordingly, extra attention to the neuromuscular recovery status of high speed/power athletes during congested schedules can be beneficial.

The SL_{perc} group reported worse fatigue and vigor AUC, representative of worse scores relative to baseline 24h and 48 h after the session. However, these players also despicted better CMJ and CK recovery profiles. These results contradicts our expectations of an overall slower recovery profile, and is likely to represent differences often reported by practitioners between an athlete's perception of recovery and the observed physical performance in a session[28]. The environmental or psycho-physiological factors that affect these perceptions remain speculative, but this profile highlights perception of recovery as an important factor to consider in sub-groups of players. Given these players were older than SL_{phy} participants, it is possible that age and experience affected players' perceptual mood/recovery contributing to the observed mismatch between objective and subjective parameters' timeline of recovery in SL_{perc} and SL_{phy}

clusters. As evidence, years of experience in professional Australian football have been associated with higher RPE for a constant external training load[29].

Despite the attempt to classify and explain recovery clusters, several limitations need to be further acknowledged. To partially overcome the restricted number of players constituting a futsal team, we evaluated two age/skill level groups in separate sessions; albeit it appears that training load *per se* was not the determinant of the different recovery profiles, the influence on the current findings remains uncertain. We also acknowledge that sample size can still restrict the extrapolation of our findings, as well as the limitation of the physiological dimension to a single muscle damage marker (CK). Moreover, it is important to address that 3 players were not nested to any cluster, showing that not all athletes fit in a general classification of recovery, and therefore the use of this technique to guide training loads and recovery practices can be limited. Finally, we recognise that this study represents responses to one session and the methodological assessment may not be practical to high performance teams.

Practical Applications

Given the distinct timeline of recovery of physical, physiological, perceptual and mood markers, recovery monitoring should include both objective and subjective measures, alongside training load measures to aid appropriate interpretation. Based on such multifactorial recovery timeline, our results provide initial insights to the use of statistical tools as a diagnostic approach, discriminating smaller groups within a team to support the prescription of training and recovery according to main individual needs. Future studies are thus encouraged to adapt more functional approaches for recovery profile assessment.

Conclusions

Differing post-training recovery profiles were evident in futsal players. A faster global (physical and psychological) recovery profile existed, possibly positively affected by higher aerobic capacity. Interestingly, two groups were classified with distinct slower recovery profiles conditioned by responses in either physiological or perceptual parameters, potentially influenced by higher speed/power performance and higher age/experience of athletes, respectively.

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References

1. Kellmann M, Bertollo M, Bosquet L, et al. Recovery and Performance in Sport: Consensus Statement. *Int J Sports Physiol Perform.* 2018;13(2):240-245.
2. Minett GM, Duffield R. Is recovery driven by central or peripheral factors? A role for the brain in recovery following intermittent-sprint exercise. *Front Physiol.* 2014;5:24.
3. Silva JR, Rumpf MC, Hertzog M, et al. Acute and Residual Soccer Match-Related Fatigue: A Systematic Review and Meta-analysis. *Sports Med.* 2018;48(3):539-583.
4. Johnston RD, Gabbett TJ, Jenkins DG, Hulin BT. Influence of physical qualities on post-match fatigue in rugby league players. *J Sci Med Sport.* 2015;18(2):209-213.
5. Skein M, Duffield R, Minett GM, Snape A, Murphy A. The effect of overnight sleep deprivation after competitive rugby league matches on postmatch physiological and perceptual recovery. *Int J Sports Physiol Perform.* 2013;8(5):556-564.
6. Wanner SP, Wilke CF, Duffield R. Nutritional strategies for maximizing recovery from strenuous exercise in the heat: An important role for carbohydrate (sago) supplementation. *Temperature (Austin, Tex.).* 2016;3(3):366-368.
7. Nedelec M, McCall A, Carling C, Legall F, Berthoin S, Dupont G. Recovery in soccer: part I - post-match fatigue and time course of recovery. *Sports Med.* 2012;42(12):997-1015.
8. Doeven SH, Brink MS, Kosse SJ, Lemmink K. Postmatch recovery of physical performance and biochemical markers in team ball sports: a systematic review. *BMJ open sport & exercise medicine.* 2018;4(1):e000264.
9. Guo Q, Lu X, Gao Y, et al. Cluster analysis: a new approach for identification of underlying risk factors for coronary artery disease in essential hypertensive patients. *Sci Rep.* 2017;7:43965.
10. Shannon W. Cluster analysis *Epidemiology and Medical Statistics.* Vol 27. 1 ed: Elsevier; 2007:342-366.
11. Evans KL, Hughes J, Williams MD. Reduced severity of lumbo-pelvic-hip injuries in professional Rugby Union players following tailored preventative programmes. *J Sci Med Sport.* 2018;21(3):274-279.
12. Moreira A, Costa EC, Coutts AJ, Nakamura FY, Silva DAd, Aoki MS. Cold water immersion did not accelerate recovery after a futsal match. *Revista Brasileira de Medicina do Esporte.* 2015;21:40-43.
13. Tessitore A, Meeusen R, Pagano R, Benvenuti C, Tiberi M, Capranica L. Effectiveness of active versus passive recovery strategies after futsal games. *J Strength Cond Res.* 2008;22(5):1402-1412.
14. Charlot K, Zongo P, Leicht AS, Hue O, Galy O. Intensity, recovery kinetics and well-being indices are not altered during an official FIFA futsal tournament in Oceanian players. *J Sports Sci.* 2016;34(4):379-388.
15. Soares-Caldeira LF, de Souza EA, de Freitas VH, de Moraes SM, Leicht AS, Nakamura FY. Effects of additional repeated sprint training during preseason on performance, heart rate variability, and stress symptoms in futsal players: a randomized controlled trial. *J Strength Cond Res.* 2014;28(10):2815-2826.
16. Foster C, Daines E, Hector L, Snyder AC, Welsh R. Athletic performance in relation to training load. *Wis Med J.* 1996;95(6):370-374.
17. Boyd LJ, Ball K, Aughey RJ. The reliability of MinimaxX accelerometers for measuring physical activity in Australian football. *Int J Sports Physiol Perform.* 2011;6(3):311-321.
18. Edwards S. *The Heart Rate Monitor Book*: Polar CIC; 1993.

19. Howatson G, Milak A. Exercise-induced muscle damage following a bout of sport specific repeated sprints. *J Strength Cond Res.* 2009;23(8):2419-2424.
20. Kentta G, Hassmen P. Overtraining and recovery. A conceptual model. *Sports Med.* 1998;26(1):1-16.
21. Rohlfs ICPdM, Rotta TM, Luft CDB, Andrade A, Krebs RJ, Carvalho Td. A Escala de Humor de Brunel (Brums): instrumento para detecção precoce da síndrome do excesso de treinamento. *Revista Brasileira de Medicina do Esporte.* 2008;14:176-181.
22. Hopkins WG. A Scale of Magnitudes for Effect Statistics 2002. 2002. Accessed May 5, 2018.
23. Rowell AE, Aughey RJ, Hopkins WG, Stewart AM, Cormack SJ. Identification of Sensitive Measures of Recovery After External Load From Football Match Play. *Int J Sports Physiol Perform.* 2017;12(7):969-976.
24. St Clair Gibson A, Swart J, Tucker R. The interaction of psychological and physiological homeostatic drives and role of general control principles in the regulation of physiological systems, exercise and the fatigue process - The Integrative Governor theory. *Eur J Sport Sci.* 2018;18(1):25-36.
25. Pimenta EM, Coelho DB, Cruz IR, et al. The ACTN3 genotype in soccer players in response to acute eccentric training. *Eur J Appl Physiol.* 2012;112(4):1495-1503.
26. Pimenta EM, Coelho DB, Veneroso CE, et al. Effect of ACTN3 gene on strength and endurance in soccer players. *J Strength Cond Res.* 2013;27(12):3286-3292.
27. Nakamura FY, Pereira LA, Rabelo FN, Ramirez-Campillo R, Loturco I. Faster Futsal Players Perceive Higher Training Loads and Present Greater Decreases in Sprinting Speed During the Preseason. *J Strength Cond Res.* 2016;30(6):1553-1562.
28. Doeven SH, Brink MS, Frencken WGP, Lemmink K. Impaired Player-Coach Perceptions of Exertion and Recovery During Match Congestion. *Int J Sports Physiol Perform.* 2017;12(9):1151-1156.
29. Gallo T, Cormack S, Gabbett T, Williams M, Lorenzen C. Characteristics impacting on session rating of perceived exertion training load in Australian footballers. *J Sports Sci.* 2015;33(5):467-475.

FIGURE CAPTIONS

Figure 1. A) Dendrogram resulted from the cluster analysis. **B)** Area under the curve (AUC) of each recovery variable for the 3 clusters. The data in panel B is expressed as mean ± SD. ; A = different from Cluster 1; B = different from Cluster 2. Legend: CMJ: countermovement jump, CK: creatine kinase, TQR: total quality recovery scale.

Figure 2. Percentage difference from baseline obtained at each time point (post-training, 3 h, 24 h and 48 h hours post training) of the 3 clusters in each recovery parameter. a) countermovement jump (CMJ), b) 10m sprint, c) creatine kinase (CK), d) total quality recovery (TQR) scale, e) Vigor, e) FatigueA = different from SL_{phy}; B = different from FR; C = different from SL_{perc}.

Tables

Table 1: Training load parameters of the three clusters (mean ± SD).

Training load parameter	Cluster 1	Cluster 2	Cluster 3	p	ES
Player Load	596 ± 94	536 ± 113	652 ± 104	0.292	-0.50 / -0.95 / 0.51
% HRmax	81 ± 5%	77 ± 4%	79 ± 4%	0.343	-0.86 / -0.54 / -0.44
TRIMP	228 ± 29	215 ± 22	242 ± 22	0.301	-0.42 / -1.07 / 0.49
RPE	5.8 ± 1.3	6.3 ± 2.0	7.0 ± 1.7	0.502	0.25 / -0.36 / 0.71
sRPE	397 ± 83	446 ± 137	503 ± 110	0.353	0.25 / -0.36 / 0.71

ES = Effect size, presented in the following order of comparisons: Cluster 1 *vs* Cluster 2 / Cluster 2 *vs* Cluster 3 / Cluster 1 *vs* Cluster 3. B = different from Cluster 2.

Table 2: Age, anthropometry, physical performance and pre-training measures of the three clusters (mean ± SD).

	Cluster 1 (SLphy)	Cluster 2 (FR)	Cluster 3 (SLperc)	p	ES
Age / Anthropometry					
Age (years)	18.3 ± 1.0	20.8 ± 3.4	24.0 ± 6.5^A	0.027	0.89 / -0.55 / 1.03
Body mass (kg)	68.2 ± 10.8	70.0 ± 3.2	70.4 ± 6.1	0.857	0.19 / -0.07 / 0.22
Stature (cm)	174.2 ± 7.1	175.1 ± 7.0	172.7 ± 3.4	0.778	0.12 / 0.40 / -0.24
Physical performance					
VO_2max ($mlO_2.kg^{-1}.min^{-1}$)	48.9 ± 4.0	54.2 ± 4.5	51.9 ± 3.6	0.128	1.13 / 0.52 / 0.70
%VO_2max at VT	43.3 ± 4%	45.5 ± 12%	52.2 ± 14%	0.466	0.23 / -0.49 / 0.76
CMJ (cm)	33.7 ± 4.2	32.7 ± 4.3	30.9 ± 1.4	0.407	-0.22 / 0.51 / -0.79
Sprint 0-10m (s)	1.53 ± 0.06	1.64 ± 0.03^A	1.55 ± 0.05^B	0.002	1.99 / 1.89 / 0.33
Pre-training measures					
CK (U/L)	198 ± 129	168 ± 89	327 ± 370	0.908	-0.25 / -0.51 / 0.41
TQR	14.7 ± 1.4	13.0 ± 1.3	14.3 ± 1.5	0.099	-1.16 / -0.88 / -0.21
Vigor	11.5 ± 1.8	7.7 ± 2.6^A	10.5 ± 2.3	0.035	-1.59 / -1.05 / -0.44
Fatigue	2.8 ± 2.7	4.6 ± 2.4	1.8 ± 1.2	0.105	0.63 / 1.33 / -0.42
Tension	3.0 ± 2.5	2.9 ± 2.5	1.2 ± 1.0	0.279	-0.05 / 0.81 / -0.84
Depression	0.5 ± 0.5	1.0 ± 1.0	0.2 ± 0.4	0.142	0.57 / 0.98 / -0.63
Anger	0.7 ± 1.6	1.1 ± 2.2	0.7 ±1.6	0.867	0.23 / 0.23 / 0.00
Confusion	1.0 ± 1.5	1.7 ± 2.2	0.7 ± 1.2	0.552	0.35 / 0.54 / -0.22
Urine specific gravity	1020 ± 7	1026 ± 7	1026 ± 7	0.321	0.78 / 0.07 / 0.71
Sleep hours	7.5 ± 0.9	7.0 ± 0.9	6.7 ± 1.1	0.387	-0.46 / 0.34 / -0.73
Sleep quality	3.5 ± 0.5	3.0 ± 0.6	3.8 ± 0.8	0.100	-0.83 / -1.14 / 0.46

ES = Effect size, presented in the following order of comparisons: Cluster 1 *vs* Cluster 2 / Cluster 2 *vs* Cluster 3 / Cluster 1 *vs* Cluster 3. SL_{phy} = slower physiological recovery, FR = faster recovery, SL_{perc} = slower perceptual recovery, CK = creatine kinase, CMJ = countermovement jump, TQR = total quality recovery scale, VO_2max = maximal oxygen consumption, %VO_2max at VT = percentage of maximal oxygen consumption at the time the ventilatory threshold was reached. A = different from Cluster 1 (SL_{phy}); B = different from Cluster 2 (FR).