Review

Relevant biochemical markers of recovery process in soccer

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Received: 09.06.2016
Accepted: 13.07.2016

Summary

Training and competition provide an opportunity to enhance the performance of football players, so is essential to face every training session or competition in the best possible condition. For our knowledge, there are still doubts about the causes and mechanisms underlying fatigue and recovery in football, hence the complexity of monitoring this process. A variety of biomarkers are used nowadays (performance, perceptual and biochemical), but some may not be suitable due to the probable fatigue caused that could influence the recovery process. Despite the difficulty of obtain them in some categories where is not plausible, the information of biochemical markers should be considered whenever was possible. Since its assessment let to optimize the balance between competitive stress and recovery of football players, the aim of this review is to analyze the importance of control, monitoring and evaluate different biochemical markers of recovery in soccer players. Even so, the high variability in their response due to the individual characteristics of players and the metabolic and physiological differences caused by a soccer match or training stop us from monitoring the recovery process in soccer using only one biochemical marker, it is necessary to assess several markers together. In fact, they should be considered as an option to complement the information obtained through physical performance and perceptive markers.

Key words:
Recovery.
Biochemical markers.
Soccer.

Marcadores bioquímicos relevantes del proceso de recuperación en futbol

Resumen

Todas las sesiones de entrenamiento y competición suponen una oportunidad de mejora del rendimiento de los jugadores de futbol, por lo que es primordial afrontar cada sesión de entrenamiento o partido en el mejor estado posible. A fecha actual, y para nuestro conocimiento, todavía existen dudas sobre las causas y los mecanismos subyacentes al proceso de fatiga y recuperación en futbol, de ahí la complejidad de controlar este proceso. Existe una variedad de marcadores utilizados en la actualidad (de rendimiento, perceptivos y bioquímicos), algunos de los cuales pueden no ser adecuados debido a la posible fatiga adicional generada que influya en el seguimiento del proceso de la recuperación. Por ello, y a pesar de la dificultad de realizarse en algunas categorías en las que se disponga de los medios necesarios, la información que permiten obtener los marcadores bioquímicos debe ser considerada siempre que sea posible. Dado que su valoración permite optimizar el equilibro entre el estrés competitivo y la recuperación de los jugadores de futbol, el objetivo de esta revisión es analizar la importancia que puede tener el control, seguimiento y evaluación de diferentes marcadores bioquímicos dentro del proceso de recuperación en jugadores de fútbol. Teniendo en cuenta la alta variabilidad en su respuesta debido a las características individuales de los futbolistas y las diferencias metabólicas y fisiológicas que genera cada partido y/o entrenamiento, no podemos realizar un control adecuado del proceso de recuperación en fútbol utilizando únicamente un marcador bioquímico, pues es preciso valorar diferentes marcadores en conjunto. De hecho, deben considerarse como una opción que complemente la información obtenida a través de marcadores de rendimiento físico y/o perceptivo.

Palabras clave:
Recuperación.
Marcadores bioquímicos.
Fútbol.

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Introduction

Adequate recovery is based on the normalisation of physiological functions, the restoration of homeostasis, the replenishment of energy reserves, and the replacement of enzymatic cellular energy[1]. Even though generally recovery is associated with a homeostatic recovery process[2], not only the physiological level of the athlete should be considered, but also the psychological and social level. Therefore recovery is a physiological, psychological and social process, which is inter-individual in nature, and is orientated towards the recovery of the performance capacities specific to the athlete[3], i.e. it is an important part of the training process[4]. The effects of (peripheral or central) fatigue should be dealt with, and recovery is considered complete when the player is able to reach or exceed the reference activity[5]. Furthermore, knowing the type of fatigue is essential when identifying the best recovery strategy[6].

In professional football, the capacity to recover from an intense training session or a match is a determining part of performance[7,8]: players that recover their fatigue level faster will have a greater advantage in their performance[9], therefore it is key to achieve an optimum balance between competitive stress and recovery[10,11]. It is hugely important to optimise this process, given that the athlete spends more time recovering than training[12]. Therefore, the great challenge faced by trainers and athletes is to establish the point at which the intense demands of training and competition generate non-functional over-training which negatively affects performance[13], and for this the level of stress and physical and psychosocial recovery of the athlete should be monitored[14] and given the same degree of attention as the schedule and training sessions[1,15]. To do this, the routine assessment of fatigue and recovery is fundamental in improving the training prescription and in guaranteeing competitive preparation[16].

Football and recovery: a hard-to-assess state-process

It is difficult to assess the real influence of fatigue on the physical activity of football players if some of the variables that include the impact of the tactical and strategic factors are not incorporated into the explanatory models[17]. Together, these factors contribute to a magnitude of fatigue and muscle damage that is very variable between matches[18]. Other factors such as state of fitness, age[19], and the type of muscle fibre[20] can explain the inter-individual differences in the fatigue-recovery process of players on the same team.

The football competitive season entails weekly cycles of training, refinement, competition and recovery[21], repeated throughout the macro-cycle depending on the matches and the objectives. The large number of matches generates a high density of competition in some micro-cycles, which, along with high physical demands, may generate a high level of fatigue and stress on physiological systems[22, 23], affecting complete recovery time after a match[24].

Even though improvements have been shown at 24 hours after the match[25], between 48-72 are needed to replenish the metabolic alterations, muscle damage and anaerobic performance following a football match[21,24,26-32]. Even so, 3-4 days of recovery between successive matches may be insufficient to restore the homeostasis[8,33] thus making the achievement of a full recovery particularly complicated, associated with drops in performance in high-density periods[34,35]. It has been shown that post-match recovery and inflammatory adaptations in response to a weekly micro-cycle of three matches (Sunday, Wednesday and Sunday) reveal different response patterns, with strong signs of physiological stress and a greater degree of fatigue the fewer the days allocated to recovery[36]. This insufficient recovery time between matches may cause a deterioration in performance and/or sporting injuries[37-41].

Furthermore, and despite muscle damage and the drop in physical performance continuing for up to 72 hours after the match, research suggests that the distances covered are not affected in high-density competitive periods[42]. Various studies[37,43-47] have analysed the profile of physical activity and the injury rates during periods with 2 or 3 consecutive matches within 7 days. Unexpectedly, they reveal that the distance covered at different intensities is not influenced by the short recovery period between matches, rather that it is determined by contextual variables that arise during the matches. There are cases in which the distance covered is slightly greater in the first part compared to the second part when the matches are only separated by 3 days[47]. Moreover, players are generally able to maintain performance regarding technical skills when they compete in short, successive periods of time[48].

Sleep provides a series of important psychological and physiological functions[49], but occasionally it is not enough to guarantee complete recovery. In fact, when elite players compete at night a reduction occurs in the amount and quality of sleep and in the perception of recovery[50]. For this reason, post-exercise recovery strategies are essential in the preparation for the next match[21] or training session, which should be applied individually depending on the activities performed during the matches[51]. The effects of the different recovery strategies after specific football training tasks are still unknown, due to the lack of studies carried out in field or real conditions[52], especially regarding their capacity to ensure that posterior performance (in terms of distances covered) is not negatively affected[42].

Relevant biochemical markers for measuring recovery in football

The biomarker concept (biochemical marker) is a molecule or measurable product that objectively monitors the change of a condition or process over time, after treatment or after a training session[53]. Currently, there is no consensus in terms of its use in routinely assessing the fatigue and recovery of athletes in team sports[18,54,55]. Often a variety of indirect markers are used (subjective, neuromuscular, performance and biochemical) in resting periods or during actions requiring low metabolic and neuromuscular demands[5,18,55,56].

The change in specific performance (carrying out the specific sporting activity) represents the most relevant marker to differentiate between fatigued and recovered players[16]. However, the majority of the field tests to measure performance in football are physically demanding and produce additional fatigue, thus possibly altering the recovery kinetics regarding the initial exercise[18,57]. For this reason, the tests should be chosen by finding a balance between the number, frequency and order, so as not to affect the recovery process[18].

It is clear that sometimes it is not even appropriate to apply the physical condition test which enables the verification of the degree of adaptation, assimilation and recovery from the training, mainly due to the short time available to apply them. It is also clear that the physical load endured by the football players provokes an increase in the metabolism, with important haematological changes[27,58]. And as the plasma concentration of the biomarkers can provide a lot of information about the required recovery time, the state of preparation for the next training session or the degree of intensity of the previous training session[5], its assessment may be a truly useful option[18,59]. Even so, biomarkers should not replace performance tests, rather be used alongside them to offer a greater indication of the state of metabolic recovery[60].

For this reason, trainers and athletes are becoming increasingly interested in getting to know the biochemical evolution over the training process[61]. Consequently, trainers may be able to make more informed decisions regarding the training load taken on by the football player and the athlete's state of recovery, thus maximising the availability of players[27]. Considering this aspect enables:

The volume and intensity of training session plans to be modified.

Rotations to be implemented, and other players used to minimise fatigue.

The best time to rest football players to be identified.

More recovery sessions to be applied.

Nutritional strategy planning to be improved to improve recovery.

The biomarkers are influenced by various factors and comply with a metabolic regulation function of the organism[62]. They are therefore the reflection of a multiple - and not single - interaction, in that the interpretation of the results should be performed with caution[63]. One single biomarker that provides precise information has yet to be identified[13], therefore a combination of all of them should be used to consider all the possible mechanisms that contribute to fatigue and to carry out the follow-up of the stress of training with regards to performance in football[16,18,58,64].

Assessment of plasma enzymes

In team sports, muscle destruction has been observed[65], measured in the increase of the levels of different muscular enzymes, considered reliable biomarkers of the functional state of the muscle tissue[66].

High levels of CK-III may be linked to the state of training, and if these levels are persistent in rest, it may be an indication of over-training syndrome or an unsuitable nutritional intake[67]. In any case, given the considerable individual variability in its response, perhaps CK-III is not so relevant as a marker of muscle damage, and therefore the state of recovery[56].

It would appear that the serum activity of CK-III reaches maximum values between 6-24 hours after exercise and returns to normality between 48-72 hours[68]. It is expected that footballers already have a normal concentration of CK-III after this time, depending on the physical activities performed by the athlete during this period. In footballers, concentrations usually oscillate between 83 and 1492 U/L[69].

An increase of CK-III in the blood has been confirmed following a football match[70], with small post-match increases if the pre-match levels are high[71], but they may be 84% ($p = 0.17$) when there are normal base levels[32]. Some studies have revealed increases in CK-III ($P < 0.01$) 18 hours after the match in elite and sub-elite female football players[72]. However, a large part of the studies has detected maximum CK-III concentrations at 24[73-75],48[28,33,76-78], and 72 hours[21]. Generally, the higher the concentration, the more time it will take to return to base levels. It may be that this response is consistent ($p > 0.05$) between the different matches and the positions of play[31], though it has also been indicated that its concentration has little relation to positions of play[79]. In relation to gender, similar CK-III concentrations have been observed up to 48 hours post-match, with the maximum levels observed in both genders at 24 hours[75]. Recently significant correlations have been shown between the distance covered at speed ≤21 km/h and the concentrations of CK-III at 24 ($r = 0.56$) and 48 hours ($r = 0.54$), and between the CK-III concentration at 48 hours and the distance covered at speed >14 km/h ($r = 0.50$), accelerations ($r = 0.48$), and decelerations ($r = 0.58$)[73].

In a study in which the plasma levels of CK-III were observed in first division football players during the different days of the weekly micro-cycle, its was shown that Mondays revealed the highest levels of CK-III (697 U/l), and that Fridays revealed the lowest level (241,7 U/l) considering the gradual decrease of physical loads of the micro-cycle[80]. Moreover, if the football team has one match per week, the suitable recovery may be programmed into the training week so as to allow for muscular regeneration, but if there are two matches per week, it is likely that numerous players will have to train, and even compete, with high levels of CK-III[76]. In contrast, with a follow-up of the season among elite footballer players, another study revealed that the CK-III levels did not indicate any significant alterations between high and low-density competition periods[81]. Furthermore, changes were also not observed in the CK-III in a 12-week training period of 15 football players - probably due to the difference in the intensity of the training and recovery sessions that were carried out during the training period[82]. To avoid these contradictions, more longitudinal studies are required regarding the variations of the CK-III in response to the load of elite players[81], which will enable us to understand more about when and how to implement sessions or specific recovery measures.

Likewise, in elite and sub-elite female footballers, post-match increases have been found of LDH ($P > 0.01$)[72]. These increases may be at their maximum levels at 48 hours post-match[28] and remain high even up to 72 hours post-competition[21,28]. The behaviour of the LDH reveals the same pattern as the CK-III: the LDH values may decrease as the days of the weekly micro-cycle go by, with Mondays being the days revealing the highest concentration levels (149.7 U/l) and Fridays with the lowest (94 U/l)[80].

Even so, and despite recent research of the acute response in elite footballers, little is known about the enzymatic variations throughout a season. It is possible that there are times during the season in which the physiological responses are specific, so that the collection of biomarker data may provide valuable information regarding the state of recovery and training predisposition of the players[83].

Assessment of proteins

Muscle damage initiates a local inflammatory response, which involves the production of cytokines[18], proteins whose main action consists in regulating the mechanism of the inflammation, via pro-inflammatory and anti-inflammatory mechanisms. The presence of some of these cytokines in the plasma following intense exercise may last for days or weeks, whilst the muscle reparation, regeneration and growth take place[84-85]. They may also be triggers of central fatigue and/or alterations of the hormonal axes[86].

Interleukin 6 (IL-6) is produced in greater quantities than any other cytokine and plays an initial role in the cascade of cytokines, as it precedes others[28,84,87,88]. In football, it increases immediately after the match, but quickly decreases towards pre-match levels and generally normalises at 24[28,89] or 48 hours after the match, despite the number of neutrophils being able to remain high[78]. Correlations have also been found ($r = 0.521$, $p = 0.027$) between post-match values of IL-6 and the distance covered during the match[78].

Increases have been detected in IL-6 and Tumoural Necrosis Factor (TNF-α) between 2 and 4 times higher than resting values, with the maximum values obtained immediately after the match, whilst the increase in C-reactive protein (CRP) reached the maximum concentration at 24 hours post-match[75]. Despite the response of IL-6 and CRP being similar in footballers of both genders, the maximum TNF values-α may be 18% greater in men than in women. In any case, the increase in the acute phase of CRP may occur up to 24-48 hours post-exercise[77,90]. It is more sensitive than the CK, LDH and myoglobin (Mb) in assessing the muscle damage in impact activities[91]. Even though there do not appear to be any differences in the immunoglobuline A (IgA), M (IgM) or G (IgG) concentration, post-match increases have been detected compared to pre-match values of 238% ($p = 0.05$) in Mb, which correlated to the number of sprints performed during the match ($r = 0.75$, $p = 0.047$)[32]. Furthermore, the increase of the plasmatic Mb may remain high for up to 72 hours[21,28,77].

Assessment of other metabolism products

During a football match, reactive oxygen species (ROS) are produced, due to the high oxygen consumption values required and the muscle ischemia phenomenons[21]. This increase may stem from oxidative stress, whose most used marker in football is uric acid[28], which reflects the recovery state of the muscle glycogen[92]. It has been demonstrated that its concentration increases immediately after a football match[93] and that it remains high for up to 48[33], 72[21], and even 96 hours after the match in adult male players[28]. There are also studies that reveal that despite rising to a range of 11-75% after the match, they can return to base levels from 21 hours post-match[8,26,94]. Apart from the uric acid, other oxidative and anti-oxidant stress markers have been studied after a football match[26,28,33,94,95], but comparisons between the studies are difficult in that the biomarkers studied are different.

Over 65% VO_2max, an increase in the urea concentration may indicate an increase in the protein catabolism[96]. For this reason, it is a good control parameter of the training load and of the recovery processes, especially of muscle glycogen[97, 98]. If 24 hours post-exercise the base levels of urea in the blood have not recovered, it is an indication of insufficient recovery[99]: another day of rest should be given or a recovery session to stimulate functional adaptations suitable for football players. Despite the scarce research studies performed with elite footballers, various studies have detected significant increases in post-match urea concentrations[70,89]. It appears that during a season there are no significant alterations in the urea levels during the high and low density competitive periods[81], nor in 12-week training periods[82]. In fact, there may be matches that do not require physical efforts that provoke changes in its concentration[70]. Dehydration[100] can also affect the values found in footballers. The high levels of urea found post-match may be reduced with a correct diet and hydration, a fundamental element of training for elite players[97].

The blood lactate concentration is also a good indicator (as long as the previous values of the player are known) of the degree of metabolic requirements of a specific training load. For this reason, its assessment may be carried out during the exercise and the recovery[63]. The ammonium ion (NH4) may be valuable as a fatigue marker in the measure that its accumulation in the blood and muscles may be a powerful metabolic inhibitor. In turn, low levels of lactate and high levels of ammonium may suggest an emptying of glycogen stores[63], making a better recovery necessary. Likewise, alanine or the increase in ketone bodies indicate the emptying of muscle glycogen, the use of other energy substrates and an increase of protein destruction[101].

Hormonal assessment

The follow-up of certain hormonal parameters of footballers may be useful in assessing training, recovery and over-training processes[102]. In fact, studies by our group on basketball work[86] reveal alterations in the hormonal axes related to central fatigue, and whose results may be extrapolated to football. Excluding the Testosterone/Cortisol Index or Ratio (T/C) and testosterone (T), the rest do not appear to be very sensitive to long-term follow-up, especially in elite athletes[103,104].

There is a large dispersion in the choice of the T fraction to analyse: total (TT) or free (FT)[105]. The TT is the sum of the T added to the albumin and the FT[106,107], for which a control has been proposed of the free fraction as an indicator of the activity of this hormone. A trend has been observed in which the FT rises in training sessions with a large anaerobic or strength component, and reduces in aerobic endurance sports[108]. When the exercise continues to exhaustion, there are decreases in the T of up to 40%[109], even reaching 59% during the first 30 minutes of recovery[110]. Even with exceptions, the majority of the studies found decreases in T associated with states of over-training[4,108,111-113].

As a result of the physiological demands experienced during a football season, the antagonistic relation between the anabolic and catabolic processes may affect performance[114]. In players that were professionals for at least two seasons, TT values have been recorded of 944.1 ± 78.3 ng/dl and for FT of 36 ± 0.8 pg/dl[71]. Significantly lower T values have been found at the start of an 11-week competitive period compared to the end, which were lower though within the normal ranges (10.4 - 41.6 nmol.L^{-1}). Furthermore, the differences in the T levels were similar between the players and substitutes, despite the difference in minutes played, apart for the middle of the competitive period when the substitutes had significantly higher values[114]. On this same line, significant increases have been found (11.6%) in their concentration at the end of the pre-season compared to the start, which remained the same (12.1%) until the middle of the season, despite returning to base levels at the end (-1,5%)[115]. This data shows that adequate planning does not entail drops in T that reflect the accumulation of fatigue throughout the season. The differences in the concentrations depending on the time of the season have been confirmed in different studies[102,116]. During the transition period, no significant changes have been found in the TT and FT concentrations, even when performing a training programme for this period[117].

Furthermore, the T levels in the saliva of the footballers were significantly higher before competing at home compared to competing away, and before playing against a rival considered strong compared to one considered weak[118]. The result of the match also seems to influence its concentration[119], therefore we should consider this factor if analysing official football matches. If as well as football training, high-volume strength training is carried out, the TT and FT values increase[120].

All of these factors lead to different responses in the T compared to the metabolic stress of a match. Despite studies failing to find changes in the T for the 6 days following a match[28], others found significant post-match increases of 44% ($p = 0.004$) in semi-professional footballers[32] and of FT with elite and sub-elite female football players[72]. Conversely, in young football players reductions have been found up to 72 hours after competition matches on consecutive days[121], probably due to the extenuating nature of the matches. In elite footballers, the saliva concentration after an international friendly match reduced by 30.6% compared to pre-match levels, accompanied by a decrease of the IgA of 74.5%[122]. In this same study, the changes in the T concentration correlated ($r = 0.85$) to the distance covered, so it seems that footballers with less decreases in the T levels cover more distance and have less decreases in their immune function.

Cortisol (C) is the main hormone responsible for mobilising the fatty acids and amino acids to be used as an energy source[123]. It also contributes to the catabolic process of reducing the protein synthesis, increasing the destruction of proteins and inhibiting the inflammatory and immunity process[32]. Given that the increase of the C displays a direct link to psycho-physical stress[61], increased levels of this hormone may be found when dealing with large training loads[108,124,125].

Football has observed contradictory results, probably due to the large variability in response[126]. Even so, it appears that the C could be used to monitor recovery processes and as a marker of fatigue in footballers, even for short periods of time[78,127]. Throughout the season there is a vast variability in this hormone[102], with significant increases in its course[127]. Different concentrations have been detected in the pre-season and at the end of the season, which were high, though within the normal range (138-635 nmol.L^{-1}), but similar between players and substitutes, despite the difference in minutes played[114]. In another study, the concentration of this hormone reduced at the end of the pre-season compared to the start (-5.3%), increased in the middle of the season (23.4%) and returned to base values at the end (2.8%)[115]. The training load, pressure to achieve results and adverse weather conditions may be responsible for this mid-season increase[115]. Among professional footballers there have been significant increases in C with just 6 weeks of high-intensity training (554.6 ± 95.3 nmol.L^{-1}; $p \leq 0.05$) and with 12 weeks (612.2 ± 115.8 nmol.L^{-1}; $p \leq 0.05$) compared to the pre-training[82]. The authors of this study affirm that the intensity of training in football plays a fundamental role in this regard. A significant increase has also been detected after a 7-day training period ($p<0.001$), both upon waking and at midnight[128]

Some studies with elite footballers have not found changes in the saliva C concentration[122], or have found non-significant increases[126], putting this response down to the wide individual variability in response and adaptation to this competitive stress faced by the players. In any case, it seems apparent that the post-match C values are significantly higher than those of the pre-match, 78% ($p = 0.103$) in semi-professional footballers[32], though they return to base levels between 24 hours[28] and 48 hours after the match[77]. It has also been suggested that 72 hours are required to guarantee the optimum recovery of footballers, due to the alteration observed in some muscle damage markers[28]. Likewise, it has been discovered that the distance covered during the match correlates to post 24 hours ($r = 0.502$, $p = 0.034$) and post 48 hours C values ($r = 0.515$, $p = 0.029$)[78]. Even so, more research is needed to verify these results, as the behaviour of post-match C concentration levels in football matches held on consecutive days is still unknown[121].

The T/C ratio is used as an indicator of the relationship between anabolism (synthesis) and catabolism (destruction) of our bodily system[63], and the internal load of training in the athlete, as it enables training loads to be customised[108]. As a result, it is usually used to assess recovery processes and to detect poor adaptation to training, or likewise, to diagnose over-training syndrome[61,129]. The reduction of this ratio would indicate a predominance of catabolic processes, possibly entailing reduced performance, whilst an increase would indicate a predominance of anabolic processes (over-compensation)[130,131]. The bibliography consulted indicates a reference value to diagnose over-training with a decrease exceeding 0.3 (>30%)[132].

The use of this ratio to monitor the assimilation of training over a season has been proven in team sports[86,133], and specifically in football; it has been suggested that it is more useful to assess the variation of the ratio compared to base levels, than to use absolute values as diagnostic thresholds[134]. In fact, results with elite football players could suggest that a reduction in the T/C ratio of over 30% does not automatically lead to a reduction in the team's performance or to a state of over-training[58]. In a follow-up of a team the T/C ratio revealed significant changes during the season[115]. The initial value increased by 12.1% at the end of the pre-season (0.37 ± 0.03), in the middle of the season it dropped by 15.2% (0.28 ± 0.02) compared to the initial measurement ($p < 0.05$) and at the end of the season the value was 9.1% less (0.30 ± 0.02) than at the start of the pre-season. Similar results were found in another study[102]. It has been suggested that during the pre-season, the players are not fatigued and can respond appropriately to training demands, but that by mid-season the decrease of the T/C ratio is due to the training load, pressure to achieve results, adverse weather conditions and the increase of the C[115]. In fact, there is no need to link this to a state of over-training, rather to a failure to adapt and to hormonal dysfunction[102].

Despite not having observed differences in the pre-match and post-match values in the T/C ratio of semi-professional footballers after a competitive match[32], a post-match reduction has been indicated in this ratio, of 64.2%, indicating the catabolic stress of a match[122]. In consonance with this result, it has been confirmed that the T/C ratio can reduce up to 48 hours post-match ($p < 0.05$)[77]. These results seem to confirm that the T/C ratio is very variable in football players at the same training level.

Conclusion

Different authors have indicated the relevance of recovery on sporting performance, as it constitutes one of the basic elements of training. To assess this process, different biomarkers have been used, among which are biochemical markers. Their control, follow-up and assessment provide an understanding into how a football player recovers from a match and/or training, and offers a practical guide of when players may be more susceptible to injuries and states of non-functional over-training. In our point of view, it would seem that the CK and hormonal parameters are the most relevant biomarkers. The main problem is that these measurements may be expensive and unlikely to be carried out on the training field[5,135]. Furthermore, and with the aim of making significant interpretations, trainers should be aware of the individual variability of these markers between matches and training sessions.

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