

FOOTBALL RECOVERY STRATEGIES

PRACTICAL ASPECTS OF BLENDING SCIENCE AND REALITY

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DEMANDS OF THE GAME

In elite soccer, the number of competitive matches per season, including domestic, continental and international matches, can be very high for successful teams. Some players can play up to 70 competitive matches per season. In these conditions, the number of weeks with two matches per week is greater than the number of weeks with one match per week.

A single match leads to acute fatigue, characterised by a decline in maximal muscle strength¹, which requires several days to fully recover.

When the schedule is congested (i.e. two matches per week over several weeks), the repetition of matches can lead to a persisting chronic fatigue among the players who play regularly, as the recovery time between two successive matches may be too short. FIFA recommends at least 2 days between two

matches, but this is not a rule, it is solely a recommendation. Anecdotal interviews from managers and head coaches frequently reveal that the players are exhausted by repeated matches. Are these subjective statements justified by scientific evidence? In this instance, a congested schedule can be associated with a decrement of physical performance and with a higher injury rate. This aspect will be addressed in the first part of this article.

The second question is how much time does a professional player need to fully recover? This aspect will be addressed in the second part of the article.

The third part will deal with the actions performed during a match which may lead to fatigue and the potential mechanisms involved.

The fourth question concerns the recovery strategies available to reduce the

magnitude of fatigue and to accelerate the time to full recovery. This will be addressed in the fourth part of the article.

EFFECTS OF A CONGESTED SCHEDULE ON PHYSICAL PERFORMANCE AND INJURY RATE

Soccer involves many activities such as sprinting, changing direction, jumping, shooting, passing, tackling and physical contact, which lead to fatigue. In such a case, fatigue is characterised by a decline in physical or muscle performance induced by exercise. During a match, fatigue occurs temporarily after short-term intense periods in both halves; towards the end of the match and after the match. Many non-contact injuries occur during the latter stages of each half^{2,3}, suggesting that fatigue can be a risk factor of injury. However, fatigue can also come from the repetition of the



matches. During periods where the schedule is particularly congested (i.e. two matches per week over several weeks), the recovery time between two successive matches can be between 2 and 4 days, which may be insufficient to restore normal homeostasis. As a result, players may experience acute and chronic fatigue potentially leading to underperformance and/or injury.

Ekstrand et al⁴ investigated the relationship between exposure of footballers in European clubs to match play in the months before the FIFA World Cup 2002 and their injuries and performance during that World Cup. They found that 60% of the players who had played more than one match a week before the World Cup incurred injuries or underperformed. Dupont et al⁵ also studied match-related physical performance and injury rate when playing either one or two matches per week during two seasons on 32 professional soccer players in a top-level team participating in the UEFA Champions league. Physical performance during official matches, characterised by total distance

covered, high-intensity distance, sprint distance and number of sprints, was not significantly affected by the number of matches per week (1 vs 2), while the injury rate was more than six times higher ($P < 0.001$) when players played two matches per week (25.6 injuries per 1000 hours of exposure) compared to one match per week (4.1 injuries per 1000 hours of exposure). Bengtsson et al⁶ confirmed these results with a study involving 27 professional teams over 11 seasons. Total injury rates and muscle injury rates were increased in league matches when the recovery time was less than or equal to 4 days compared with matches where the recovery time was more than or equal to 6 days. The present data highlight the need for improved recovery strategies to maintain a low injury rate during periods with congested match fixtures. However, before focusing on recovery strategies, it is necessary to identify the time course of recovery, to determine the fatigue mechanisms as well as the actions in a match that may lead to fatigue. The knowledge of these

mechanisms should allow the application of appropriate and rationalised recovery strategies.

TIME COURSE OF RECOVERY

After a soccer match, physical performance is impaired and requires several days to fully recover. Sprint performance over 20 m is impaired immediately after a match by -37 to -9%¹. Thereafter, the recovery of sprint performance differs largely between studies with complete recovery occurring between 57 and 96 hours⁸. When tested immediately after a match, jump performance decrements range from no decrement⁹ to -12%¹. The time for jump performance to completely recover is between 48 hours⁸ and more than 72 hours after the match^{7,1}. The post-match decline in knee flexors maximal voluntary strength ranges from -7%¹⁰ to -15%¹¹ and requires 51 hours⁷ to more than 72 hours¹¹ to fully recover. Although the validity of biochemical markers for muscle damage is questionable¹², creatine kinase concentrations are frequently used to investigate the underlying physiology of the recovery process. Immediately after a match, rises in creatine kinase concentration range from +75%¹¹ to +250%¹. Creatine kinase concentrations peak at 24 to 48 hours after the match and return to baseline between 69⁷ and 120 hours⁸ following the match.

The differences between studies regarding the magnitude of performance decline and the subsequent time course of recovery could be explained by the fact that the recovery process was tracked during the post-football match period^{1,7,8,11}. Several studies^{5,13} have pointed out the high variability and poor reliability of physical

performance such as high-intensity running distance during soccer matches, which depends not only on the fitness level but also on the match status (i.e. whether the team is winning, losing or drawing), quality of the opponent (strong or weak) and the match location (i.e. playing at home or away). Secondly, some extrinsic factors may also influence players' work rate such as the climatic conditions and type of pitch (e.g. grassy, muddy, artificial). As a consequence, the amount of fatigue induced during different soccer matches may vary greatly and affect the time course of recovery. This inherent variability to a soccer match makes it difficult to translate findings from one study to another.

In summary, soccer-related physical performance is impaired immediately after the match and recovers gradually to pre-match levels. Several studies failed to observe a normalisation of physical performance within the 3 days consecutive to a soccer match^{17,11,14}, suggesting that performance can be impaired for 72 hours and more. When playing two matches per week, the 3-day recovery time between two successive matches may consequently be insufficient to fully recover. This long-lasting reduction in physical performance testifies the presence of some fatigue processes that recover slowly after the match.

FATIGUE MECHANISMS

Let us focus on the mechanisms that contribute to post-match fatigue. The decrement in performance characterises post-soccer match fatigue. A challenge for exercise physiologists is to identify the factors and mechanisms involved in this post-match fatigue. Long-lasting fatigue may be caused by both impaired excitation-contraction coupling and structural damage¹⁵. According to Rampinini et al¹⁶, fatigue in soccer is determined by a combination of central and peripheral factors both immediately after the match and within hours of recovery. Central fatigue seems to be the main cause of the decline in maximal voluntary contraction and sprinting ability, whereas peripheral fatigue seems to be more related to increased muscle soreness and therefore may be linked with muscle damage and inflammation.

Fatigue occurring in the last quarter of a match is characterised by a decline in the amount of high-intensity running and may be induced by the depletion of glycogen stores¹⁷. Although this fatigue occurs toward the end of the match, it can also affect the post-match fatigue, as muscle glycogen repletion after a high-level soccer match requires between 2 and 3 days when a specific nutrition plan is provided. Dehydration and

thirst could be additional factors involved in the fatigue observed in the last quarter of the match. After a match played in a hot environment (31.2 to 31.6°C), Mohr et al¹⁸ reported a net fluid loss of more than 2% of initial body mass. They found a significant correlation ($r=0.73$; $P < 0.05$) between the net fluid loss during the match and the fatigue index in a post-match sprint test. However, it is likely that dehydration plays a limited role in post soccer match fatigue as the time to rehydrate is relatively short (6 hours) when guidelines are respected¹⁹.

Muscle damage is likely a major factor to consider in an attempt to explain post-match fatigue. The repetition of changes of direction, acceleration and deceleration throughout a soccer match may induce muscle damage. Muscle damage is characterised by muscle soreness, increased passive muscle stiffness, muscle swelling, morphological changes such as disruption and disorganisation of sarcomeres, sarcolemma and transverse tubular system and a prolonged reduction in maximal muscle force production²⁰.

Mental fatigue is an additional factor to consider in the attempt to explain post-soccer match fatigue. When the competitive fixture list is congested, there may be insufficient time in between matches for players to recover psychologically,

During periods where the schedule is particularly congested, the recovery time between two successive matches can be between 2 and 4 days, which may be insufficient to restore normal homeostasis

potentially leading to lack of motivation and mental burnout. A congested schedule can be associated with a lot of travelling, which may lead to the disruption of circadian rhythms (jet lag or arrival during the night) and increase the level of stress induced by restricted motion, unfamiliar sleeping patterns and poorer quality of sleep.

In summary, central fatigue seems to be the main cause of the decline in maximal voluntary contraction and sprinting ability, whereas peripheral fatigue seems to be more related to increased muscle soreness and therefore seems very likely linked to muscle damage and inflammation. Post-match fatigue may be associated with glycogen depletion, muscle damage and mental fatigue.

RECOVERY STRATEGY

According to Bishop²¹, the general consensus is that the translation of sports science research to practice is poor. In order to reduce this gap between research and practice, a survey on the recovery strategies currently used in professional soccer teams was performed²². Thirty-two clubs responded that the aspects they took into account for the recovery of their players concerned nutrition and hydration (97% of the clubs) and sleep (95% of the clubs); while the recovery strategies used after the matches or during the following days were cold water immersion and contrast water therapy (88% of the clubs), active recovery (81%), massage (78%), stretching (50%), compression garments (22%) and electrical stimulation (13%). Following this survey, the level of scientific evidence justifying these recovery strategies was reviewed. For this review, the level of scientific evidence focused on the effects of the recovery strategies on change in the measured physical performance.

Nutrition and hydration

Rehydration, carbohydrate and protein consumption after a match are effective recovery techniques for replenishing

water and substrate stores and optimising muscle-damage repair. However, guidelines including quantity and timing are required in order to maximise their effectiveness.

Complete restoration of fluid balance after a match is an important part of the recovery process as loss of intracellular volume reduces rates of glycogen and protein synthesis²³. After match-induced dehydration (~2% of body mass), full rehydration status will take 6 hours, if a high-sodium (61 mmol.l⁻¹, about 3× higher than the sodium concentration found in many commercial sports drinks) drink with a volume greater than 150 to 200% of the sweat loss is consumed¹⁹. The addition of sodium to rehydration beverages (500

to 700 mg/L of water) is recommended as it promotes fluid retention, stimulates the thirst while delaying urine production and increases glucose absorption in the small intestine²⁴. As a high rate of post exercise fluid consumption also results in a faster fluid balance restoration compared to a low rate of fluid intake²⁵, it is recommended to drink a large volume of fluid after the match instead of small quantities gradually. However, a small volume of fluid should be prescribed after this initial large consumption of fluid. Addition of a small amount of carbohydrate into the water can also be advised as it stimulates fluid absorption in the gut and improves palatability²⁴.



RECOVERY PROTOCOL

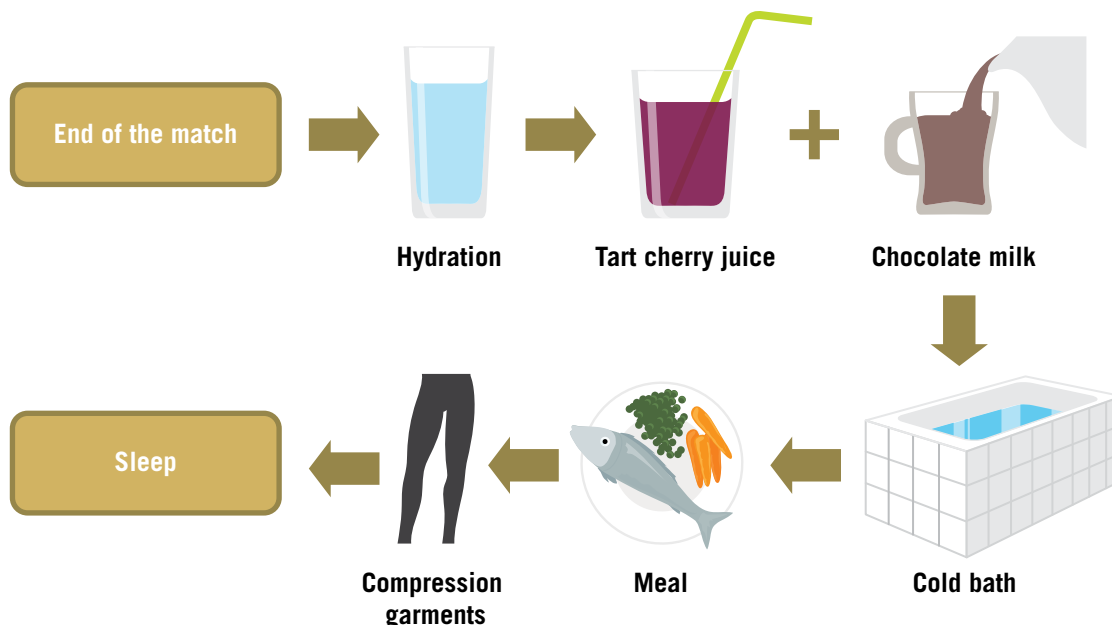


Figure 1: An example of a practical recovery protocol based on scientific evidence.

In a survey conducted on a professional team from the Italian Serie A followed over 5 years, 66% of the players reported being regular drinkers of alcoholic beverages²⁶. However, alcohol consumption should be avoided after a match as it delays the ability to recover. Firstly, alcohol has diuretic properties, which increases urinary output and consequently the level of dehydration²⁴. Secondly, it delays the muscular recovery process. The decline in maximal strength at 36 hours post-exercise was associated with muscle damage and was significantly greater in the alcoholic beverage condition (1 g.kg⁻¹ bodyweight ethanol as vodka and orange juice) compared to an isocaloric non-alcoholic beverage condition²⁷. Thirdly, it impairs sleep efficiency²⁸, a vital function in the recovery process.

The time course of muscle glycogen repletion after a high-level soccer match is between 2 and 3 days. Without specific guidelines, muscle glycogen concentration in top-level players was about 50% of the pre-match value 2 days after a match²⁹. To optimise the resynthesis of muscle glycogen stores, an intake of ~1.2 g carbohydrate.kg⁻¹.hour⁻¹ with a high glycemic index immediately after a match and at 15 to 60 minutes intervals for up to 5 hours afterwards³⁰. This enables maximum resynthesis of muscle glycogen stores.

As exercise stimulates muscle protein synthesis and muscle protein breakdown, the absence of protein intake after exercise can lead to a negative net protein balance. A positive muscle protein balance is required to repair exercise-induced muscle damage following a soccer match. Although, the quantity, type and timing of protein ingestion to maximise post-exercise muscle protein synthesis remains a topic for debate, a consumption of ~20 g milk protein or an equivalent of ~9 g essential amino acids seems to be sufficient to stimulate muscle protein synthesis rates during the first 2 hours of post-exercise recovery³¹. A high-protein diet after exercise can also improve subsequent muscle function³² and cycling exercise performance³³. Flavoured milk, which is an easily accessible and relatively inexpensive dairy product, is an effective beverage for post-exercise recovery. It contains carbohydrate and proteins in similar amounts to those used in studies demonstrating improved post-exercise recovery. Many studies have also confirmed the significant effects of post-exercise chocolate milk supplementation on subsequent exercise performance^{34,35}.

Some juices such as tart cherry juice, tomato juice or berry juice are also recommended for enhancing the recovery process. These juices have a high antioxidant

capacity, which reduces oxidative stress and inflammation. The ingestion of these juices prior to and following exercise-induced muscle damage is able to accelerate muscle strength recovery^{36,37}.

In conclusion, immediately after a match, players should drink a large volume of fluid (about 150% of the sweat loss) with a high concentration of sodium (about 500 to 700 mg/L of water), flavoured milk and tart cherry or berry juice. Then, they should eat a meal containing high-glycaemic index carbohydrate and protein within the hour following play (Figure 1).

Long-lasting fatigue may be caused by both impaired excitation-contraction coupling and structural damage

Sleep

Playing a soccer match at night (8 to 9 pm) involves high physical and mental load, as well as a high emotional stress. In addition, post-match routines (medical care, recovery strategies, meal and return trip) frequently lead to a very late bedtime, which may also alter sleep quality and quantity. Sleep loss is associated with reductions in endurance performance, maximal strength and cognitive performance³⁸. Close links also exist between sleep and the immune system. Cohen et al³⁹ showed that subjects with less than 7 hours of sleep per night in the weeks preceding exposure to rhinovirus are about three times more likely to develop a cold than those with 8 hours or more of sleep.

A high-glycaemic index meal, which is recommended for rapid restoration of muscle glycogen stores, significantly reduced sleep onset latency compared with a low-glycaemic index meal⁴⁰ and was most effective when consumed 4 hours before

bedtime compared with the same high-glycaemic index meal given 1 hour before bedtime. Some other nutrients such as those containing tryptophan or melatonin^{41,42} are also recommended to decrease sleep onset latency and/or to improve sleep quantity and quality. Tryptophan-containing foods include milk, meat, fish, poultry, eggs, beans and leafy green vegetables, while high concentrations of melatonin are contained in tart cherries.

A poor night's sleep may be compensated by a short post-lunch nap. Waterhouse et al⁴³ found that a nap, followed by a 30-minute recovery period, improved alertness and aspects of mental and physical performance following partial sleep loss. The ability to nap for short periods during the day may be a useful skill for players especially during a congested schedule. Another strategy to improve physical performance could be to extend sleep quantity over multiple weeks. According to Mah et al⁴⁴, extended sleep beyond one's habitual nightly

sleep contributes to improved athletic performance, technical skills, reaction time and daytime reduces sleepiness in basketball players.

Other recommendations for sleep induction include benefiting from a dark and quiet environment by using eyeshades and earplugs, listening to relaxing music and adopting regular sleep-wake schedules. Conversely, consumption of caffeine prior to the match for performance enhancement, alcohol as a means of celebrating after the match and hyper-hydration could lead to sleep disturbance.

Sleep is an essential part of recovery management, as sleep disturbances after a match are common which may negatively impact on the recovery process.

Cold-water immersion

Several meta-analyses have confirmed the positive effects of cold-water immersion on recovery of performance^{45,46}. Cold water immersion post-exercise provided



worthwhile benefits on anaerobic performances i.e. maximal strength, sprint ability and countermovement jump^{47,48}. In a meta-analysis focusing on the effects of cold-water immersion on muscle soreness, Bleakley et al⁴⁹ found that this strategy was effective to reduce onset of muscle soreness. The percentage of performance change associated with cold-water immersion would be considerably smaller in non-weight-bearing sports (swimming, cycling) compared to weight-bearing sports (running, weight training, eccentric muscle damage models). The positive effects of cold-water immersion on recovery of performance are higher when body contacts leading to damage are involved⁵⁰. The following protocol could be recommended to optimise the effects of cold-water immersion on recovery of performance: whole-body immersion lasting 10 to 20 minutes at a temperature of 12 to 15°C^{45,51} immediately after the match or a high-training load session⁵².

Active recovery

This strategy involves running, biking or swimming at low intensities for durations of 15 to 30 minutes. This recovery strategy is often implemented after soccer match, as active recovery, performed between 30 and 60% of maximal oxygen uptake and lasting at least 15 minutes, enhances blood lactate removal⁵³ in comparison with passive recovery. However, lactate removal should not be the criterion used to test the quality of recovery. Faster lactate removal does not necessarily involve better performance during subsequent exercise. In several studies aimed at comparing active and passive recovery modalities, exercise performance after active recovery did not improve, despite lower lactate concentrations^{54,55}, while other studies showed that passive recovery improved performance in subsequent exercise^{56,57}. In addition, some studies have reported that active recovery performed immediately after high-intensity exercises significantly impaired glycogen synthesis^{58,59}.

In a set of studies on recovery between two soccer matches separated by 3 days in elite female players, Andersson et

al^{7,60} investigated the effects of 1 hour of active recovery (low-intensity cycling and resistance training) performed at 22 and 46 hours after the first match. Results showed that active recovery had no effects on the recovery pattern of physical performance markers (i.e. countermovement jump, 20-m sprint performance, maximal isokinetic knee flexion and extension), perceived muscle soreness and biochemical markers (i.e. creatine kinase, urea and uric acid), oxidative stress markers and antioxidants. According to these results, active recovery performed after a match does not present any benefit for soccer-related physical performance.

Massage

In terms of recovery of performance, most studies have failed to find a significant beneficial effect of massage on subsequent exercise after local exercises⁶¹ or global exercises⁶². Massage therapy attenuates inflammatory signalling after exercise-induced muscle damage⁶³ and presents

psychological benefits. Massage decreased the subjective symptoms of delayed onset muscle soreness and increased perceptions of recovery⁶⁴. In conclusion, benefits of massage are still lacking regarding recovery of performance. Conversely, the majority of the evidence points towards massage being effective in alleviating muscle soreness and improving perceptions of recovery.

Stretching

Elite soccer teams devote a substantial amount of training and match preparation time to stretching. Dadebo et al⁶⁵ reported that the English Premiership clubs allocated almost 40% of total training time to flexibility training. Stretching exercises are performed for several reasons: to improve range of motion, to reduce musculotendinous stiffness, to prevent injury, as well as to promote recovery. However, there is no substantial scientific evidence to support the use of stretching to enhance the post-exercise recovery of soccer players. In a meta-analysis including 12 studies, Herbert et al⁶⁶



Recovery strategies such as hydration, diet, sleep, cold-water immersion and compression garments are effective at accelerating the recovery process



reported that stretching is not clinically worthwhile in reducing muscle soreness in the days following exercise. Recovery of physical performance is not improved after stretching⁶⁷.

Compression garments

The principle of compression garments is to increase the pressure on the ankle and to decrease it on the mid-thigh in order to improve the venous return and thus reduce venous stasis in the lower extremities. A meta-analysis on the effects of compression garments on recovery following damaging exercise was led by Hill et al⁶⁸. Data were extracted from 12 studies, where variables were measured at baseline and at 24, 48 or 72 hours post-exercise. Results indicated that the use of compression garments had a moderate effect on recovery of muscle strength, muscle power, creatine kinase and in reducing the severity of delayed onset muscle soreness. As studies did not have a placebo condition (i.e. using a garment but no compression), a placebo effect due to wearing the garments should not be excluded. Another potential limitation of studies on compression garments is that the actual pressures applied by the garments to subjects are not measured.

In conclusion, the use of compression garments may provide an easy-to-use recovery strategy in a team. They could be useful during air travel, especially during long flights, to reduce the risk of deep vein thrombosis⁶⁹.

Electrical stimulation

Electrical stimulation involves the transmission of electrical impulses via surface electrodes to peripherally stimulate motor neurons thus eliciting muscular contractions. Transcutaneous electrical nerve stimulation and low-frequency electrical stimulation are the modalities most frequently used for recovery purposes. The effects of electrical stimulation on the recovery of strength production capacity and on the reduction of muscle soreness were reviewed by Babault et al⁷⁰. Among the 12 studies reviewed, 11 studies failed to find a significant effect of electrical stimulation on the ability to maintain performance after

exercise, while three out of nine studies reported a significant effect of electrical stimulation on the reduction of muscle soreness.

In conclusion, while electrical stimulation is often used for recovery purposes, no scientific evidence exists regarding its ability to maintain physical performance. The level of scientific evidence concerning the effect of electrical stimulation on subjective ratings such as muscle soreness is also limited.

CONCLUSION

In summary, some recovery strategies such as hydration, diet, sleep, cold-water immersion and compression garments are effective to accelerate the recovery process. An example of a practical recovery protocol based on scientific evidence is proposed in Figure 1.

As described in the Figure 1, the recovery protocol includes six steps and should start immediately after the match:

1. The first step is hydration; the mass of the players should be measured and compared to the pre-match body mass in order to propose the appropriate quantity of fluid to drink (150% of body mass lost). The fluid should contain a combination of water and a large amount of sodium (500 to 700 mg/L of water).
2. The second step consists of drinking a tart cherry juice and chocolate milk in order to restore glycogen, to reduce oxidative stress and inflammation, to stimulate muscle repair and to promote quality and quantity of sleep.
3. The third step is the cold bath. The players should immerse themselves up to the neck at a temperature between 12 and 15°C for 10 to 20 minutes to accelerate the recovery process.
4. The fourth step is to wear a compression garment until bedtime.
5. The fifth step is to eat a meal high in carbohydrate with a high-glycaemic index and protein within 1 hour of the end of the match (for example soup, well-cooked white pasta or mashed potatoes, chicken or fish, yogurts or cake).

6. The final step is to have a good night's sleep.

Scientific evidence for the other strategies reviewed, such as active recovery, stretching, massage and electrical stimulation is still lacking in the ability to accelerate the return to the initial level of performance. This does not mean that these strategies do not help recovery, but that the protocols implemented up until now were unable to accelerate the recovery of physical performance.

In the survey on recovery administered to the professional soccer teams, practitioners revealed that recovery strategies are combined in recovery protocols. Although it remains important to isolate each strategy to determine its effects in the future research, it would also be interesting to analyse the interactions between the techniques. Longitudinal research protocols should also be led to take into account the chronic effects of cellular to molecular adaptations.

References

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