



## Evidence-Based Recovery in Soccer – Low-Effort Approaches for Practitioners

by

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*Strategies to improve recovery are widely used among soccer players at both amateur and professional levels. Sometimes, however, recovery strategies are ineffective, improperly timed or even harmful to players. This highlights the need to educate practitioners and athletes about the scientific evidence of recovery strategies as well as to provide practical approaches to address this issue. Therefore, recent surveys among soccer athletes and practitioners were reviewed to identify the recovery modalities currently in use. Each strategy was then outlined with its rationale, its physiological mechanisms and the scientific evidence followed by practical approaches to implement the modality. For each intervention, practical and particularly low-effort strategies are provided to ensure that practitioners at all levels are able to implement them. We identified numerous interventions regularly used in soccer, i.e., sleep, rehydration, nutrition, psychological recovery, active recovery, foam-rolling/massage, stretching, cold-water immersion, and compression garments. Nutrition and rehydration were classified with the best evidence, while cold-water immersion, compression garments, foam-rolling/massage and sleep were rated with moderate evidence to enhance recovery. The remaining strategies (active recovery, psychological recovery, stretching) should be applied on an individual basis due to weak evidence observed. Finally, a guide is provided, helping practitioners to decide which intervention to implement. Here, practitioners should rely on the evidence, but also on their own experience and preference of the players.*

**Key words:** football, performance, practical interventions, intermittent exercise, strength and conditioning.

### Introduction

A consensus among coaches and scientists exists about the outstanding importance of recovery as the balance between loads and recovery will result in optimal performance in training and games. On the other hand, a chronic state of incomplete recovery may cause non-functional overreaching, which may be counteracted by applying recovery strategies in a systematic fashion (Calleja-Gonzalez et al., 2018; Kellmann et al., 2018a). Recovery modalities may help athletes reduce the negative effects of fatigue, restore performance, tolerate higher loads, and improve sport-specific fitness (Barnett, 2006;

Gabbett, 2016; Kellmann, 2010; Tavares et al., 2017).

In soccer, players at all levels can be exposed to a high workload, such as playing additional games during the week. This sometimes results in players having to play three games in seven days, which increases the need for recovery strategies. Therefore, a variety of modalities such as massage, cold applications, stretching, or foam-rolling is often prescribed by coaches and applied by athletes to optimally use the time between two exposures and keep the recovery time as short as possible (Eder et al., 2016). When applying certain recovery strategies, practitioners often rely on

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"trial and error" approaches, they "mimic" strategies from other coaches or apply methods that are practicable, timesaving and where they can rely on previous experience (Simjanovic et al., 2009; Venter and Grobbelaar, 2017). Under the pressure to address this hot topic, both coaches and players frequently apply strategies that are believed to be effective, while the scientific evidence and the physiological benefits are often unclear (Crowther et al., 2017; Kellmann, 2010; Venter, 2014). In some cases, however, recovery modalities are either ineffective (Afonso et al., 2021), ineffectively timed (Ivy et al., 1988) or even harmful to athletes, i.e., an application impairing the adaptation of a training stimulus (Roberts et al., 2015), or a recovery treatment leading to potential damage in tissues and bones (Freiwald et al., 2016a). These obstacles underline the need to educate practitioners and athletes towards an effective use of commonly applied recovery strategies (Crowther et al., 2017; Murray et al., 2018). It has been shown that soccer players at all levels use different recovery strategies on a regular basis. However, some players do not have the opportunity to elaborate and receive costly recovery strategies, and differences in the usage of recovery modalities between the playing levels exist (Crowther et al., 2017; Venter, 2014). Even in elite soccer clubs, logistics and resources may play a significant role when applying certain recovery strategies (Altarriba-Bartes et al., 2020).

Therefore, the purpose of this narrative review is to provide an evidence-based manual for soccer practitioners with practical and low-effort approaches for all playing levels to effectively enhance recovery. Here, a comprehensive overview of the most important and commonly used recovery strategies in soccer is given, including three approaches for each strategy to enhance recovery, i.e., i) knowledge transfer based on the physiological mechanisms and its effectiveness, ii) a practical intervention, iii) a practical intervention with a particular focus on individualization. As each team and also each player have individual needs and resources at hand (Calleja-Gonzalez et al., 2018; Kellmann et al., 2018a), different steps allow practitioners to design a program specifically adapted to the particular team and player. Coaches can choose methods they prefer, they feel comfortable applying, and they consider evidence-based from

their practitioners' point of view like a building-block approach.

## **Factors contributing to fatigue – starting points for recovery strategies**

### *Recovery in soccer*

Recovery, defined as the "return of the full biological system to homeostasis without maladaptation" (Soligard et al., 2016), is considered an "umbrella term" (Kellmann et al., 2018a) that demands a multilevel (physiological, psychological, social) approach to restore performance (Heidari et al., 2017; Kellmann, 2002). Recovery strategies generally aim to "shift from stress to recovery" (Barnett, 2006). During soccer games, a total distance of about 9-12km per game is covered by field players depending on the position played performed as walking (0.7-7.1km·h<sup>-1</sup>), jogging (7.2-14.3km·h<sup>-1</sup>), running (14.4-19.7km·h<sup>-1</sup>), high-speed running (19.8-25.1km·h<sup>-1</sup>), sprinting (>25.1km·h<sup>-1</sup>), jumping, and stopping actions (Bangsbo et al., 2006; Barnes et al., 2014; Ispirlidis et al., 2008; Mohr et al., 2003). Non-professional players tend to run shorter total distances, and high-speed running seems a key differentiator between elite and lower level players, but the relative intensity is comparable between these settings (Bangsbo, 2014; Stolen et al., 2005).

Soccer matches typically lead to inflammatory responses, muscle damage and potential performance decline that can persist for 3 to 4 days post-exercise (Ispirlidis et al., 2008). Moreover, mental fatigue and glycogen depletion are potential consequences of soccer training and games (Nedelec et al., 2012). Thus, recovery strategies should be applied with the purpose to rapidly "re-establish psychological, physiological, emotional and social components to allow the athlete to tax these resources again" (Venter, 2014) with the overall aim to achieve optimal performance and minimize the risk of injury (Nedelec et al., 2012).

### *Soccer-related fatigue, starting points for recovery interventions*

"Fatigue following a soccer match is multifactorial and related to dehydration, glycogen depletion, muscle damage and mental fatigue" (Nedelec et al., 2012). Thus, practitioners must address these fatigue-related factors in a targeted manner to restore performance in a

multifactorial way.

Dehydration typically occurs in an endurance-based exercise due to insufficient fluid intake (Rodriguez et al., 2009) and is moderated by climatic conditions such as wind, weather and temperature (Nedelec et al., 2012). Negative effects of dehydration such as cognitive decline, increased fatigue and decreased symptoms of alertness may occur when fluid deficits reach 1-2% of total body mass (Maughan, 2003). Mohr and colleagues reported more than 2% of total body fluid loss resulting in decreased running performance towards the end of the game that took place in a 31°C environment (Mohr et al., 2010). In another study, the post-match performance, indicated by results obtained in a Yo-Yo Intermittent Recovery Test, was impaired when fluid intake was denied in amateur soccer players (Edwards et al., 2007). Therefore, adequate hydration and rehydration are recommended to maintain and restore optimal performance since dehydration may result in performance deterioration and an increased perception of effort (Edwards et al., 2007; McArdle et al., 2010). In addition, glycogen is regarded as the decisive substrate for energy metabolism in soccer (Mohr et al., 2003). Glycogen depletion after soccer training/games may result in reduced sprint performance and enhanced feelings of fatigue (Bangsbo et al., 2006). According to Nedelec et al. (2012), muscle glycogen repletion might take 48-72h. Glycogen depletion in some muscle fibers might be related to fatigue and impaired performance towards the end of a game (Bangsbo et al., 2007). Therefore, a diet high in CH content is recommended to quickly replenish glycogen stores to fully recover for the upcoming training session.

Repeated soccer-specific actions such as jumping, sprinting, and shooting may lead to reversible muscle damage. This results in an inflammatory response which in turn reduces maximal force generated by muscles (Nedelec et al., 2012). Markers of muscle damage and oxidative stress were shown to be increased throughout a 72h post-exercise recovery period after a soccer match (Ascensao et al., 2008). In line with this finding, markers of muscle damage remained increased for 48-72h after an elite soccer game (Ispirlidis et al., 2008). Thus, muscle damage is considered an important fatigue

pattern that may be effectively targeted by recovery strategies. Finally, researchers have stressed the importance of preventing or at least alleviating mental fatigue due to potential performance impairment (Smith et al., 2018b). Studies have demonstrated that mental fatigue possibly affects technical performance (Badin et al., 2016) as well as tactical and physical performance in small-sided soccer game situations (Coutinho et al., 2017). The cognitive demands of soccer are enormous including scanning the environment, implementing tactical strategies and the requirement to make precise decisions in a short time (Smith et al., 2018a). Since mental fatigue can also impair recovery (Smith et al., 2016), it is recommended that this area should not be neglected in the implementation of recovery strategies, specifically using psychological recovery strategies to counteract the effects of mental fatigue (Kellmann et al., 2018a).

## Methods

### *Approach to the problem*

We searched for evidence-based post-exercise recovery strategies (i.e., physiological, psychological, and social recovery; (Kellmann, 2002; Kellmann et al., 2018a)). The respective applications must be applicable at all levels of soccer, i.e., a team sport setting, requiring low monetary cost and personnel effort. Commonly used recovery strategies were identified by reviewing recent surveys conducted among soccer players or team sport athletes that included soccer players (Altarriba-Bartes et al., 2020; Crowther et al., 2017; Murray et al., 2018; Venter, 2014); i.e., sleep, hydration, nutrition, mental recovery, active recovery, foam-rolling/massage, stretching, cold-water immersion, and compression garments. Sauna, acupuncture and electromyostimulation were excluded because athletes, especially in non-professional settings, may not have permanent access to such strategies (Van Hooren and Peake, 2018).

Some modalities mentioned in the respective surveys were categorized under one approach. For instance, discussion with teammates and discussion with coaches were classified as "psychological recovery". Each method is presented with its objective, physiological mechanisms, and scientific

evidence, followed by three steps for practical implementation (Table 1). The rationale of these steps is explained in the following section. Evidence for recovery interventions was obtained from soccer-specific settings when available. Moreover, to reduce the number of references as well as to provide overall effect sizes, reviews and meta-analyses were cited (Sawka et al., 2007), which provide further original publications. Evidence for interventions enhancing recovery was classified within three categories, i.e., good evidence (high-quality studies or systematic reviews (SR) with high-quality studies), limited/moderate evidence (SR with lower quality studies, inconsistent findings in studies), and weak/no evidence (usual practice, opinion papers) for enhancing recovery; an approach similar to “the strength of recommendation taxonomy (SORT)” (Ebell et al., 2004). In addition, consensus expert papers were cited when available and used for comparison of the evidence grade.

*Step 1: Knowledge transfer – Educate and increase players’ belief*

“It is important for both coaches and sport scientists to educate their athletes on the benefits of recovery and also encourage belief in the practice” (Broatch et al., 2014). Thus, the first step for each method is a knowledge transfer from practitioners to players to provide physiologically sound information about the effectiveness of particular methods (Roelands and Hurst, 2020). This approach aims to i) increase players’ belief in interventions delivered during/after regular training/games (e.g., nutrition; (Venter and Grobbelaar, 2017)), and ii) to educate towards self-implementation outside regular training/game (e.g., sleep management). Scientifically based methods with a physiological benefit that meet high players’ belief can maximize their potential impact (Broatch et al., 2014).

While players may already have their individual recovery routines, coaches play here a crucial role as they can expose their athletes to novel methods and increase their belief in them. If coaches implement a recovery strategy, besides scientific evidence, players’ belief should be considered (Venter and Grobbelaar, 2017) because motivation, conditioning and expectancy are considered factors that may lead to a positive outcome (Beedie and Foad, 2009). Players seem open-minded towards new methods. According

to a survey, more than 60% of participants would agree to take a performance-enhancing drink if their coach explained the physiological effects and assured them that it did not contain banned substances. Additionally, more than 80% of the respondents stated that they believed in a placebo effect (Berdi et al., 2015), defined as “a favorable outcome arising purely from the belief that one has received a beneficial treatment” (Clark et al., 2000). Besides increasing players’ belief in a recovery method, knowledge transfer also addresses the main reasons why players refrain from using a method, i.e., the lack of knowledge about its application and about its effects (Venter and Grobbelaar, 2017). This first step ideally serves as the basis for further ones.

The rationale behind this approach can be derived from clinical trials (Amanzio et al., 2001; Benedetti et al., 1995), but exercise-related studies have shown similar results, yet research in this field is comparably emerging (Beedie and Foad, 2009). For instance, in a water immersion setting with three groups, athletes were convinced about positive effects of thermoneutral water immersion of 35°C before the actual exercise intervention was carried out. This approach resulted in similar recovery effects compared to the recommended temperature of 10°C, but superior effects to the condition where participants also immersed in thermoneutral water without facilitating a placebo effect. Thus, the effects of recovery methods may at least partly be placebo-related (Broatch et al., 2014; Hurst et al., 2019). In line with this, small to moderate effects of the placebo on performance were recently shown in a systematic review (Hurst et al., 2019).

Increasing players’ belief and education towards self-implementing specific behaviors may work via expert counseling, team talks, motivational tasks, behavioral strategies, fact sheets (Bonnar et al., 2018; Caia et al., 2018b; Holway and Spriet, 2011) or by just stating a disclosure about possible effects to players (Roelands and Hurst, 2020). It should be noted, however, that this approach is not meant to use alternative medical therapy approaches without evidence to only achieve a placebo effect (Beedie and Foad, 2009). Placebo effects are subject to high variance and can lead to both positive and negative effects. In addition, the use of alternative therapies may prevent the implementation of a

more physiologically effective strategy (Beedie et al., 2018b).

*Step 2: An intervention to enhance recovery*

The second step ideally follows on from the first step, which means that expectations of a method have optimally been raised (i.e., combining psychological and physiological effects). It is designed as a team intervention, i.e., one approach fits all players. Therefore, monetary costs and personal effort are comparably low for coaches. In this step, practitioners actively improve the players' recovery by providing a physiologically/psychologically based intervention such as a nutritional intervention or a rehydration strategy after a regular training session/game. Ideally, this intervention targets a specific type of fatigue, such as muscle damage or mental fatigue (Calleja-Gonzalez et al., 2018; Kellmann et al., 2018a).

*Step 3: An individualized intervention to enhance recovery*

It is well-established that each training stimulus leads to an individualized physiological response (Halson, 2014). Therefore, consensus exists that players have individual needs regarding recovery strategies (Eder et al., 2016; Kellmann et al., 2018a; Nedelec et al., 2013; Venter and Grobbelaar, 2017). The third step is thus designed as an intervention with a particular focus on individualization which usually requires increased resources (personnel or monetary costs). Consequently, it is intended for higher-level or even professional teams. If a rigorous individualized approach is limited due to a lack of financial and human resources and is thus considered too elaborate, clustering into groups constitutes a practical approach to account for individual preferences and rituals (Venter and Grobbelaar, 2017). Further practical ideas regarding individualization are given in the following chapters. Once again, step 1 is recommended to maximize the effects, while step 2 may be replaced by this step.

## Recovery strategies

*Strategies with good evidence for enhancing recovery*

*Nutritional interventions*

*Overall aim: to target glycogen depletion*

"Recovery from exercise is enhanced by optimal nutrition" (Rodriguez et al., 2009). The

restoration of glycogen stores is essential, especially if the time between two subsequent exposures is condensed (Burke et al., 2011). A survey among collegiate athletes revealed that nutrition was believed to be an effective intervention. However, the combination of belief and actual use was mentioned by only 15% of respondents (Murray et al., 2018). In a further survey, eating snacks shortly after exercise was mentioned by international top-class athletes only, hinting at an educated player type, while national club players did not rate nutritional aspects among the most important interventions (Venter, 2014).

CH are the main energy source for soccer players during high-intensity actions in games and training, and CH availability directly affects performance (Bangsbo et al., 2007; Burke, 2010). It was shown that muscle fibers were partly or completely replenished after a soccer game (Bangsbo et al., 2006; Krstrup et al., 2006). Thus, early refueling post-exercise increases the chance of fully restored glycogen stores in subsequent training sessions, which is important to maintain performance and minimize injury risk. Moreover, low glycogen levels post-exercise may be associated with increased feelings of tiredness (Bangsbo et al., 2006; Burke et al., 2011). Immediate refueling after games is also recommended as a delay of CH ingestion may result in a reduced storage rate of glycogen (Ivy et al., 1988). A low CH ingestion of only 3 g CH per kg body mass (BM) starting 3.5 days prior to a game was shown to reduce subsequent running performance (mean percentage: 17%) compared to a high CH intake of 8 g per kg BM in professional soccer players (Souglis et al., 2013). In another study, soccer players who ingested a CH solution during exercise maintained their soccer skill level and showed a better sprint performance compared to a placebo group, while both groups started the trial with a reduced CH storage (Ali et al., 2007). A recent meta-analysis also highlights the importance of regular post-exercise CH intake, especially when time between exercise is limited (Craven et al., 2021).

Nutritional interventions with CH, but also CH with proteins for enhancing recovery, are widely rated with good or fair evidence (Rodriguez et al., 2009; Thomas et al., 2016). Athletes are supposed to intake 1.0-1.5g CH per

kg BM and 20g of proteins, respectively, 9g of essential amino acids per hour within a period of 4-6h post-exercise (Burke et al., 2011; Nedelec et al., 2013; Rodriguez et al., 2009). Refueling can be achieved with liquid or solid meals (Burke et al., 2006).

As a first step, knowledge transfer and education towards a CH-rich diet can be applied via fact-sheets or team talks (Holway and Spriet, 2011). Providing high glycemic index (GI) food post-exercise can serve as the second step. This can be inexpensively achieved by providing drinks and small snacks each 15 min post-exercise (Burke et al., 2011; Sawka et al., 2007). Examples may include fruits with yoghurt, cereals, or rice cakes. Protein bars can be provided for proteins intake (Ranchordas et al., 2017). Alternatively, coaches can provide a complete high CH and protein-rich meal after the exposure (Nedelec et al., 2013). An individualized approach may consist of i) creating servings dependent on BM (e.g., 80g CH for an 80kg player during the first hours post-exercise), ii) differentiation between position-specific needs (increased need for midfielders, fullbacks; or differentiation between players and exchange players), iii) providing meals according to different cultural preferences (Nedelec et al., 2013; Ranchordas et al., 2017). Moreover, feedback about the intensity of the training unit/game may help determine individualized CH servings (Burke et al., 2011). Table 2 summarizes nutrition-related interventions.

#### *Rehydration*

Overall aim: to target dehydration (and glycogen depletion)

Dehydration is the result of insufficient fluid intake during exercise (Rodriguez et al., 2009). Fluid replacement is rated among the most important recovery modalities in both club and international athletes (Venter, 2014). In another survey, team sport local players reported “food/fluid” as a typically used recovery strategy (Crowther et al., 2017). The aim of rehydration is to compensate for fluid and electrolyte losses and start the forthcoming exercise in a euhydrated (i.e., normal body water content) state as a lack of fluid intake may substantially affect exercise performance and health. Besides fluids, sodium replacement plays a key role in the recovery process because a lack of sodium intake prevents

the return to the euhydrated state. Negative effects of dehydration on perceived effort and aerobic exercise performance, especially under warm weather conditions, are rated with good evidence (Sawka et al., 2007).

Pre- and post-exercise hypohydration is a common observation in soccer players and may impair technical performance and cognition as well as increase fatigue (Chapelle et al., 2019; Nuccio et al., 2017). It has been shown that abstaining from fluid intake during a 90-min soccer practice significantly impairs performance in a skill test setting (McGregor et al., 1999). In another study, a 45-min cycling protocol followed by a 45-min soccer game led to a 2.4% fluid loss when abstaining from fluid intake (Edwards et al., 2007). This resulted in a 13% decline in a subsequent Yo-Yo intermittent recovery test performance compared to the group that was allowed to consume fluids during and after the protocol.

Therefore, as a first step, coaches should educate about the positive effects of regular fluid intake before, during and after the exercise to maintain and restore performance/skill/cognitive functions (Nuccio et al., 2017). McDermott et al. (2017) suggest educating players about the consequences of dehydration on performance and recovery and on hydration-monitoring strategies (McDermott et al., 2017). Moreover, the widespread of hypohydration pre-exercise could be thematized (Chapelle et al., 2019). In this regard, it may also be of importance to educate players about the negative effects of post-exercise alcohol consumption on recovery (Parr et al., 2014; Vella and Cameron-Smith, 2010). On the other hand, drinking alcoholic beverages together can be seen as a reward for the accomplished work (Barnes, 2014) and may thus be considered as psychological recovery. Therefore, if players refuse to abstain from alcohol consumption, it seems reasonable to educate them towards moderate drinking.

Interventional strategies (second step) aim to replenish fluid losses by providing liquids post-exercise. To combine rehydration and refueling, fluids should be loaded with CH and sodium to enhance glycogen repletion (Bishop et al., 2008), aiming to reach a quantity of 1.0-1.5g per kg/h in frequent intervals (Burke et al., 2006, 2011). This could be achieved via beverages that contain

5-8g/100 ml of CH (McArdle et al., 2010), which is equivalent to fruit spritzers with a ratio of around 40-50% of water and 50-60% of fruit content complemented by a small amount of sodium so that it is still palatable. An alternative is to provide sports drinks that contain about 60 g of CH per liter (L) (Maughan and Shirreffs, 2008). The addition of sodium is important to promote fluid intake because it stimulates thirst and the urge to drink (McArdle et al., 2010; Rodriguez et al., 2009). Sodium is available in many sports drinks, while common soft drinks are not appropriate in this direction (Rodriguez et al., 2009). Suitable sports drinks are characterized by “good taste, rapid absorption, cause no gastrointestinal stress, maintain extracellular fluid balance, and the potential to enhance performance” (McArdle et al., 2010). CH ingestion via liquids can serve as an alternative to solid meals as some athletes may not feel comfortable eating directly post-exercise (Venter, 2014).

Problematically, fluid and sodium losses due to sweating are highly individual (Maughan and Shirreffs, 2004; Sawka et al., 2007), also depending on environmental factors such as temperature and humidity (Nedelec et al., 2012; Sawka et al., 2007) as well as training content (Nuccio et al., 2017). Moreover, due to individual differences in prehydration of soccer players (Chapelle et al., 2019), fluid and sodium requirements should be calculated on an individual basis (third step) (Maughan and Shirreffs, 2010). Changes in BM reflect sweat losses during exercise. Thus, players should be encouraged to perform a weight measurement (difference between the weight before and after the exercise) that helps determine individual fluid losses that can be compensated by 1.0-1.5L per kg of weight loss (Maughan and Shirreffs, 2008; Sawka et al., 2007). To further promote (re-)hydration, an educational lecture combined with providing urine color charts helps monitor the individual hydration status, as shown in youth athletes (Kavouras et al., 2012). To account for individual sodium losses, “salt sweaters” can be identified by wearing black shirts to look for salt stains (Maughan and Shirreffs, 2008). Increased salt intake via fluids or food may be required for those players.

Under regular conditions (upcoming session/game within 1-2 days), players restore

their fluid balance and plasma volume post-exercise within a few hours when fluids are regularly taken up over time (Barnett, 2006; Sawka et al., 2007). If the upcoming training session begins within 24h (e.g., during a training camp) or in the event of severe dehydration, a faster rehydration strategy should be used, encouraging players towards a quick intake of around 1.5L per kg fluid loss (Sawka et al., 2007; Shirreffs and Sawka, 2011). These scientifically based approaches (Table 3) may complement the already existing rehydration strategies of athletes (Shirreffs and Sawka, 2011).

### *Strategies with moderate evidence for enhancing recovery*

#### *Sleep management*

Overall aim: to target all types of fatigue

Recovery mechanisms (glycogen repletion, muscle repair, rehydration, mental recovery) can run optimally when players have appropriate sleep quantity and quality (Nedelec et al., 2013, 2015b). Sleep deprivation may affect glycogen resynthesis, exercise-induced muscle damage, injury risk and mental fatigue (Nedelec et al., 2015a). Sleep deprivation can also result in reduced toleration of exercise loads (Herring et al., 2019), an increase in illness risk or a decrease in physiological adaptations (Fullagar et al., 2015a). It should, however, be noted that mechanisms by which insufficient sleep affects recovery and subsequent performance are not well understood (Fullagar et al., 2015a, 2015b). Since sleep can be considered a “natural recovery strategy” (Venter and Grobbelaar, 2017) and interventions during/directly after the exercise are hardly possible, emphasis is placed on knowledge transfer (Table 4).

A survey among soccer players revealed that sleep was rated the most meaningful (Venter, 2014) and an effective strategy among collegiate athletes (Murray et al., 2018). Players should sleep 7-9 hours with an increased need after training or games due to the high physical and psychological effort (Caia et al., 2018a). However, sleep disturbances are common in both elite and amateur athletes (Erlacher et al., 2011; Kolling et al., 2019), and athletes lack strategies to improve their sleep (Erlacher et al., 2011). A congested schedule (e.g., playing 3 games in 7 days), playing games after 8 PM with an associated exposure to lights, travelling (Fullagar et al., 2015a; Nedelec et

al., 2015a) and certain habits such as alcohol consumption after games or training may influence sleep quality and quantity (Barnes, 2014; Feige et al., 2006). Thus, education towards effective sleep management strategies is important (Erlacher et al., 2011). Knowledge transfer should educate on “the nature of sleep, common sleep issues faced by athletes, the importance of sleep for optimal performance/recovery, and methods to improve overall sleep” (Bonnar et al., 2018).

To actively improve the athletes’ regular sleep, sleep hygiene strategies can be introduced to players as a second step to improve sleep quantity and subsequently, performance (Bonnar et al., 2018). Sleep hygiene includes the creation of a sleep-promoting environment, the development of bed routines and the creation of a cool (18-19°C) and dark room. Moreover, nutritional aspects such as the ingestion of a high protein drink before bedtime may be considered to improve sleep (Nedelec et al., 2015b). Bedrooms should only be used for sleeping and not for eating or watching television. Comfortable sleeping clothes and blankets, as well as pillows, contribute to adequate sleep quality (Caia et al., 2018a; Nedelec et al., 2015b). Electronic devices should be avoided shortly before bedtime (Fullagar et al., 2015b; Kolling et al., 2019). For this purpose, educational material, motivational tasks, and strategies delivered by an expert are suggested (Bonnar et al., 2018). In a study among university soccer players, a leaflet with information on the importance of sleep was applied, which resulted in improved sleep behavior and subsequent performance (Harada et al., 2016). Another study examined the effects of a sleep hygiene intervention with two 30-min education sessions that resulted in improved sleep behavior in a team sport setting. However, the follow-up could not confirm long-term effects of this finding (Caia et al., 2018b). An acute sleep hygiene strategy was also applied to amateur soccer players after games in the evening compared to a control condition (Fullagar et al., 2016). In the intervention group, sleep duration was significantly increased, but performance and recovery variables remained unaffected. Taken together, sleep hygiene interventions appear reasonable to improve the sleep of athletes, but studies to date provide mixed results (Bonnar et

al., 2018). There is still a lack of research in this area and too little is known about the efficacy of these interventions to draw definite conclusions (Fullagar et al., 2015a).

In order to account for individualization (third step), identifying players who have issues with regular sleep and providing specific recommendations to this target group is the most reasonable, but also the most elaborate step (Fullagar et al., 2015b). Therefore, identifying players with a particular need for sleep interventions using a questionnaire or a diary could be an option (Bonnar et al., 2018). Besides sleep hygiene, napping strategies to improve overall sleep may be appropriate if players lack habitual sleep and if napping is feasible for them. Daytime napping of around 30 min showed an increase in sprint performance and alertness when partially sleep deprived (Waterhouse et al., 2007). It should be noted, however, that napping during the day may lead to inappropriate sleep during the next night (Nedelec et al., 2015a).

#### *Cold-water immersion*

Overall aim: to target muscle damage and inflammatory response

Cold-water immersion (CWI), i.e., immersion of the whole body or body parts into cold water, is applied to attenuate the effects of strenuous exercise as an analgesic to reduce muscle pain and post-exercise inflammation. However, the exact mechanistic insight remains elusive (Leeder et al., 2012; Poppendieck et al., 2013; White and Wells, 2013). Cold applications may also consist of ice packs or dry air of -80 to -110°C (White and Wells, 2013). In surveys among team sport and soccer athletes/practitioners, CWI was used by all practitioners (Altarriba-Bartes et al., 2020) and was considered one of the most effective treatments for recovery purposes by athletes (Crowther et al., 2017).

Ascensao et al. (2011) observed in their study with 20 soccer players that the application of CWI (10 min at 10°C) led to a significant group difference compared to the thermoneutral group (10min at 35°C) in ratings of delayed onset of muscle soreness (DOMS), biomarker concentrations and performance outcomes (quadriceps strength after 24h) following a match (Ascensao et al., 2011). In this regard, it has been discussed whether placebo effects might contribute to a decrease in muscle pain and

increased readiness after CWI (Leeder et al., 2012). This hypothesis was supported by a study, showing similar positive effects of a placebo thermoneutral (35°C) immersion compared to a 10°C CWI condition after a high-intensity training exercise (Broatch et al., 2014). This notion is in line with a similar study (Sellwood et al., 2007), that could not demonstrate significantly different effects between cold water (5°C) and tepid water (24°C) immersion after eccentric exercise in untrained individuals. Systematic reviews have shown small to moderate positive effects of cooling methods on recovery variables such as muscle soreness (MD=0.29) (Machado et al., 2016) and sprint performance (Hedges  $g=0.69$ ) (Poppendieck et al., 2013). It should be noted, however, that the effect size of cooling on sprint performance can also be attributed to two studies that reported effect sizes up to  $g=2.9$ . Machado et al. (2016) observed a dose-response relationship in their systematic review with the greatest effects at immersion times of 11-15min in 11-15°C water and Poppendieck et al. (2013) showed that effects of whole-body immersion exceeded extremity (arm or leg) immersion ( $g=0.62$  compared to  $g=0.10$ ). At lower temperatures, a shorter immersion time should be selected (Versey et al., 2013). As of yet, the overall methodical quality of the studies in this field is poor, and exercise protocols are highly different between studies. Thus, no further detailed instructions on how to apply CWI can be given. It is also uncertain if contrast water (the alternation between hot and cold water), thermoneutral water (>20 to <36°C) or hot water therapy (>36°C) enhances recovery (Versey et al., 2013).

It cannot be ruled out that CWI has detrimental effects on muscular adaptations. Long term adaptations after CWI in resistance exercise seem impaired as satellite cell activity was shown to be suppressed, which may inhibit muscle hypertrophy (Frohlich et al., 2014; Roberts et al., 2015). However, the results of a recent review suggest that long-term training adaptations in endurance sports may not be affected (Broatch et al., 2018). Findings of another review indicate that primarily resistance training adaptations such as strength endurance are negatively affected by the regular use of CWI, but not aerobic exercise performance (Malta et al., 2021). Further research will clarify the effects of chronic CWI application

on physiological adaptations.

To conclude, the application of CWI might be slightly more effective than passive recovery for enhancing recovery. Thus, under certain circumstances, such as a condensed schedule, or in a hot environment, CWI can be applied aiming to reduce DOMS and to improve recovery (Nedelec et al., 2013; Rey et al., 2018; Versey et al., 2013). Initial knowledge transfer (first step) should highlight possible positive effects on pain reduction. CWI may then be used on an individual basis (second/third step) by those players who think to benefit, as it was shown that CWI was considered an effective treatment among athletes (Crowther et al., 2017). The possibility of long-term harms may be balanced towards small recovery benefits of acute CWI application (Frohlich et al., 2014). Thus, we recommend applying CWI in an individualized, but also context-related manner.

If CWI is considered too elaborate, a feasible approach is to place a barrel of cold-water post-exercise. The temperature of tap water is about 15°C and, thus, within the recommended range. Moreover, if players were previously convinced about positive effects, placebo effects may contribute to positive effects if water temperature cannot be held constantly to 11-15°C. Due to logistical circumstances, CWI might be applied after home rather than away games (Meyer et al., 2014). Table 5 summarizes key facts on CWI interventions.

#### *Foam-Rolling/Massage*

Overall aim: to target muscle damage

Foam-rolling (FR) and massage are popular and often applied by/to players after intense exercise (Freiwald et al., 2016a; Poppendieck et al., 2016). At present, however, the physiological mechanisms by which these interventions promote recovery are largely unexplained (Wiewelhove et al., 2019). Both strategies can offer similar benefits, but FR provides a greater and easier access (D'Amico and Paolone, 2017), and can thus be seen as a comparable low-effort approach.

FR is a type of self-massage where athletes use their body mass to induce pressure on soft tissue using foam rollers or massage sticks. FR aims at reducing DOMS through changes in muscle connective tissue and increasing the blood flow (Cheatham et al., 2015; Wiewelhove et al.,

2019). Surveys demonstrated a wide use of FR (Altarriba-Bartes et al., 2020). One survey revealed that FR was thought to be effective and regularly used by 25% of respondents (Murray et al., 2018). As of yet, there is evidence of small to negligible effects of FR on performance recovery in terms of sprinting (+3.1%,  $g=0.34$ ), strength (+3.9%,  $g=0.21$ ) and jump performance (-0.2%,  $g=0.06$ ) (Wiewelhove et al., 2019); characteristics that all play a significant role in soccer. In addition, a substantial effect of FR on pain relief was shown after heavy resistance exercise (MacDonald et al., 2014; Pearcey et al., 2015) and recently after a standardized soccer training session in professional soccer players (perceived muscle soreness,  $ES=1.02$ ) (Rey et al., 2019), which may lead to subsequent performance benefits.

Therefore, after the initial knowledge transfer (first step), coaches may allow players, who believe in the effects of FR, a time slot post-exercise of around 15min to enhance recovery (second/third step). Athletes may benefit in an upcoming training session if feelings of pain are reduced (MacDonald et al., 2014; Rey et al., 2019). It should be noted, however, that i) results on pain relief and performance are inconsistent (Wiewelhove et al., 2019), ii) excessive rolling with high pressure may lead to harmful effects on nerves, vessels and neuronal tissues (Freiwald et al., 2016a), and iii) to date, no definitive instructions in terms of time, repetitions, and pressure can be given. It remains unclear whether FR substantially affects recovery or whether a placebo effect is responsible for pain relief and, thus, small performance improvements (Freiwald et al., 2016b; Wiewelhove et al., 2019).

A similar situation arises for classical manual massage performed by a physiotherapist. Massage is the mechanical manipulation of body tissues consisting in rhythmical pressure and stroking for the purpose of promoting health and well-being (Cafarelli and Flint, 1992). Elite soccer players consider classical massage by a therapist as an important recovery modality, and most top-class athletes use it on a regular basis (Altarriba-Bartes et al., 2020; Crowther et al., 2017; Venter, 2014). In contrast, only 22% of local players use therapist massage, which indicates limited access to therapists for amateur players (Crowther et al., 2017). In a recent review, the effects of passive massage on performance recovery were shown to

be small ( $g=0.19$ ) (Poppendieck et al., 2016). Improvements in perceived fatigue and muscle soreness were shown in two meta-analyses (Dupuy et al., 2018; Guo et al., 2017). The observed effects could be moderated by mood enhancement and muscle relaxation (Poppendieck et al., 2016). Improvements in mental well-being are considered the main effect of this intervention (Bishop et al., 2008; Poppendieck et al., 2016; Weerapong et al., 2005). However, another meta-analysis found no significant improvement in measures of performance (Davis et al., 2020).

Practitioners must therefore decide whether it is reasonable to employ a physiotherapist and create time slots for players when other interventions could be equally effective (Weerapong et al., 2005). Despite possibly small effects of classical massage on performance recovery, improved mental well-being might justify its application and may explain performance improvements after the intervention (Bishop et al., 2008; Poppendieck et al., 2016; Weerapong et al., 2005). Duration of 5-12min seems sufficient to maximize recovery effects which are not further enhanced by longer periods (Poppendieck et al., 2016). Consequently, players may be treated using this strategy after a game/training session; an important aspect for clubs that have limited resources. If clubs have access to a physiotherapist, it appears reasonable that players can individually decide whether to use it (second/third step). Key facts on massage and FR are provided in Table 6.

#### *Compression garments*

Overall aim: to target muscle damage

The use of compression garments (CGs) using stockings, socks or tights (Beliard et al., 2015) ranges from limited use in team sports and soccer (Crowther et al., 2017; Venter, 2014) to very high popularity in elite soccer (Altarriba-Bartes et al., 2020) considering recent surveys. CGs aim to reduce space for swelling, enhance the blood flow and remove waste products post-exercise. However, the concrete mechanisms are not fully understood (Beliard et al., 2015; Hill et al., 2014). As of yet, the effects of CGs on muscle soreness and performance recovery are mixed, likely due to different types of exercise, wearing duration as well as the applied pressure of CGs (MacRae et al., 2011). In a recent review (Beliard et al., 2015), the included studies used different exercise

modalities, CG types and wearing times that ranged from 15min to 48h.

Positive, but non-significant effects of CGs on biomarkers were shown in semi-professional soccer players after friendly soccer matches (Marques-Jimenez et al., 2018). Two recent meta-analyses (Hill et al., 2014; Marques-Jimenez et al., 2016) demonstrated small to moderate effects on DOMS and muscle strength. Despite these findings, it should be noted that many of the included trials lack sufficient sample size and methodical strength. Thus, the interpretation of the results should be made cautiously. Long-term effects are moreover unclear (MacRae et al., 2011). Beliard et al. (2015) observed that the degree of pressure did not make a difference, while longer wearing duration might be associated with larger effects on recovery.

Thus, there might be a small to moderate effect of CGs on DOMS and performance recovery compared to passive recovery, but further research about optimal pressure and wearing duration is needed. As most studies did not report any negative effects on performance recovery, the use of compression garments may provide an easy-to-use recovery strategy (Calleja-Gonzalez et al., 2018; Nedelec et al., 2013) that could be applied after home and away games during traveling (Rey et al., 2018). After the initial knowledge transfer about physiological benefits that may occur (first step), it seems reasonable to apply CGs post-exercise in an individual fashion (second/third step; Table 7).

**Table 1**

*Rationale behind the three-step system to implement a recovery strategy.*

Step	Approach	Detailed approach and background	Costs
I	Knowledge transfer	<ul style="list-style-type: none"> <li>• Knowledge transfer with important information about positive effects</li> <li>• Aims to increase players' belief and to educate towards self-implementing</li> </ul>	Low
II	Intervention	<ul style="list-style-type: none"> <li>• An intervention to enhance recovery</li> <li>• Optimally based on knowledge transfer</li> </ul>	Medium
III	Individualization	<ul style="list-style-type: none"> <li>• An intervention to enhance recovery with particular focus on individualization</li> <li>• Optimally based on knowledge transfer</li> </ul>	High
!	<ul style="list-style-type: none"> <li>➤ Important considerations</li> <li>➤ Dos and Don'ts</li> </ul>		

*Step 1=knowledge transfer, step 2=intervention, step 3: intervention with focus on individualization. Cost estimation: Low=(nearly) no additional effort, purchases, staff required; medium=significant additional effort and / or additional purchases required; high = additional purchase and expert personnel, e.g., a physiotherapist, required.*

**Table 2**

*Practical approaches for enhancing recovery using nutritional strategies*

Step	Approach	Detailed approach and background	Costs
I	Knowledge transfer	<ul style="list-style-type: none"> <li>• Increase players' belief</li> <li>• Educate towards a CH-rich diet</li> <li>• Highlight the relationship between CH and performance</li> <li>• Provide information about quantities for meals</li> </ul>	Low
II	Intervention	<ul style="list-style-type: none"> <li>• Provide snacks post-exercise with high GI to encourage players to rapidly refuel</li> <li>• Alternatively, offer a meal with a high GI</li> </ul>	Medium to high
III	Individualization	<ul style="list-style-type: none"> <li>• Provide CH individually adapted to the body mass</li> <li>• Provide position-specific meals or differentiate between starters and exchange players</li> <li>• Provide meals to meet different cultural preferences</li> <li>• Provide CH according to the subjective intensity of the training unit/game</li> </ul>	Medium to high
!	<ul style="list-style-type: none"> <li>➤ Nutrition is of high importance for soccer players</li> <li>➤ Time of immediate food intake is crucial when the schedule is congested</li> <li>➤ Refueling can be done with either fluids or solid meals</li> </ul>		

**Table 3***Practical approaches for enhancing recovery using rehydration strategies*

Step	Approach	Detailed approach and background	Costs
I	Knowledge transfer	<ul style="list-style-type: none"> <li>• Increase players' belief</li> <li>• Highlight the importance of rehydration</li> <li>• Provide information about quantity and quality of adequate rehydration</li> </ul>	Low
II	Intervention	<ul style="list-style-type: none"> <li>• Promote rehydration during/after exercise by providing fluids</li> <li>• Combine rehydration with refueling (add CH of 5 to 8 g CH per 100 ml and sodium)</li> <li>• Provide beverages such as spritzer with added sodium or sport beverages</li> </ul>	Medium
III	Individualization	<ul style="list-style-type: none"> <li>• Determine individual fluid requirements</li> <li>• Determine the amount of the required fluid amount by a weighing test (pre-/post-exercise)</li> <li>• Replace losses by 1.0 to 1.5 L fluid per kg weight loss</li> <li>• Identify "salt-sweaters"</li> </ul>	Medium
!	<ul style="list-style-type: none"> <li>➢ Rehydration can be effectively combined with refueling</li> <li>➢ Be aware of hypohydration</li> <li>➢ The need to quickly rehydrate may depend on the time of the upcoming training session/game</li> </ul>		

**Table 4***Practical approaches for enhancing recovery using sleep management strategies*

Step	Approach	Detailed approach and background	Costs
I	Knowledge transfer	<ul style="list-style-type: none"> <li>• Increase players' belief</li> <li>• Educate towards self-implementing</li> <li>• Emphasize the overall importance of sleep</li> <li>• Highlight the sleep demand of 7 to 9 hours including an increased sleep demand post-exercise</li> </ul>	Low
II	Knowledge transfer/ Intervention	<ul style="list-style-type: none"> <li>• Provide ideas to improve sleep quality using sleep hygiene strategies, i.e., bedroom design, avoidance of electronic devices before falling asleep</li> <li>• (Consider consulting an expert)</li> </ul>	Medium (to high)
III	Knowledge transfer/ Individualization	<ul style="list-style-type: none"> <li>• Identify if players or parts of your team have sleep issues; identify poor practice of sleep management</li> <li>• Give individualized recommendations in terms of napping (in the event of insufficient sleep length/quality at night), or sleep hygiene when desired and necessary</li> <li>• (Consider consulting an expert)</li> </ul>	Medium (to high)
!	<ul style="list-style-type: none"> <li>➢ Important recovery strategy</li> <li>➢ Figure out if players or your team have sleep issues</li> <li>➢ Sleep quality should be improved if sleep length is insufficient</li> </ul>		

**Table 5***Practical approaches for enhancing recovery using CWI strategies*

Step	Approach	Detailed approach and background	Costs
I	Knowledge transfer	<ul style="list-style-type: none"> <li>• Increase players' belief</li> <li>• Emphasize positive effects of CWI on DOMS and performance recovery</li> </ul>	Low
II/III	Intervention /Individualization	<ul style="list-style-type: none"> <li>• Temperature: 11-15° C</li> <li>• Duration: 11-15 min per player</li> <li>• Whole-body &gt; extremity immersion</li> <li>• Individualize to those players who think to benefit</li> </ul>	Medium
!	<ul style="list-style-type: none"> <li>➢ Acute positive effects of CWI on recovery may occur</li> <li>➢ Consider negative side effects of chronic application on strength variables</li> <li>➢ Consider logistical aspects</li> </ul>		

**Table 6***Practical approaches for enhancing recovery using FR/massage strategies*

Step	Approach	Detailed approach and background	Costs
I	Knowledge transfer	<ul style="list-style-type: none"> <li>• Increase players' belief</li> <li>• Emphasize positive effects of FR and/or massage on DOMS, performance recovery and well-being</li> </ul>	Low
II	Intervention	<ul style="list-style-type: none"> <li>• Provide foam-rollers / massage sticks</li> <li>• Apply moderate pressure during self-massage</li> <li>• Be aware of excessive rolling (consider side effects)</li> <li>• No detailed instructions possible</li> </ul>	Medium
III	Individualization	<ul style="list-style-type: none"> <li>• Individualized massage by a physiotherapist</li> <li>• Duration: 5 to 12 min per player</li> <li>• Consider mental well-being as a major effect</li> <li>• Massage for players who think they can benefit</li> </ul>	High
!	➤	<ul style="list-style-type: none"> <li>➤ Positive effects of FR or massage on recovery may occur</li> <li>➤ No detailed instructions (time, pressure) of FR exist</li> <li>➤ Consider side effects of excessive FR</li> </ul>	

**Table 7***Practical approaches for enhancing recovery using compression garments*

Step	Approach	Detailed approach and background	Costs
I	Knowledge transfer	<ul style="list-style-type: none"> <li>• Increase players' belief</li> <li>• Emphasize positive effects that may occur such as reduced soreness or effects on performance recovery</li> </ul>	Low
II/III	Intervention/ Individualization	<ul style="list-style-type: none"> <li>• Individualized possibility of CG post-exercise</li> <li>• Longer wearing time might be beneficial compared to shorter wearing duration</li> <li>• No detailed instructions possible</li> </ul>	Medium
!	➤	<ul style="list-style-type: none"> <li>➤ Positive effects of CG on recovery may occur</li> <li>➤ No specific recommendations possible</li> <li>➤ If players believe in it, consider using it</li> </ul>	

***Strategies with weak evidence for enhancing recovery – individualized only?***

The evidence for the following interventions to enhance recovery is weak or based only on usual practice. From here on, we do not provide tables with recommendations, as there is hardly any evidence for such recommendations. Regarding knowledge transfer, practitioners should not convince athletes about the positive effects if these conclusions cannot be derived from studies. It seems appropriate to create sensitivity and leave room for individuality if one of the following methods is preferred by the team or certain athletes; for instance, active cool-down as this represents a usual practice in team

sports. Therefore, being transparent about the true effects of interventions seems reasonable, but also to emphasize that some players could benefit.

***Mental/Psychological recovery strategies***

Overall aim: to target mental fatigue/psychological well-being

Recovery is affected by psychological determinants. Mental fatigue was shown to impair performance in soccer-related technique and endurance drills (Smith et al., 2016, 2018b). This type of fatigue may be compensated by the application of mental recovery strategies such as self-regulation and relaxation (Kellmann et al., 2018a). In a survey among soccer players, socializing with friends or the discussion with

coaches, but also progressive muscle relaxation (i.e., an intervention to keep the “inner balance, to accelerate recovery and to self-regulate” (Kellmann et al., 2018b)) were cited as meaningful interventions by athletes (Venter, 2014) and practitioners (Altarriba-Bartes et al., 2020). Further methods such as reviewing games, meditation, visualization of positive experiences, praying, music, breathing exercises, and mood-lightening activities may be considered as psychological recovery from intense exercise (Eliakim et al., 2013; Kellmann et al., 2018b).

Despite the perceived importance of psychological recovery, there is a lack of research in this area. In a recent review, Pelka et al. (2016) observed potentially positive effects of biofeedback and hypnosis interventions, but not of progressive muscle relaxation on performance. However, studies lack sufficient methodical quality and conducting a meta-analysis was not possible in this review. Issues of research in this field are: i) external validity (can the results be transferred from one setting to another?), and ii) ecological validity (can the results be transferred from laboratory settings to the real world?) (Pelka et al., 2016). Thus, the scientific evidence is inconclusive, and concrete mechanisms of these recovery methods remain unknown. Moreover, the need for relaxation techniques seems highly individual. Future studies should clarify which of the eligible strategies are best suited for enhancing recovery in soccer (Pelka et al., 2016; Smith et al., 2018b). To overcome this lack of knowledge, authors claim to perform more research (Kudlackova et al., 2013; Pelka et al., 2016) as studies have revealed promising results. For instance, relaxation (systematic breathing) between high-intensity exercise bouts was shown to increase sprint performance, which is an important characteristic in intermittent exercise, such as soccer (Pelka et al., 2017).

Due to the absence of side effects, psychological recovery interventions may constitute a good field to test different methods and to obtain feedback on players' acceptance on a regular basis (Kellmann et al., 2018b). Coach-player dialogue helps address habits, preferences and needs of players (Pelka et al., 2016). It may be of importance to strengthen rituals and leave room for mental recovery after games/training. Simple interventions such as creating comfortable

situations or sitting together and review the game might be appropriate to enhance social support, which is considered effective to decrease stress and help players deal with disappointments (Venter, 2014). Experts in this field, such as sport psychologists, may educate coaches on how to teach different psychological recovery strategies (Venter, 2014).

#### *Active recovery*

Overall aim: to target muscle soreness

Team sport athletes evaluate active recovery or an active cool-down (i.e., low-intensity exercise) as the most or one of the most meaningful post-exercise interventions (Crowther et al., 2017; Murray et al., 2018; Venter, 2014). The rationale is to reduce muscle soreness and be able to better compete in forthcoming sessions (Crowther et al., 2017). However, neither performance recovery nor injury prevention has conclusively been demonstrated (Van Hooren and Peake, 2018). Lactate removal after exercise is positively affected, but the physiological relevance of this mechanism is doubtful (Barnett, 2006; Van Hooren and Peake, 2018). Moreover, detrimental effects on recovery may arise when active recovery of long duration is performed, leading to glycogen depletion in type 1 muscle fibers that are addressed at low intensities (Fairchild et al., 2003). In female players, 1 h of active recovery after a game had no significant effect on either performance recovery or biochemical marker concentrations (Andersson et al., 2008). On the other hand, positive effects on DOMS (SMD=-0.94), but not on perceived fatigue, were found in a meta-analysis (Dupuy et al., 2018).

Consequently, the scientific evidence and physiological benefits of active cool-downs are questionable, but players' belief appears to be high. Coaches may consider applying active recovery strategies if it represents a team's preference or otherwise, in an individual fashion, as some athletes may individually benefit from an active cool-down. If applied, knowledge transfer could emphasize that some players may benefit. If a team intervention is carried out, it should be of low intensity and not exceed 30 min in order not to interfere with glycogen resynthesis and not to induce additional muscle damage (Van Hooren and Peake, 2018). An individualized intervention could address i) the individual decision to apply,

and ii) the nature of the application (e.g., cycling, jogging). A treatment combination of active recovery combined with rehydration/refueling could be appropriate to enhance recovery. Another combination was used after a soccer match applying active recovery and CWI, which enhanced perceived recovery, but not subsequent performance (Kinugasa and Kilding, 2009).

#### *Stretching*

Overall aim: to target muscle soreness

Stretching is applied after strenuous exercise to reduce muscle soreness and improve performance recovery (Herbert and Gabriel, 2002). It is often used by team sport athletes and considered effective for reducing muscle soreness and allowing to compete better in the next session (Crowther et al., 2017). According to a recent survey, around 60% of athletic coaches prescribe static stretching post-exercise (Popp et al., 2017). However, neither muscle soreness nor perceived fatigue is relevantly affected by stretching (Dupuy et al., 2018; Herbert et al., 2011). In a recent meta-analysis (Afonso et al., 2021), stretching was shown to have no significant effects on strength recovery ( $ES=-0.08$ ) and 24h, 48h and 72h post-exercise DOMS ( $ES=-0.09$  to  $-0.24$ ) compared to passive recovery. However, the included trials had a high risk of bias. In addition, stretching seems to have no beneficial effect on injury risk (Barnett, 2006). Consequently, practitioners must decide whether stretching should be part of the team's recovery program as it may often be considered a ritual (Sands et al., 2013). In this respect, it seems reasonable to let players decide for themselves whether they want to perform stretching.

### **Which recovery strategy should be implemented?**

Practitioners are faced with the issue of which recovery strategy to apply. The optimal intervention to enhance recovery combines good scientific evidence that matches teams/players preference and practitioners' expertise. Resources (monetary costs, personnel staff) and time that is necessary to implement should be considered because these factors will determine its feasibility (Kellmann, 2010; Simjanovic et al., 2009; Venter, 2014). Moderators such as the lifestyle, age and the preference towards a particular strategy can cause coaches to implement modalities that are

not strongly evidence-based, if side effects can be ruled out (Meyer et al., 2014). However, when choosing between options, emphasis should be placed on best-evidence strategies, i.e., nutrition and rehydration. The definitive evidence of massage, FR, CG, CWI, and psychological recovery for improving recovery is emerging, but still lacking (Carling et al., 2015).

Another key aspect is to assess how great the demand for regenerative methods truly is, which may depend on i) the playing level, ii) training status, and iii) factors such as schedule congestion, weekly training loads and training content (Calleja-Gonzalez et al., 2018; Nedelec et al., 2013). For instance, if training intensity is low to moderate, immediate CH refueling is not necessarily required. On the other hand, it is of great importance after training sessions at high intensity or after matches during a congested schedule.

Moreover, fatigue in soccer is multifactorial, and recovery strategies target different types of fatigue-related factors (glycogen repletion, rehydration, muscle damage, mental fatigue) to re-establish performance (Calleja-Gonzalez et al., 2018; Kellmann, 2010). Every training load leads to a training-specific and individual outcome (i.e., an external load leads to an individual internal load (Halsen, 2014)). Players thus differ in their need for recovery, i.e., recovery time and modality as well as in their personal preference (Eder et al., 2016; Kellmann et al., 2018a; Nedelec et al., 2013). Practitioners should consider a range of inter- and intraindividual recovery responses, including responders and non-responders to certain interventions (Calleja-Gonzalez et al., 2018). Ideally, interventions are thus individualized. To determine the individual need for recovery, performance testing, non-invasive and invasive physiological tools (such as heart rate or biomarkers) and questionnaires such as POMS or REST-Q (Heidari et al., 2017; Herring et al., 2019) are typically used as surrogate variables (Kellmann et al., 2018a). If coaches have limited resources and to improve athletes adherence, simple questionnaires such as the RPE (Impellizzeri et al., 2004) or the "Total quality recovery scale" (Kentta and Hassmen, 1998), which is similar to the 6-20 Borg-scale, are practical at all levels (Brink and Lemmink, 2017) and can help estimate the individual need for

recovery. Stress opposed and the need to recover may also be assessed via coach-athlete dialogue (Heidari et al., 2017).

If a strict individualization is considered too elaborate, the dichotomization into groups seems to be a simplified, but practical approach that still takes individuality into account (Venter and Grobbelaar, 2017). Examples include a position-adapted approach reflecting different activity/intensity profiles (Nedelec et al., 2013), or the distinction between starters and exchange players. It also seems reasonable to account for personal preferences and give players the option of choosing a preferred recovery approach after matches/training if the practitioner considers them to be of equal value, such as FR or stretching. Due to the organizational and financial expenditure, some elaborate strategies such as CWI might be implemented, especially when the schedule is congested (Rey et al., 2018).

To summarize, the suitable approach for practitioners depends on several factors, but certain approaches are considered to be both effective and easy to implement and can therefore be recommended.

- Knowledge transfer and interventions on nutrition and rehydration to target glycogen depletion and dehydration
- Knowledge transfer regarding sleep management to target all areas of fatigue-related aspects
- If applicable, individualized massage or FR, if players have a personal preference towards one of these interventions to target muscle damage
- If the schedule is condensed (i.e., additional games during a week), CWI as an additional tool for enhancing recovery
- If applicable, ease-to-use interventions (such as psychological recovery to target mental fatigue), especially if it reflects a team's preference

To save time and resources, strategies, such as nutrition and rehydration, are often combined (Nedelec et al., 2013). However, there is little evidence that the effects of combining various modalities simply add up. In this regard, "plausible physiological thinking is the best advice that can be given at the moment" (Meyer et al., 2014) when combining strategies. Finally, when implementing a recovery strategy to the

team, it seems reasonable to include a feedback loop (Kellmann et al., 2018b) from players to coaches. Here, the aim is to roughly evaluate the acceptance as well as the efficiency of the intervention to maintain, modify or change a strategy. Further ideas summarize the current knowledge and help coaches before implementing a recovery modality.

- Is there a need for enhancing recovery? Address this issue via coach-athlete/team dialogue and by analyzing factors such as the schedule, season period, fitness level and training loads.
- Which type of fatigue-related aspects (such as glycogen depletion) would I like to address (Calleja-Gonzalez et al., 2018)?
- Is the strategy simple and effective (Calleja-Gonzalez et al., 2018)?
- Analysis of the available resources – are there any tools (such as foam-rollers) already available in the club?
- Is the strategy feasible in my environment (consider personal and monetary costs)?
- Estimate the players' acceptance – recovery is individual and may be moderated by players/team's belief and their compliance towards particular methods (Venter and Grobbelaar, 2017).
- Is there already an evidence-based and well-accepted team's preference? Use it and support it with scientific information. Coach-athlete dialogue is important (Venter and Grobbelaar, 2017).
- Allow time for implementation and explanation of the intervention (Simjanovic et al., 2009).
- Do not confront or overwhelm players with a method (Calleja-Gonzalez et al., 2018).
- Is the method suitable for individualization (Calleja-Gonzalez et al., 2018)?

## Discussion

This review provides i) an overview of typically used recovery interventions in soccer, ii) an assessment of their evidence for improving recovery, iii) evidence-based and low-effort approaches to foster recovery, ranging from knowledge transfer up to individually tailored interventions, and iv) a decision support on which

strategy to implement. The practical approaches presented here can be selectively included in a training regimen depending on the evidence, playing level, coaches' expertise, teams' preferences, and available resources. Practitioners may focus on simple and effective strategies. The interventions should be carried out based on the type and intensity of training and further factors such as fixture congestion (Calleja-Gonzalez et al., 2018; Nedelec et al., 2013; Venter and Grobbelaar, 2017). Some of the modalities presented here, such as active recovery, may merely be applied if it represents an athlete or team's preference as there is limited evidence that such interventions enhance recovery.

Regarding practical interventions, precise recommendations, such as the amount of CH or fluid, could be provided for rehydration or nutrition in the context of soccer. Considering further recovery strategies such as FR, CWI, or CG, it was not possible to provide such precise recommendations due to a limited amount of well-designed research in this area (for instance, regarding optimal duration, pressure, or temperature). Moreover, evidence was partly acquired from non-soccer specific settings or meta-analysis, which generally aggregate data of different studies. Transferability to soccer may therefore be somewhat difficult, as some studies did not apply soccer-specific demands (Nedelec et al., 2013). Another aspect is to consider negative side effects of a chronic application of certain strategies, such as CWI. Potential recovery enhancements of an application should be balanced against the risk of dampening physiological adaptations. One solution is to use these methods only under certain conditions, such as a congested schedule or warm environmental conditions (Calleja-Gonzalez et al., 2018; Nedelec et al., 2013).

A key element of the approach presented here was to provide an initial knowledge transfer before implementing a practical intervention. This idea to enhance recovery is theoretically based. Several authors have already emphasized the importance of using words to increase players' belief as well as to educate players towards self-implementation. A placebo effect that may occur in a subsequent practical intervention should be considered a desirable outcome and a powerful tool to augment a physiologically based

intervention (Beedie et al., 2018a; Roelands and Hurst, 2020). It should be noted, however, that some athletes may show remarkable placebo responses, whereas others do not respond at all (Beedie and Foad, 2009). The effectiveness of combining knowledge transfer with an intervention (i.e., step 1 combined with steps 2 or 3) was already shown for performance enhancement through nutritional supplements (Beedie and Foad, 2009) while the science to reveal the effects of the approach presented here is emerging, and recent publications already underlined the importance to enhance recovery (Broatch et al., 2014; Wilson et al., 2018). Future studies will clarify the effects of implementing knowledge transfer to enhance the effect of practical recovery interventions. Upcoming studies should also focus on medium and long term effects of knowledge transfer as, for instance, an educational lecture on sleep hygiene has initially led to improved sleep behavior, but did not lead to sustained effects (Caia et al., 2018b).

This review delivers particularly low-effort approaches and is thus intended for all playing levels. It may be argued that recovery strategies are primarily meaningful for elite athletes with a substantial training load. However, both professional and non-professional team sport athletes use recovery modalities on a regular basis (Crowther et al., 2017). Moreover, the relative game intensity of soccer matches is quite similar when comparing non-professional and elite soccer players (Stolen et al., 2005). Injuries due to overreaching are common in amateur soccer settings. Amateur players have been shown to suffer 10 injuries per 1000 hours of play during a regular soccer season (van Beijsterveldt et al., 2014). Moreover, a higher rate of moderate to severe injuries was shown for amateur compared to elite players (van Beijsterveldt et al., 2015). Daily life demands such as working, personal and social stress can cause additional stress on players (Heidari et al., 2017; Meeusen et al., 2013) which may contribute to an increased need for recovery. Thus, the need to rapidly recover is likely to be present in both professional and non-professional settings.

Finally, some limitations regarding our narrative review approach should be mentioned. First, the selection of recovery interventions considered here is based on relevant surveys in

team sports and especially in soccer. It cannot be ruled out that there are other interventions that have not been considered. However, we carefully searched for recent surveys and included all commonly used and feasible interventions. In addition, this review covers a broad range of original studies to support the evidence for all interventions. In this respect, there is the possibility of a selection bias (i.e., the possibility that e.g., positive results are reported preferentially for a certain intervention). To mitigate this risk, recent systematic reviews, meta-analyses and expert consensus were also used to support our recommendations when available for the intervention in question.

### Practical applications

The purpose of this review was to provide evidence-based strategies for practitioners to effectively enhance recovery. The approach using three different steps accounts for different settings (playing level, resources, environmental factors) and may also be used by team sport coaches with a similar intermittent exercise character such as basketball or by sports practitioners in general.

Nutrition and rehydration interventions can be considered, especially from a physiological perspective, as evidence-based interventions to improve recovery, while the evidence for complementary strategies to enhance recovery such as CWI, CG or FR is emerging, but limited and it is partly unclear how these interventions physiologically affect recovery. These complementary strategies could especially be an option when the athletes' preferences are high, or the schedule is congested, and physiological adaptations are a secondary consideration. More well-designed studies to detect short- and long-term effects of novel recovery strategies such as FR or CWI are needed as an excessive application may also lead to a lack of physiological adaptations. While recommendations, such as the precise amount of fluid or CH intake, could be extracted from studies and guidelines, instructions on how to apply FR, CG or CWI to achieve the greatest benefits remain to be determined.

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