BARÇA INNOVATION HUB

MUSCLE INJURY GUIDE:

Prevention of and Return to Play from Muscle Injuries

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Summary

1

General Principles of Muscle Injury Prevention in Football

1.1.1

AN INTRODUCTION TO PREVENTING MUSCLE INJURIES

The objective of football is to win games and there are many factors (i.e. tactical, technical, physical and mental) interacting to achieve this objective. However, one key, contributing factor that the medical and performance team can influence is player availability i.e. through a lower impact of injuries (incidence and severity).
— With Alan McCall and Ricard Pruna

This makes sense, given that one would logically agree that having the best players available to play, enhances the likelihood of winning. A higher player availability means that the coach will have more players available to train and in turn more opportunity and time to work on tactics, technical aspects and team dynamics. There is also strongs cientific evidence to support this notion; less injuries have been associated with increased success in domestic league competition[1, 2] and UEFA Champions / Europa League.[3] In addition to performance and success, injuries also carry with them a significant financial cost. It has been estimated that the financial cost of one player missing one month due to injury equates to an average of ~€500,000.[4] Remember that this is an average, imagine the costif this was a star player. A third important potential consequence of injury is an adverse effect on players' long term physical and mental health.[5]

While in an ideal world, we would be able to prevent all injuries from ever occurring, this is, in reality, impossible and our aim is really to minimise the risk of players suffering an injury. Life is full of risky decisions, from mundane ones to matters of life and death.[6] Risk is something that we must accept exists; even walking down the street has a meaningful (albeit small) risk for our safety.[7] The fact is,that injury is so complex, multifactorial and dynamic[8] that prevention must also be complex, multifactorial and dynamic. We should aim to identify and minimise known risk factors for injury while simultaneously identifying and maximising protective factors. Communicating the risks and the benefits of preventative strategies to key stakeholders (players, coaches, board level administrators etc) is essential if we are to succeed in at least reducing the risk and minimising the occurrence of injuries, and in particular muscle injuries which are one of the most common types of injuries that we are faced with.

The purpose of this opening chapter of the FC Barcelona Muscle Injury Guide: 'General Principles of Muscle Injury Prevention in Football' is to highlight, explain and delve into some of the key general principles to consider when the goal is to prevent muscle injury in footballers. Specifically, we will provide a new injury prevention model specific to team sports, followed by taking you through a journey of this model, providing practical guidelines along the way.

1.1.2

A NEW MODEL FOR INJURY PREVENTION IN TEAM SPORTS: THE TEAM-SPORT INJURY PREVENTION (TIP) CYCLE

Recently there has been growing interest in injury prevention for football and other team sports, including the development of models and frameworks to guide injury prevention efforts[1,2] , and improve understanding of injury aetiology[3,5].

— With James O'Brien, Caroline Finch, Ricard Pruna and Alan McCall

The most widely cited injury prevention model, called the 'sequence of prevention', was introduced by van Mechelen and colleagues in 1992.[2] This model builds on previous public health approaches[6] and consists of four key steps:

1. Establishing the extent of the injury problem
2. Identifying the key risk factors and mechanisms of injury
3. Introducing preventive strategies to mitigate the risk of injury
4. Evaluating the effectiveness of preventive strategies by repeating Step 1.

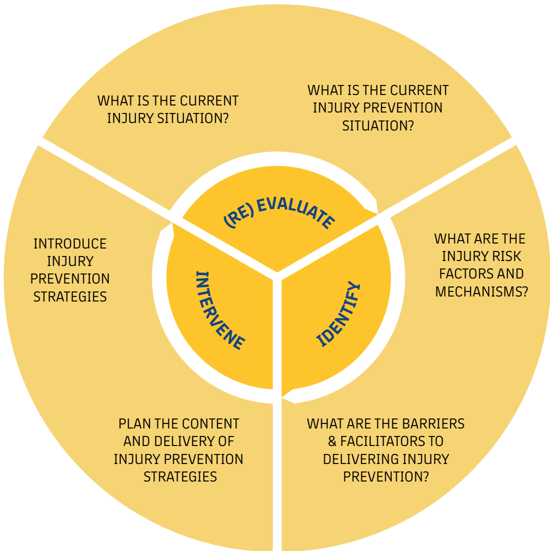

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Figure 1: The Team-sport Injury Prevention (TIP) Cycle

Phase 1: (Re) evaluate
Phase 2: Identify
Phase 3: Intervene

These phases incorporate key aspects of previous models,[1,2] along with important implementation aspects applicable to team sports such as football.

In 2006, Finch[1] introduced an extension of the van Mechelen model called the 'Translating Research into Injury Prevention Practice (TRIPP)' framework, which emphasises the key role of implementation aspects in achieving real-world injury prevention success. Subsequently, several further models have been proposed, each aiming to address potential limitations of previous models. These limitations include linear,[5,7] reductionist[8] or generic approaches,[9] a lack of operational steps[9,10] and the failure to incorporate player workloads.[4]

The applicability of each of these models will be context-dependent, with the majority being geared towards the conduct of injury prevention research,[1,2] and developing etiological theory.[5,8] However, practitioners working at the injury prevention "coalface" will be better served by a model more reflective of risk management approaches.[11,12] Such a model should be simple, directly applicable to the team's specific context and also acknowledge real-world implementation challenges. Furthermore, the model should reflect the cyclical nature of injury prevention, involving ongoing evaluation and adaptation of preventive strategies as opposed to a linear step-by-step process.

In the process of developing this Muscle Injury Guide, it became apparent that no existing model adequately reflects the everyday injury prevention approach of sports medicine and performance staff working in professional football teams. To remedy this, we developed a new model, the Team-sport Injury Prevention (TIP) cycle, specifically aimed at the sports team medicine/performance practitioner. It involves a simple continual cycle with three key phases (figure 1):

PHASE 1: EVALUATE

This phase involves evaluating the current "state-of-play" in your team. Addressing the question, "What is the current injury situation?" involves evaluating the type, incidence and severity/burden of injuries in the team. The second question, "What is the injury prevention situation?" involves analysing which injury prevention strategies are currently being used (or not used) and the reasons why. For example:

1. Is the team implementing evidence-based exercises (e.g. Nordic Hamstring[13] and the Copenhagen Adduction exercise[14])?
2. What is the team's current strategy for managing high-speed running load?
3. What recovery strategies are in place following match-play?
4. Is squad rotation being used?
5. Which other preventive strategies are currently in place, and with what rationale?

A detailed understanding of all team members' perceptions towards injury risk and injury prevention is important to inform subsequent phases in the cycle.

In addition to establishing what is being done, it is essential to determine precisely how these strategies are being carried out. For example, in the case of exercises, key considerations are the number and frequency of sessions, the exercise dose within these sessions (e.g. sets, repetitions, intensity) and also the quality of exercise execution.

PHASE 2: IDENTIFY

The next phase in the cycle involves exploring the risk factors and mechanisms of the injuries identified during the evaluation. This process will be primarily driven by the team's internal data (e.g. injury, tracking and monitoring data), along with consideration of established risk factors and mechanisms from the published literature. It is important to appreciate the multi-factorial nature of injury epidemiology,[4,8] assess injury risk at an individual player level[9] and consider the degree to which identified risk factors can be modified.

This second phase also involves identifying barriers and facilitators to implementing injury prevention strategies, which will strongly impact on the ultimate success of a preventive strategy. These factors will be context-specific, but recent research has highlighted a number of potential barriers/facilitators to implementing injury prevention exercise programs.[15,16] These relate either to the content and nature of the prevention program itself, or to how it is delivered and supported by players, coaches and team staff members. In large, multi-disciplinary sports medicine/performance teams there is potential for conflict among staff,[17,18] which can jeopardise the success of injury prevention efforts. Identifying these staff-related factors will inform the subsequent intervention phase.

PHASE 3: INTERVENE

The next phase involves planning both the content (what to do) and delivery (how to do it) of injury prevention strategies. This process will be influenced by the team's current situation, the identified injury risk factors and implementation barriers/facilitators, published injury prevention research and the team staff members' previous experiences from working in the field. Implementation research highlights the importance of securing administrative support for preventive strategies[10] and engaging all key partners in the design process.[19] In the professional football setting, this means involving club officials (who decide on club policy), coaches and team staff members (who deliver injury prevention) and key players (the targeted health beneficiaries) from the onset. Through involvement of all key partners in the design phase, context-specific strategies can be developed which have adequate support and account for barriers/facilitators in the team's specific context. The multi-factorial epidemiology of muscle injuries in football implies the need for multiple preventive strategies (e.g. load management, recovery strategies and specific exercise-based interventions).

ONGOING RE-EVALUATION AND MODIFICATION

Injury prevention is a dynamic, cyclical process. Having introduced or modified a preventive measure, ongoing evaluation is required. In the re-evaluation phase, successful implementation can be judged against metrics such as injury and physical performance data, team members' perceptions and the degree of fidelity to the injury prevention strategy (e.g. the number and quality of completed injury prevention exercise sessions). With continual progression through the model's three phases, the team's injury prevention strategy can dynamically evolve, responding to various changes in the team's environment (e.g. new players, new staff members and varying game schedules). While evaluation of certain metrics will occur on a daily basis in professional teams (e.g. wellness scores, workload data), it is recommended that teams also undertake more formal injury prevention evaluation, involving all key individuals, at least two or three times per season.

In the following chapters of this opening section on preventing muscle injuries we will take you through each of the 3 key phases in more detail.

1.2.1

EVALUATING THE MUSCLE INJURY SITUATION (EPIDEMIOLOGY)

Muscle injuries are one of the biggest medical problems in modern football, regardless of the playing level.[1,2] Specifically, muscle injuries represent almost one third of time-loss injuries and account for more than one-quarter of the overall injury burden as it was shown in the largest available study involving more than 9,000 injuries in men's professional football players in Europe.[2] Numbers from this investigation also reveal that on average, an individual player will sustain a muscle injury every other season.[2]

— With Markus Waldén, Tim Meyer, Matilda Lundblad, Martin Hägglund

MUSCLE INJURY LOCATIONS AND RATES

Most of the muscle injuries (92%) are located within the four big muscle groups of the lower limbs (hamstrings, quadriceps, adductors and calves).[2] A men's professional football team, typically consisting of a squad of around 25 players eligible for first team match play, can expect about 16 muscle injuries leading to time-loss each season (table 1).

MUSCLE GROUP	N. OF INJURIES
Hamstring	6
Quadriceps	3
Adductors	3
Calf	1-2
Other Locations	2-3

^
Table 1 Average number of muscle injuries in a men's professional team per season (adapted from Ekstrand et al.[2])

Muscle injuries also occur at a high rate among, for example, female elite players and male youth academy players.[1,3] The muscle injury spectrum in those cohorts is essentially similar to high-level male players, whilst quadriceps injuries may be more frequent in early adolescence than in adulthood.[1]

HAMSTRING MUSCLE INJURIES

Hamstring injury is the single most common time-loss injury type representing 12% of all injuries in men's professional football.[2] In that study, 37% of all muscle injuries were in the hamstrings (figure 1). The injury rate during match play is almost nine times higher than during training (table 2). This means that a typical 25-player squad in men's professional football can expect about six hamstring injuries each season. Studies incorporating imaging modalities have shown that a clear majority of these injuries involve the long head of the biceps femoris, i.e. the typical 'sprinting injury'.[4,5]

Other studies on high-level male players have reported similar findings as those outlined above.[6,7] However, two studies on US collegiate players found a lower rate of hamstring injuries in female players,[8,9] whereas one study on Swedish elite players observed no sex-related difference in the rate of hamstring injuries[3]

MUSCLE GROUP	INJURY INCIDENCE	MATCH INJURY INCIDENCE
Hamstring	0.4 per 1000 hours	3.7 per 1000 hours
Quadriceps	0.3 per 1000 hours	1.2 per 1000 hours
Adductors	0.3 per 1000 hours	2.0 per 1000 hours
Calf	0.2 per 1000 hours	1.0 per 1000 hours

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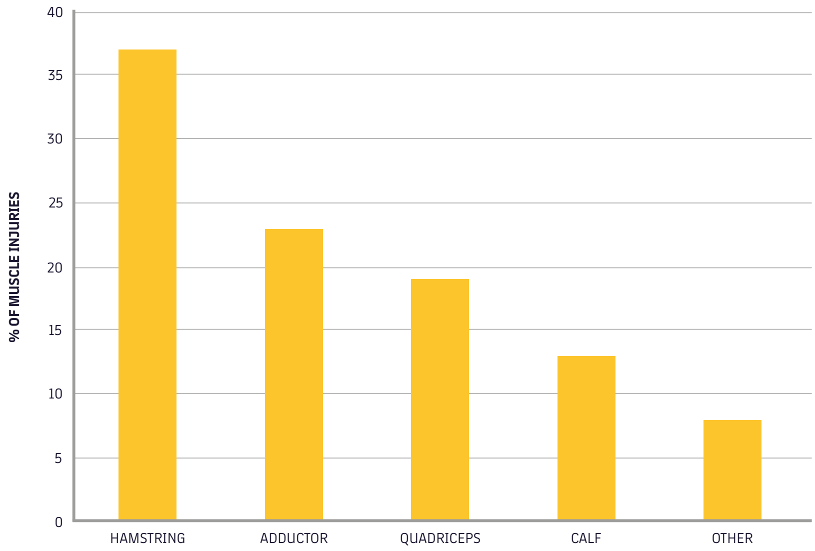
Table 2
Muscle injury rate in men's professional football players (adapted from Ekstrand et al.[2])



QUADRICEPS MUSCLE INJURIES

Quadriceps injury represent 5% of all time-loss injuries and 19% of all muscle injuries in men's professional football (figure 1), which means that a 25-player squad can expect about three quadriceps injuries each season. Similar to the findings for hamstring injuries, the injury rate during match play is higher, approximately four times, than during training (table 2). Studies involving imaging modalities have shown that rectus femoris is the most common injury location in the quadriceps.[2 10]

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Figure 1 Muscle injury location in men's professional football players (adapted from Ekstrand et al.[2])

ADDUCTOR-RELATED MUSCLE INJURIES

Each season a typical 25-player squad in men's professional football can expect four to five muscle injuries to the hip and groin.[2] The most relevant muscle groups from an injury perspective are the adductors and the hip flexors, whereas injuries in other muscles such as the abdominal, sartorius and tensor fascia latae muscles are less frequent,or even rare.[11-12] Adductor-related injuries are the second most common muscle injury among men's professional players representing 23% of all muscle injuries (figure 1) and 7% of all time-loss injuries.[2] A typical 25-player squad in men's professional football can therefore expect about three adductor-related muscle injuries each season (table 1). The injury rate during match play is more than six times higher than during training (table 2). Studies involving imaging modalities have documented that most of the adductor-related injuries involve the adductor longus.[12 13] Although less detailed, publications on male sub-elite or amateur players have reported similar findings on the location and rate of muscle injuries to the hip and groin.[14 15]

Finally, substantially less is known about hip and groin muscle injuries in youths and in female players, but a recent review on 34 epidemiological studies on football players concluded that hip and groin injury in general was twice as common in males as in females.[16]

CALF MUSCLE INJURIES

There is a lack of studies on lower leg muscle injuries in football, especially in females and in males from non-professional settings. However, one or two of all muscle injuries incurred by a typical 25-player squad in men's professional football will be located to the calf (table 1). In this sample, calf muscle injuries represented 13% of all muscle injuries (figure 1),and 4% of all time-loss injuries.[2] The calf muscle injury rate during match play is almost six times higher than during training (table 2). The classical injury involves the medial gastrocnemius, but less is known about soleus injuries even though these injuries probably are more frequent than once thought.[17]

MUSCLE INJURY BURDEN AND SEVERITY

Injury severity is commonly based on the number of days that the player is unable to train and compete due to injury. The average lay-off time due to a muscle injury is approximately two weeks with little variation between muscle groups.[2] About 10-15% of all injuries in the big four muscle groups are severe with a lay-off time longer than four weeks (table 3). There is a tendency that thigh and calf injuries are more severe than hip and groin injuries.

Higher grade hamstring injuries, as classified on MRI, are associated with longer lay-off, but there seems to be no differences in average lay-off between the three hamstring muscles (semimembranosus, semitendinosus and biceps femoris).[18]

The term injury burden is increasingly used in sports injury surveillance. It is a combined measure of frequency and severity and is usually expressed as the number of days lost per 1000 hours. Since the percentage of injuries in the severity categories and the average number of lay-off days are similar for the big muscle groups, the same pattern is seen as for the rates, with hamstring injuries having the highest and calf injuries the lowest burden (table 4).

MUSCLE GROUP	1-3 DAYS(%)	4-7 DAYS(%)	8-28 DAYS(%)	>28 DAYS(%)
Hamstring	13	25	51	11
Quadriceps	12	25	48	15
Adductors	18	31	41	10
Calf	14	25	48	13

<
Table 3
Muscle injury severity according to lay-off in men's professional football players (adapted from Ekstrand et al.[2])

MUSCLE GROUP	INJURY BURDEN (days lost per 1000 h)
Hamstring	18.2 per 1000 hours
Quadriceps	10.3 per 1000 hours
Adductors	8.1 per 1000 hours
Calf	6.5 per 1000 hours

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Table 4
Muscle injury burden in men's professional football players (adapted from Ekstrand et al.[19])

MUSCLE INJURY TRENDS

Two recent studies from the UEFA Elite Club Injury Study have delineated muscle injury rates over time in men's professional football.[20 21] In the first report on 1614 hamstring injuries in 36 clubs between 2001 and 2014, there was an average annual increase of 2%,[20] and in the second report on 1812 hip and groin injuries in 47 clubs between 2001 and 2016, there was, in some contrast, an average annual decrease of 3% for adductor-related injuries.[21] Up to now, little is known about the injury trends in other cohorts or for other muscle groups.

1.2.2

EVALUATING THE MUSCLE INJURY SITUATION IN YOUR OWN TEAM

— With Alan McCall, Markus Waldén, Martin Hägglund and Ricard Pruna

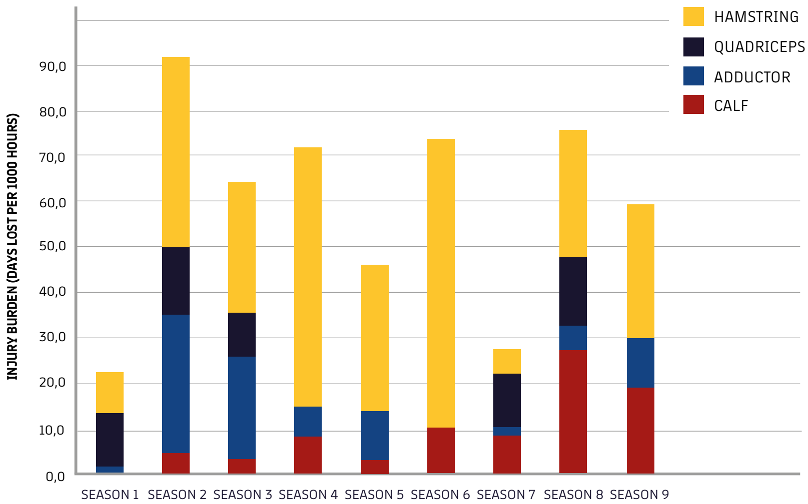

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Figure 1
Muscle injury burden in FC Barcelona during nine seasons: (2008/09 to 2016/17).

EVALUATING YOUR OWN TEAM'S INJURY SITUATION

The previous section has evaluated the muscle injury situation of professional football in general, i.e. studies using data from multiple teams and over various leagues, to highlight specific average characteristics and trends in injury epidemiology. While this information is essential to help guide our knowledge of injury in football and possible preventative strategies, it is essential that you evaluate the injury trends within your own team, as these can differ between and even within seasons. This is a key focus to ensure that your evaluation of the injury problem in your own team is accurate and that the subsequent strategies implemented in the Team-Sport Injury Prevention cycle are relevant.

As an example on why this is important, we illustrate in figure 1 the injury burden at FC Barcelona over 9 consecutive seasons (2008/09 to 2016/17). You will see that in line with the research literature, the hamstring injury burden is generally the main muscle injury we are faced with, however, you will also see that there are differences in the injury burdens of other muscle types. So, with continual (re) evaluation, it is possible to follow how the burden of muscle injuries varies. These insights then allow us to continually adapt our own preventative strategies to match the most current and relevant injury situation to our team.

1.3.1

RISK FACTORS AND MECHANISMS FOR MUSCLE INJURY IN FOOTBALL

— With Markus Waldén, Khatija Bahdur, Matilda Lundblad, Martin Hägglund

WHY AND HOW DO MUSCLE INJURIES OCCUR?

Most studies on potential risk factors for injury in football have addressed all injuries or injuries to the lower limbs in general and not muscle injuries specifically. There are, however, a number of risk factor studies on football players that have targeted hamstring injuries,[1] whereas risk factor data on quadriceps and calf muscle injuries in football are scarce.[2 3] Also, although there are many studies reporting on groin injuries among football players,[4] the majority of these report on hip and groin injuries combined and few studies on risk factors for groin injury in sports have reported data on groin muscles separately.[5 6]

The majority of the studies with risk factor data on muscle injuries in football have been carried out on professional or elite male senior players with considerably less literature on female and youth players. The findings on suggested risk factors are often identical or similar between studies but could occasionally be muscle-specific or even contradictory. Muscle injuries are, however, unlikely to result from a single risk factor, but rather as a consequence of several risk factors interacting at the time of the inciting event.[7]

In addition to traditional risk factor research, there are an emerging number of studies, mainly using systematic video analysis, describing injury mechanisms for typical football injuries such as concussions, lateral ankle sprains and anterior cruciate ligament injuries. Little is, however, known about football-relevant injury mechanisms or playing situations leading up to muscle injuries, and studies in this field are therefore urgently needed.

RISK FACTORS FOR MUSCLE INJURY

Risk factors in football have traditionally been divided into intrinsic (player-related), such as age and sex, and extrinsic (environmental-related) ones.[1] They can, however, also be categorized into non-modifiable (unalterable) and potentially modifiable (alterable) factors which might be more relevant from a prevention perspective (table 1).

INJURED TISSUES	NON-MODIFIABLE	MODIFIABLE
Intrinsic	Sex	Strength
	Age	Flexibility
	Previous injury	Fitness level
	Leg dominance	Psychological factors
Extrinsic	Playing level	Workload and congestion
	Playing position	Rules and regulations
	Playing activity	Equipment
	Time of season	Playing time
	Weather conditions	Playing surface

<
Table 1
Examples of modifiable and non-modifiable risk factors for muscle injury

NON-MODIFIABLE RISK FACTORS

SEX

One study on elite players showed a significantly higher rate of muscle strains in males compared with females, but no sex-related difference for hamstring injuries.[12] Similarly, a study on collegiate players also found a higher rate of muscle strains in males, but only during match play.[13] Moreover, studies on collegiate players report a lower hamstring injury rate in female players compared with their male counterparts.[14-16] In one of these studies, male players also had a lower recurrence rate than their female counterparts.[14] Finally, a recent systematic review identified that male players had a more than doubled aggregated groin injury rate compared with female players, although this comparison was not done for muscle injuries exclusively.[4] However, this is in line with recent data showing that both hip flexor,[17] and adductor strain rates were significantly higher in male players at the collegiate level.[16 17] In summary, the literature on sex as a risk factor for muscle injury in football is somewhat inconclusive, but it appears that male players have similar or higher groin and hamstring muscle injury rates compared with female players.

AGE

Age is a frequently studied risk factor for injury per se but is also important to adjust for when analysing other potential risk factors due to the apparent risk of confounding. The calf muscle injury rate was approximately doubled in male professional players older than the average age (>26 years), but there was no such age effect with adductor, hamstring and quadriceps injuries.[18] Similar findings were found in male elite players where older age (>23 years) was associated with a significantly higher percentage of calf muscle injuries, but again no association with adductor, hamstring and quadriceps injuries.[19] Similarly, increasing age was not associated with higher odds of sustaining hamstring injury in male amateur players,[20] but was so in two studies on male elite players.[21 22] The literature is also here somewhat inconclusive, but it appears that increasing age is associated with similar or higher muscle injury rates in male players.

In addition to the literature on senior players, recent data from FC Barcelona indicate that academy players have an increased frequency of rectus femoris injuries compared with professional players, whereas the reverse is seen for hamstring injuries.[23] No effect of age was, however, seen for groin muscle injuries in that study.

PREVIOUS INJURY

Previous injury is one of the most consistent and scientifically best validated risk factor for muscle injury.[1 5 6] In a large study on male professional players, previous injury was a significant risk factor (1.4 to 3.1 times higher rate) for all the big four muscle groups of the lower extremities (adductors, hamstrings, quadriceps and calf muscles).[18] Interestingly, a previous adductor and calf muscle injury also increased the quadriceps injury rate, and a previous adductor and hamstring injury increased the calf muscle injury rate in that study. Moreover, male elite players with previous groin and hamstring strains had seven and twelve times higher odds of sustaining new groin and hamstring strains, respectively.[21] Similarly, previous hamstring injury was associated with a significantly higher hamstring muscle injury rate in another study on male elite players,[22] and in male amateur players.[20] Although not specified for muscle injuries, male amateur players with previous acute groin injury in the latter cohort had more than doubled odds of sustaining future groin injury.[24]

There are, however, also a few studies showing no association with previous muscle injury. One study on male professional players showed in fact a significantly increased hamstring injury rate with no previous injury,[25] and two studies on female players showed no association between previous injury and future muscle injury; for thigh muscle injuries in youth players,[26] and for hamstring injuries in elite players.[27] In summary, a majority of studies have found previous injury to be a risk factor for future muscle injuries even if there are a few exceptions.

LEG DOMINANCE

Leg dominance in football is usually defined as the preferred kicking leg. Interestingly, both adductor and quadriceps injury rates are higher in the kicking leg,[18] which probably is due to increased exposure of high-risk player actions (shooting, passing, crossing, blocking, etc). Conversely, leg dominance has not been identified as a risk factor for hamstring injuries[18 28] and calf injuries,[18] probably due to other injury mechanisms involved.

PLAYING LEVEL

The influence of playing level on the muscle injury risk is currently under-studied, but it has been shown for hamstring injuries that the injury rate is highest and the recurrence rate is lowest at the highest professional level.[29] The same pattern with higher injury rates and lower recurrence rates at the professional level compared with amateur level is seen for injuries in general,[30] and there are therefore good reasons to assume that this would be similar also for other muscle injuries than hamstring injuries.

PLAYING POSITION

Goalkeepers carry a lower injury risk in general compared with outfield players and this seems to be the case also for adductor, hamstring, quadriceps and calf muscle injuries in male professional football players.[18 28 29] In one of these studies, it was also shown that forwards had the highest hamstring injury rate of all player positions.[29] Finally, goalkeepers also had fewest muscle injuries in a study on male academy players aged 8-16 years where the highest thigh injury rate was seen among midfielders.[31]

PLAYING ACTIVITY

It is well-known that the injury rate in general is several-fold higher in matches than during training regardless of the setting and playing level. Muscle injury rates are also higher, of approximately the same magnitude, during match play; the adductor, hamstring, quadriceps and calf muscle injury rates were, for example, 4-9 times higher during match play in male professional players.[32] A higher match injury rate has also been shown in other studies on male elite/professional players for groin muscle injuries,[21] hamstring muscle injuries,[21 28 33-36] and quadriceps muscle injuries,[34 35] as well as in studies on male and female players at the collegiate level.[14 15]

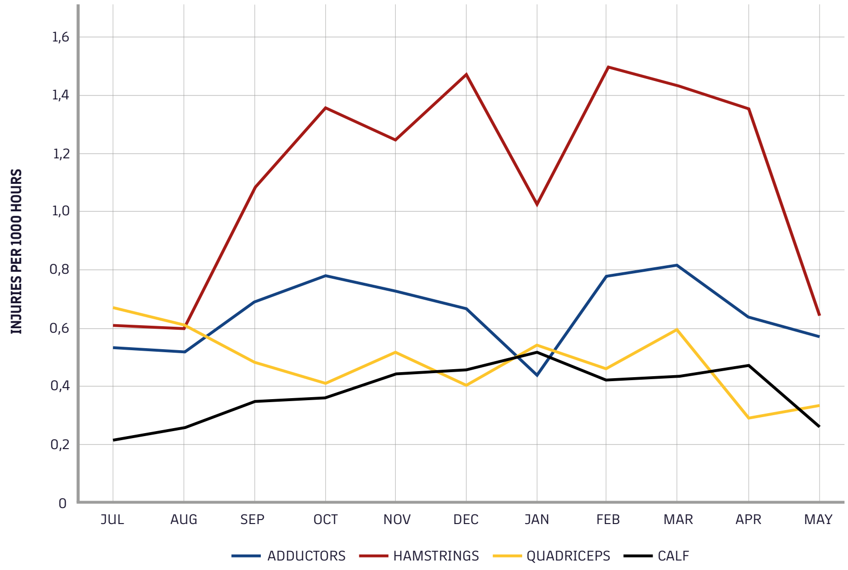

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Figure 1
Seasonal distribution of muscle injury in men's professional football players (adapted from Hägglund et al.[18])

TIME OF SEASON

For male professional players in teams with an autumn spring season, the rates of adductor, hamstrings and calf muscle injuries are significantly higher during the competitive season, whereas the reverse finding for is seen quadriceps muscle injuries with a higher injury rate during the pre-season period (figure 1).[18] Another study on male elite players showed that there was an accumulation of hamstring injuries in the spring season after the winter break.[36] Similarly, most thigh muscle injuries in male youth players occurred in September (after the summer break) and in January (after the winter break).[31]

WEATHER CONDITIONS

Although insufficiently investigated, there are currently no studies indicating that weather conditions, such as air temperature and evaporation, are associated with increased or decreased muscle injury rates in football. However, one study on male professional players showed no regional differences in adductor, hamstring, quadriceps and calf muscle injury rates between teams from northern Europe compared with teams from southern Europe, indicating that weather (and pitch) conditions are not equally important for muscle injuries as perhaps for other injuries such as ligament sprains and tendinopathies.[37]

MODIFIABLE RISK FACTORS

STRENGTH

Muscle weakness and strength imbalances are frequently suggested risk factors in the sports injury literature. A pioneer study carried out on a mixed cohort of athletes, mainly consisting of high-level male football players, with previous hamstring injury and recurrent strains and discomfort showed that muscle strength deficits were common and that a rehabilitation programme with normalisation of the muscle strength reduced the risk of re-injury.[38] Moreover, in a separate study on male professional players, the hamstring muscle injury rate was increased four-fold in players with thigh muscle strength imbalances compared with players without any muscle imbalances.[39] Similarly, male professional players with eccentric hamstring strength asymmetries at pre-season had four-fold higher odds of sustaining hamstring strain during the following season.[25] More recent research has shown that male professional players with hamstring injury were weaker during eccentric contractions than uninjured players, but between-limb imbalances did not infer a higher rate of hamstring injury.[40] Conversely, only one of 24 studied muscle strength variables was associated with increased hamstring muscle injury rate in a recent study on male professional players.[41] Similarly, hamstring strength had no association with future occurrence of hamstring muscle injury in female elite players.[27]

Male amateur players with weak adductor muscles had four-fold increased odds to sustain a future groin injury.[24] In addition, male elite and sub-elite players with ongoing adductor-related pain had lower hip adduction strength compared with asymptomatic control players,[42] a finding that was also seen in male amateur players with current groin pain.[43] In the latter study, previous long-standing groin pain (>6 weeks) during the preceding season was associated with lower hip adduction strength.[43]

There is no published data yet on the potential association between muscle strength deficits and/or imbalances and future calf muscle injury risk.[3]

FLEXIBILITY

Poor flexibility, sometimes also described as muscle tightness or reduced muscle length, has for long been suggested as a risk factor for muscle injury, but one of the first studies in the field showed that there was no difference in range of motion between male amateur players with or without hamstring strains.[44] In one subsequent study on male elite players, there was no difference in muscle tightness between players with and without muscle strains, but players with previous quadriceps strain had significantly shorter rectus femoris than those without strains.[33] In professional football, one study showed that male players with hamstring and quadriceps muscle injuries had lower flexibility in these muscles than uninjured players, whereas no difference was seen for adductor and gastrocnemius muscle injuries.[45] Similarly, male professional players with hip and knee flexor muscle strains had significantly lower range of motion in these muscle groups compared with uninjured players.[46] There is also more indirect evidence of muscle tightness as a risk factor in a study where hamstring-injured male professional players had significantly shorter fascicles of the long head of the biceps femoris than uninjured players.[40] Moreover, two studies on male professional players have found that found that decreased range of motion in the hip was significantly associated with muscle injury; lower hip flexion increased the odds for sustaining hamstring muscle injury,[47] and the total hip rotation (internal plus external) was lower in players who sustained adductor strains compared with uninjured players.[48] Finally, decreased hip abduction was a risk factor for sustaining new groin strain in male elite players.[21] In summary, there is some conflicting evidence on poor flexibility as a risk factor for muscle injuries in football and further well-designed studies appears to be needed.

FITNESS LEVEL

There is emerging evidence that poor intermittent aerobic fitness is associated with an increased odds to sustain lower limb injuries, especially muscle injuries, in male professional players.[49 50] Specifically, players with lower fitness level were unable to tolerate acute:chronic workloads of at least 1.25 and had a five-fold higher odds to sustain a lower limb injury compared with players on a higher fitness level in one of these studies.[49] Future studies in this field and on other fitness variables are, however, needed.

PSYCHOLOGICAL FACTORS

The literature in this field is still scarce compared with studies on physical factors. A recent cross-sectional study of male professional players, however, showed that players who had suffered at least three severe (>28 lay-off days) muscle injuries during their career had 2.6 times higher odds of reporting distress than players without previous severe muscle injuries.[51]

WORKLOAD AND CONGESTION

The influence of workload on sports injury risk has received a lot of interest in recent years with both high absolute and relative loads being associated with increased injury risk as shown in a recent review by the International Olympic Committee.[52] At the time of the publication of that paper, there were only a few studies on workload and injuries in football, but thereafter a number of studies on male professional players have been added; these studies show essentially the same findings by mainly including muscle injuries in their analyses.[49 50 53-55]

The influence of congested match periods on injury rates is another area of interest. It was recently shown that high match load in male professional players was significantly associated with an increased muscle injury rate during match play.[56] In that study, the overall muscle injury rate was significantly higher in league matches with ≤ 4 recovery days compared with ≥ 6 recovery days; significantly higher rates were also identified for hamstring and quadriceps injuries, but not for adductor and calf muscle injuries. This tallies with previous findings where the muscle injury rate in a men's professional team was more than five-fold higher in congested match periods with two matches per week compared with periods one match per week.[57] Looking at individual player match loads, it seems that six days or more are needed between match exposures to reach a baseline level of the muscle injury rate.[58]

RULES AND REGULATIONS

The majority of all muscle injuries (>90% regardless of muscle group) in male professional players occurred in non-contact situations with few match-related injuries being the result of foul play in the view of the referee.[32] Consequently, re-enforcements of the existing rules will probably have negligible impact on the panorama and burden of muscle injuries. However, as discussed further below, muscle injuries might be associated with fatigue and regulations on reducing individual playing time and/or increasing the recovery window between matches might therefore be of value.

EQUIPMENT

Currently, there are no studies indicating that any particular equipment, such as taping or type of footwear, are associated with increased or decreased muscle injury rates in football.

PLAYING TIME

Muscle injuries in male professional players tend to occur less frequently in the beginning of a match (or match halves);[32] there were fewer quadriceps injuries in the first quarter of the first half, fewer groin muscle injuries in the first quarter of the first and second halves, and more calf muscle injuries during the last quarter of the second half, whereas there was no differences between quarters for hamstring injuries. Other studies on male professional players have, however, shown that there could be a fatigue effect for hamstring injuries with more injuries occurring in the final quarter of the first and second halves[28], and in the later parts of training sessions and matches[29]. Finally, thigh muscle injuries in male youth players have been shown to be more frequent in the end of the first half and then persisting throughout the second half[31].

PLAYING SURFACE

Studies comparing artificial turf with natural grass have yielded conflicting findings. The first study comparing play on so-called third-generation artificial turf with natural grass, showed a significantly lower rate of lower extremity strains on artificial turf, but not for groin and hamstrings strains.[59] In a subsequent follow-up, also including female elite players, the same pattern was seen with a significantly lower muscle strain rate on artificial turf in male players, but with no difference between surfaces in female players.[60] In that study, the rates of calf strain and quadriceps strain in male players were significantly lower on artificial turf during training and match play, respectively. Other studies on male professional players showed, however, neither a difference in the overall muscle strain rate,[61-63] nor for sub-analyses of the big muscle groups between third-generation artificial turf and natural grass.[61 62] Finally, in a study on male and female players at the collegiate level, there was no between-surface difference in the rate of lower extremity strains during match play and training for either sex, respectively.[16 64]

INJURY MECHANISMS

There is yet no published study that has used systematic video analysis for describing different injury mechanisms for playing situations leading up to muscle injuries in football. From epidemiological studies, however, it appears that a majority of hamstring injuries occur during sprinting or high-speed running also in football.[28 32 40] Conversely, many quadriceps injuries occur when shooting or kicking the ball and therefore mainly affects the dominant leg.[32] Kicking is also the most frequently reported injury mechanism for adductor longus injuries, which reaches its highest muscle activity and maximal rate of stretch in the swing phase of kicking.[65]

1.3.2

THE COMPLEX, MULTIFACTORIAL AND DYNAMIC NATURE OF MUSCLE INJURY

While risk factor identification is important, athletic injuries do not occur because of any single risk factor. Rather, injuries (muscle injuries included) occur as several risk factors interact at the time of an inciting event during training or competition (Figure 1).[1,2] In other words, athletic injury etiology is complex, dynamic, multifactorial, and context dependent.

— With Natalia Bittencourt, Mario Bizzini, Johann Windt and Alan McCall

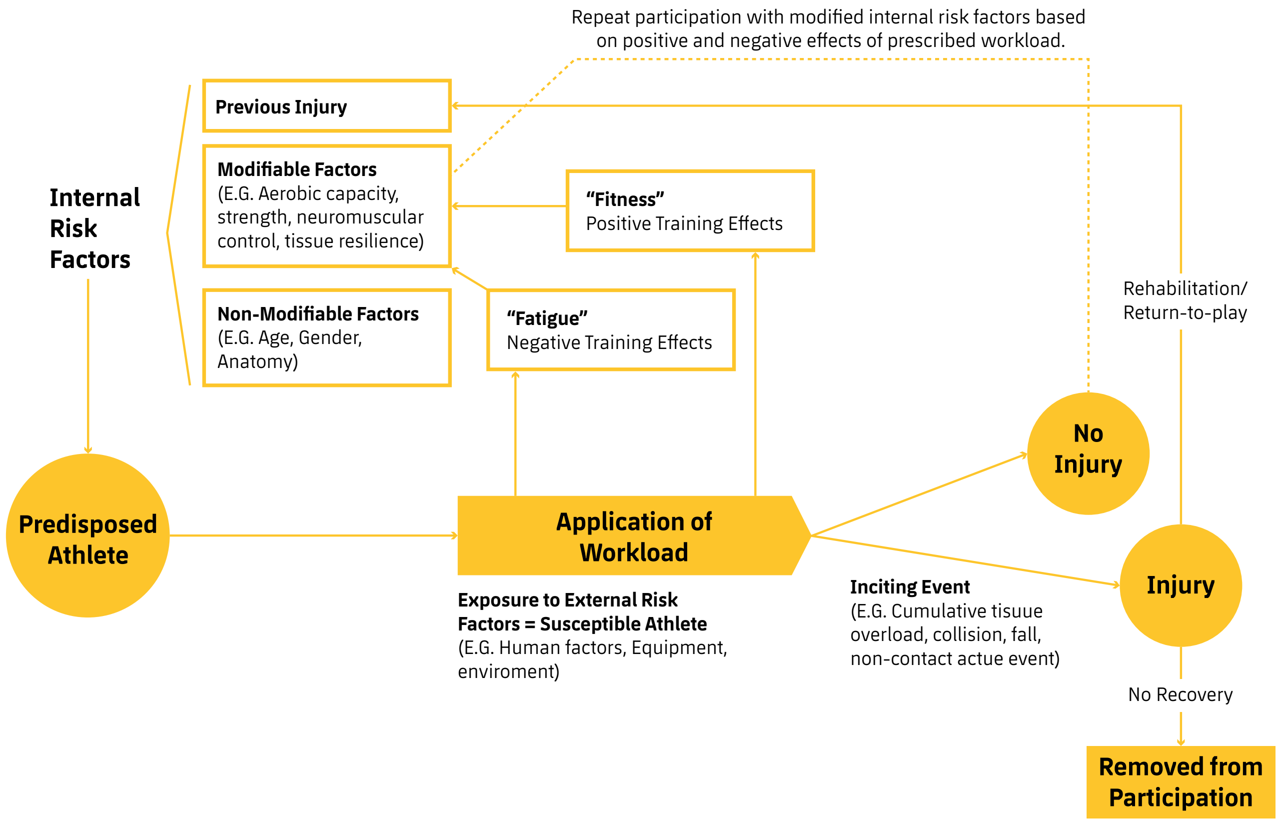

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Figure 1
The workload—injury etiology model.[2] According to the model, every player will have a given internal predisposition to injury based on their collection of internal risk factors. Muscle injuries will occur during training or competition workloads during which they are exposed to external risk factors for injury, and potential inciting events. However, whether or not they experience an injury, the player's predisposition for injury dynamically changes with each training or competition session, as both positive (e.g. improved fitness) and negative (e.g. neuromuscular fatigue) occur.
Redesigned by FC Barcelona

The complex, multifactorial nature of muscle injuries means that a given risk factor – e.g. low eccentric hamstring strength[4] – may only result in injury if accompanied by other risk factors, such as a previous hamstring injury and the presence of fatigue. Even this collection of risk factors may never cause injury if a player isn't exposed to activities (e.g. high-speed running and sprinting), which can trigger the inciting event.

The dynamic nature of etiology means that in the ever-changing football environment, many risk factors constantly change within- and between-days, weeks, months, and seasons. [1,2]

To better understand muscle injury risk in our players, adopting a complex systems approach has been proposed. [3] Namely, this approach will allow us to identify 'risk profiles' associated with injuries, rather than individual risk factors alone.

IDENTIFYING RISK PROFILES

A complex patterns model considers patterns in risk factor relationships that may increase injury likelihood.[3]
In this model, risk factors and potential interactions result in a 'web of determinants' (figure 2). In each sporting context, one may use the model to determine patterns of relationships (interactions) between factors (regularities), what certain interactions produce (emerged patterns), as well as the regularities that may lead to injury (risk profile). [3] Notably, multiple risk profiles may exist for the same outcome (i.e. injury), since individual risk factors within the web of determinants may have varying effects, depending on other factors. For example, the consequences of factor A (i.e. weak eccentric muscle strength) will differ if it interacts with factor B (i.e., congested match schedule), factor C (i.e., previous injury), or both. Ultimately, identifying these regularities (i.e. risk profiles) may improve our understanding of injury etiology and inform future preventative interventions.

To our knowledge, there is currently no web of determinants that exists for muscle injury in football. Until future robust statistical analyses are carried out that identify the relevant factors and risk profiles, we encourage a critical thought process and the creation of potential webs of determinants. Below, we created an initial example of what a web of determinants for muscle injury in football may look like. Whilst not validated, our web is based on a combination of known evidence in the scientific literature and our practical experience, with the purpose of illustrating this concept.

Figure 2
Complex systems approach to muscle injuries in football. Factors associated with injuries form a web of determinants, and certain associations between these factors will be regularities that contribute to an emerged pattern/ outcome (in this case muscle injury). Redesigned by FC Barcelona
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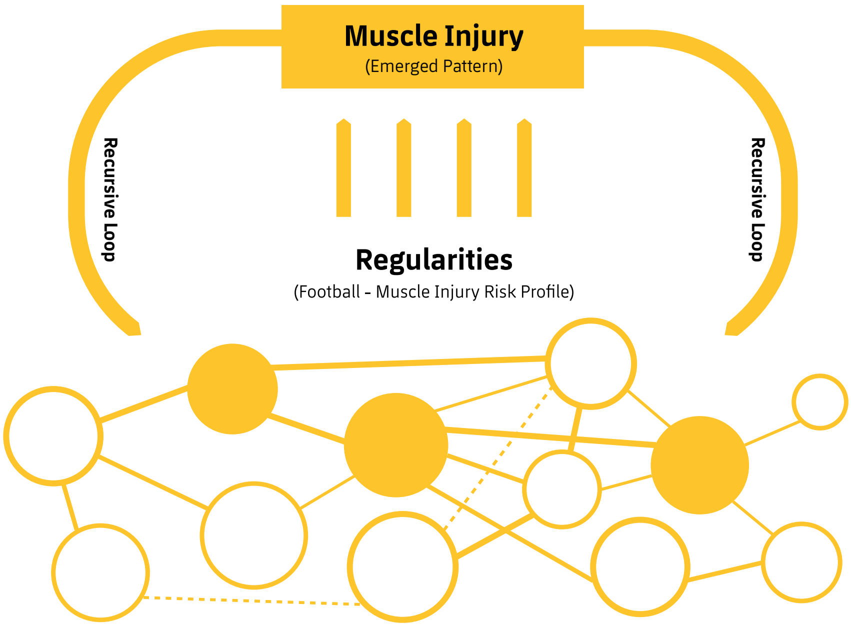

Figure 3
Theoretical web of determinants for muscle injury in football. Redesigned by FC Barcelona
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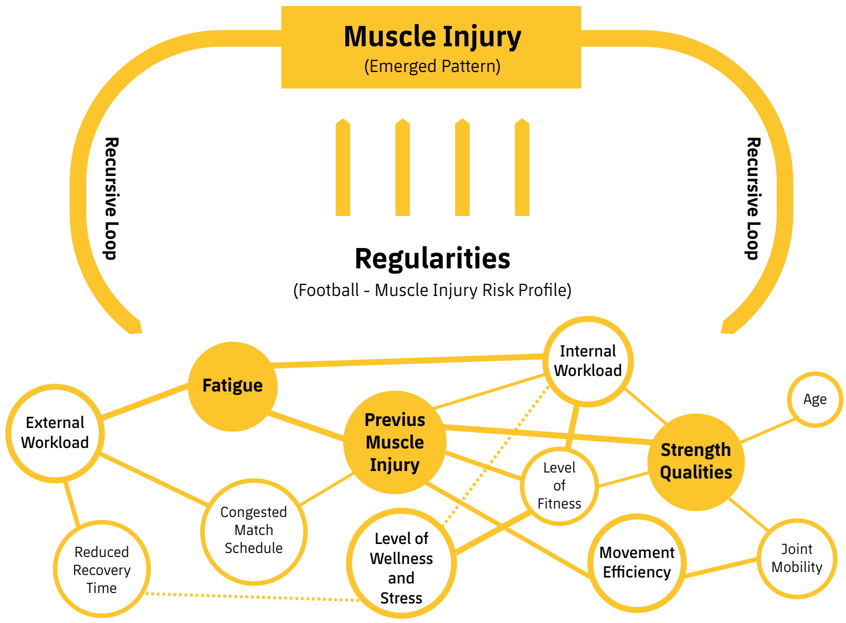

For football players, the main factors within our web of determinants (thicker nodes) are: 1) previous muscle injury; 2) fatigue and 3) strength qualities. The second level of nodes include: external and internal workload, movement efficiency, and psychological aspects. Within this theoretical web of determinants, players who exhibit a profile including a previous muscle injury, high fatigue levels and low strength are considered to be at an increased risk for muscle injury. Further, these three factors may interact, as previous muscle injuries will change the level of fitness, strength qualities, and may alter the fatigue process. FATIGUE is the global result of the relationship between external and internal workload. The player's external workload (work completed) is modulated by factors such as reduced recovery time and congested match schedule, which increase workload density and may add stress to the players, indirectly altering internal workload. Internal workload is influenced by player's internal characteristics, including physical fitness, strength qualities, and stress. PREVIOUS MUSCLE INJURY can change muscle tissue (e.g., scar and angle of peak torque), [5] which may produce muscle weakness and imbalance. Movement efficiency could therefore be altered, with other factors like joint mobility contributing. Finally, several of these previous factors, along with age, have the potential to modify STRENGTH QUALITIES.

1.3.3

MUSCULOSKELETAL SCREENING IN FOOTBALL

It is common practice in professional sport to perform some manner of periodic health evaluation (PHE), commonly referred to as "screening". In elite football, 90% of the teams do some form of screening throughout the season.[1] Professional teams and football governing bodies aim to protect the health of the player through screening and monitoring to identify potential risk of injury, which, if possible, could positively impact performance, economical aspects at the club, and the health of players.[2,3]

— With Nicol van Dyk, Robert McCunn, Phil Coles, Roald Bahr

INTRODUCTION

Organisations such as the International Olympic Committee (IOC) and Fédération Internationale de Football Association (FIFA) have released guidelines on the screening of athletes and players, attempting to set a standard of care that would assist in the early detection of cardiovascular and other potential health (medical) risks.[4] Typically, this consists of (i) a comprehensive cardiovascular examination, (ii) a general medical evaluation (including blood tests) and (iii) musculoskeletal assessment to be performed on all players. Here, we will focus on the musculoskeletal component of screening.

Scientific evidence demonstrating how valuable musculoskeletal testing is, which are the best tests to use, and whether these test results are actually associated with muscle injury is unfortunately, scarce. This section contains important factors to consider when building your own battery of tests where the objective is to screen for some of the potential risk factors such as those identified in section 1.3.1. Importantly, these test results should be interpreted for the individual player, which allows appropriate intervention and decision-making by the medical staff, based on a combination of research evidence and current best practice. Although no emperical evidence exists, there is a growing consensus among practitioners that regular monitoring of risk factors will allow more appropriate and timely interventions.

WHY DO WE SCREEN?

At present, none of the tests used to perform the musculoskeletal screening or monitoring appropriately separate players who are at high risk of injury from the rest of the group.[6] These tests simply do not have the appropriate properties to perform such a function, and we continue to see the injuries that occur across all the players in the team, irrespective of their screening results. For injury prevention in elite football, large group based interventions are likely still key.

However, the interventions that we apply should ideally be monitored for each individual player, as adaptation and reaction to these interventions might differ between players, and individualization of these exercises might be necessary to ensure effectiveness is maximised.

The complex, multifactorial and dynamic nature of muscle injuries is becoming more and more accepted by practitioners,[5] and explained in the previous section. Although screening to predict future injury is not possible,[6] we screen each individual player to detect ongoing musculoskeletal conditions, identify health issues that may require intervention, create a rapport between practitioner and player, and identify how these aspects may impact team performance.

DETECTING CURRENT MUSCULOSKELETAL CONDITIONS

Screening performed for each individual player should focus on early identification of current health problems and assessing the status of 'old' injuries to prevent their recurrence.[7,8] Of course not every player would need an individual follow-up after screening. Value may be found in simply reassuring a player regarding the rehabilitation from a previous injury or management of physical symptoms. However, we might introduce a specific program for selected players, in particular those that have returned from previous injury, to ensure they reach their optimal level of performance after return to play.

ESTABLISH PERFORMANCE BASELINE AND HEALTHY STATE

Another reason to conduct screening is to establish a performance baseline for the player in the absence of injury or illness. For example, if a player sustains a hamstring injury during the season, the strength or functional tests performed during screening can represent a useful reference point for the practitioner to determine responses/success throughout the return to play process, and can assist in decision making during this period. Alternatively, if the club decides to add a specific training/ strengthening programme during the season, a baseline test can assist the performance team to establish whether or not the program has been successful and where to target future injury prevention programs.

BUILDING THE PRACTITIONER-PLAYER RELATIONSHIP

The relationship between the player and the medical team is essential to build trust and create a safe environment where the player will openly and honestly share his/her concerns and physical information. This allows an optimal shared decision making process.[9] It is also an opportunity to provide education regarding certain health policies or injury prevention strategies and to receive both subjective and objective feedback from the players on their current health status.

MAIN COMPONENTS OF SCREENING

Screening is usually performed at the beginning of a season, although additional screening opportunities should be sought, such as a mid year review, or at the end of the season to establish off-season programs. We recommend end-of-season screening, which allows for the identification of ongoing musculoskeletal issues to receive attention before players resume training at the start of the next season.

Although the most comprehensive screening will likely still happen during the pre-season, musculoskeletal screening should sensibly be repeated throughout the season to determine how variables respond to training and competition for each individual player, as well as at a team level. This might assist the medical and performance team to make better informed decisions regarding the health of the players, as well as reducing their injury risk.

Once a battery of tests has been selected, it is important that they are standardized and if repeated, done so in the same way. Time of day, influence of practice sessions or training, and other external factors should be considered whenever possible to ensure that the screening measures used are consistent, and comparison with previous results are meaningful.

Ideally, the entire medical team should be involved in screening. Although the testing might be performed by specific members, it is important to have the team doctor, physiotherapist, and even manager present to emphasize the value and importance of the testing. Furthermore, it makes direct and immediate communication and interpretation of the results possible, allowing greater transfer of the results in a practically meaningful way.

Screening includes both a review and consideration of non-modifiable information (age, previous injury, etc), as well as modifiable potential risk factors (e.g. strength, flexbility, fitness, psychological status, workload, movement quality, and performance tests). Although many options are available, we have summarized some key components and their characteristics in table 1. Workload monitoring will be explained in detail in the upcoming 'Preventative Strategies' section.

	TESTS AVAILABLE	ADVANTAGES	DISADVANTAGES	CONSIDERATIONS
Strength[10-14] **Strength**	Isokinetic dynamometer (eccentric strength, side-to-side imbalances, functional ratios e.g. hamstring:quadriceps) Field devices (Nordbord®)[14] (eccentric strength, side-to-side imbalances) Hand held dynamometer (HHD) (isometric strength) Force platform (isometric strength, concentric power and/or eccentric duration e.g. during countermovement reactive strength e.g. from drop jump and between leg functional imbalances	Moderate accuracy and validity for all these tests Testing can be performed as part of training	Player buy-in, difficult for players competing in 2 matches per week Cost Requires expertise to interpret the data outputs e.g. graphs	When interpreting Nordbord strength results, it may be important to normalise it to body mass Isometric testing might be a safe alternative during congested periods in the season and form part of recovery monitoring
Flexibility[3,16,17] **Active & passive range of motion**	Straight leg raise test Sit and reach test Passive and active knee extension test Bent knee fall out (BKFO) Hip internal/external range of motion Dorsiflexion lunge test Thomas test Standing forward flexion test Knee-to-wall	Moderate accuracy and validity for all these tests Low cost, easy to perform Simple tests to inform daily physiotherapy interventions e.g. manual therapies	Player buy-in, difficult for players competing in 2 matches per week	When is the best time to perform the test? Before or after training Might be useful in return to sport decision making Could form part of recovery monitoring battery Can form part of a simple daily ‚general medical screen' Selection - can't use all of them
Movement quality[18-24] **Determine how well (controlled) movements are performed**[23,24]	Functional Movement Screen (FMS) Functional movement test 9+ Landing Error Scoring System (LESS) Soccer Injury Movement Screen (SIMS) Laboratory based jump-landing assessments	Low to moderate accuracy Holistic view of athleticism and movement patterns Easy to administer (once trained and players familiarised)	Large season to season variability in scores Subjective (excluding laboratory tests) Questionable link to injury risk	If used, consider the same assessors at minimum performing the scoring Careful intepretation of the results (i.e. many of these have shown no association with injury, and none of shown predictive accuracy)

^
Table 1. Some available tests that could be included in the musculoskeletal screening protocol

INTERPRETATION OF THE RESULTS

FOR THE INDIVIDUAL

The test results for each individual player may be compiled to form an overview or holistic impression of the players' current status. Ideally, previous data on a particular player exists and allows comparison to a previous time point, or a moving average of ongoing monitoring of these factors, this may be used to determine whether a player has improved, worsened or stayed the same. Alternatively, the player may be compared with the rest of the team or data on the entire league, if available. This would indicate whether specific action or intervention may be needed on an individual level to improve his/her current status to be on par with the rest of the team (or league).

1. Overview of the players risk profile, and health status.
2. Compare to previous status or test results
3. Determinate specific interventions needed to address any identified musculoskeletal issues or risk factors

FOR THE TEAM

The results from the different screening measurements may allow the medical team to identify trends throughout the season. For instance, if the entire squad displays lower strength compared to the previous season, coupled with an increase in muscle injury, it might indicate effects of a pre-season training camp or inappropriate training methods. Such findings may help the overall management of the squad to protect the players from injury and avoid larger scale injury patterns.

Furthermore, it might assist in the design of group-based prevention programmes that are aimed at the entire squad. Certain key areas may be identified that need priority. Although a prevention programme would still contain all the elements needed to provide holistic prevention, some test data may help to tailor it to the team profile, which may improve the overall effectiveness of the intervention. It is important to present this information in a way that is understandable to the medical, performance and management team.[25]

1. Overview of the team status and health
2. Identify trends that develop during a season. (i.e, lower strength compared to the previous season, coupled with an increase in muscle injury).
3. Design group based prevention programmes that are aimed at the entire squad.
4. Certain key areas may be identified that are given higher priority

TAKE HOME MESSAGE

Although we cannot eliminate risk of injury, the goal of screening is to aid in the protection of our players, minimize risk, and contribute to their overall well-being, ultimately contributing to team success.

1.3.4

BARRIERS AND FACILITATORS TO DELIVERING INJURY PREVENTION STRATEGIES

Published information on barriers and facilitators to delivering injury prevention strategies is scarce,[1] but initial research on injury prevention exercise programs has identified a wide range of factors, relating either to the content and nature of the program itself, or how the program is delivered and supported by players, coaches and team staff members.[2 3]

— With James O'Brien and Caroline Finch

In relation to the program, examples of barriers include lack of individualisation, progression, variation and football specificity, along with the program being too long or too monotonous. Example of barriers relating to players include lack of acceptance/motivation regarding the program, fatigue, absences (e.g. national team, illness) and muscle soreness. In the case of coaches and team staff members, acceptance and support of the prevention program is a key factor. Other factors, relating to the team staff members who design and deliver preventive exercise programs (e.g. fitness coaches and physiotherapists), include lack of staff continuity, teamwork, communication and planning.[2]

Acceptance of and active support for injury prevention strategies are particularly important factors, applicable to several different groups (e.g. players, coaches and administrators). Successfully addressing these factors in order to increase "buy-in" may require tailoring messages to each of these different groups. Table 1 outlines some tips on what you could do to overcome some of the barriers that can limit the effectiveness of injury prevention programs.

TARGET GROUP	KEY MESSAGES
Club officials	Injuries are expensive. The costs to a professional club for a player being injured for one month can reach 500 000 Euros.[4] Teams with fewer injuries are more successful in both their national league and in UEFA competitons.[5]
Coaches and team staff members	Avoiding injury increases player availability for training and matches Having more players available can help in managing the physical demands on all players.[6] Injury prevention exercises can be easily incorporated into team training (e.g. warm-up and cool-down) with minimal time cost. Lower injury rates correlate with team success[5] Large randomised-controlled trials support the effect of injury prevention exercise programs in elite and sub-elite teams.[7-9] Avoiding injury can protect players from both the short- and long-term negative effects of injuries.[10]
Players	Injury prevention is important to keep you on the pitch, extend your career and invest in your long-term health.

<
Table 1
Key messages for promoting injury prevention strategies in professional teams

1.4.1

STRATEGIES TO PREVENT MUSCLE INJURY

When we think of prevention strategies for muscle injuries, we typically think of exercises targeted at strengthening the muscles and related modifiable risk factors that exercise can influence. However, in contemporary professional football, we are moving away from the thought that preventing muscle injury means simply implementing specific exercises but rather looking at it as a more holistic strategy that is multifaceted.
— With Alan McCall and Ricard Pruna

2 COMPETITIONS PER WEEK

3 x season	14 x season	25 x season
EXTRA LONG CYCLE	LONG CYCLE	SHORT CYCLE
MATCH DAY	MATCH DAY	MATCH DAY
MD+1 / MD-4	MD+1 / MD-3	MD+1 / MD-2
MD+2 / MD-3	MD+2 / MD-2	MD -2
MD -2	MD -2	MACH DAY
MD -1	MACH DAY	
MACH DAY		

^
Figure 1.
Typical match schedule of FC Barcelona during an in-season period

We only need to look at the playing schedule of elite level football teams to understand why we need to think bigger than just exercise alone. Elite football teams are regularly required to play in periods with 2 matches per week throughout the season e.g. domestic league, national cups, confederation competitions etc. Figure 1 illustrates the congested match schedule that FC Barcelona are typically exposed to. You will see that the majority (25 matches) are played with only 2 full days recovery, fourteen with 3 full days and only 3 where the recovery between matches is considered 'extra long' i.e. 4 full days. With such a congested match schedule it is difficult to plan any focussed, high-intensity exercise programs that may be able to help prevent muscle injury, at least for the regular playing squad. As such we need to look at other ways to minimise the risk of muscle injury and this calls for other 'preventative strategies'. Even for the non-playing or substitute squad, preventative strategies other than exercise-based should be beneficial to optimise the training process i.e. maximise performance and minimise injury.

During the process of putting the FC Barcelona Muscle Injury Guide together, we realised that there was limited scientific evidence for preventative strategies in the elite football environment. We therefore decided to perform a Delphi Survey of 18 elite teams from the Big 5 Leagues (England, France, Spain, Italy and Germany) to ask performance practitioners what they do and what they consider to be important strategies to prevent muscle injury in their players. The Delphi survey process involves various rounds of questionnaires in which we ultimately come to a consensus among the respondents as to the most effective strategies to prevent muscle injury and how to integrate these into the football program. The following sections on preventative strategies are based on the results of this Delphi process in addition to what we know from the scientific literature and the FC Barcelona practical experience.

The overall results of our Delphi survey of the Big 5 leagues revealed the most effectively perceived preventative strategies to prevent muscle injury (table 1). We will now go through each of these in more detail, providing practical recommendations on implementation in practice.

PREVENTATIVE STRATEGY	EFFECTIVENESS RATING
Overall control of load / management of the training week	+++
Exercise based strategies	+++
Recovery strategies	++
Consideration of previous injury	++
Team communication and ability to work together	++

^
Table 1 Perceived effectiveness of strategies to prevent muscle injury in elite footballers (EBMIP Delphi Survey results)

Key to perceived effectiveness:

+++ Very Effective
++ Effective
+ Somewhat Effective

THE BARÇA WAY

At FC Barcelona, we do not consider injury prevention to be made up of one specific strategy, but rather the simultaneous integration of many strategies, which alone, cannot 'prevent' an injury.

Instead it is most likely, the combination of many strategies including, controlling the training load, maximising recovery, optimising communication in addition to performing a variety of specific exercises etc as the best way to reduce the risk of our players incurring a muscle injury.

1.4.2

CONTROLLING TRAINING LOAD

Athlete monitoring is now common practice in high performance football. Fundamentally, athlete monitoring involves quantifying the players training load and their responses to that training. The main reasons for monitoring players are that it can provide information to refine the training process, increase player performance readiness and reduce risk of injury and illness. Through a systematic approach to data collection and analysis an improved understanding of the complex relationships between training, performance and injury can be obtained.
— With Aaron J Coutts

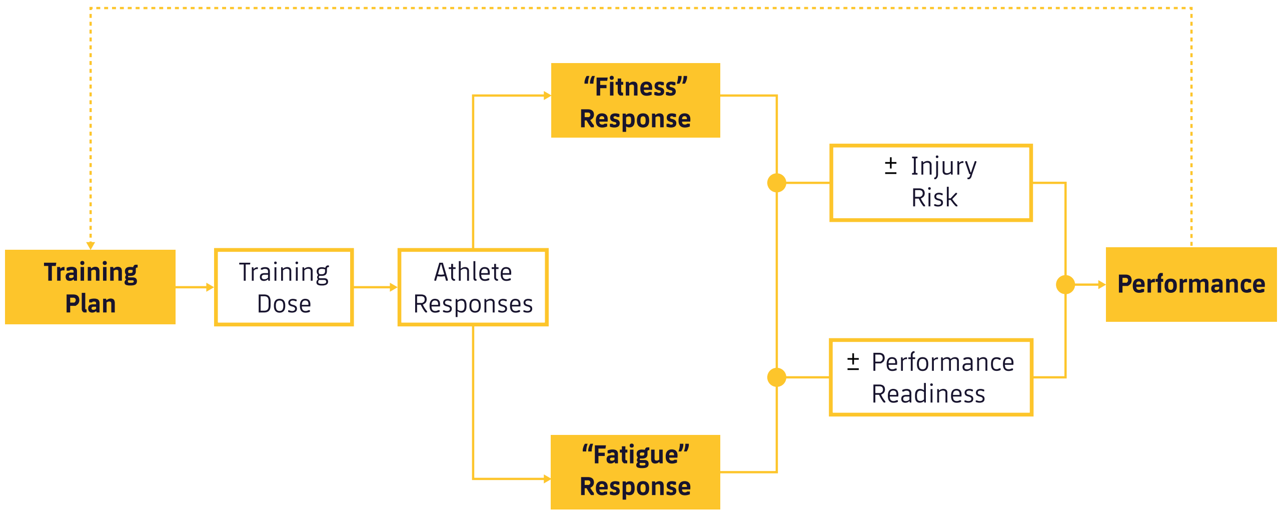

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Figure 1 Conceptual model for athlete monitoring systems (modified from Coutts, Crowcroft, Kempton[1]).

THEORETICAL BASIS OF ATHLETE MONITORING

The main aim of athletic training is to provide a stimulus that is effective in improving the players' capacity to perform. For positive training adaptations to occur, the balance between training dose and recovery (i.e. rest and/or recovery interventions) needs to be obtained. At the simplest level, the performance responses can be explained by the fitness-fatigue model first described by Banister, Calvert, Savage, Bach [2]. The fitness-fatigue model is a simple approach to quantify a dose-response relationship of training load to fitness, fatigue and performance. In its simplest form, the model estimates performance outcomes as a result of the fitness and fatigue responses that result of the training dose applied through training. According to the model, fitness was referred to as the average weekly training dose completed in the previous 4 weeks whilst the fatigue was determined as the training load completed during the most recent week.

TRAINING LOAD MEASURES

The training dose applied and experienced by athletes - commonly referred to as the training load – can be measured using a variety of methods and is typically categorised as either an internal or external training load [3]. The external load is the training dose applied to the athletes and is commonly monitored using microtechnology devices (e.g. GPS) and athlete tracking systems whilst the internal training load is the load experienced by the athlete and is measured using physiological (e.g. heart rate) and/or perceptual (e.g. perception of effort) tools. Due to the nature of the physical demands of football (i.e. it requires players to complete high-intensity, intermittent exercise), total distance travelled, distances covered at higher running speeds (e.g. >14.5 km/h, sprint efforts (i.e. efforts > 23 km/h) and the number of accelerations and decelerations are the most commonly used metrics used to quantify the external training load in football. Whilst there are many other variables that can be obtained from various athlete tracking devices (e.g. estimated metabolic power, accelerometer loads, etc.), an approach with relatively few variables that have good measurement precision and supported by a strong proof of concept are recommended for load monitoring.

Unfortunately, the important activities that require high speeds and/or accelerations – which have been reported to be important constructs of load in football[4] - tend to be more difficult to accurately quantify with current technology. Indeed, despite recent improvements with increased sampling rate and improved chipsets,[5,6] GPS devices cannot yet precisely assess players accelerations/decelerations characteristics using intensity-based

thresholds[7]. To overcome this limitation, it is recommended that averaging the acceleration/deceleration demands during training and match play may be a more appropriate method compared to threshold-based methods.[8]

The internal training load is the response of the player to the external load applied and is usually measured using heart rate or the session-RPE method.[9,10] The session RPE-method requires players to rate their perceived intensity of a session according to a standard rating of perceived exertion (RPE) scale (see Figure 2). The load for a session is then determined as the product of the session duration and the players RPE. For example, a 40-minute session rated as being 'hard' by a player would provide a load of 200 arbitrary units (i.e. 5 x 40 min = 200 AU).

0	Nothing at all	"No I"
0.3		
0.5	Extremely weak	Just noticeable
0.7		
1	Very weak	Light
1.5		
2	Weak	
2.5		
3	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	Extremely strong	"Strongest I"
11		

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Figure 2 The category-ratio (CR10) scale of perceived exertion [11] commonly used in determination of the session-RPE training load.

Heart rate measures may also be used to assess the internal training load during football, but due to the technical and practical issues such as the high risk of technical issues and data loss and a low level of player compliance in measurement, the session-RPE method is the most widely recommended approach.[12] An additional advantage of the session-RPE method over heart-rate derived approaches is that loads can easily be obtained from all types of training, including cross training and resistance training which are common in football. However, despite this a recent report showed that heart rate was more widely adopted in top level clubs than the session-RPE method, likely due to the reservations of players and coaches in providing RPE following match play.[13]

Many performance practitioners measure these variables during each training session and use this information to assess player output during training and to understand longitudinal changes in training load for individual players. However, the best use of these data is when they are stored and the historical data are used to understand the loads applied to players over the short and longer-term and this information can be used to identify risks of players who may be at risk of injury or reduced performance.

MEASURING THE PLAYER'S RESPONSE

Measuring the players response to training is also a basic aspect of athlete monitoring systems in football.[14] Common responses that are of interest to scientists include player fatigue, sleep and muscle soreness, although other factors (e.g. mood, stress etc.) are also commonly assessed. These factors are often assessed using short customised questionnaires which are relatively simple to administer to players, often using cloud-based computing applications.[15] Notably, it has recently been shown that various customised single item psychometric measures - such as perceptions of fatigue, mood, soreness and fatigue have greater sensitivity to acute and chronic training loads than commonly used objective measures.[14]

Objective response markers (e.g. heart rate and biochemical markers) have also been suggested as useful components of athlete monitoring systems. Specifically, markers such as muscle damage markers, heart rate variability, hormonal and immune measures have shown to respond to changes in training intensity and dose and have been associated with overreaching in a variety of athletes.[16,17] However, due to logistical issues such as the invasiveness of drawing blood or obtaining saliva samples from players, along with the costs and time for analysis, these measures are not suited for daily monitoring.

Recent research has shown that systems that consist of multidimensional measures of load and response are most appropriate for monitoring athletes.[18] Moreover, these monitoring systems should consist of valid and reliable measures that are simple to collect and of low invasiveness to players. When training load and response data are interpreted in the context of each other and with the current training goals, performance practitioners are able to make training decisions at the individual level of the player that can inform performance and reduce injury risk.

USING TRAINING LOAD DATA TO MAKE DECISIONS ABOUT FUTURE TRAINING

Recent research has shown that systems consisting of multidimensional measures of load and response are most appropriate for monitoring athletes.[18] When training load and response data are interpreted in the context of each other and with the current training goals, performance practitioners are able to make training decisions at the individual level of the player that can inform performance and reduce injury risk.

Common training or periodisation errors can be avoided using a systematic approach to load monitoring and by following some common-sense rules in prescribing training. Basic heuristics for avoiding training errors follow the Goldilocks' approach to training prescription such that we should avoid players completing too much work (increasing fatigue), avoid players completing too little training (under prepared) or changing workloads too quickly (acute stress-response).

Through monitoring of the load data, we can assess for acute changes in these load metrics during the previous week or longer-term changes over the past month (i.e. chronic load). Indeed, increases in week-to-week training load of more than 15% from the preceding week increases injury risk ~50%.[19] Another simple check commonly used by performance practitioners is to check how the recent change in training load compares to the chronic load. Now commonly referred to as the acute-to-chronic workload load ratio (ACWR),[20] this measure has recently been associated with elevated injury risk when the ACWR exceeds 1.50 or is less than 0.80.[21] Importantly however, performance practitioners should be aware that this measure cannot be used to predict injury, but used as a rule of thumb when making decisions about future training decisions.

These data can also be used to ensure we build robust players through appropriate exposure to training loads, with the general goal for players to maintain moderate-to-high workloads, whilst minimising high variation in the ACWR. Conversely, we should also avoid having players being underprepared by completing low chronic loads, combined with extreme ACWRs as this has been associated with high injury risk.

Load monitoring systems can also be used to help ensure players are being prepared for the demands of match play.

In particular, frequent exposure to higher sprint speeds and distances have been shown to reduce injury risk in both Gaelic football[22] and professional Australian Rules football players.[23] As a general rules, exposing players to speeds >90% maximum sprint speeds 1-2 per week along with providing sufficient long term exposure to sprint speed distances may provide a prophylactic effect against injury.[22] Similar variables could be included in a football player monitoring system to ensure are prepared for the high speed demands of match play.

Making decisions to intervene on training for a player is usually a collective decision between sport science, medical and coaching staff using data from monitoring systems but also the collective expertise on the group. Specific risk markers need to be developed for each group or athletes and according to the specific system and markers that are available. However, the common scenarios for risk are elevated loads, spikes in load following periods of low or high chronic loads, inappropriate recovery/rest periods from previous intense efforts. Table 1 provides examples of scenarios that may be used to identify players at risk.

HIGH RISK SCENARIOS	
Overload	
ACWR spike	Very high ACWR as determined by sessions categorized in the top 20%
Week-to-week change	Previous (2-weeks ago) to current week (last 7 days) change >15%
Very high chronic load	Very high 4-week chronic load for current season
Acute workload ceiling	Individual's highest 1-week acute load for the current season
Chronic workload ceiling	Individual's highest 4-week chronic load for the current season
Over expose to speed	>4 sessions in a week with exposure to high sprint speeds >90% maximum speed
Underload / Under prepared	
ACWR trough	Very low ACWR as categorized by sessions in the lowest 20%
Very low chronic load	Very low 4-week chronic load as determined by sessions in the lowest 20%
Exposure to maximal speed	Week with low exposure to maximal speed (<85% maximum sprint) prior to intense speed session or match
Acute Response Alerts	
Increased soreness	Elevated muscle soreness >1.5 standard deviation from usual levels, combing with plan for high speed or high load session
Multiple wellness alerts	Sustained period for reporting multiple response markers > 1.5 standard deviation from usual levels.
Perfect Storm	Low chronic loads, elevated ACWR with increased report of soreness, fatigue and/or sleep

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Table 1 Example of increased risk metrics available from player monitoring systems (adapted from Colby, Dawson, Peeling, Heasman, Rogalski, Drew, Stares [23])

TAKE HOME MESSAGE

Athlete monitoring systems are now common-place in football. The goal of these systems is to monitor how individual players are responding to training. Fundamental measures that should be incorporated in these systems include quantifying training load, and the players response to this load. Following this, correct interpretation of the data requires that all changes be contextualised in relation to the actual training load completed by the player, whilst accounting for the magnitude of change required for practical importance in monitoring the training response. In practice, these measures can be used to inform coaches and sport science staff on individual players. If collected carefully and interpreted effectively, important feedback can be provided to players and coaches that enhances their readiness to perform and reduces their injury risk.

1.4.3

RECOVERY STRATEGIES

Our Delphi survey revealed recovery as an effective strategy to prevent muscle injury in elite footballers. Although fatigue has been highlighted by football practitioners as one of the most important non-contact injury risk factors in elite players,[1] it is surprising that the actual scientific level of evidence for fatigue and injury is currently weak.[2]

— With Abd-Elbasset Abaidia, Gregory Dupont, Antonia Lizarraga and Shona Halson

There are, however, several, indirect sources of evidence that can be extrapolated to suggest a plausible link between fatigue and injury in footballers. For example, injuries are more common at the end of each half during professional matches,[3,4,5] whilst there is also a known significant reduction in muscle force at the end of matches.[4] A study of a French Ligue 1 professional football team[6] also provides indirect evidence to support the fatigue-injury belief of practitioners, in which the authors observed that a significantly lower than normal recovery time between high-intensity actions prior to injury was evident (35.6+/-16.8 s vs. 98.8+/-17.5s).

Finally, further support lends itself with the widely accepted and established finding that, periods of match congestion (e.g. weeks with multiple matches) significantly increases the risk of injury.[7,8] Elite football teams are regularly exposed to periods of match congestion (e.g. 2 to 3 matches per week with typically 3 to 4 days recovery between) in which the time allowed between matches may be insufficient to restore normal homeostasis within players [9] i.e. to fully recover. A recent multi-team, multi-year study performed by the UEFA Football Research Group[7] showed that muscle injury rates were 21% lower when there were 6 days or more recovery compared to 3 or less days. These results show that a recovery period from 48h to 96h between two matches is associated with an increased injury risk, suggesting insufficient time to fully recover. Recovery strategies aimed at accelerating the time for players to fully recover may therefore be useful in the overall injury prevention strategy.

ACCELERATING RECOVERY: WHAT RECOVERY STRATEGIES TO USE (AND WHY)

NUTRITION

Consuming proteins after a match enables repair of muscle damage following exercise. Scientific evidence has shown a beneficial effect of a protein dose of 20–40 g, including 10–12 g of essential amino acids and 1–3 g of leucine on muscle protein synthesis rates.[10] Optimization of the resynthesis of muscle glycogen stores is effective when consuming carbohydrates with a high glycemic index. An intake of 1.2 g carbohydrate per kg per hour immediately after a match, at 15-60 min intervals for up to 5h, enables maximum resynthesis of muscle glycogen stores.[11] Post-game re-hydration is an important issue, it is recommended to consume a fluid (150% of body mass lost) with a high amount of sodium (500 to 700 mg.l-1 of water).[12]

SLEEP

The recovery process may be affected and recovery kinetics slowed following a perturbed sleep at night.[14] Indeed sleep is often considered the best recovery strategy available to athletes, and it is critical to manage sleep disturbances when playing multiple games per week. Many elite footballers complain of sleep difficulties after night matches, which may be due to physiological factors (fatigue, soreness, temperature), psychological factors (arousal, stress) or environmental factors (bright light, travel requirement, room environment). Optimizing sleep may be possible by sleeping at least 8 to 10 hours, and increasing sleep hygiene by measures such as switching-off lights, decreasing the temperature of the room, limiting screen time and social media use, and adapting the food ingested in the afternoon by avoiding drinks such as coffee or tea. If the first night's sleep is poor, it should be compensated with a nap the following day.[13]

COLD-WATER IMMERSION

Immersing the body into water with a temperature of 10°C for an exposure period of 10 minutes immediately after muscle-damaging exercise session is beneficial for recovery.[14] Results have consistently shown a beneficial effect of this strategy on force, sprint and jump recovery.[15,16] While the use of acute cold-water immersion is supported by research, the effect of chronic use of immersion has been questioned.[17] This is due to the potential role that cold water immersion may play in reducing adaptation. Therefore, a periodised approach is likely best, whereby cold water immersion is used acutely to influence performance (for example during congested schedules) and limited or reduced at other times (pre-season or weeks with only one match).

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Figure 1
Schematic representation of a recovery protocol following a football match

COMPRESSION GARMENTS

Wearing compression garments following a match may have beneficial effects on recovery kinetics. The effectiveness of compression garments on muscle force and power is underpinned by scientific evidence. [18-20] It is recommended to wear compression garments with a high level of pressure (for example: 15mm Hg at the thigh level and 25 mm Hg at the calf level) until bed time and the days following the match. [21] Some individuals may prefer to sleep in the garments for additional recovery benefits, however they should not be worn if sleep is disturbed.

THE DAY AFTER THE MATCH

UPPER LIMB STRENGTH TRAINING

Scientific evidence for effective recovery strategies the day following a match is scarce. Teams typically perform low intensity and low volume exercise based strategies such as active recovery run, pool session, or bike and tend to avoid rigorous intense activities. While only preliminary evidence, performing an upper-limb strength training session the day after fatiguing and muscle damaging lower-limb exercise may accelerate the recovery kinetics of concentric force. [22] This strategy may be implemented the day after a match. It also represents a time-efficient modality to enhance upper-limb strength in players that may not be possible later in the week or allows an additional exposure to such training.

MASSAGE

Massage may have a beneficial effect on decreasing muscle soreness and on increasing the perception of recovery. [12] The best results on muscle soreness are obtained with a combination of effleurage, petrissage, tapotement, friction and vibration techniques and for a duration of 5 to 12 minutes.

IMPORTANT CONSIDERATIONS

INDIVIDUAL VARIATION

Due to the fact that individuals will likely have different levels of fatigue/soreness, a different time course of recovery and respond differently to specific recovery strategies, an individualized approach to recovery may be necessary. Some players may respond positively or negatively to different strategies, and therefore consideration should be given to finding the optimal strategy for each player based on performance and perceptual data if possible.

THE FUTURE OF RECOVERY

While the area of recovery research is relatively new in comparison to other fields in physiology and nutrition, future areas of interest include periodisation of recovery, individualisation of recovery, psychological recovery (meditation, relaxation, mindfulness) and how athletes recover from mental fatigue.

1.4.4a

EXERCISE-BASED STRATEGIES TO PREVENT MUSCLE INJURIES

Exercise is one of the most common preventative strategies implemented by football teams to prevent muscle injury.[1] The following summary and recommendations are a combination of relevant scientific research findings with current best practice.

— With Maurizio Fanchini, Eduard Pons, Franco Impellizzeri, Gregory Dupont, Martin Buchheit and Alan McCall

***Special contribution from Nick van der Horst, Ida Bo Steendhal and the EBMIP Delphi Group**

Specifically, this chapter is based on the results of an internally performed systematic review and expert led Delphi survey of key football performance practitioners operating in teams from the Big 5 Leagues (Bundesliga, English Premier League, La Liga, Ligue 1, Serie A) and combined with the philosophy and practices of FC Barcelona medical and performance staff.

Our systematic review showed that there is no convincing evidence for many exercise-based strategies to prevent muscle injury in elite football players. Our results highlighted a low quality of studies (systematic reviews and randomized control trials) and overall weak scientific evidence supporting eccentric exercise to prevent hamstring injuries. The Delphi survey revealed (Table 1) the perceptions of elite level practitioners regarding the effectiveness of various exercise types to prevent muscle injuries in footballers. The following piece will focus primarily on the two most highly rated exercise types; high-speed / sprint running and eccentric exercise. A secondary emphasis highlights the importance of a multi-dimensional approach to exercises based prevention and other potentially effective exercises that can be incorporated into the prevention program.

PREVENTATIVE EXERCISE TYPE	EFFECTIVENESS RATING
High-speed running / sprinting	+++
Eccentric	++
Concentric	+
Isometric	+
Plyometrics (Horizontal & vertical orientations)	+
Activation / coordination (e.g. sprint movements & mechanic drills	+
Flexibility (dynamic & static)	+
Core stability	+
Multi-joint exercises (e.g. Olympic lifting, squats, functional strength)	+ to +++
Single leg strength and stability	+ to +++
Agility	+ to +++
Kicking (shooting, crossing, long passes)	+ to +++
Resisted sprints (e.g. sleds, parachutes)	+ to +++

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Table 1
Perceived effectiveness of exercise strategies to prevent muscle injury in elite footballers (EBMIP Delphi Survey results)

Key to perceived effectiveness:

+++ Very Effective.
++ Effective.
+ Somewhat Effective.
+ to +++ No consensus as to precise effectiveness.

HIGH-SPEED RUNNING AND SPRINTING (HSR)

During running and sprinting i.e. at high velocities (HSR), lower limb muscle-tendons systems experience high values of torque at stance and late swing phases. During the stance phase, muscles of the hip and knee work to both counteract the ground reaction force and generate propulsion. Muscles of the ankle and foot systems contract eccentrically and concentrically (with higher power compared to knee and hip joints muscles) to absorb the ground reaction force and to push the body forward to the subsequent swing phase. [2] During the swing phase, muscles control the movement direction of the limb extremity with hamstrings muscles responsible for both hip extension and knee flexion. [2] The high power expressed by the muscles results in high horizontal net force that maximize the forward propulsion. [2] A lower maximal horizontal force output during sprinting has been proposed as a possible risk factor and mechanism for hamstring muscle injury in football, especially in players with a high maximal running velocity. [3] Specific focus on HSR within the training program should therefore be considered important to expose and condition the lower limb muscles in a specific manner to cope with the demands of football training and match-play. Importantly, reaching HSR velocities requires the player to accelerate and given the nature of football, then decelerate and change direction and change intensity with and without the ball (e.g. dribbling, passing, shooting) according to the context of the game.[4,5] These situations, requiring neuromuscular load[6] can present potentially injurious situations and therefore exposing players to these high-intensity actions (HIA) is also recommended within the muscle injury prevention strategy. Exposure to targeted HSR and HIA can have the additional benefit of developing physical qualities such as intermittent aerobic fitness that has been shown to protect players from lower limb injury. [7]

HOW TO INTEGRATE HSR AND HIA INTO THE FOOTBALL TRAINING PROGRAM?

The nature of football as a running based sport means that the coaches' normal football training sessions inevitably involve a varied amount of contribution of HSR and HIA depending on the type and duration of the session. We recommend that wherever possible, HSR and HIA should be integrated into the coaches' typical football drills. While, ideally HSR and HIA targeted sessions are integrated seamlessly into normal training, it is also appropriate to prescribe separate football specific drills and generic running (e.g. maximal aerobic speed, repeated straight line sprints etc) to ensure players are exposed to sufficient amounts of this type of preventative and performance based training.

While not in football (soccer), it has been shown in Gaelic Football [8] that players producing moderate (> 6 to 10) exposures (i.e. the number of athese activities performed) of →95% of their maximal running velocity within the week were at reduced risk of lower limb injury, while both low (<5) and high (>10) exposures increased the risk of injury. Importantly, a high chronic overall training load (all trainings) allowed players to tolerate higher exposures (between 10 and 15) ≥95% without increasing the risk of injury. Additionally, minimal exposure to HSR efforts (i.e. maximum speed and sprint volume) has been shown to be a risk factor for injury in Australian Rules Footballers. (Please refer back to section 1.4.2. Controlling Load with Prof. Aaron Coutts).

Position specific HSR and HIA should be developed to contextualize running bouts in relation to tactical activities, the work-to-rest ratio and method of recovery can be manipulated as well as the introduction of change of direction and turns to simulate specific match and positional patterns. [9,10] An integrated approach of physical, tactical and technical elements is also time efficient and well accepted and liked by players and coaches, and therefore buy in is likely to be greater. It is important to individualise the prescription of HSR and HIA according to each player's individual match and positional activity, there is no one size to fit all.

WHEN IN THE TRAINING WEEK, TO PERFORM HSR AND HIA?

There is no strong scientific evidence to guide when the optimal time is in the training week to perform specifically focussed HSR and HIA training and there are likely various possibilities depending on a number of factors, including but not limited to; the number of days from the last match and the next match (e.g. 2 to 6 + days), starters versus non-starters/ substitutes, loads performed and experienced during the match, the planned content of the coaches football session, individual players needs, strengths, weaknesses, likes and dislikes, current and on-going medical issues, whether or not they are accustomed and adequately prepared to be exposed to and tolerate such demanding exercise.

We recommended in general, (based on our expert led Delphi survey) that during periods of 1 match per week (i.e. >5 days full recovery between matches), HSR and HIA specific exercise is performed on Matchday -3. During periods with ←4 days recovery between matches, it is generally considered to perform football training only as the HSR and HIA targets will most likely be achieved during the games. Within even a congested fixture list, coaches normal training will involve higher running intensities (including sprints), and therefore it is likely not necessary to perform any additional work. It is even possible to perform HIA drills i.e. short acceleration, deceleration and change of direction drills (typically coined speed & agility by players) on the M-1 as long as a low volume and adequate recovery times between repetitions are respected. Anecdotally, many players actually enjoy performing these types of activities on the M-1 (e.g. as part of the warm up or after the session) as it makes them feel "sharp" for the match the next day.

NON-STARTERS / SUBSTITUTES

It is important to remember that while the playing squad is 11 players, the typical elite football squad comprises ~ 25 + players and not all can play. It is imperative that players not playing regularly are also prepared for the rigorous demands of a match not only from an injury perspective but also from a performance standpoint. Carling and colleagues[11] found that substitutes directly winning more games was one of the potential contributors to a championship winning season compared to 4 other non-winning seasons. Therefore, careful consideration should be given to these players and although involved in the same main training sessions as the starting players, they will likely require additional HSR and HIA to ensure they are prepared if called upon. Specifically, it is recommended that non-starters and substitutes perform additional HSR and HIA exercise on M+1 or M+2 (but not on both), depending on the training schedule e.g. days off, upcoming match etc.

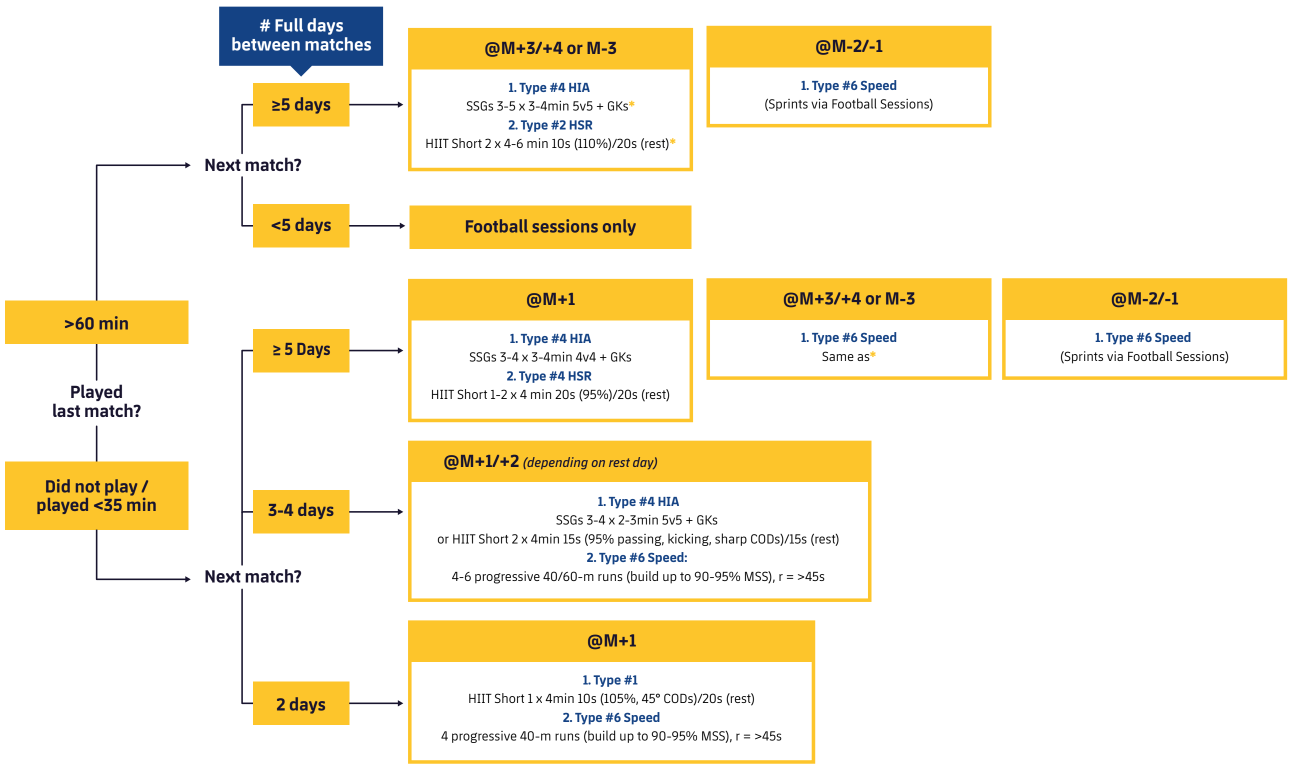

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Figure 1
Decision process when it comes to programming the different running e.g. High-intensity intermittent training (i.e. HSR & HIA) drills with respect to competition participation and matches macrocycles. Note that only HIIT sequences are shown – most sessions would also include technical and tactical components and possession games. SSGs: small-sided games. HIA: high-intensity activities (> 2ms^2 accelerations, decelerations and changes of directions). HSR: high-speed running (>19.8 km/h). The different HIIT types are the following: Type #1) aerobic metabolic, with large demands placed on the oxygen (O^2) transport and utilization systems (cardiopulmonary system and oxidative muscle fibers), Type #2) metabolic as 1) but with a greater degree of neuromuscular strain, Type #3) metabolic as 1) with a large anaerobic large glycolytic energy contribution but limited neuromuscular strain, Type #4) metabolic as with 3) but with both a large anaerobic glycolytic energy contribution and a high neuromuscular strain, Type #5) a session with limited aerobic demands but with a anaerobic glycolytic energy contribution and high neuromuscular strain Type #6)not considered as HIIT) with a high neuromuscular strain only, which refers to typical speed and strength training for example. Note for all HIIT Types including a high neuromuscular strain, possible variations exist in the form of this neuromuscular strain, i.e. more oriented toward HSR (likely associated with a greater strain on hamstring muscles) or HIA (acceleration, decelerations and changes of directions, likely associated with a greater strain of quadriceps and gluteus muscles). Note for example that Type #1 can be achieved while using 45°-CODs, is likely the best option to reduce overall neuromuscular load (decreased absolute running velocity and no need to apply great force to change of direction, resulting in a neuromuscular strain lower than straight line or COD-runs with sharper CODs.) Reference (for both HIIT types and Figure): Science and Application of High Intensity Interval Training, Laursen P, Buchheit M. Human Kinetics, In Press.

ECCENTRIC EXERCISE

In our expert led Delphi survey, exercises with an eccentric focus were rated as the 2nd most important exercise mode to prevent muscle injury in elite footballers. This is in line with the perceptions of worldwide Premier League,[1] UEFA Champions League[12] and National teams competing in the FIFA World Cups.[13] Eccentric exercise may be particularly useful as they target various modifiable risk factors including; eccentric strength, optimal angle of peak torque and muscle architecture e.g. fascicle length[14]. It is likely that these reasons explain why this exercise mode is favoured by practitioners not only in football but also in many other team sports.[15] Importantly, player buy in and the quality to which the exercises are performed are likely key to ensuring optimal adaptations and beneficial effects on muscle injuries.[12-16] As such, exercise with an eccentric focus should be considered in the overall injury prevention program for footballers and buy in and quality execution of these should be encouraged and monitored by practitioners.

WHEN IN THE TRAINING WEEK TO PERFORM THE MAIN ECCENTRIC EXERCISES?

As with high-speed running and sprinting exercise, there is no clear scientific evidence as to when is the best period to perform the main eccentric exercises during the football training week. There are a number of similar contextual factors running based training that need to be considered surrounding the decision of when is most appropriate to include eccentric exercise.

In general, when playing 1 match per week and 6 days recovery between matches, the most appropriate day is perceived to be on M+ 3 (M-4 from the next match). This timescale likely allows opportunity for muscles to recover from the previous match and enough time for them to recover again before the next match 4 days later e.g. Saturday – Tuesday – Saturday.

When the recovery between matches is 5 full days (e.g. Saturday – Friday) the preferred day is again on the M+3, however this will also correspond to a M-3 i.e. 3 days before the next match. While only preliminary evidence, it has been shown in semi-professional football players that performing eccentric exercise on the M+3 i.e. M-3 during a week with 5 full days recovery resulted in elevated levels of creatine kinase and hamstring muscle soreness 24h before the next match.[17] However, perhaps importantly was that muscle function (i.e. muscle force) was not affected. Muscle force is considered the gold standard measure of muscle damage[18] and may be more useful to inform injury risk estimation. It is also vital to consider if players are accustomed to performing eccentric exercise as this may allow them to perform such exercise on a M-3 in a 5 day week without experiencing any muscle soreness.

During periods with ←4 days it is generally considered that specific high-intensity type eccentric exercise is not necessary. There may however be options to include low intensity, low volume eccentric type exercises coined as 'activation' exercises. The specific muscle section of this Guide will provide further details on specific eccentric exercise types e.g. for the hamstring, adductor, quadriceps and calf.

PERFORMING ECCENTRIC EXERCISES BEFORE OR AFTER THE FOOTBALL SESSION?

Once we have decided on the day to perform the eccentric session, another key question for practitioners is when to implement it i.e. before (non-fatigued) or after (fatigued) football training? While scientific evidence is limited currently, there are some preliminary findings suggesting that specific timing of the eccentric exercise around the football session may result in different adaptations that could contribute to reducing muscle injury risk.

BEFORE THE SESSION

One potentially modifiable risk factor for muscle injury are increases in fascicle.[19] Performing eccentric exercise before the training session has revealed fascicle length increases but not when performed after the session. [20] Similar chronic adaptation of peak torque production of the hamstring muscles has been shown to be similar when eccentric exercise is performed before and after the training session.[20]

AFTER THE SESSION

A training intervention where eccentric exercise is performed after the session has shown to increase muscle thickness and pennation angle[21] as well as a chronic adaptation towards an improved ability of players to maintain their eccentric strength at half-time and upon cessation of a simulated football match versus those performing in a fresh state before training.[22]

CONSIDERATIONS WHEN DECIDING BEFORE OR AFTER THE FOOTBALL SESSION

An important consideration when planning the timing of the eccentric exercise session is that an acute effect of eccentric exercise performed before the training session may result in muscle fatigue that could actually increase the probability to sustain an injury in the subsequent session.[21] Therefore, as a practitioner you should consider carefully the context surrounding the planned eccentric exercise; in particular consideration of the coaches training session and determine the risk:benefit of performing such exercises before or after the session. This is best done at the individual player level also. It has been recommended that eccentric exercise performed both before (fresh) and after (fatigued) is likely optimal to the injury prevention program.[23] This is in line with the actual practices of the expert practitioners from the Big 5 leagues.

EXERCISE-BASED INJURY PREVENTION STRATEGIES SHOULD BE MULTI-DIMENSIONAL

While this section has focussed on running and eccentric exercise specifically, in reality, the injury prevention program is and should be multi-dimensional that includes various other exercise modes. Therefore, the global injury prevention program should not be limited to HSR, HIA or eccentric exercise alone but involve the addition of other exercises targeting modifiable risk factors. Table 1 illustrates the wide array of exercise types available to the practitioner who wants to reduce injury in his/her team. While there is limited evidence for many of these exercise types e.g. plyometrics, flexibility, core stability, static and dynamic flexibility, activation etc to prevent muscle injuries of the lower limbs in footballers, they should also be considered due to their perceived effectiveness and widespread use in elite football teams i.e. current best practice.

PLYOMETRICS, CORE AND MULTI-JOINT EXERCISES

Plyometric exercises are commonly used to improve sprint and jump performance in team sport in addition to increasing the neuromuscular control and lead to less torque working on the knee.[24] The introduction of plyometric exercises into the injury prevention program could be promising however several parameters of load (volume, intensity, frequency) should be accurately evaluated during the design of the training program. Specific exercises targeting the motor control of the core muscles have been found to result in fewer games missed in Australian Footballers,[25] however, multi-joint exercises such as the squat and deadlift are at least and in some cases more effective in the activation of core muscles.[26] An important consideration for the practitioner is that the inclusion of other exercise modes such as plyometrics and multi-joint exercises should be performed in both vertical and horizontal orientations. Using both orientations in the football training program has been shown to improve neuromuscular performance of players in comparison to vertically oriented only exercises.[27]

FLEXIBILITY

There is no clear evidence for lower limb flexibility alone to reduce muscle injuries, however they have been integrated into global prevention programs that have shown beneficial effects on muscle injury.[28-29] Static and dynamic lower limb flexibility training may logically be useful to allow the hip and knee muscle to move within ranges of motion necessary during kicking and sprinting.

EFFECTIVENESS OF MULTI-DIMENSIONAL INJURY PREVENTION PROGRAMS ON MUSCLE INJURY IN FOOTBALLERS

Although scarce, there is some scientific evidence for the use of multi-dimensional injury prevention programs in elite footballers. In 2005, Verrall and colleagues[30] found that a global prevention program incorporating sport specific running drills, high-intensity interval anaerobic training, strength training and flexibility resulted in a significant reduction in hamstring muscle injuries and the number of competition games missed. Owen et al.[28] implemented a multi-dimensional prevention program in elite European footballers incorporating eccentric, general strengthening exercises, dynamic flexibility, core, balance, coordination and agility based runs into the overall football training program resulting in significantly less muscle injuries in players.

KEY PROGRAM VARIABLES FOR EXERCISE BASED STRATEGIES

There is no one specific guideline on the optimal programming e.g. sets, repetitions, loads etc for exercise-based strategies, however there are some general guidelines that can be adopted according to the goal of your program. Below we provide a table (table 2) with some potential options for key programming guidelines adapted from Dupont and McCall in the Soccer Science textbook by Tony Strudwick.[31]

Table 2
Potential key programming variables and considerations when implementing exercise-based strategies'
v

	ACTIVATION/LOW LOAD EXERCISES	HYPERTROPHY	STRENGTH	POWER	SPEED
Sets	2 to 6 (in total for full session)	3 to 6 (in total for full session)	2 to 6 (in total for full session)	2 to 6 (in total for full session)	2 to 6 (in total for full session)
Reps	6 to 12 (or time based e.g. 10 to 20s)	6 to 12 (per exercise)	1 to 8 (per exercise)	1 to 10 (per exercise)	1 to 10 (per exercise)
Load	+ No load / elastics / low external loads / manual resistance	70% to 85% 1RM (6RM to 12RM)	≥ 80% (1 repetition maximum i.e. RM to 8RM)	0% to 80% 1RM	0% to 30% of body mass
Rest	Self-determined (how you feel)	1 to 2 mins	2 to 5 mins (3 mins preferred)	2 to 5 mins	2 to 5 mins
Velocity	Controlled – focus on movement quality	Eccentric – moderate to slow (2 to 3 sec) Concentric – fast intention (1 to 2 sec)	Eccentric – moderate to slow (2 to 3 sec) Concentric – fast intention (1 to 2 sec)	Eccentric – fast to moderate (<1 sec to 2 sec) Concentric – as fast as possible	As fast as possible
Frequency	Possible on each training day (including match warm-ups) Vary the exercises if doing daily	Pre-season – 2 to 3 times per week In-season – 0 to 3 times per week (depending match schedule)	Pre-season – 2 to 3 times per week In-season – 0 to 3 times per week (depending match schedule)	Pre-season – 2 to 3 times per week In-season – 0 to 3 times per week (depending match schedule	Pre-season – 2 to 3 times per week In-season – 0 to 3 times per week (depending match schedule)
Number of exercises	3 to 6	4 to 6	3 to 6	3 to 6	3 to 6
Type of exercises	Balance / Proprioception Flexibility (dynamic & static) Movement based drills (e.g. sprint movement drills) Core stability exercises Specific muscle activation	Traditional resistance exercises	Traditional resistance exercises	Ballistic exercises Plyometrics Olympic style lifts Traditional resistance exercise (explosive mode)	Straight line acceleration (0 – 10m) Soccer specific acceleration Explosive and leading starts Longer sprint running (20 – 40m) Sled Running Downhill & Uphill sprints
Main effects	> range of motion > movement quality > activation > balance and proprioception	> max strength > muscle mass	> max strength > muscle mass (*less extent than hypertrophy training)	> power > sprinting/acceleration > jump > rate of force development > change of direction ability	> acceleration > rate of force development > change of direction ability
Special considerations	Focus on quality movement execution of the exercise rather than load or speed of movement	Do not perform lower body in 2 days prior to match or in 2 days following the match Focus on quality movement execution of the exercise rather than load or speed of movement	Focus on quality movement execution of the exercise. If quality suffers, reduce the load Do not perform lower body in 2 days prior to match or in 2 days following the match	Perform during hardest session of the week Focus on quality movement execution of the exercise. If quality suffers, reduce the load Possible to perform during day before game with lower sets, repetitions and low load for 'activation'	Perform during hardest session of the week Focus on quality movement execution of the exercise. If quality suffers, reduce the load Possible to perform during day before game with lower sets, repetitions and load for 'activation'

1.4.4b

EXERCISE SELECTION FOR THE MUSCLE INJURY PREVENTION PROGRAM

At FC Barcelona, it is our belief that any one exercise or exercise session performed in isolation, cannot prevent a muscle injury from occurring e.g. doing a set of Nordic hamstrings alone is not enough to stop a hamstring muscle strain, but then neither is any other strategy on it's own

— With Xavi Linde, Juanjo Brau and Ricard Pruna

The idea is that, specific exercise strategies can add to the overall strategy to try and reduce the risk of a muscle injury occurring. When performing exercises within the overall prevention strategy we have some key considerations;

1. Variation - It is important to train using a variety of exercises, with varying number of sets, repetitions and rest durations. We also believe that continual adjustment of stimulus is necessary through manipulation of the surface type, resistances and decision-making. The main objective is not to make the exercises a restricted, closed and predictable task, but rather to simulate a variety of situations. In the gym there are many exercises available to choose from and varying these is a key component of our exercise-based muscle injury prevention program.
2. Continuing with the concept of variation, as well as gym based exercise strategies, we aim to implement specific exercises outside in the field, where different surfaces such as sand, artificial and natural grass, uphill & downhill running tracks can be used. By using such surfaces it is possible to propose different circuits to achieve our objectives of generating the specific demands that players require.
3. We believe that working within a full range of motion while performing exercises is important for muscles. Many of our exercises are performed with active tension stretching, which of course we can guide, but we also allow the player to develop this tension him/herself. The own feeling of the player performing the stretch will help to achieve the maximal range of motion as well as adjust the intensity of exercises according to his/her sensation.
4. With exercise strategies it is important to train with functional patterns related to movements performed by players on the pitch and in matches. Of course, it is sometimes necessary to perform some specifically focussed exercises (such as leg curl, leg extension etc) e.g. to build basic strength, however, building strength during functional patterns with bodyweight, free weights and elastic resistances all form a part of our training, using both closed-chain kinetic and open-chained exercises.
5. Following the theme in number 4 above, we favour closed kinetic chain exercises where possible in order to train muscles in the specific patterns that they are used to during football activities.

In the following chapters focussing on exercise selection for specific muscles, we provide a variety of exercises that practitioners can choose from according to their needs. We want to re-emphasise that exercise-based strategies are just one component of the overall muscle injury prevention program.

1.4.4c

EXERCISE SELECTION: HAMSTRING INJURY PREVENTION

As highlighted previously, the hamstring muscles are the most frequently injured muscles in elite footballers and carry with them the highest injury burden (days lost). The contribution of the hamstring muscles (i.e. biceps femoris long and short heads, semitendinosus and semimembranosus), and their responses to exercise vary according to the type of exercise performed[1]
— With Maurizio Fanchini, Xavier Linde, Juanjo Brau, Edu Pons and Nicol van Dyk

Exercises can be differentiated between hip-extension-based, knee-flexion-based and multi joints-based (Table 1). Hip-extension-based exercises (Table 1) provide higher activity of biceps femoris long head instead of the knee-flexion exercises (Table 1) that activate more the semitendinosus.[1-3] Multi joint based exercises such as lunges involve mainly the proximal part of the adductor magnus and biceps femoris long head.[4] The lunge and squat exercises eccentrically involve the hamstrings to control the hip during knee flexion. In addition, kettlebell swings activate more semitendinosus and semimembranosus (medial hamstrings) compared to biceps femoris (lateral hamstring), which may be important for sprinting.[5]

The majority of hamstring injuries happen whilst players are sprinting or accelerating, and it has been suggested that activations patters in each hamstring muscles are not uniform during maximal sprint.[6,7] During the early stance phase of acceleration, hip-extension is dominant, and there is higher activity of the biceps-femoris long head compared to semitendinosus. During the late stance and terminal mid-swing of a maximal sprint the semitendinosus demonstrates higher activity compared to the biceps femoris long head.[8]

Scientific evidence for the optimal hamstring exercises is weak, however a combination of different exercises should be included in a hamstring injury prevention protocol,[9] targeting all hamstring muscles. This protocol should also focus on the implementation of sprinting and high speed running exercises, as well as on the preservation of flexibility all of which are likely key to reducing the risk of injury.

IMPLEMENTATION REASON	EXERCISE	CLASSIFICATION
Activation / strength endurance / strengthening (low intensity injury prevention	Good morning	Hip-extension
	Bilateral deadlift	Hip-extension
	Hip hinge	Hip-extension
	Bilateral supine bridge	Hip-extension
	Unilateral supine bridge	Hip-extension
	Russian belt	Hip-extension
	Single leg deadlift	Hip-extension
	Single Leg Romanian Deadlift	Hip-extension
	Single leg Sliders	Knee-flexion
	Nordic Hamstring	Knee-flexion
	Glut-ham isometric	Multi joints
	Razor curls	Multi joints
	Bulgarians	Multi joints
	Reverse lunging	Multi joints
Strength	Lying hip flex/extension with versa pulley	Hip-extension
	Leg curl (sitting, standing, prone)	Knee-flexion
	Leg curl with isoinertial devices	Knee-flexion
	Standing hip extension with resistance (elastic bands, cable)	Hip-extension
Plyometrics and performance conditioning	Thrusts (Final swing phase and contralateral hip extension).	Multi joints
	Lunges and multidirectional movements with versa pulleys	Multi joints
	Foot catch exercise (very functional regarding sprint)	Multi joints
	Kettlebell swings	Multi joints
	Sprinting and High speed running	Multi joints
Flexibility	Dynamic and static stretching	
	The Extender	
	The Glider (also useful for strengthening)	

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Table 1
Examples of exercises that may be included in a prevention program for hamstring muscle injuries

THE BARÇA WAY

We perform a variety of hamstring focussed exercises using devices, manual resistance and elastic bands, switching between standing, sitting and lying in addition to eccentric, isometric and concentric contractions. In particular multi-joint exercises such as the squat, lunges, step ups (figures 1A to 1C), and single/double leg bridges on stable and unstable surfaces are used to train functional patterns (1D to 1F). We also place high importance on active stretching of the posterior chain before, in-between and following gym based exercises (figures 2A to 2C). Kick-backs (figure 3) are used to train the glute and hamstring muscles.

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Figures 1A, 1B and 1C.
Squat, lunge, step ups (respectively)

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Figure 1D.
Single leg bridge on stable surface

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Figure 1E.
Double leg bridge on unstable (swiss ball) surface

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Figure 1F.
Isometric single leg bridge on unstable (bosu ball) surfacee

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Figures 2A, 2B, 2C
Active stretches of the
posterior chain

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Figures 3
Kick-backs with
elastic band

1.4.4d

EXERCISE SELECTION: QUADRICEPS INJURY PREVENTION

The rectus femoris is a bi-articular muscle of the quadriceps, and of the quadriceps muscles, it is the most susceptible to injury in footballers. Rectus femoris injuries usually occur in open kinetic chain (OKC) movements, when players are sprinting or kicking.[1] These actions can involve hard eccentric contractions and fast and forceful change of muscle action. There is scarce evidence for the effectiveness of specific exercise types to prevent rectus femoris injury in footballers.
— With Maurizio Fanchini, Xavier Linde, Juanjo Brau, Edu Pons and Andreas Serner

However, a clinically relevant review combining limited scientific findings and expert opinion in regards to quadriceps injury prevention[2] recommends that, rectus femoris injury prevention strategy should include targeting general flexibility of the lower limb muscles, ensuring adequate balance between concentric and eccentric strength of the hip flexors and knee extensors, and adequate core stability.[2]

When focusing on minimizing injury risk, both basic prevention exercises and more functional/football specific exercises may be incorporated. Basic prevention exercises are usually differentiated between open and closed kinetic chain (OKC and CKC). Open kinetic chain exercises refer to movements that are performed with the most distal aspect of the extremity moving freely and non-weight-bearing, whereas CKC exercises correspond to multi-joint movements performed in weight bearing or simulated weight bearing with a fixed distal extremity.[3]

The simple leg extension is an OKC exercise frequently used to strengthen the quadriceps (with different type of contraction's combinations and resistance: weight pack, elastic bands, cables, active physiotherapist resistance). Performing CKC (e.g. leg press, squats, lunges) exercises results in more simultaneous activation of the four different muscle portions of the quadriceps, and can provide a more balanced initial quadriceps activation[3] compared to OKC exercises. A limitation of the CKC exercises is that they are often performed with hip flexion and therefore may be more relevant for the vastii muscles than for the rectus femoris specifically. As rectus femoris strains are considered to occur at long lengths with both hip extension and knee flexion, exercises improving the capacity of the muscle to withstand rapid high loads at long lengths should be considered. A 4-week eccentric exercise program has been shown to increase the length of the knee extensor muscles (i.e. "shift the peak of the torque–angle curve in the direction of longer muscle lengths").[4] For simple implementation of an eccentric quadriceps strengthening exercise, the Reverse Nordic Hamstring exercise[2] can be implemented on the pitch without equipment. In order to target the rectus femoris at full length, an OKC exercise may be implemented, for instance using a cable pulley with the strap fixed around the ankle to incorporate a simultaneous hip flexion and knee extension. Whilst kicking, iliacus and psoas are also highly activated to produce hip flexion force.[5] Therefore, improving proximal hip strength with a specific focus on the deep hip flexors, as well as knee extension strength may also be appropriate targets to reduce rectus femoris injury.

Considering the primary injury mechanisms of kicking and sprinting, these actions should receive extra attention in relation to rectus femoris injuries with specific monitoring. Although no specific evidence is available, the approach may simply be to avoid large fluctuations in the amount of sprinting and kicking, and ensure that the training loads meet the requirements of the individual players. It could potentially also be relevant to training these functions with added resistance.

Finally, considering common practice in elite teams, as covered in the general principles of exercise prevention strategies section of this guide (Table 1), plyometric and multi-joints exercises should also be included in a multi-dimensional program. Specific exercises (e.g. plyometrics, sprints, accelerations, decelerations, agility) are usually adopted to enhance explosiveness, and can be implemented during on-field session in technical exercises.

IMPLEMENTATION REASON	EXERCISE	CLASSIFICATION
Activation / strength endurance / strengthening (low intensity injury prevention	Seated leg extension with elastic bands or cables	Knee extension/Hip flexed/ OKC
	Standing leg extension with elastic bands or cables	Knee extension/Hip flexed/ OKC
	Lying leg extension with elastic bands or cables	Knee extension/Hip extended/OKC
	Mini-squats	Knee extension/Hip extension/CKC
	Lunges	Knee extension/Hip extension/CKC
	Reverse lunge	Knee extension/Hip extension/CKC
	Reverse Nordic Curl	
	Reverse Russian Belt	
Strength	Seated leg extension machine	Knee extension/Hip flexed/ OKC
	Hops to stabilisation (forward, lateral, backwards)	
	Horizontal Leg press	Knee extension/Hip extension/CKC
	Inclined Leg press	Knee extension/Hip flexed/ CKC
	Squats	Knee extension/Hip extension/CKC
	Yo-Yo Multigym (eccentric overload leg press)	Knee extension/Hip extension/CKC
	Yo-Yo squat (eccentric overload)	Knee extension/Hip extension/CKC
	Yo-Yo leg extension (eccentric overload)	Knee extension/Hip flexed/ OKC
Plyometrics and performance conditioning	Plyometrics	Knee extension/Hip extension/CKC
	Down-hill sprinting	
	Sledge accelerations	
	Accelerations/decelerations	
Flexibility	Sliding board (dynamic stretching)	
	TRX inverted lunge	

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Table 1
Examples of exercises that may be included in a prevention program for quadriceps muscle injuries

THE BARÇA WAY

Our approach to exercise selection for quadriceps muscle injury prevention focuses on a variety of open and closed chain kinetic exercises on stable and unstable surfaces in order to provide a wide array of stimuli to the players. As with the hamstrings, multi-joint single and double leg exercises such as the squat, lunge and leg press can be prescribed (see hamstring exercise selection section). Exercises with an eccentric focus are emphasised (figures 1A and 1B) in addition to training functional patterns (figures 2A and 2B). Finally, as with other muscle groups, we prescribe active stretching of the quadriceps, before, during and following specific exercises (figures 3A and 3B). Field based exercises include downhill sprinting, plyometrics and sled running.

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Figures 1A and 1B
Quadriceps exercises with an eccentric focus

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Figures 2A and 2B
Training quadriceps functional patterns

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Figures 3A and 3B
Active stretching of the quadriceps

1.4.4e

EXERCISE SELECTION: ADDUCTOR INJURY PREVENTION

During football training and match-play, the adductor muscles are often placed under high loads, especially during high-speed running, hard changes of direction with accelerations and decelerations and kicking.[1,2] Among the adductor muscles the adductor longus has been found to be the most frequently injured (i.e. 62% of injuries) and therefore, exercises targeting the strengthening of this muscle should be incorporated into the global exercise-based adductor injury prevention program.
— With Maurizio Fanchini, Xavier Linde, Juanjo Brau, Andrea Mosler and Joar Haroy

The activation of this muscle from different hip-adduction exercises has been examined in various studies.[3-5] These studies showed that the adductor longus is preferentially activated during ball-squeeze exercises, the Copenhagen Adduction exercise and the hip adduction with elastic bands.[3-5] These aforementioned exercises have been shown to be superior at activating the adductor longus compared to other adductor focussed exercises such as rotational squats, sumo squats, standing adduction on a Swiss ball, side lunges, side-lying hip adduction and supine bilateral hip adduction.[3,5] However differences between methods in the studies (for example EMG assessment and frequency collection, signal filtering and exercise load) doesn't allow an accurate draw-up of intensity-based guided ranking of the most used exercises. Several exercises (Table 1) can be included in on-field warm-up as they can be performed at any training facility without requiring special equipment.

The effect of strength exercises on adductors muscles has been examined in various studies on soccer players.[6,7] One study reported an increase of eccentric hip-adduction strength after 8-weeks strength training with elastic band on adductors muscles, and therefore could be incorporated into a injury prevention program.[5,6] Another study by Ishøi et al.[7] showed an increase of eccentric hip adduction and abduction strength of 36% and 20% in Danish football players after 8-weeks of a progressive in-season protocol with the Copenhagen Adductor exercise. In regard to its effect on muscle injuries, a study by Haroy and colleagues (currently in review) showed a 41% reduction in groin related injuries in sub-elite footballers in Norway with the integration of the Copenhagen Adductor exercise into the injury prevention program (Haroy et al., in review).

Different exercises should be incorporated in a global exercise-based injury prevention program, for example a study examining a combination of adductor and abdominal strengthening, jumping, coordination exercises and stretching found a 31% (albeit non-significant) reduction in groin related injuries in amateur footballers.[8,9] Therefore a preventative exercise program should be multi-dimensional, including not only exercises targeting the specific muscle (such as the Copenhagen Adductor protocol), but also sport specific activity and performance conditioning exercises (Table 1) as suggested in the general principles of injury prevention in the present guide.

IMPLEMENTATION REASON	EXERCISE
Activation / strength endurance / strengthening (low intensity injury prevention	Side-lying hip-adduction
	Ball squeezes (45-cm Swiss ball between knees)
	Side lunges
	Isometric adduction with a ball between ankles
	Standing hip adduction on Swiss ball
	Rotational squats (with elastic band around knees)
	Sumo squats
	Supine bilateral hip adduction
Strength	Copenhagen Adduction
	Hip adduction with elastic band/cable
	Hip adductor machine
	Sliding hip abduction/adduction
	Side-lying hip adduction with conic pulley (eccentric)
Plyometrics and performance conditioning	Agility (turns, change of directions)
	Sprints and High speed running
	Hops (forward and lateral)
	Carioca and sliding runs
	Lateral running
Flexibility	Sliding hip abduction
	Stretching of lower limb
	Dynamic stretching of lower limb

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Table 1
Examples of exercises that may be included in a prevention program for adductor muscle injuries

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Figure 1
Active stretching and mobilisation of the adductor muscles

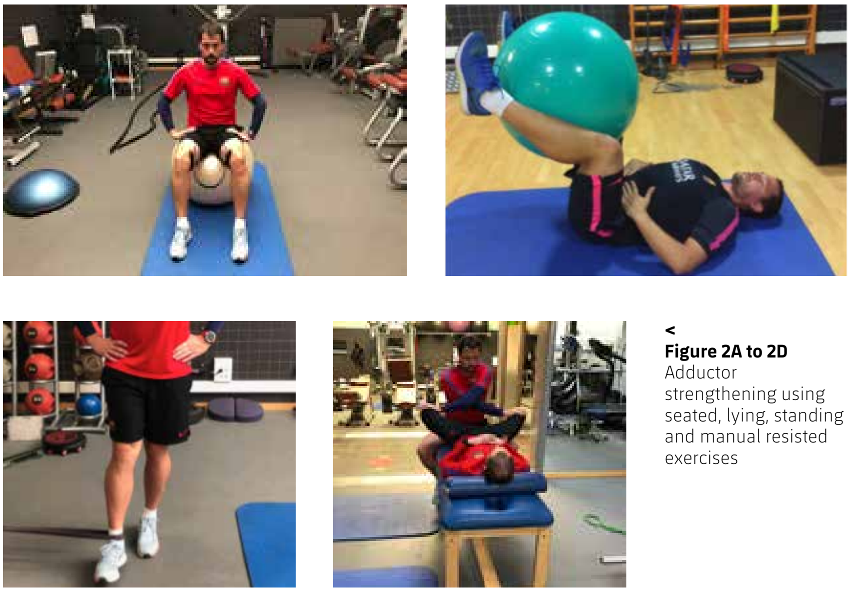

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Figure 2A to 2D
Adductor strengthening using seated, lying, standing and manual resisted exercises

THE BARÇA WAY

We use active mobilisation and stretching of the hips and adductor muscles (figure 1). A variety of exercises are incorporated on stable and unstable surfaces, standing, sitting or lying and sometimes with manual resistance (figures 2A to 2D). Exercises such as the side lunge train allow us to train using functional patterns in the gym (figure 3). Finally, we like our players to train with a focus on proprioception on the hip and core muscles (figure 4).

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Figure 3
Side lunge (can be performed with or without weight).

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Figure 4
Proprioceptive exercise for the hip and core muscles.

1.4.4f

EXERCISE SELECTION: CALF INJURY PREVENTION

Despite a lack of scientific evidence, there are a number of exercises and training activities that are likely useful in calf muscle strain injury prevention. The role of these exercises is to train the calf muscles to function optimally and to make the triceps surae more resilient to injury. Different variations of calf raise involving the knee in a straight (soleus and gastrocnemius) and flexed (soleus) position should be incorporated to fully promote calf muscle function.[1]
— With Tania Pizzari, Brady Green, Karin Silbernagel and Anthony Schache

These exercises can be classified according to the adaptations they are intended to bring about in the calf muscles: muscle activation, strength-endurance, maximal strength, plyometric and explosive muscle action, and flexibility and mobility. Due to the different nature of these exercises, they are best implemented during different parts of the overall training program. For example, calf muscle strengthening may be completed as part of the lower body-strengthening program, while plyometric drills can be performed during field-based training sessions as part of the on-field warm up (Table 1).

THE BARÇA WAY

Calf exercises are performed on stable and unstable surfaces, providing the player with a variety of stimuli (figures 1A to 1C) to on simultaneously with coordination drills of the lower and upper body are a key component of our exercise based preventative program for calf muscle injury (figures 2A to 2C). Running technique is trained using elastic bands, placing more stimulus on the calf muscles (figures 3A & 3B). As with the hamstring muscles, a key focus during the gym based exercises is to perform active stretching before, in-between and following the exercises (figures 4A & 4B). While calf exercises such as those mentioned above, form part of our preventative program for calf muscle strain injury, we want to emphasise that managing the on-field loads has more emphasis for us.

POSITION	KEY DEMANDS
Activation / Strength endurance / strengthening	Calf raise in knee extension (target gastrocnemius and soleus)
	Calf raise in knee flexion (mainly target the soleus)
Strength	Standing calf raise machine (Single leg standing calf raise in machine or Smith machine or free weights or isoinertial machine)
	Seated calf raise machine
Plyometrics and performance conditioning	Hopping drills
	Bounding drills
	Sprint and footwork drills (Marching A skips) (B skips)
	Hill runs (Forwards running up a hill)
Flexibility	Local calf stretch in knee extension
	Local calf stretch in knee flexion
	Global posterior line stretches (Long sitting) (Single leg downward dog)

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Table 1
Examples of exercises to include in the prevention program for calf muscle injury

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Figure 1A. Calf exercises on stable surface

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Figure 1B & 1C. Calf exercises on unstable surface

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Figures 2A, 2B and 2C. Calf exercises combined with coordination exercises.surface

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Figures 3A and 3B. Training running technique using elastic bands

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Figures 4A and 4B. Active stretches of the calf and soleus muscles

1.4.5

COMMUNICATION

Another of the most important injury prevention strategies as highlighted by elite football practitioners from the 'Big 5' Leagues in our Delphi Survey was 'communication'. A common opinion among football practitioners is that, to maximise the preventative effects of strategies such as controlling load and implementing exercise and recovery strategies, we must be able to communicate effectively with key stakeholders such as players and coaching staff, as well as among ourselves.
— With Mike Davison and Ricard Pruna

Good internal communication should help in the implementation of preventative strategies and perhaps more importantly, gain the 'buy in' of players and coaches. Whilst there is currently no scientific evidence for the effectiveness of communication to prevent muscle injury in elite football specifically, it makes sense that effective communication could be beneficial to maximise injury prevention strategies. A UEFA-led survey of 33 of the 34 Champions League teams competing in the 2014/15 season, revealed 'internal communication' as one of the most important risk factors for non-contact injury (muscle injury being a large component of non-contact injuries), and successful buy in from players and coaches as crucial to the success of injury prevention strategies.[1] The following is a philosophical view of how effective communication may help in the elite football setting and provides some examples of the FCB philosophy regarding communication.

WHAT IS COMMUNICATION?

Communication is simply the act of transferring information from one place to another. Although this is a simple definition, in a high-pressure environment such as that in elite football, it becomes a lot more complex. Successful communication can be considered as a combination of several important factors. Firstly, the right language needs to be used. Secondly, it is important to know the audience, considering their own injury experience, their cultural context, and their potential heuristics and biases. Finally, it is important to evaluate and ensure that the desired message has reached its target, and has been understood.

CATEGORIES OF COMMUNICATION

There are various categories of communication, of which more than one may occur or interact at any time. The different categories of communication include:

- Spoken or Verbal Communication: e.g. face-to-face, telephone
- Non-Verbal Communication: e.g. body language, gestures, how we dress or act
- Written Communication: e.g. e-mails, reports and medical notes
- Visualisations: e.g. graphs, charts, photos and other visualisations can communicate messages

Professor Albert Mehrabian is internationally well known for his publications on the relative importance of verbal and nonverbal messages. Some of the key findings from Mehrabian's work,[2-5] include; (i) 7% of the understanding of the message comes from the feelings and attitudes in the words that are spoken (verbal communication), (ii) 38% of the understanding of the message comes from the feelings and attitudes invoked by the words that are said (paraverbal communication), (iii) 55% of the understanding of the message comes from the feelings and attitudes translated in facial expression (non verbal communication).

We have to recognise there are many types of communication at play in a football club. They range in setting, in structure and in forms of interaction. However, it is often not the information itself that is important for the outcome, it is the way it is delivered. In the emotionally and often paranoid setting of a football club, the body language and tone dominate. Thinking more specifically about Football Medicine, the diversity and scope of potential conversations and communications is wide. Perhaps it is the widest in the football club environment, and this means that the doctors, physiotherapists, fitness coaches, sports scientists and team psychologists need to be skilled in communication to be effective.

WHY IS IT LIKELY TO BE IMPORTANT IN FOOTBALL?

Simply put, communication is at the heart of every successful organisation. It disseminates the information needed to get things done, and builds relationships of trust and commitment. Without it, team members end up working in silos with no clear direction, with vague goals and little opportunity for improvement. A team with high quality communication between different roles are likely to have good collaborations, and benefit from multiple perspectives in making informed decisions, for instance in those regarding players' well-being.

However, team morale can plummet when communication is ambiguous, unfocused, lacking in important details and where it does not allow for genuine two-way dialogue. A situation like this, where this low quality of internal communication, is one where there is increased risk of misunderstandings, one-sided decision-making and wrongful decisions.

We know from experience that organisational stress can have a negative impact on player welfare. An organisation with a lot of miscommunication, where members experience a lack of or insufficient information, and where their opinions are not considered, might create stress on staff and players. Football is a dynamic industry and with a constant transfer of coaches and players from different nations between different clubs, where the workplace can change from one day to another, there are common cultural as well as communication challenges to overcome.

It is therefore crucial for the Football Medicine and Performance team to try to maintain consistency and high quality levels of internal communication irrespective of organisational change, in order to avoid a potential deleterious effect on injury burden, and player welfare.

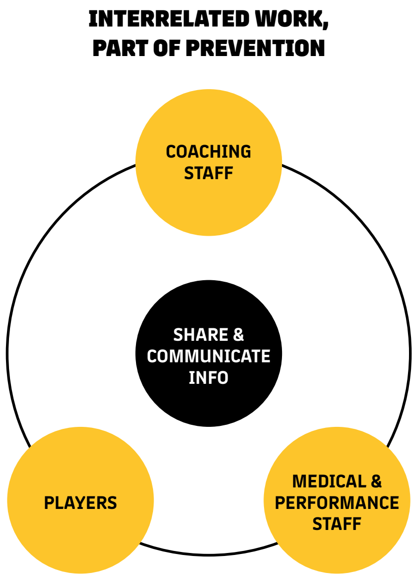

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Figure 1
A key component of the multi-faceted injury prevention program in FC Barcelona

THE BARÇA WAY

The Medical and Performance team have to be confident as well as willing and able to communicate their recommendations using simple language and even drawings to clearly illustrate their points and recommendations.

We need to be patient and take the time to educate the players, coaching staff and board members on key medical and performance concepts.

It is essential that we are honest and act in the best interests of the players, the club and fellow staff and not concerned with our own ego.

1.5

CONTINUOUS (RE) EVALUATION AND MODIFICATION OF PREVENTION STRATEGIES

A key phase of the Team Sport Injury Prevention (TIP) cycle is ongoing (re) evaluation of the injury situation to find out whether prevention strategies are actually having an impact. Are any new or different injury patterns emerging? This information is essential to allow the medical and performance team to adapt to a constantly changing injury landscape and ensure maximum prevention effectiveness over time.
— Alan McCall, Ben Clarsen, James O'Brien and Robert McCunn

RE-EVALUATING THE LANDSCAPE OF MUSCLE INJURIES IN YOUR TEAM

The key to ongoing evaluation of the injury landscape in your team throughout the entire season is injury surveillance.[1] The medical and performance team should record injuries consistently to ensure that data is comparable within and between seasons. We recommend using well-established injury definitions from published research. In this way, practitioners can compare not only within their own team, but also with data published in the scientific literature. Specifically, injury definitions and collection procedures should follow the guidelines set out in the 2006 Consensus Statement for the definition and data collection procedures for football (soccer) injuries.[2] This method is also used by the UEFA Elite Club Injury Study (ECIS), which provides insights into the largest database of football injuries anywhere in the world. The key aspects of the UEFA ECIS method include:

- An injury is defined as any physical complaint sustained by a player that results from a football match or training and leads to the player being unavailable to take full part in future football training or match-play (i.e. time loss).
- A player is considered injured until the club medical staff clear the player for full participation in training and availability for match selection.
- Injury severity corresponds to the number of days absence due to the injury.
- Individual player exposure (in minutes) for all training sessions and matches should be recorded to allow calculation of injury statistics.

Recording this information correctly is essential to the subsequent interpretation and actions decided. There are two particularly useful methods to calculate, report and monitor the muscle injury situation within your club (and indeed all injury types can be recorded this way), allowing accurate comparison to the published research literature.

1. Injury Incidence – corresponds to the rate of injuries and is calculated and reported as a number of injuries per 1000 hours of exposure (e.g. match exposure, training exposure and match + training exposure). For example, if a team has 10 injuries during 5,000 hours exposure, the injury incidence is 2 injuries for every 1,000 hours.* equation: #injuries/1000 hours of exposure
2. Injury Burden – corresponds to the cross product of severity AND incidence i.e. provides a combination of the rate of injury as well as a measure of loss i.e. days lost due to the injury (total number of days lost per 1000h). For example, if a team has 10 injuries during 5,000 hours exposure, each resulting in an average absence of 10 days, the injury burden is 20 days for every 1,000 hours. *equation: #days absence/1000 hours of exposure

WHY IS INJURY BURDEN SO IMPORTANT?

Although injury incidence can be useful to provide an evaluation of how often injuries will occur in your team, it says nothing about how severe they are. In contrast, burden measures incorporate both injury likelihood and severity.[1] This approach has been used for many years in rugby union[3] as well as in the UEFA ECIS during the last decade.[4,5]

Burden is best illustrated using a risk matrix illustrating injury likelihood (incidence) and severity (time loss).[1] Figure 1 illustrates the incidence plotted against the severity of various injuries, with the lighter to darker yellow shading representing the burden. This figure highlights the importance of evaluating both incidence and severity and how reporting one alone, does not provide the full picture of the muscle injury landscape in your team.

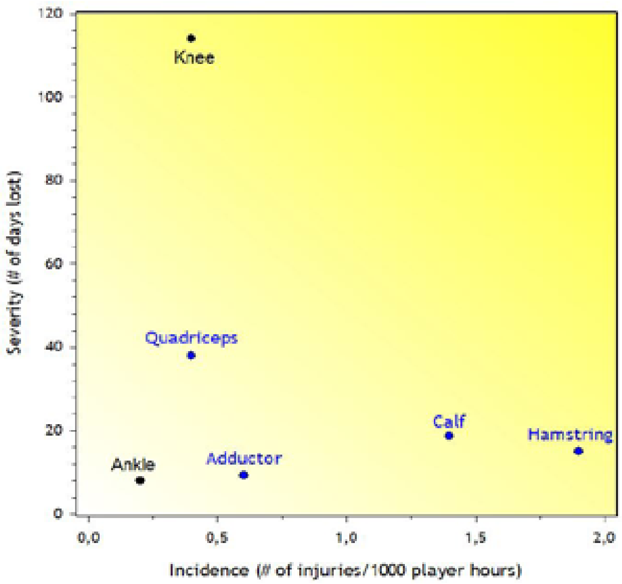

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Figure 1
Injury risk matrix showing reporting the incidence AND severity of various muscle injury locations and joint injuries for comparison. The yellow shading represents the injury burden i.e. the lighter the yellow shading, the lower the injury burden and vice versa, the darker the yellow shading, the greater the injury burden.

EVALUATING CURRENT INJURY PREVENTION PRACTICES IN YOUR CLUB

In addition to collecting injury data, it is essential to evaluate the injury prevention situation in your club. Are prevention strategies affecting the injury situation? Are they being consistently implemented? What do players and coaches think of the strategies? There is no gold standard for how these questions should be answered – it requires combining a quantitative (i.e. measurable, data-driven) and a qualitative approach.

In general, quantitative data tells us the what and the when (e.g. injury types, locations, incidences and burdens), whereas qualitative data may tell us the how and the why. For example, a qualitative approach is needed to investigate why a particular preventative strategy might be popular with players and coaches, and another one unpopular. A multitude of factors influence the injury prevention behaviour of players, coaches and team staff members. Even strategies shown to be highly effective in controlled research studies may not be utilised by players, coaches and support staff in the real world. The Nordic hamstring exercise is a perfect example of this conundrum; scientific evidence shows the exercise reduces the risk of initial hamstrings injuries by 59% and recurrent injuries by 86%, (though not in elite players) yet a majority of UEFA Champions League teams do not use it.[6] Qualitative research methods can be an important tool for understanding the reasons behind your team's injury prevention situation.

Qualitative methods include, but are not limited to, interviews, focus groups and surveys.[7] While it may seem unnecessarily over complicated to refer to 'qualitative data collection' instead of simply 'talking to your colleagues', incorporating scientific rigour to the process can be valuable. Using tools such as standardised surveys and semi-structured interviews, and considering factors such as how, when and where you ask certain questions might allow you to collect more relevant, systematic insights and present your conclusions with credibility. Table 1 provides some suggestions for employing qualitative methods to evaluate the injury prevention situation in your team, taking the implementation of the Nordic Hamstring Exercise (NHE) program as an example:

WHO TO ASK*	HOW TO ASK	WHEN TO ASK	WHAT TO ASK (Ex)
Players Football coaches Medical and performance staff Club officials	Surveys Focus groups Interviews	As part of routine team meetings Formal injury prevention evaluation sessions Individual player performance reviews	How many of the planned NHE sessions were carried out? Were the correct number of sets and repetitions performed? What was the quality of exercise execution? Do you see any benefits of using the NHE program? Does the program have any negative side-effects? Are there any barriers for using the NHE program? Was the program modified? (Why?) Do you use alternate strategies? (Why?) Do you intend to continue using the NHE program? Could the NHE program be adapted to better fit your team's situation?

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Table 1
Suggestions for employing qualitative evaluation in a team setting

* It is important to ask individuals from all the groups involved in the injury prevention strategy; players (who perform the program); team staff members (who deliver the program) football coaches (who often act as "time-keepers") and club officials (who determine club policy and provide resources e.g. financial).

Acknowledging the fast and frenetic pace of football, continual evaluation is crucial in this phase of the Injury Prevention cycle. This will allow the medical and performance team to audit and identify emerging patterns in the injury situation and take subsequent action. Although it may be normal to discuss the injury situation in daily and weekly medical meetings, we recommend a more formal evaluation performed 2 to 3 times per season, including coaches, other support staff and even some players. During this evaluation, injury statistics, qualitative analyses and reviews of injury prevention research and innovative strategies can be discussed in depth.

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