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LA PRÉVENTION DES BLESSURES DANS LE FOOTBALL PROFESSIONNEL

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LISTE DES PUBLICATIONS

1) Publications en relation avec l'objet de la thèse

1. **McCall A,** Carling C, Nedelec M, Davison M, Le Gall F, Berthoin S and Dupont G. Injury risk factors, testing and preventative strategies for non-contact injuries in professional football: Current perceptions and practices of 44 teams from various Premier Leagues British Journal of Sports Medicine. Published online first May 16 2014; doi: 10.1136/bjsports-2014-093439 (**Publication acceptée**).

2. **McCall A**, Carling C, Davison M, Nedelec M, Le Gall F, Berthoin S and Dupont G. Injury risk factors, testing and preventative strategies for non-contact injuries in football: A systematic review of the current perceptions and practices of 44 teams from various Premier Leagues In review at British Journal of Sports Medicine. July 2014 (**Publication soumise**).

3. **McCall A,** Nedelec M, Carling C, Le Gall F, Berthoin S and Dupont G. A simple isometric posterior lower limb muscle test in professional soccer players. In review at International Journal of Sports Medicine. April 2014 (**Publication soumise**).

4. **McCall A,** Fanchini M, Impellizzeri FM, Carling C, Berthoin S and Dupont G. Internal workload and non-contact injury incidence in elite soccer players competing in the UEFA Champions and Europa Leagues. In Review at Medicine and Science in Sport and Exercise. August 2014 (**Publication soumise**).

5. **McCall A,** Carling C, Davison M, Nedelec M, Le Gall F, Berthoin S and Dupont G. Effect of an injury prevention program on injury rate in a professional soccer team participating in European

competition. In revision at Journal of Strength and Conditioning Research. June 2014 (**Publication soumise en révision**).

2) Autres publications

1. Chris Carling, **Alan McCall**, Franck Legall, Mathieu Nedelec, Gregory Dupont. Squad management, injury, tactical and technical performance over a professional Championship winning season. In revision European Journal of Sports Sciences. July 2014

2. Maurizio Fanchini, Franco Schena, Carlo Castagna, Adam Petruolo, Franco Combi, **Alan McCall**, Franco Impellizzeri. External responsiveness (longitudinal validity) of the YO-YO intermittent Recovery Test in soccer players. In revision – Journal of Sports Sciences. July 2014

3. Maurizio Fanchini, Carlo Castagna, Aaron Coutts, Franco Schena, **Alan McCall**, Franco Impellizzeri. Are the Yo-Yo Intermittent Recovery tests level 1 and 2 both useful? Reliability, responsivenenss and interchangeability. In revision Journal of Sports Science June 2014.

4. Mathieu Nedelec, **Alan McCall**, Chris Carling, Franck Legall, Serge Berthoin, Gregory Dupont. The influence of soccer playing actions on the recovery kinetics after a soccer match: Journal of Strength & Conditioning Research 2013: Epub: Ahead of print.

5. Mathieu Nedelec, **Alan McCall**, Chris Carling, Franck Legall, Serge Berthoin, Gregory Dupont. Recovery in Soccer – Part II: Recovery Strategies. Sports Medicine. 2013: 43(1): 9-22.

6. Mathieu Nedelec, Ulrik Wisloff, **Alan McCall**, Serge Berthoin, Gregory Dupont. Recovery after an intermittent test. International Journal of Sports Medicine: 2013; 34(6): 554-558.

7. Mathieu Nedelec, **Alan McCall,** Chris Carling, Franck Legall, Serge Berthoin, Gregory Dupont. Physical performance and subjective ratings after a soccer-specific exercise simulation: comparison of natural grass versus artificial turf. Journal of Sports Sciences. 2013; 31(5): 529-536.

8. Mathieu Nedelec, **Alan McCall**, Chris Carling, Franck Legall, Serge Berthoin, Gregory Dupont. Recovery in Soccer – Part I: Post match fatigue and time course of recovery. Sports Medicine. 2012: 1:42(12): 997-1015.

9. Mathieu Nedelec, **Alan McCall**, Serge Berthoin, Gregory Dupont. Recovery kinetics of cognitive performance, physical performance and subjective ratings in soccer goalkeepers and outfield players..Journal of Sports Sciences. 2012. Nov 5 Epub ahead of print.

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13. Gregory Dupont, **Alan McCall**, Fabrice Prieur, Mathieu Defontaine, Grégoire Millet, Serge Berthoin. Oxygen uptake kinetics and repeated sprints. European Journal of Applied Physiology: 2010; 110: 627-634.

14. Gregory Dupont, Mathieu Nedelec, **Alan McCall**, Derek McCormak, Serge Berthoin, Ulrik Wisløff. Effect of two soccer matches in a week on the physical performance and on the injury rate. American Journal of Sports Medicine: 2010; 38(9): 1752-1758.

<u>3) Présentations orales en relation avec l'objet de la thèse</u>

1. **Athletic Club Bilbao, Bilbao, Spain**

Sport Science and soccer: Reducing the gap from research to field. April, 2014

2. **Swedish Football Federation, Stockholm, Sweden**

Sport Science and soccer: Reducing the gap from research to field. March, 2014

3. **Tunisian Science & Soccer Association, Tunisia, Africa**

Sport Science and soccer: Reducing the gap from research to field - Injury risk, testing and prevention in premier league soccer clubs. December, 2013

4. **University of Lugano, Switzerland**

Injury risk, testing and prevention in premier league soccer clubs. October, 2013

5. **University of Napier, Edinburgh, Scotland, UK**

Recovery strategies in elite football. February, 2013

6. **Lille University, Lille, France**

Cultural Differences in Soccer Europe vs Australia. October, 2012

7. **Norwegian Football Federation, Oslo, Norway**

Application of Science in Elite Soccer: Department structure and training program. February, 2012

8. **University of Rennes, Rennes, France**

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RÉSUMÉ

Dans le football professionnel, les blessures ont un impact négatif sur la performance, les finances du club et la santé des joueurs. Dans une équipe professionnelle de football de 25 joueurs, la moyenne des blessures est de 50 par saison, ce qui correspond à 2 blessures par joueur par saison. Les trois principaux objectifs de la présente thèse étaient : 1) d'analyser le lien entre les évidences scientifiques relatives à la prévention des blessures en football et les pratiques, 2) d'étudier les nouvelles stratégies qui pourraient permettre d'identifier les facteurs de risque des blessures sans contact, et 3) de mettre en œuvre un programme d'entrainement de prévention de blessures afin de réduire la fréquence des blessures sans contact chez des footballeurs professionnels. Cinq études ont été menées dans cette thèse: (1) une enquête sur les facteurs de risque, les tests d'évaluation et les stratégies de prévention des blessures utilisés dans le football professionnel; (2) une revue systématique sur les facteurs de risque, les tests d'évaluation et les stratégies de prévention des blessures sans contact dans le football professionnel; (3) la fiabilité et la sensibilité d'un test isométrique des muscles postérieurs des membres inférieurs ; (4) la relation entre la charge de travail et son incidence sur la fréquence des blessures sans contact chez les joueurs professionnels du football ; (5) les effets d'un programme de prévention des blessures sur l'incidence des blessures dans une équipe professionnelle de football. Les résultats ont permis une analyse du lien entre les évidences scientifiques et les principales perceptions et pratiques des équipes de football professionnel concernant les facteurs de risque, les tests d'évaluation et les exercices de prévention (études 1 et 2). Le test isométrique s'est révélé fiable et sensible pour détecter les changements de force après un match de football (étude 3). La charge de travail global n'est pas associée à l'incidence des blessures dans le football professionnel de haut niveau ; par contre, l'incidence des blessures est associée avec une charge de travail hebdomadaire plus importante que celle habituellement réalisée et cela dans les 3 semaines précédant la blessure (étude 4). Le programme de prévention des blessures a permis une réduction significative de l'incidence des blessures (étude 5). Ces résultats devraient permettre de réduire dans le futur l'incidence des blessures dans le football professionnel de haut niveau.

Mots clés : Charge d'entraînement, Test, Enquête, Risque.

ABSTRACT

In Professional football, injuries have a negative impact on the performance and economy of a club and on the health of the players. An elite professional team of 25 players can expect 50 injuries per season, corresponding to 2 injuries per player per season. The three principal objectives of the present thesis were: 1) to analyse the link between the scientific evidence concerning injury prevention and the injury prevention practices in professional football teams, 2) to investigate novel strategies that can allow identification of risk factors for non-contact injuries and 3) to implement an injury prevention program to reduce non-contact injury incidence in professional footballers. Five studies were conducted during the course of the present thesis: (1) a survey concerning the risk factors, testing and preventative strategies used to prevent non-contact injuries in professional football teams; (2) a systematic review of the risk factors, tests and preventative strategies used to prevent non-contact injuries in professional football teams; (3) the reliability and sensitivity of an isometric test of posterior lower limb muscle force; (4) the relation between workload and non-contact injury incidence in professional footballers; (5) the effects of an injury prevention program on injury incidence in a professional football team. The results have analysed the link between the scientific evidence and risk factors, tests and preventative strategies used by professional football teams (studies 1 and 2). The isometric test was shown to be reliable and sensitive to detect changes in force after a football match (study 3). The total workload was not associated with injury incidence in professional football; the injury incidence was however, associated with a greater weekly workload than the ‘usual’ workload, which was evident in the 3 weeks before the injury (study 4). The injury prevention program demonstrated a significant reduction in injury incidence (study 5). These results should aid in reducing future incidence of injury in elite professional football.

Keywords: Training load, Test, Survey, Risk.

SOMMAIRE

1° Introduction

Bien que bénéfique, la pratique d'exercices et de sports comporte des risques, notamment des blessures musculaires et articulaires. Selon Bahr et al. (2002), une consultation médicale sur 6 est liée à la pratique sportive, alors qu'une hospitalisation sur 3 est également liée à la pratique sportive chez l'enfant. Il y a actuellement plus de 65000 joueurs de football professionnels actifs à travers le monde (FIFPro, 2014). Le football a été décrit comme une activité à très haut risque, la probabilité de se blesser en football est 1000 fois plus importante que dans les emplois industriels les plus risqués (Drawer et Fuller, 2002). Les blessures sans contact représentent 28 à 76% de la totalité des blessures en football (Arnason et al., 2004 ; Dupont et al., 2010 ; Ekstrand et al., 2011). Face à ce constat, la prévention des blessures apparaît importante pour réduire cette incidence. Van Mechelen et al. (1992) ont proposé un modèle de prévention des blessures en 4 étapes :

1) Etablir l'importance des blessures : incidence et sévérité
2) Etablir l'étiologie et les mécanismes des blessures
3) Introduire une mesure préventive
4) Evaluer l'efficacité en répétant l'étape 1.

La première étape de ce modèle, relative à l'importance du problème des blessures dans le football professionnel, a été décrit dans la littérature scientifique. Dans le football professionnel, les blessures ont une influence négative sur la performance, l'économie et la santé. Concernant la performance, une incidence de blessures moindre est corrélée de manière forte ($r=0.93$, $p<0.01$) avec le classement final en championnat d'une équipe (Eirale et al., 2012) et le succès en Ligue des champions UEFA ou en Europa League (Hagglund et al., 2013). D'un point de vue financier, étant donné que les salaires des joueurs professionnels de football sont élevés, cela représente un coût très important pour les clubs dont les joueurs sont blessés. Le coût moyen d'un joueur blessé a été estimé à 500 000 euros pour une équipe professionnelle européenne de football (Ekstrand, 2013). Enfin, il peut y avoir des répercussions importantes sur la santé à plus long terme des joueurs. Il a été rapporté que 47% des footballeurs professionnels étaient obligés de prendre leur retraite à cause d'une blessure (Drawer & Fuller, 2001). En ce qui concerne les blessures dans cette population, une équipe professionnelle de football de 25 joueurs serait confronté à environ 50 blessures par saison, c'est à dire deux blessures par joueur par saison (Ekstrand et al., 2011; Ekstrand et al., 2013). La moitié de ces blessures est mineure et entraînent une absence du joueur inférieure à une semaine, tandis que huit à neuf blessures sérieuses engendrent une absence supérieure à quatre semaines (Ekstrand et al., 2011). Les blessures identifiées comme les plus fréquentes chez les footballeurs professionnels sont les blessures aux ischio-jambiers (12.8%), les blessures aux muscles adducteurs (9%), les entorses de la cheville (7%), les blessures aux quadriceps (5%), les blessures aux mollets (4.5%) et les entorses du genou (4.3% ; Ekstrand et al., 2013). Parmi toutes ces blessures, les blessures aux ischio-jambiers sont les plus fréquemment touchées chez les joueurs de haut niveau (Ekstrand et al., 2013; 2011) et celles générant l'indisponibilité la plus longue (Ekstrand et al., 2013).

La deuxième étape du modèle concerne la détermination des facteurs associés aux blessures. Différents facteurs de risque ont été avancés chez les footballeurs de haut niveau. Cela inclut, par exemple, les antécédents de blessures (Hagglund et al., 2013; Hagglund et al., 2006; Arnason et al., 2004), les déséquilibres musculaires (Fousekis et al., 2011; Croisier et al., 2008) et la fatigue (Small et al., 2010). Bien que de tels facteurs de risque soient considérés comme élevés pour les blessures dans cette population, tous ne sont pas validés par la littérature scientifique. Les antécédents de blessures sont considérés comme le facteur de risque le plus avéré chez le footballeur professionnel (Ekstrand 2013; Arnason et al., 2004), alors que les autres facteurs sont encore débattus. A notre connaissance, aucune étude qui ait examiné le niveau d'évidence scientifique des facteurs de risque fréquemment cités. Il serait intéressant d'étudier ces niveaux d'évidence scientifique pour guider les praticiens dans le choix des tests et les chercheurs dans les études à mener. Bien qu'elles n'aient pas encore été validées, la fatigue et la baisse de force concomitante des ischio-jambiers sont fréquemment présentées comme étant un facteur de risque pour les blessures aux ischio-jambiers (Ekstrand et al., 2011; Small et al., 2010). De ce fait, tester régulièrement la force des ischio-jambiers chez les joueurs à la fin des matches et pendant la période de récupération pourrait permettre d'identifier les joueurs à risque. Cependant, traditionnellement, les tests de la force des ischio-jambiers sont réalisés en utilisant un dynamomètre isocinétique (Robineau et al., 2012; Small et al., 2010; Rahnama et al., 2003) qui présente un manque de portabilité et nécessite un temps trés long pour tester régulièrement une équipe d'onze joueurs (plus d'une heure). Certains tests de terrain pratiques ont été proposés pour détecter le risque de blessures aux ischio-jambiers (Mendiguchia et al,, 2014; Sconce et al., 2014; Freckleton et al., 2014; Opar et al., 2013), cependant leur utilisation lors de la période de récupération suite à un match est limitée puisqu'elle implique une très forte contrainte sur les ischio-jambiers, qui pourrait accentuer le risque de blessure. Néanmoins, étant donné que les blessures aux ischio-jambiers sont les plus fréquentes, il serait intéressant d'élaborer un test suffisamment fiable et sensible pour tester la récupération de ce groupe musculaire après un match de football, sans accentuer le risque de blessure lors du test.

D'autres facteurs de risque, comme la charge d'entraînement mérite également d'être étudié. La charge de travail englobe la charge subie à entraînement et en match. La charge de travail interne peut être quantifiée en utilisant une échelle de perception de l'effort (Borg CR-10) en multipliant la valeur de perception par la durée de la séance ou du match (Foster et al., 2001) ; cela fournit une représentation de la perception propre d'un sportif à un stress physique et psychologique (Impellizzeri et al., 2004). L'utilisation de la perception de l'effort pour mesurer la charge de travail interne a été validée pour être utilisée dans le football (Impellizzeri et al. 2004). Bien que cela n'ait pas été montré dans le football professionnel, la charge de travail interne imposée à un joueur lors des entraînements et des matches pourrait être liée aux blessures sans contact au sein de cette population. Il serait intéressant d'étudier la relation entre la charge de travail et l'incidence des blessures sans contact chez des joueurs professionnels.

L'étape 3 du modèle concerne l'introduction de la mesure de prévention. Un programme de prévention des blessures a pour but de réduire l'incidence des blessures. Des exercices spécifiques de prévention ont été caractérisés en ciblant les facteurs de risque chez le joueur comme la force et l'équilibre musculaire. Le travail en excentrique des ischio-jambiers est recommandé pour prévenir les blessures les joueurs de football professionnels (Petersen et al., 2011; Arnason et al., 2008; Askling et al., 2003). Les exercices d'équilibre et de proprioception ont également été recommandés pour réduire l'incidence des entorses de la cheville (Mohammadi, 2007; Tropp et al., 1983) et les ruptures des ligaments croisés du genou (Carraffa et al., 1996) ; cependant l'effet sur d'autres blessures du genou n'est pas encore connu pour cette population. Les études ayant étudié d'autres exercices de prévention des blessures chez le footballeur professionnel de haut niveau sont manquantes. Jusqu'à présent, des programmes de renforcement musculaire des adducteurs (exercices excentriques, concentriques et fonctionnels ; Fredberg et al., 2008) n'ont pas montré d'effet significatif sur l'incidence des blessures. De même, les renforcements en excentrique du tendon rotulien et du tendon d'Achille n'ont pas montré d'effet significatif sur les blessures chez le footballeur professionnel de haut niveau (Holmich et al., 2010). Il serait intéressant de déterminer l'efficacité d'exercices de prévention sur l'incidence des blessures chez le footballeur professionnel.

La dernière étape du modèle concerne l'évaluation de l'efficacité des stratégies préventives. L'incidence de la blessure chez le footballeur professionnel a été analysée au cours d'une période allant de 2001 à 2012 (11 saisons sportives) chez des équipes évoluant au plus haut niveau du football européen (Ekstrand et al., 2013). Il a été trouvé que pendant la période impliqué, l'incidence globale de blessures et les blessures musculaires n'avaient pas diminué. Selon ces auteurs, des programmes de prévention qui ciblent la force, l'équilibre et la coordination pourraient ne pas être suffisants pour réduire les blessures dans cette population (Ekstrand et al., 2013). Les effets d'un programme de prévention multifactoriel se focalisant sur la réduction de l'incidence de toutes les blessures sans contact n'ont pas encore été étudiés chez des joueurs professionnels de haut niveau.

L'utilisation de ce modèle (Van Mechelen et al., 1992) a contribué à la mise en œuvre de la présente thèse. Un des objectifs de la démarche scientifique est d'étudier les évidences scientifiques de la littérature pour aider les chercheurs dans l'élaboration des études à mener. L'étude de ces évidences scientifiques peut également permettre aux praticiens de choisir les évaluations et les pratiques les plus pertinentes. Dans le domaine de la prévention des blessures la science peut aider les praticiens à identifier les facteurs de risque, les tests et la stratégie de prévention les plus appropriés. Cependant, le nombre de publications scientifiques sur ces thématiques est limité. Une recherche de la littérature via la base de donnée ‘Pubmed’ réalisée le 24 février 2014 en utilisant les termes suivants : ‘injury, prevention, soccer/football’ a identifié 26 articles se focalisant sur des joueurs de football professionnels de sexe masculin. Il y a actuellement un fossé entre la science et la pratique (Bishop et al., 2008). Une démarche scientifique intéressante pour rapprocher ces deux pôles pourrait consister : 1) à valider ou réfuter les croyances et pratiques qui sont couramment utilisées par les équipes professionnelles et 2) de prendre en compte les problèmes importants rencontrés dans la pratique de tous les jours et fournir des solutions significatives.

La principale question posée dans cette thèse était **‘Est-il possible de réduire les blessures sans contact dans le football professionnel au plus haut niveau ?’**

Les trois principaux objectifs de cette thèse étaient : 1) d’étudier le fossé entre ce qui est actuellement fait sur le terrain et ce qui est connu dans la littérature scientifique dans le domaine de la prévention des blessures, **2)** d’expérimenter de nouvelles stratégies qui peuvent fournir des informations pour identifier les joueurs présentant un risque de blessure sans contact et **3)** fournir un programme d’exercices de prévention pour réduire les blessures sans contact.

Cinq questions de recherche ont été posées :

Question 1) Quelles sont les perceptions actuelles et les pratiques dans les équipes de football de haut niveau concernant les facteurs de risques, l’évaluation et les stratégies de prévention des blessures sans contact ?

Question 2) Quel est le niveau d’évidence scientifique des perceptions actuelles et des pratiques utilisées par les équipes professionnelles ?

Question 3) Peut-on développer un test simple et pratique qui soit à la fois fiable et sensible pour identifier le risque de blessures du groupe musculaire des ischio-jambiers ?

Question 4) Quelle est la relation entre la charge de travail et les blessures sans contact chez les footballeurs professionnels jouant au plus haut niveau ?

Question 5) Un programme de prévention des blessures peut-il être appliqué à une équipe de football professionnel qui joue régulièrement deux matches par semaine pour réduire le risque de blessures ?

Les parties suivantes de cette thèse montrent étape par étape le processus permettant de répondre à ces questions spécifiques.

2° Relation entre recherche et pratique dans la prévention des blessures dans le football professionnel

2.1 Étude 1 : Facteurs de risques, tests et stratégie de prévention des blessures sans contact dans le football professionnel : représentations et pratiques de 44 équipes.

Introduction

There are currently more than 65,000 actively participating professional footballers registered worldwide.[1] The risk of injury in professional football is approximately 1000 times greater than other occupations, therefore injury prevention is of utmost importance.[2] In professional football, injuries have a negative influence on performance, economy and health. Regarding performance, a lower injury incidence has been shown to be strongly correlated ($r=0.93$, $p<0.01$) with a team's final League ranking[3] and success in the UEFA Champions League or Europa League.[4] From a financial perspective, given that the player salary costs for professional football clubs are high, a substantial cost for the club is incurred if a player cannot play due to injury. In addition, injuries involve medical fees and increased insurance premiums.[5] Finally, there can be severe repercussions on the long-term health of players. It has been reported that 47% of professional football players were forced to retire due to injury and 32% medically diagnosed as suffering from osteoarthritis.[6]

Despite the significant impact of injuries, little is known about the injury prevention practices employed by professional football teams. A literature search via the Pubmed database (24th February 2014) using the following keywords; 'injury, prevention, soccer/football' identified only 26 articles focusing on professional male football players. Although science should help practitioners to identify risk factors and to choose the most appropriate preventative strategies, there is still a gap between science and practice.[7] To the best of our knowledge, no large-scale survey on injury prevention has been published, and it is not known what practitioners do in terms of tests and prevention. There is a need therefore, to determine the perceived injury risk factors, as well as the injury risk tests and preventative strategies employed for non-contact injuries in professional football teams. A survey could help to analyse and subsequently reduce this gap in knowledge. The purpose of the present study was to determine through an international survey, the current perceptions and practices of medical and science professionals working at the highest level of elite football regarding injury risk factors, injury risk testing and preventative strategies for non-contact injuries.

Methods

Participants

Ninety-three clubs in total were invited to participate in this structured survey. The choice of clubs was determined by access to direct contact details. The invitation was sent to either the Head of the Medical or Head of the Science department by email, depending on the direct contact we had for the club. The email explained the purpose of the survey. Clubs were asked to complete and return the survey by email. An option to call to take responses over the phone was also offered. The telephone calls were undertaken by the first author. Only 2 clubs were interviewed by telephone (both English speaking). During the telephone calls, questions were asked, as per the guidelines of a structured interview. This was to ensure that there was no bias between responses collected via email and those collected via telephone. When a questionnaire was only partially completed, follow-up contact was made with 14 clubs via email and no follow up telephone calls were made. Eleven clubs responded to this follow up action. If a question was still unanswered it was excluded from the analysis. Data were collected between January and May 2013, and concerned the full season 2012/13 or in the case of Major League Soccer (MLS) and Australian, A-league Season 2012. A report of the global results was sent to all participating clubs. Forty-four of the 93 (47.3%) clubs invited to participate completed a survey, 3 clubs (3.2%) declined to participate, and 46 clubs did not reply (49.5%).

Clubs were asked to tick either 'agree' or 'disagree' in response to the following statement; 'The global results of the survey could be published in congress, courses and scientific articles. Individual responses filled will be anonymous'. All clubs who responded with a completed survey ticked 'agree'. All clubs were informed of the purpose and objectives of the study. A full list of participating clubs and corresponding country and league is presented in Table 1.

Table 1: Details of survey respondents (country, league and name of club).

	League and Country									
	Argentinan Primera Division	**Australian A-League**	**English Premiership**	**French Ligue 1**	**Dutch Endrivise**	**Italian Serie A**	**Scottish Premier League**	**Spanish Primera Liga**	**Swedish Allvensk an Liga**	**USA & Canadian Major League**
Club name	CA Boca Juniors	Adelaide United	Arsenal FC	SC Bastia	AFC Ajax	FC Internazionale Milano	Heart of Midlothian	Athletic Club Bilbao	Orgyte IS	Chicago Fire
		Brisbane Roar	Everton FC	Lille OSC			Rangers FC	RCD Espanyol		Columbus Crew
		Melbourne Heart	Liverpool FC	FC Lorient			St Mirren FC	SAD Vallodolid		FC Dallas
		Melbourne Victory	Newcastle United FC	Olympique Lyonnais						FC Kansas City
		Newcastle Jets	Norwich City FC	AS Nancy						Montreal Impact
		Perth Glory	Reading FC	OSG Nice						New England Revolution
		Western Sydney Wanderers	Southampton FC	Stade Rennais						Portland Timbers
			Sunderland FC	Troyes AC						Seattle Sounders
										Toronto FC
										Vancouver Whitecaps

Survey

The survey consisted of 17 questions (appendix A) and included 4 sections: (1) the persons involved in the injury prevention program, (2) perceptions regarding non-contact injury risk factors, (3) tests used to identify non-contact injury risk and (4) non-contact injury prevention exercises utilised, their perceived effectiveness and implementation strategies. Two closed questions and 15 open questions were posed to the clubs. The questions were designed during a round-table discussion involving 2 sport scientists and 1 sports medicine doctor. The design of the questions took into consideration their combined knowledge and experience in professional football and their work in peer reviewed research.

The survey was pilot-tested with 3 professional teams before the official invitation to clubs to participate. Following the pilot survey, we deleted one question: asking clubs to specify their injury rates as it was deemed to be too sensitive.

Statistical analyses

The absolute and relative values were calculated from information contained in the returned questionnaires. The normality distribution of the data was checked with the Shapiro-Wilk test. Differences were tested using student t-test when parametric methods were used or the unpaired Mann Whitney test when non-parametric methods were used and with a one-way ANOVA. Where appropriate, post hoc comparisons were made with the Bonferroni test as data were normally distributed. The magnitude of differences between quantities of staff type was also expressed as standardized mean difference (effect size, ES). The criteria to interpret the magnitude of the ES were as follows: 0.0 – 0.1 trivial, very small, 0.1 – 0.3 small, 0.3 – 0.5 moderate, 0.5 – 0.7 large, 0.7 – 0.9 very large, >0.9 almost perfect, >1 perfect.[8] To calculate the overall importance of each risk factor, a points system was used where a risk factor perceived to be ‘very important’ was awarded 3 points, ‘important’ corresponded to 2 points, ‘somewhat important’ was given a score of 1 point and ‘not important’ was awarded 0 points. The total of these points were summed and then risk factors were ranked in order of highest overall summed points to lowest. A similar method was used to determine the ‘the 5 most important exercises’ in the injury prevention program. Clubs were asked to rank in order of importance (1st to 5th) the exercises they considered as the most important in their injury prevention program. Points were awarded as follows; exercises rated in 1st position were given 5 points, 2nd position scored 4 points, 3rd position – 3 points, 4th position 2 – points and 5th position – 1 point. Points for each exercise were summed and ranked in order from highest score to lowest score. Significance was accepted at $p<0.05$.

Results

Survey

Background information

Forty-four questionnaires were included in the analysis; the respondents consisted of 27 sport science staff, 9 physiotherapists and 8 medical Doctors.

Persons involved in the injury prevention program design

Quantity of staff type

Table 2 details the quantity of staff type involved in the injury prevention program. There were significantly more physiotherapists than doctors ($p<0.0001$, ES=1.16, perfect), and sport science staff ($p<0.0001$, ES=0.29, small). Also there were significantly more sport science staff than Doctors ($p<0.0001$, ES=0.53, large).

Table 2: Quantity of staff per premier league club (Mean±SD and range) directly involved in the injury prevention program.

Position	Quantity (mean)	Standard Deviation	Range
Doctor	0.8	1.1	0 – 5
Physiotherapist	2.5*	1.4	0 – 7
Sport Science	1.6	1.0	0 – 4
All combined	5.1	2.4	1 - 11

* Significantly more physiotherapists than doctors and sport scientists ($p<0.0001$)

Qualifications of staff

Of the 25 doctors whose qualifications were specified, 2 (9.1%) held a PhD. Of a total of 93 physiotherapists, 1 (1.1%) possessed a PhD. Regarding the sport science staff, 8 (13.3%) of 60 successful responses possessed a PhD.

Specific role of staff

Table 3 details the specific roles of staff in regards to the design, testing and application of the injury prevention program.

Table 3: Specific role of staff involved in the injury prevention program (%)

Position	Design (%)	Test (%)	Application (%)	Design+ Test (%)	Design+ Application (%)	Test+ Application (%)	Involved in all 3 aspects (%)
Doctor	11.8	35.3	5.9	5.9	0	0	41.2
Physiotherapist	3.8	0	3.8	3.8	2.6	7.7	78.2
Sport science staff	5.6	0	11.1	43.7	7.4	9.3	63

Perceived non-contact injury risk factors

The 5 most important risk factors for non-contact injury rated by practitioners are presented in Table 4.

Table 4: Perceived importance of non-contact injury risk factors according to premier league teams: Ranked in order of 'most important to least important'.

Ranked importance	Risk factor	Accumulated 'points of importance' (maximum points = 132)
1st	Previous Injury	121
2nd	Fatigue	105
3rd	Muscle imbalance	99
4th	Fitness	97
5th	Movement efficiency	83

Tests used to identify non-contact injury risk

All clubs tested for injury risk during pre-season, 36 (81.2%) in-season and 18 (40.9%) at the end of the season.

The type of tests used by clubs is presented in Figure 1. Additionally, 10 (22.7%) clubs tested flexibility, 9 (20.5%) employed orthopaedic evaluations, 7 (15.9%) used an adapted Functional Movement Screen (FMS), 6 (13.6%) measured biochemical markers (e.g. vitamin D, magnesium, copper, lactate, full blood profile, salivary immunoglobin A, testosterone and cortisol), and 5 (11.4%) assessed balance/proprioception/coordination. Twenty-two (50%) clubs used other types of tests to detect injury risk. These included MRI and X-ray (2), running function (2) and verbal interview with players (2).

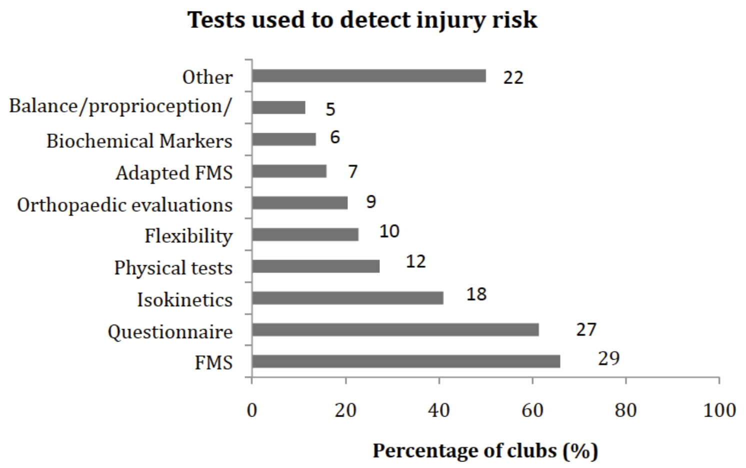

Figure 1: Tests used by premier league clubs to detect non-contact injury risk (number on bar corresponds to n of teams).

Non-contact injury prevention exercises utilised, perceived effectiveness and implementation strategies

For all clubs an injury prevention program was stated to be of benefit and all prescribed an injury prevention program to their players. Thirty-two (72.7%) clubs prescribed both an individualized and global injury prevention program to their players. The exercises used by clubs in the injury prevention program are detailed in table 5.

Table 5: Exercises used by premier league clubs to prevent non-contact injuries (%).

Exercise type	Clubs using this exercise type (%)
Core	100
Balance/proprioception	95.5
Stretching	81.8
Eccentric	79.5
Nordic	65.9
Isokinetic	40.9
Functional training (movement & strength)	40.9
Pilates	34.1
Lower body multi-joint strength	31.8
Glute activation & hip/pelvis disssacociation	29.5
Flywheel	20.5
Yoga	6.8
Foam roller	6.8
Slide board	6.8
Upper body strength	4.5
Oblique activation	4.5

The five most effective exercises implemented in the injury prevention program

The 5 most effective exercises used in the injury prevention program as rated by practitioners are presented in Figure 2 (six exercises in total, 2 of the exercises scored the same points).

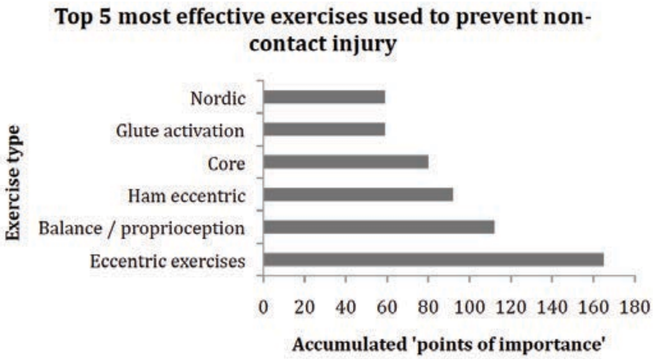

Figure 2: Top 5 exercises in the injury prevention program of premier league clubs (maximum number of points possible – 220).

Frequency of injury prevention programs

Pre-season vs. In-season

The frequency of the sessions for the injury prevention program is presented in Table 6.

Table 6: Frequency of injury prevention program during pre-season and in-season (% of clubs).

	Percentage of clubs using this frequency of injury prevention program				
Period of season	**1 x per week**	**2 x per week**	**2 to 5 x per week**	**1 x per month**	**2 x per month**
Pre-season	9.1	38.6	47.7	2.3	2.3
In-season	21	36	43	Not applicable	Not applicable

One match per week vs. two matches per week

The frequency of the sessions for the injury prevention programs is detailed in Table 7. The number of sessions per week was significantly higher (p=0.0003, ES=0.95, almost perfect) when 1 match per week was played in comparison with two matches per week (2.4±1.2, range; 1 – 5 vs 1.6±1.3, range; range 0 – 5 respectively).

Table 7: Frequency of injury prevention program when playing one match per week compared to when playing two matches per week (% of clubs using this frequency).

	Percentage of clubs using this frequency of injury prevention program						
Number of matches per week	**0**	**1 x per week**	**2 x per week**	**3 x per week**	**4 x per week**	**Daily (at least 5 x per week)**	**Between 1 to 5 per week**
One	2.3	22.7	40.9	9.1	4.5	4.5	16
Two	11	55	9	5	9	0	11

Recovery time between injury prevention session and other sessions

The recovery time between an injury prevention session and a match ranged from 24h (7 clubs) to ~96h (1 club, Figure 3). The recovery time between two injury prevention sessions ranged from 12-24h (1 club) to 96h (2 clubs, Figure 4). The recovery time between an injury prevention session and a lower-body strength session ranged from 12-24h (3 clubs) to 72h (3 clubs, Figure 5).

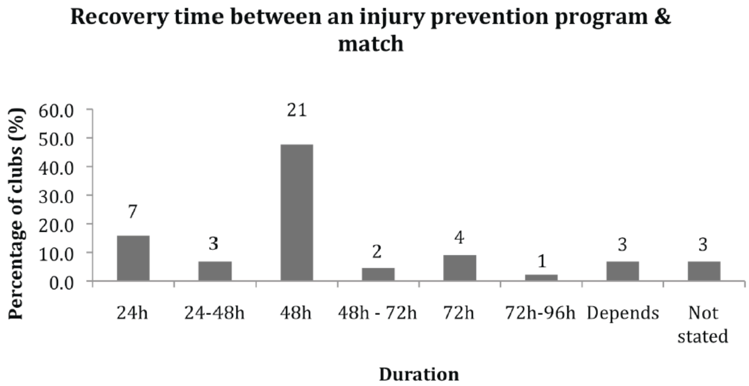

Figure 3: The recovery time afforded between an injury prevention program and a competitive match (number on column corresponds to n of teams).

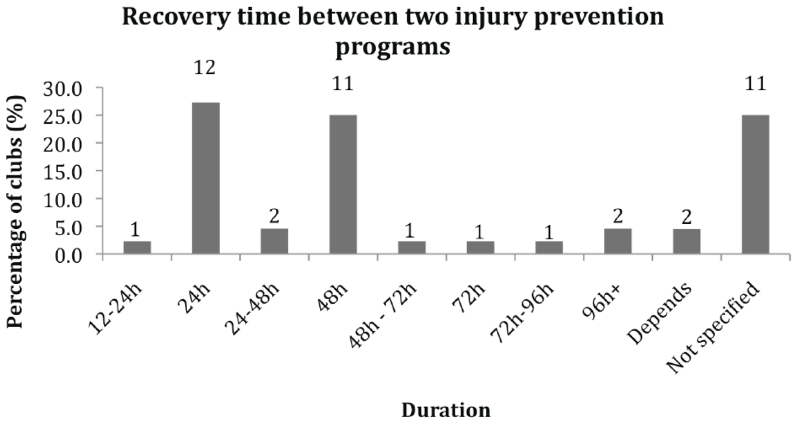

Figure 4: The recovery time afforded between an injury prevention program and another injury prevention program (number on column corresponds to n of teams).

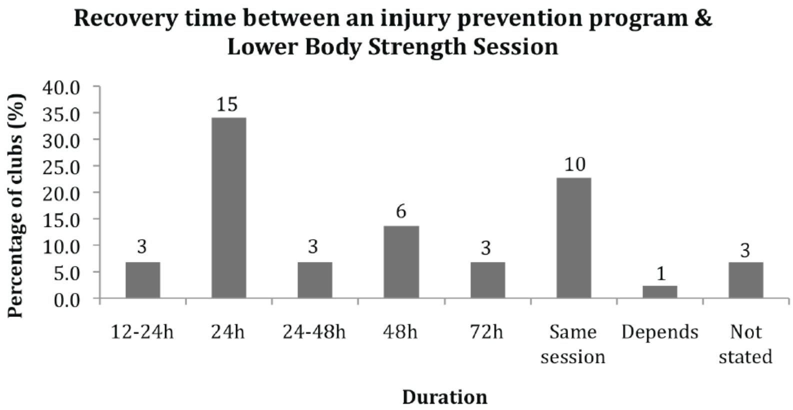

Figure 5: The recovery time afforded between an injury prevention program and a lower body strength training session (number on column corresponds to n of teams).

Discussion

The perceptions and practices of professional football teams were studied with regards to non-contact injury risk factors, testing and preventative strategies. The aim of the study was to reduce the gap between what is actually conducted in practice and what is currently identified in the scientific research literature.

Injury risk factors

The diversity of responses concerning risk factors highlights the multi-factorial nature of non-contact injuries. Of the top 5 risk factors identified, 4 are modifiable: fatigue, muscle imbalance, fitness and movement efficiency while the remaining one, previous injury is not.

In line with the perceptions of medical and science staff in this survey, previous injury (1st) is also a well-supported risk factor for injury in professional footballers in the research literature.[4,9,10] Fatigue (2nd) and fitness (4th) can be considered to be inter-related. Fatigue experienced during a soccer match has been suggested to increase the risk of injury.[11-13] There is conflicting evidence regarding muscle imbalance as a risk factor in professional football with some supporting a relationship [14,15] while others do not.[16,17] Regarding movement efficiency, it has been suggested that by adopting inefficient movement strategies, individuals may reinforce poor movement patterns that, despite achieving high performance, may eventually result in injury.[18] However, there are no studies as yet supporting this as a risk factor in professional football players.

Injury testing

Many tests are used by clubs to identify non-contact injury risk. The most common were FMS, questionnaire and isokinetic assessments. To our knowledge, despite a lack of direct scientific evidence for the use of FMS as a tool to identify injury risk in professional footballers, 66% of clubs use this test. A further 16% of clubs also use their own adapted version. It is also interesting to note that whilst the premier league clubs identified fatigue and fitness as top 5 risk factors, only 27% tested the physical capacities of their players as a tool to potentially identify injury risk. Similarly, although muscle imbalance was the 3rd most important risk factor, only 41% of clubs used isokinetic tests in their testing protocol. It is therefore important to understand why some discrepancies exist regarding the use of tests, especially those with limited scientific evidence. Equally there is a discrepancy in the non-utilisation of tests considering the clubs' perceived risk factors. One conclusion is that the clubs have found some important relationships between practices that research has yet to validate. Additionally, the non-use of some tests may be due to factors such as the time required to perform and/or acceptance by coaches and players to allow implementation of certain tests such as those including maximal effort or the cost to purchase specific testing machines make these difficult to introduce. The combination of 'best practice' and the available scientific evidence is crucial. The practices of experts in the field should also guide the activities conducted in research in order to confirm or refute such practices.

Injury prevention perceptions and practices

Top 5 exercises:

Eccentric exercise was rated as the most important exercise in the injury prevention program of premier league clubs. Hamstring eccentric and Nordic exercise in particular were rated independently as 3rd and joint 5th most important exercises respectively. It is suggested that eccentric resistance exercise may prevent injury by improving the muscles' ability to absorb more energy before failing.[19] Although there is evidence for the beneficial effect of hamstring eccentric exercise to prevent hamstring injury in professional footballers,[20-22] evidence linking eccentric exercise with a reduction in injury of other muscle groups such as the adductors, quadriceps, calf and ankle dorsiflexors and plantarflexors is lacking.

Similarly, the evidence for balance/proprioception exercises (2nd most important exercise) to prevent ankle and knee injuries is surprisingly lacking for professional football players. Two studies have been conducted in semi professional footballers with one reporting a beneficial effect on ankle injuries[23] and the other on knee ACL injury.[24] Another study has demonstrated a beneficial effect on ankle injury[25] in 'first division' male players but the level i.e. professional or otherwise was not specified.

It is surprising that considering the importance of balance training as a preventative strategy, tests of balance were used by only 11% of clubs to predict non-contact injury although the FMS test does assess some aspects of proprioceptive and balance ability.

In a group of elite professional Australian Rules Footballers, core training (4th) has been shown to reduce the risk of severe injuries[26] and result in fewer matches missed. [27] To our knowledge however, no studies have been conducted in professional footballers. Interestingly, a systematic review comparing specific core exercises with traditional free weight multi-joint exercises[28] showed that the free weight exercises such as the squat and deadlift are optimal to produce activity of the lumbar multifidus and with no difference in activation of transverse abdominis between exercises. Concerning glute activation (5th), there are many studies investigating gluteus muscle activation (5th) in response to different exercises.[29-31] However, none have checked the effects on reducing injuries. It is noteworthy that the top 5 rated exercises correspond to components of the '11+' program. This is an injury prevention warm-up developed by Soligard et al.[32] focusing on eccentric, balance, core stability and dynamic stabilization exercises and is recommended by *Fédération Internationale de Football Association (*FIFA).[33]

In the scientific literature there are some guidelines regarding the type of exercises that can reduce injuries as well as some information on programming (e.g., sets, reps, frequency and progression) these in the professional football setting (e.g., Nordic hamstring[20] and yoyo hamstring curl[22]). There is, however, no clear consensus on how to most effectively integrate a multi-dimensional injury prevention program. Similarly, there are no clear guidelines regarding when the program should be performed in relation to matches or other exercise sessions, for example during congested schedules when 2 matches are played per week and recovery time is reduced. Additional research is thus needed to determine the optimal type, timing and prescription of exercises within a multi-dimensional injury prevention program for use in the practical setting.

It is worth noting that there are other important considerations or perhaps more fittingly, challenges faced at the elite professional level that can also impact the implementation strategy of injury prevention programs. For example, internal club factors; getting the ‘buy in’ from coaches and having a senior position in the hierarchy to successfully influence the training program.[2]

Limitations

There are some limitations of our survey. First, the clubs from different leagues were not equally represented so we could not compare cultural differences. Second, there is a gap concerning the professional level of some clubs, in which resources (e.g., equipment and staff numbers) will vary and will influence the practices of teams. Third, there are some major leagues that we do not have any data from (e.g., Germany, Portugal, Brazil, Japan). Finally, the response rate can be considered low (47%). The low response rate could be explained by various reasons; (1) the clubs do not implement injury risk testing and/or prevention programs and therefore felt uncomfortable about completing the survey, (2) they did not have time to fill in the survey, (3) they do not believe in linking science with practice by following of an evidence based approach incorporating knowledge and findings from the scientific research literature, (4) they deemed the nature of the information to be too sensitive to disclose.

In conclusion, the most important risk factors for non-contact injury in premier league football clubs were previous injury, fatigue and muscle imbalance. The most commonly used tests were FMS, Questionnaire and isokinetics. Also, the most important exercises were eccentric exercise (in general), balance, and specific hamstring eccentric. Premier league clubs appear to be following guidelines in research regarding certain perceptions and practices. These include previous injury and fatigue as risk factors, questionnaires to identify risk factors such as previous injury and implementation of hamstring eccentric exercise to prevent injury. However, clubs’ perceptions and practices are not always well supported by the research literature.

Future directions

It would be worthwhile to determine the level of evidence in the scientific literature for these beliefs and practices. A follow-up study by the present research group will systematically review the most important risk factors, the most commonly used tests and the most important injury prevention exercises.

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2.2 Étude 2 : Facteurs de risques, tests et stratégie de prévention des blessures sans contact dans le football professionnel : revue systématique des représentations et pratiques de 44 équipes.

Introduction

In a previous survey,[1] the current perceptions and practices of 44 premier league football teams, from around the world, regarding non-contact injuries were investigated. Results showed that the 3 most important risk factors were previous injury, fatigue and muscle imbalance. Additionally, the 3 most utilised tests to detect injury risk were functional movement screen (FMS), questionnaires and isokinetic dynamometry. Furthermore the most important preventative exercises for non-contact injuries were eccentric exercises and balance/proprioception. Specifically, eccentric exercise for the hamstring was independently ranked as the 3rd most important exercise.

There are however, within the scientific literature and research community, a series of conflicting results and ongoing debates in this field. These include aspects such as which variables constitute significant risk factors in elite football players, which tests can be performed to identify a player who is at risk of injury, and which preventative exercises can significantly reduce the incidence of injuries. Scientific research should aim to guide practice by either validating or refuting certain processes and procedures, however, there is currently a gap between science and practice.[2] In our previously published survey[1] the aim was to start the process of closing this gap by determining the perceptions and practices of top-level professional teams concerning risk factors, testing and preventative strategies for non-contact injuries. The second step in this process is to link these perceptions and practices with a corresponding level of scientific evidence currently shown in the research literature.

There is, to our knowledge, no systematic review concerning injury prevention and professional football that has yet assigned a specific level of evidence for the consideration of risk factors and/or use of specific tests and exercises based on the quality of studies. It is imperative that research can successfully guide practitioners and it is important to provide practitioners with a level of evidence and recommendations so that they can be confident that they are implementing the current best evidence based practice. Furthermore researchers should be guided to concentrate on future research that ultimately will help guide practice.

The aim of the present article therefore was to systematically review the scientific level of evidence for the afore-mentioned ‘Top 3’ risk factors, tests and preventative exercises and to provide a graded recommendation for their use and consideration in practice based on the current research literature. This systematic review should therefore lead to closing the gap between science and practice.

Methods

Literature search and selection process

This systematic review was performed following the guidelines of Harris et al.[3] A systematic search of the scientific literature was performed via the Pubmed and SPORTSDISCUS databases. Various combinations of the following key words were used: ‘soccer, football, injury, risk, non-contact, prediction, prevention, test, muscle, strain, sprain, eccentric, balance, proprioception, core, stability, isokinetic, functional movement screen, fatigue, muscle imbalance, hamstring, groin, adductor, knee, ankle, calf, quadriceps’. This search was performed between 2nd and 8th February 2014. Criteria for inclusion were; male, sub-elite and elite players from all football codes (soccer, rugby, Australian Rules Football, American Football), ≥18 years, prospective and retrospective studies and all languages. Studies were excluded if they contained females, non-football codes, <18 years and non-elite. Returned abstracts from the search were screened for inclusion. Full articles were then retrieved and included or excluded based on the criteria set out above. Reference lists of included articles were screened for additional papers. Additionally, 2 research experts in each field of ‘injury risk’, ‘injury risk testing’ and ‘injury prevention’ were contacted to reduce the risk of missing relevant articles. A ‘Preferred Reporting Items for Systematic Reviews and Meta-Analyses’ (PRISMA) flow chart was used to illustrate the study identification, screening, eligibility, inclusion and analysis (figure 1). Two of the principal authors (AM and CC) independently performed the literature search using the same keywords and combinations. Some articles were included in more than one section: an asterisk ‘*’ denotes these papers.

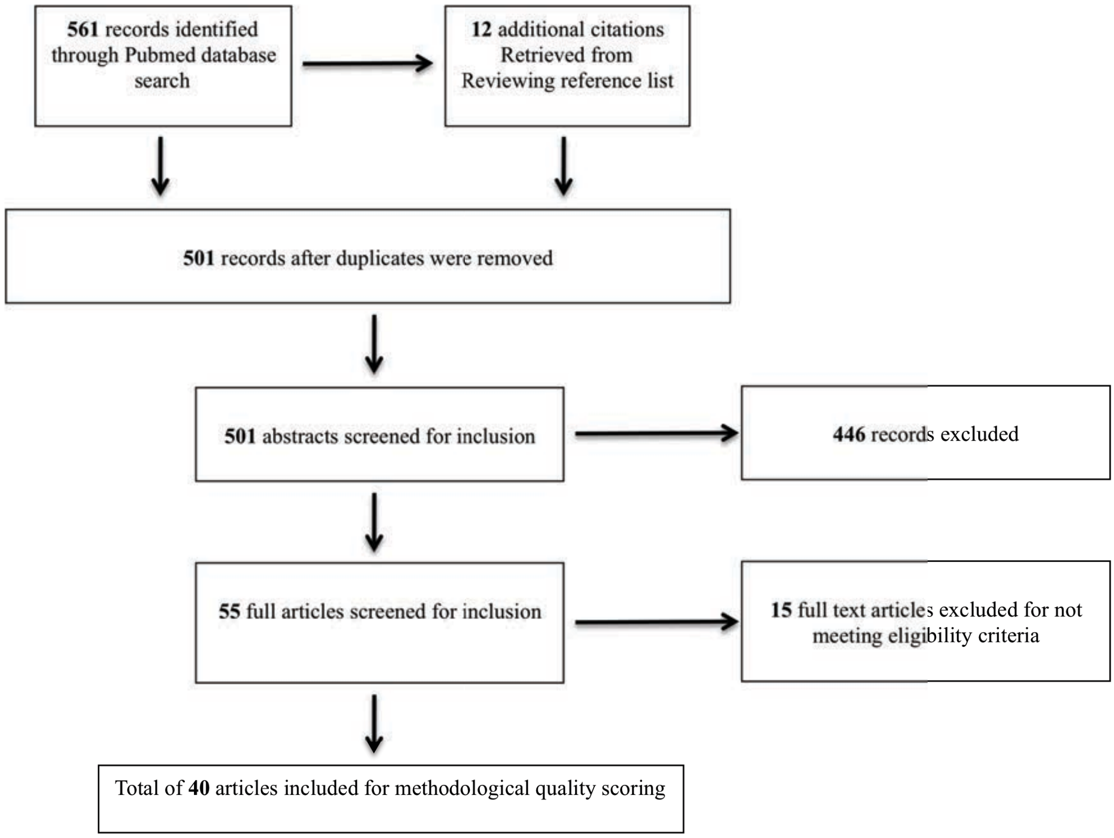

Figure 1: A 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA) flow chart outlining the study identification, screening, eligibility, inclusion and analysis for the present systematic review.

Methodological quality and level of evidence

The methodological quality of studies was assessed using a validated checklist for retrospective and prospective studies[4] assessing aspects of 1: 'reporting', 2: 'external validity', 3: internal validity – bias', 4: 'internal validity – confounding' and 5: 'power'. For analysis of risk factors and tests utilised, questions not appropriate to cohort and descriptive epidemiology studies were excluded. Questions excluded were appropriate only for intervention studies. Questions included for the quality check in this instance were numbers 1, 2, 3, 5, 6, 7, 10, 11, 12, 18, 20, 21, 22, 25 as previously used.[5] For the quality check of preventative exercise articles (i.e. intervention studies), only Q16 was omitted as this question was deemed not applicable by the authors. Two of the principal authors (AM and CC) independently performed the methodological quality check for all articles. Any disagreements were sent to corresponding author GD whose decision was final. A percentage score was awarded for each article. Articles were then assigned a ‘level of evidence’ following the procedure for grading recommendations in evidence based guidelines from the Scottish Intercollegiate Guidelines Network (SIGN).[6] Scientific levels of evidence range from 1 to 4 according to the type of study e.g. RCT, high quality systematic review and meta-analysis are level 1: well-conducted systematic reviews, plus cohort and case control studies are a level 2: non-analytic studies are level 3 and expert opinion has a level of evidence of 4. Within these levels of evidence, levels of 1 and 2 can score an additional mark of ‘++’, ‘+’ and ‘-‘ according to the specific quality and risk of bias of the study. The percentage cut off scores to determine if a paper was either a) of high quality with very low risk of bias, b) well conducted with low risk of bias or c. low quality with high risk of bias were ≥75%, =50 – 74% and <50% respectively.

Graded recommendation

Following the methodological quality checklist and assignment of a level of evidence, a graded recommendation for each of the top 3 tests and preventative exercises was given following the SIGN guidelines. Graded recommendations involved assessment of the body of evidence (i.e. all of the articles in that area) and their respective levels of evidence in conjunction with a considered subjective judgement by professionals. Graded recommendations were considered as A – Strong recommendation, B – Moderate recommendation, C – Weak recommendation or D – Insufficient evidence to make any recommendation. The considered judgement and graded recommendation were assigned during a round table of 2 researchers and one sports medicine doctor.

Results

Search results

Altogether, forty articles were included for methodological quality assessment. The total number of articles assessed for 'risk factors' were: previous injury (15), fatigue (2), and muscle imbalance (10). The 'testing' section corresponded to functional movement screen (2), questionnaire (6) and isokinetic testing (7). Finally, for the section concerning 'preventative based exercises': eccentric exercises (9) and balance/proprioception (3).

Overall graded recommendation

The overall level of evidence for risk factors and graded recommendations for tests and exercises utilised are outlined in table 1.

Table 1: Overall graded recommendation for the 'top 3' rated perceptions and practices of premier league football teams regarding (1) risk factors, (2) testing and (3) preventative exercises for non-contact injury in professional football players

Risk factor	**Level of Evidence**
Previous injury	2++
Fatigue	4
Muscle imbalance	Inconclusive
Test	**Graded recommendation**
Functional movement screen	C
Questionnaire : Psychological	C
Questionnaire : Function score	D
Isokinetic	Inconclusive
Preventative exercise	**Graded recommendation**
Hamstring eccentric	A
Other eccentric	D
Balance and proprioception : Ankle	A
Balance and proprioception : Knee	D

Methodological quality and characteristics of the studies

The quality score (%) and corresponding level of evidence are displayed in tables 2 to 10. The quality of risk factor articles ranged from 73% to 100%. Testing articles from 73% to 100%. Preventative exercises 34% to 100%. The individual breakdown of scoring of articles is shown in Appendices B.

Injury risk factors

Previous injury

The level of evidence for each article assessing previous injury as a risk factor[7-21] is in table 2. The overall level of evidence for previous injury as a risk factor for both injuries of the same type and/or another location is '2++'.

Table 2: The quality score and scientific level of evidence for articles investigating previous injury as a risk factor for injury

Study name	Quality score (%)	Level of evidence
Hagglund et al. 2013	100	2++
*Fousekis et al. 2011	80	2++
*Engebretsen et al. 2010a	93	2++
*Engebretsen et al. 2010b	100	2++
*Engebretsen et al. 2010c	100	2++
*Engebretsen et al. 2010d	100	2++
Gabbe et al. 2010	93	2++
Gabbe et al. 2006	100	2++
Koulouris et al. 2007	93	2++
Walden et al. 2006	100	2++
Hagglund et al. 2006	100	2++
Arnason et al. 2004	100	2++
Orchard et al. 2001	100	2++
Verrall et al. 2001	93	2++
*Bennell et al. 1998	100	2++

* articles used in more than 1 section

Fatigue

The quality score and level of evidence for articles concerning fatigue and injury risk[22,23] are shown in table 3. Only one study investigated a direct link between fatigue and non-contact injury risk.[22] There is no direct evidence for acute or accumulated fatigue as a risk factor for injury in professional football and therefore the level of evidence is ‘4’.

Table 3: The quality score and scientific level of evidence for articles investigating fatigue as a risk factor for injury

Study name	**Quality score (%)**	**Level of evidence**
*Zvijac et al. 2013	93	2++
Carling et al. 2010	80	2++

* articles used in more than 1 section

Muscle imbalance

The quality score and level of evidence for articles regarding muscle imbalance and injury risk are shown in table 4. The results are conflicting for muscle imbalance as a risk factor for injury. Three prospective studies[8,24,25] and 1 combined prospective and retrospective study[26] (all rated 2++) support an association between muscle imbalance and hamstring injury whereas 2 prospective studies[22,27] and 1 combined prospective/retrospective study[28] (also all rated 2++) found no association. Another study[21] found no association for mixed ratio and hamstring injury and the risk of hamstring injury did not differ between players with and without side-to-side eccentric ratios and <0.90 except for eccentric 180°/s where those with ratios >0.90 were at significantly higher risk. Concerning groin, 1 prospective study[29] (2++) found an association for adductor-to-hamstring peak torque ratio. Additionally 1 prospective study[30] showed muscle imbalance of the ankle plantar and dorsalflexors were a significant predictor of ankle injury. A level of evidence cannot be assigned for muscle imbalance as a risk factor as the current research findings are inconclusive.

Table 4: The quality score and scientific level of evidence for articles investigating muscle imbalance as a risk factor for injury

Study name	Quality score (%)	Level of evidence
*Zvijack et al. 2013	100	2++
*Fousekis et al. 2012	87	2++
*Fousekis et al. 2011	80	2++
*Henderson et al. 2010	87	2++
*Croisier et al. 2008	87	2++
*O'Connor 2004	80	2++
*Dauty et al. 2003	100	2++
*Cameron et al. 2003	80	2++
*Bennell et al. 1998	100	2++
*Orchard et al. 1997	73	2+

* articles used in more than 1 section

Testing

Functional movement screen

The quality score and level of evidence table for functional movement screen includes only 2 relevant articles[31,32] both with a level of evidence of 2+ (Table 5). Based on the paucity of articles directly applicable to the professional football population, the graded recommendation for functional movement screen in elite football players is ‘C’.

Table 5: The quality score and scientific level of evidence for articles investigating functional movement screen as a test to identify injury risk

Study name	Quality score (%)	Level of evidence
Kiesel et al. 2013	73	2+
Kiesel et al. 2007	73	2+

Questionnaire

The quality score and level of evidence for articles using questionnaires to predict injury are provided in table 6. Questionnaires, as a tool for effectively determining medical history information (e.g. previous injury), were not included. We have focussed on specifically themed questionnaires Two types of questionnaires have been investigated in elite football, psychological questionnaire and assessment of function. Two prospective studies implementing psychological questionnaires[33,34] (2++ and 2+ respectively) showed an association between injury and some psychological factors. Four studies (rated 2++ used a questionnaire to assess (1) hamstring,[9] (2) groin,[10] (3) ankle[11] and (4) knee[12] function. These studies showed no association between function score questionnaires and injury risk. The graded recommendation for psychological questionnaires to identify injury risk is ‘C’. The graded recommendation for questionnaires assessing joint or muscle function to identify injury risk is currently ‘D’.

Table 6: The quality score and scientific level of evidence for articles investigating Questionnaire as a test to identify injury risk

Study name	**Quality score (%)**	**Level of evidence**
Ivarsson & Johnsson, 2010	73	2+
Devantier, 2011	87	2++
*Engebretsen et al.2010a	93	2++
*Engebretsen et al.2010b	100	2++
*Engebretsen et al.2010c	100	2++
*Engebretsen et al.2010d	100	2++

* articles used in more than 1 section

Isokinetic testing

The quality score and level of evidence for isokinetic testing as a tool to identify injury risk in professional footballers can be found in table 7. The results are conflicting for isokinetic, as testing tool. As with muscle imbalance, three prospective studies[8,24,25] and one combined prospective/retrospective studies[26] (all rated 2++) support an association between muscle imbalance and hamstring injury, whereas two prospective studies[22,27] and one combined prospective and retrospective studies[28] (all rated 2++) do not. Another study[21] found no association for tests assessing mixed ratio with hamstring injury. However, eccentric side-to-side ratio using a testing speed 180°/s found that players with ratios >0.90 were at significantly higher risk. Ratios from testing at 60°/s were not predictive of hamstring injury. Concerning groin, one prospective study[29] (2++) found an association for adductor-to-hamstring peak torque ratio. Additionally, one prospective study[30] (2++) showed muscle imbalance of the ankle plantar and dorsalflexors was a significant predictor of ankle injury. A graded recommendation cannot be assigned for muscle imbalance as a risk factor for injury in football as the current research findings are inconclusive.

Table 7: The quality score and scientific level of evidence for articles investigating isokinetic testing as a test to identify injury risk

Study name	Quality score (%)	Level of evidence
*Fousekis et al. 2012	87	2++
*Fousekis et al. 2011	80	2++
*Henderson et al. 2010	87	2++
*Croisier et al. 2008	87	2++
*Cameron et al. 2003	80	2++
*Bennell et al. 1998	100	2++
*Orchard, 1997	100	2++

* articles used in more than 1 section

Preventative exercises

Eccentric exercise

The quality score and level of evidence for articles concerning eccentric exercise and injury prevention are presented in tables 8 and 9. The evidence for incorporating hamstring eccentric exercise into the injury prevention program of professional footballers is 1++ (the highest possible). Only one study used isolated eccentric hamstring exercise[35] (1++) while the others used eccentric hamstring exercise within a combined program using other modes of contraction.[24,36-39] The graded recommendation for hamstring eccentric exercise is ‘A’. There is limited evidence for eccentric exercise and prevention of injury in other locations. One randomised controlled trial[40] checked the effects of a groin exercise program incorporating an eccentric component (1++). There was no significant effect of the intervention. Another study[41] checked the effect of incorporating eccentric exercises for Achilles and patellar tendon (1++). There was no significant effect. In fact, there was a significant increase for developing symptoms of jumpers knee in patellar tendons that were severely abnormal pre-exercise program. Therefore, the graded recommendation for eccentric exercise to prevent injuries other than hamstrings is ‘D’

Table 8: The quality score and scientific level of evidence for articles investigating hamstring eccentric exercise as a preventative exercise to prevent injury

Study name	**Quality Score (%)**	**Level of Evidence**
Petersen et al. (2011)	88	1++
Arnason et al. (2008)	56	2+
*Croisier et al. (2008)	75	2+
Brooks et al. (2006)	59	2+
Gabbe et al. (2006)	84	1++
Askling et al. (2003)	72	1+
Croisier et al. (2002)	34	2-

* article used in more than 1 section

Table 9: The quality score and scientific level of evidence for articles investigating ‘other’ eccentric exercise as a preventative exercise to prevent injury

Study name	**Quality Score (%)**	**Level of Evidence**
Holmich et al. 2010	88	1++
Fredberg et al. 2008	78	1++

Balance / Proprioception

The quality score and level of evidence for balance/proprioception exercise as a preventative exercise is presented in table 10. Two studies[42,43] assessed the effects of balance/proprioception training in top-level football players on ankle sprain injury (1+). In one study,[42] the incidence of ankle sprain was significantly reduced in the training group. In the other study[43] ankle sprains were significantly reduced in players with a previous ankle sprain however no significant difference for players with no previous ankle sprain. The recommendation for balance/proprioception exercise to prevent ankle sprain injury is ‘A’**.** Only one study[44] assessed the effects of this type of training on ACL injury (2+) in which ACL injury rate was reduced in the intervention group. However, no study has checked the effects on other knee injury types. The graded recommendation for balance/proprioception exercise and knee injuries in general is ‘D’.

Table 10: The quality score and scientific level of evidence for articles investigating balance/proprioception exercise as a preventative exercise to prevent injury

Study name	**Quality Score (%)**	**Level of Evidence**
Mohammadi et al. 2007	59	1+
Carraffa et al. 1996	53	2+
Tropp et al. 1985	63	1+

Discussion

The present study is a follow up to a previously published survey[1] that revealed the most common perceptions and practices of 44 premier league football teams regarding risk factors, testing and preventative strategies for non-contact injury. The purpose of the present study was to analyse the gap between science and practice by systematically reviewing these perceptions and practices. This was achieved by assigning a level of evidence and graded recommendation in order to help guide practitioners to make the best decisions and use the best evidence based practices in the practical setting. A further aim was to provide direction for researchers in regards to where to concentrate efforts of future research into risk factors, testing and preventative exercises for professional footballers based on what is done in practice.

Risk factors

Previous injury

The level of evidence for previous injury as a risk factor is ‘2++’. According to the grading guidelines used, a level of evidence 2++ is the highest available for cohort studies and therefore no higher score was possible. There were no systematic reviews or meta-analyses in the target population, which could have resulted in a level evidence of 1. Randomised controlled trials can also achieve a level of evidence 1; however, such a study design is not possible when investigating risk factors and injury.

Previous injury increases the risk of the same injury type.[7,9-12] Additionally, previous injury has been shown to increase injury risk in another location e.g. calf injury can increase hamstring injury risk,[7,19] hamstring injury can increase the risk of calf injury[7] and knee injury can put the hamstring at risk.[20] Due to the high level of evidence, practitioners should, as appears to be the case according to the survey published, continue to use such information in the practical setting. In regard to research, future attention should be focussed on establishing risk factors other than previous injury.

Fatigue

The level of evidence for fatigue is ‘4’. Acute fatigue occurring during a football match has been proposed to be a cause of injuries[45] due to studies showing that injuries are more common at the end of halves of a match.[45,46] Additionally, accumulated fatigue has been identified as a potential risk factor through studies showing a higher injury incidence when playing two matches compared to one match per week where recovery time is reduced.[47,48] Despite this common belief and studies showing indirectly that fatigue may be associated with injury its’ current level of evidence is low, scoring only level 4. Only one study has directly investigated fatigue as a risk factor in American Football players,[22] and no difference was found for fatigue index in players sustaining a hamstring strain compared to players who did not. Although the level of evidence for fatigue is low, it does not mean that it should be ruled out as being unimportant. It implies simply that research has yet to validate or refute this variable as a risk factor.

Muscle imbalance

The level of evidence for muscle imbalance is ‘inconclusive’. Two studies[25,26] found that hamstring/quadriceps concentric ratio and a low hamstring muscle side-to-side difference in concentric muscle action were significantly associated with hamstring muscle injury. However, other studies found no such association.[21,22,27] Eccentric contractions are more specific to when the hamstring muscle is injured and therefore may represent a more specific test. However, findings here are also inconclusive. One study[8] revealed that eccentric hamstring asymmetry (>15%) has been found to be a significant predictor of injury. Bennell et al[21] found that this was test dependent i.e. players with eccentric side-to-side ratios >0.90 tested at 180°/s were at significantly higher risk of hamstring injury, however this was not the case when tested at 60°/s. The mixed ratio (Hamstring eccentric:Quadricep concentric) is also inconclusive; it has been shown not to identify recurrence or new hamstring injury,[21,28] while another study revealed that no player with a mixed ratio of higher than 1.40 sustained a hamstring muscle injury.[24] As yet there is no consensus in the literature to validate muscle imbalance as a significant risk factor.

There is a lack of studies investigating the effect of imbalance of other muscle groups and injury risk. One study[30] found that eccentric asymmetry (≥15%) of ankle dorsal and plantarflexors was a significant predictor of ankle sprain. A predictive model has also been found for groin injury, which included knee extensor bi-lateral deficit at non-dominant adductor-to-hamstring peak torque ratio in concentric muscle action.[29] Practitioners should be aware of the limitations when using results of tests to assess muscle imbalances in their players. Researchers are encouraged to investigate muscle imbalance to finally validate or refute this as a risk factor.

Testing

Functional Movement Screen

The level of evidence for Functional Movement Screen is ‘3’ with a graded recommendation ‘C’ (weak). Two relevant studies met the criteria for inclusion. The first study[32] found that American Football players who scored ≤14 were related to serious injury. However, injuries were defined as a time-loss of 3 weeks and it is not known if these were contact or non-contact. All injuries resulting in time-loss and in particular non-contact in nature should be considered. The second study[32] considered musculoskeletal injuries (excluding contusions) resulting in any time lost. This study found that the combination of scoring ≤14 and exhibiting a movement asymmetry was highly specific of injury. Unfortunately, it was not stated which asymmetries in particular were related with injury. Currently, there have been no studies in professional male football players. Caution should be used with this test as the scores have been shown to change when performers are made aware of the grading criteria.[49] Additionally, adequate training for the FMS tester should improve the reliability of this testing modality.[50] Therefore it is currently recommended not to give feedback or advice on the movements and scoring system to players. Interestingly, our previously published injury survey[1] revealed that some teams use their own ‘adapted’ version of the FMS. It would be interesting to investigate which modifications practitioners are implementing and the reasons why, in order for research to investigate their relation with injury.

Questionnaire

The level of evidence for psychological questionnaire is ‘3’ with a graded recommendation ‘C’. For questionnaires assessing ‘function’ the level of evidence is ‘4’ with a graded recommendation of ‘D’ The effectiveness of a questionnaire depends on the type of questionnaire. It is fair to assume that a simple questionnaire regarding the medical history will be clearly of use in identifying players at higher risk due to prior injury. However, for other questionnaire types graded recommendation for their use is varying. Function score based questionnaires to assess function of the hamstring,[9] groin,[10] ankle and foot[11] and knee[12] all showed no significant association with injury occurrence in their respective body parts. Again, this does not mean to say that these questionnaires are not useful in practice, it may simply be that research has yet to validate these.

While the use of psychological questionnaires in male professional football players is currently weak (C), there is some promising research[33,34] suggesting a link between some psychological traits and injury.

Isokinetic

The level of evidence for isokinetic testing is ‘inconclusive’ and therefore scores a recommendation D. It is important to point out that there are other methods that can be used to measure muscle force and imbalances in football players. Previous studies have used force plate,[51] sphygmomanometer[52] and non-motorised treadmill.[53] The use of such testing devices and specific testing protocols need to be established and validated to allow practitioners to be confident that a reduction in muscle force and/or an imbalance can be predictive of an injury.

Preventative exercises

Eccentric exercise

The level of evidence for eccentric exercise for hamstring is ‘1++’ and recommendation ‘A’. The level of evidence for eccentric exercise for other body locations is ‘3’ and recommendation ‘D’. Various high quality studies have shown that hamstring muscle injury can be reduced by incorporating hamstring eccentric exercise.[35,36,38] A concern is the finding that during 11 consecutive seasons in elite European football teams the muscle injury rates did not decline. Future research should focus on implementation strategies and compliance of prevention program as player compliance is vital for maximum effectiveness.

Currently, the recommendation for use of eccentric exercise to prevent injury to other body parts is D. Hip adduction eccentric exercise as part of a multifaceted groin injury prevention program had no significant effect on injury.[40] It does not mean that eccentric exercise for the groin is ineffective, again it may be that research has so far failed to find the optimal program to elicit its' benefits. Similarly, eccentric exercise for the Achilles or patellar tendon has been shown to have no significant effect.[41] In fact, eccentric exercise was shown to significantly increase the risk of developing symptoms of jumpers knee from 5% to 24% in players with ultrasonographically severely abnormal patellar tendons. As eccentric exercise is considered as the most important exercise in teams injury prevention program. It is of utmost importance that research determines the optimal programming of such exercises in a multifaceted injury prevention programs. Practitioners need to be aware of the potential adverse effects of eccentric exercise for other parts of the body.

Balance / proprioception

The level of evidence for balance/proprioception exercise to prevent ankle sprain is '1++', graded recommendation 'A', while for knee injury in general, '4' with a graded recommendation 'D'. There were 2 high quality randomised controlled trials[42,43] showing that balance/proprioceptive exercises can significantly reduce the incidence of ankle sprains. The evidence for the role of balance/proprioception training injury and prevention of knee injury is less clear. One study[44] showed that proprioceptive training significantly lowered ACL injury rate, however, the effect on other knee injuries applicable to professional footballers is not known. Future research is required to determine the effectiveness and optimal protocol for balance/proprioception exercises for the prevention of knee injuries in professional footballers.

Conclusion

The present systematic review analysed the gap between what is conducted in practice in professional football in regard to perceived risk factors, tests utilised and preventative exercises implemented for non-contact injuries. The relation between practice and science can be analysed in two ways: the application of scientific recommendations by the practitioners (from science to practice) and the scientific validation of practices by the researchers (from practice to science). In this systematic review, we have shown that some perceptions and practices of practitioners follow scientifically validated recommendations from research (previous injury, hamstring eccentric and balance/proprioception exercise for ankle sprain injury); however, the level of evidence for most of their practices remains low. Further investigation is required by researchers to validate or refute the perceptions and practices used in the practical setting in order to further close the gap between science and practice.

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3° La détection des blessures sans contact chez les footballeurs professionnels

3.1 Étude 3 : Un test isométrique des muscles inférieurs postérieurs chez les joueurs de football professionnel.

Introduction

The hamstring is the most commonly injured structure in elite professional soccer players[4,5,6] and represents the highest injury burden (i.e. number of days absent per 1000h) of all injury sites.[4] Fatigue has been suggested as a risk factor for hamstring strain injury[22] with more injuries occurring during the final 15 minutes of halves.[10] Hamstring muscle force has consistently been shown to decrease as a function of time in response to soccer-specific exercise during all modes of contraction (concentric, eccentric and isometric).[19,22]

As a reduction in hamstring muscle force is a potential risk factor in hamstring strain injury,[22] routine testing of the hamstring force of players at the end of matches and during the ensuing recovery period could identify ‘at-risk’ players. However, in the practical settings such tests can be difficult to implement, as they have traditionally been performed using isokinetic dynamometry[18,19,22] which lacks portability and which is time-consuming when testing a full team of 11 players. Some practical field based tests have been proposed to detect hamstring strain injury risk.[8,13,16,21] Although these tests could be valuable in determining hamstring injury risk and are highly applicable for use in the practical setting, their usage immediately and during the recovery days following a competitive match may present some limitations as they involve either maximal eccentric contractions,[16,21] maximum repetitions performed till failure involving an eccentric component[8] or maximum speed running.[13] Additionally, with the exception of the single leg bridge test,[8] these tests do not allow a comparison between dominant and non-dominant legs, while the single leg bridge test does not provide an objective value of the precise force produced. An alternative simple and practical test proposed in the literature is an isometric test of hamstring muscle force using a sphygmomanometer.[20] Using this test, assessment of hamstring isometric muscle force at a knee angle of 90° has shown that an increased asymmetry in isometric maximum voluntary contraction was associated with the occurrence of a hamstring strain injury in a professional Australian Rules Footballer. This simple and quick test could provide an objective measure concerning the level of fatigue of the posterior lower limb muscle muscles following match-play. However, before using this test routinely in professional soccer players, it is necessary to determine the level of reliability and verify the sensitivity of this test. Therefore, the purposes of the present study were 1) to check the reliability of isometric posterior lower limb muscle force using a force plate in professional football players and, 2) to assess the sensitivity of this test through evaluating the decline in force following a competitive soccer match.

Methods

Participants

Twenty-nine professional soccer players (age: 19.6±3.5 yr; height: 181±6 cm; body mass: 74.3±7.4 kg; body fat: 8.8±2.1%) participated in this study. Prior to the experimentation, players completed a medical examination to verify the following inclusion criteria: 1) not to have been injured during the previous two months, 2) not to feel any pain in the lower limb muscles and, 3) not taking any medication/drug. Concerning the reliability tests, the following inclusion criteria for the players were 1) not to have participated in any hard and long training session or strength session for lower limbs during the 3 days before testing. A 'hard' session was defined as a training session where the player rated the training intensity >4 on a modified rating of perceived exertion scale,[7] and a long session was defined as training session > 60 min; and, 2) not to have elevated lower limb muscle soreness before testing. Elevated leg muscle soreness was defined as a rating of ≤2 (i.e. less than 'very low') on a 1-7 likert scale of leg muscle soreness.[11] According to these criteria, 23 players among the 29 initial participants performed all of the tests for the reliability assessment and 11 outfield-players performed the tests for the sensitivity assessment. The criterion for the sensitivity tests was that players had to play the full 90-minute competitive match.

All players were fully informed of the purpose, benefits and risks involved with participation before giving their written informed consent. This study was made in accordance with the ethical committee on biomedical research (N°5905092102) which conforms with ethical standards of the International Journal of Sports Medicine [9] and the standards set by the Declaration of Helsinki.

Reliability and sensitivity testing procedures

One week before recording the data, players performed two familiarization sessions with the force plate to measure isometric posterior lower limb muscle force. All of the tests were performed at the same time of day. Regarding the reliability assessment, players performed a standardized 10-min warm-up on a cycle ergometer before each test consisting of 7-min pedalling at 90 W followed by 3-min at 120 W.

The isometric force test was performed 5 min following cessation of the warm-up. Two tests were performed to check the reliability, the 2nd of which was performed on the same day and time the 7 days later. To assess the sensitivity, only the players who had played a full professional competitive match (90 min) were tested between 5 and 15 minutes following the end of the match.

Isometric posterior lower limb muscle force was tested with a force plate (1000 Hz sampling rate, Kistler 9260AA6, Winterthur, Switzerland) for both right and left legs. This test was performed at 90° and 30° (Appendices C.1. and C.2.). Players were laid on a mat, positioned firstly with their hips and knee flexed to 90° and secondly with the knee was flexed to 30° using a goniometer (Lafayette Instrument Company, USA). These angles were chosen as the biceps femoris muscle is maximally activated between 15° and 30° of knee flexion (from full knee extension) whereas between 90° and 105° knee flexion are the angles at which the semi-membranosus and semi-tendinosus muscle are maximally activated.[15] The heel of the non-working leg rested on the floor below the plinth with the leg lying flat, knee straight while the other heel of the working leg was set on the force plate, which was placed on a firm plinth. The player pushed their heel into the force platform as hard as possible without lifting their buttocks, hands or head off the mat. Players wore running shoes and investigators checked that players were always tested with the same shoes. The contraction was held for 3 seconds and repeated three times with 2 minutes of rest between sets. The highest peak force (N) was recorded. Data were classified according to dominant and non-dominant legs. The two same investigators were involved in all tests: one checked the position of the players' body and the other recorded the force during the tests. Standardised verbal encouragement was provided during the contraction.

Statistical analysis

Data are presented as means ± standard deviations (mean ± SD). The normality distribution of the data was checked with the Shapiro-Wilk test. Comparisons between best peak IF values were analysed using 2-way analysis of variance (ANOVA) for repeated measures. Bonferroni post hoc was then applied if a significant F-value was found. Differences between the two trials for the reliability and between pre-match and post-match for the sensibility were tested for significance using Student's paired t-test. The magnitude of differences between consecutive trials was also expressed as standardized mean difference (Cohen effect sizes, ES). The criteria to interpret the magnitude of the ES were as follows: 0.0 – 0.1 trivial, very small, 0.1 – 0.3 small, 0.3 – 0.5 moderate, 0.5 – 0.7 large, 0.7 – 0.9 very large, >0.9 almost perfect, >1 perfect.[12] The spreadsheet of Hopkins was also used to determine the change in the mean between trials, intraclass correlation coefficient (ICC) and the typical error of measurement (TE), expressed as a coefficient of variation (CV, %), calculating 90% confidence limits [14]. The 'smallest difference needed to be considered as real' (MD, corresponding to a change likely to be 'almost certain') was calculated as TE × 1.96 × √2.17.[25] Statistical significance was set at $p<0.05$.

Results

There was no effect of either the angle or the side (dominant versus non-dominant leg) regarding the best peak isometric force values of the dominant leg at 90° (318±38 N), at 30° (310±43 N) and the non-dominant legs at 90° (317±54 N) and at 30° (294±41 N). There was no significant difference between the trials, regardless of the isometric at 90° and at 30° for both legs. Table 1 presents the reliability variables (intraclass coefficient, typical error, coefficient of variation and minimal difference) for the tests performed on the force plate. Differences in all indices between repeated trials displayed 'trivial' or 'small' effect sizes.

Table 1. Reliability of simple and quick test for isometric hamstring force

	TE (90% CL)	CV	Change in mean (90% CL)	ES (rating)	ICC (90% CL)	MD
Dominant leg at 90°	9.4 N (7.3-13.6)	4.34%	2.1 N (-3.8-7.9)	0.15 Trivial	0.95 (0.88-0.98)	26.2
Non-Dominant leg at 90°	11.5 N (8.9-16.8)	5.48%	-2.3 N (-9.7-5.1)	0.14 Trivial	0.95 (0.88-0.98)	31.9
Dominant leg at 30°	13.3 N (10.4-18.9)	6.31%	1.0 N (-6.9-9.0)	0.05 Trivial	0.86 (0.69-0.94)	36.9
Non-Dominant leg at 30°	9.7 N (7.6-13.7)	4.84%	-4.1 N (-9.9-1.7)	0.30 Small	0.93 (0.84-0.97)	26.8

Table 2 presents the differences expressed as a percentage and change in the mean and the effect size between pre-match and post-match isometric force values at the two angles for both legs. Significant differences (p<0.01) were found between pre-match and post-match isometric force values for both legs and at both angles. No significant differences were found between dominant and non-dominant legs post-match isometric force values at 90° (ES=0.30) and at 30° (ES= 0.37). Similarly, no significant differences were found between 90° and 30° post-match isometric force values for the dominant (ES=0.20) and non-dominant legs (ES=0.19).

Table 2 – Sensibility of the test to detect a drop in isometric hamstring force after a competitive match

	Difference (%)	Change in mean	ES (rating)	MD
Dominant leg at 90°	-16%**	-50.8 N	1.56 Large	26.2
Non-dominant leg at 90°	-13%**	-39.9 N	1.00 Large	31.9
Dominant leg at 30°	-15%**	-47.9 N	1.66 Large	36.9
Non-dominant leg at 30°	-11%**	-29.3 N	1.06 Large	26.8

** p<0.01

Discussion:

To our knowledge, this is the first study to check the reliability of a simple and quick test to measure the isometric posterior lower limb muscle force in professional football players and the sensitivity of this measure of force following a professional competitive soccer match. In the present study, a force plate was used to measure the level of force instead of a sphygmomanometer, as initially proposed[20]; as the force plate is the gold standard for measuring force.[23]

The isometric posterior lower limb muscle force tested in the present study showed high to good reliability. Several criteria are used to check the level of reliability. Coefficient of variation is one of most common and robust criteria to test the reliability. A CV of ≤10% is often used as the criterion to declare a variable as reliable [1,3]. The CV calculated for the dominant leg at 90° (4.3%), the non-dominant leg at 90° (5.4%), dominant leg at 30° (6.3%) and the non-dominant leg at 30° (4.8%) were lower than this 10% CV cut-off point. Intraclass correlation coefficient is another one of these criteria. It is generally considered that reliability is high for ICC above 0.90 [22] and good for ICC above 0.75 [2]. According to these criteria, the reliability can be considered high for dominant leg at 90° (ICC=0.95), non-dominant leg at 90° (ICC=0.95), non-dominant leg at 30° (ICC=0.93), and good for dominant leg at 30° (ICC=0.86).

The sensitivity of this test was also shown to be appropriate to detect drops in isometric posterior lower limb muscle force induced by competitive match-play at both knee angles and for both dominant and non-dominant limbs. Using the traditional statistical approach, the present test detected a significant drop in isometric force ($p<0.01$, ES>1) for dominant leg (-15% at 30° and -16% at 90°) and non-dominant leg (-11% at 30° and -13% at 90°) following the match (table 2). Additionally, the change in the mean was higher than the smallest difference needed to be considered as real (tables 1 and 2), therefore, practitioners can be confident that the drops in isometric force measured using this test represent meaningful changes in their players.

The drop in isometric posterior lower limb muscle force seen in the present study is similar to the drops in hamstring force seen in not only isometric, but also concentric and eccentric contraction modes in response to football-specific exercise [19,22]. One of the factors explaining this drop in force at the end of a soccer match is the muscle damage induced by eccentric contractions such as changes of direction, accelerations and decelerations during a soccer match [14]. Reductions in maximal voluntary contraction torque resulting from exercise induced injury persist over the entire span of the progression of the degenerative and regenerative process i.e. until the muscle returns to its' pre injury condition.[24] As muscle function measures are considered to be the best tool for quantifying muscle damage[24] the present test may provide a useful, objective measure in quantifying the level of posterior lower limb muscle damage induced by a match and in monitoring recovery in the days following a match.

Limitations

A limitation of this study concerns the precise contribution and activation of the various muscles that may have contributed to the overall force produced during the test. Knee flexion can also be influenced by other muscles that cross the knee joint such as the gastrocnemius.[17] It is also possible that activation of hip extensor muscles such as the gluteus maximus and adductor magnus contributed to the overall isometric force output. Using electromyography to record the activity of the medial/lateral hamstrings during the test would have improved the value of the test.

Conclusion

In conclusion, the present findings show that this simple and quick test is reliable and sensitive enough to detect decreases in isometric posterior lower limb muscle force following a professional competitive match. The present test represents a useful and practical field tool to determine the level of match-induced fatigue and muscle damage of the posterior lower limb muscles of professional soccer players and may be able to identify ‘at risk’ players who exhibit large drops in isometric force and asymmetries between dominant and non-dominant legs.

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3.2 Étude 4 : Charge de travail et incidence des blessures chez les joueurs de football professionnel de Champions League et d'Europa League.

Introduction

Injuries in elite professional soccer are a major concern for teams in terms of success, finance and the long-term health of players. It is concerning that over an 11-season period (between 2001/2002 to 2011/2012 seasons) in elite European soccer, the global, match, training and muscle injury rates remain unchanged.(4) Injury prevention is of utmost importance for and is widely used by professional teams.(14) Although some injury prevention programs are effective in reducing the injury rate,(1,15,17) some other factors can also influence the risk of injury. According to Ekstrand et al.(4), risk factors such as training load should be investigated further. There has been no study, to the authors' knowledge, investigating the effects of the training load as a risk factor in elite professional soccer.

As both training and match loads contribute to the overall load experienced by the elite soccer player, a more appropriate term may be 'workload' or more specifically 'internal workload' as it is a measure of how each individual player has experienced an external stimulus i.e. training or match load. This internal workload can be quantified using a rating of perceived exertion (RPE) scale (Borg CR-10) multiplied by the duration of the training session or match(6) and represents an athlete's own perception of both physical and psychological stress.(13) The RPE method for measuring internal workload has previously been validated for use in soccer.(13) This method is simple, easy to implement and free and enable to quantify workload from different type of exercises in the gym (upper and lower body strength, plyometric sessions), and on the pitch. These advantages enable to use in a large cohort of players especially if they are familiarised and honest. The internal workloads from training and matches experienced by rugby league players(8-10) and Australian Rules footballers(2,16) have been shown to be associated with injury in these populations. Although not shown in professional soccer, the physical workload experienced by a player from training and matches may also be important in regards to injury in this population.

In elite soccer, non-contact injuries such as muscle strain and joint sprains represent a major injury source(4,5) and are considered to be largely preventable compared to contact type injuries (e.g. collisions with opposition players(9,16). For this reason, the present study focused specifically on the effects of internal workload on non-contact injuries.

The aim of this study was therefore to analyse the association between the internal workload experienced by elite soccer players from both training and matches with non-contact injury occurrence. It was hypothesised that (1) total workloads and (2) large increase in weekly workloads will be associated with a non-contact injury incidence.

Methods

Participants

During the pre-season and competitive season 2012/13, 92 professional soccer players from 4 elite European teams were prospectively followed (age: 26.6±4.7 yr; height: 182.4±7.2 cm; body mass: 77.5±7.2 kg, the 1st week of July 2012). Team A competed in the French Ligue 1 and UEFA Champions League competitions (n=24). Team B competed in the Italian Serie A and UEFA Champions League (n=19). Team C competed in the Spanish Primera Liga (n=26). Team D competed in the Spanish Primera Liga and the UEFA Europa Cup competitions (n=23). The season was split into two distinct periods: pre-season (early July to early - mid August 2012 depending on the pre-season and league start date), and in-competitive season (early to mid August to end May 2013). Pre-season period lasted 41±5 days (from 34 for Team A to 46 days for Team B), the in-competitive season period lasted 279±13 days (from 269 for Team B to 298 days for Team D).

Quantification of workload

The intensity of training sessions and matches was determined using the rating of perceived exertion Borg CR-10 scale.(6) Players were asked to rate the intensity of all sessions and matches within 20 to 30 minutes after completion of the session/match. Workload was calculated using the method proposed by Foster et al.(6), whereby the intensity rating of the session is multiplied by the duration for each player for each training session or match. Workloads included both training and match. Training loads included on field sessions, gym sessions and recovery sessions. Matches included all friendly and competitive matches. Total workload corresponded to the sum of the workload per session for all of training sessions and matches during the season. The weekly workload corresponded to the sum of the workload for all of training sessions and matches for each week. A mean of the weekly load for all of the weeks, called 'usual' workload was also calculated for each player. The 'usual' workload was then compared with each week of the season.

Injury Data collection

Injury collected corresponded to 'time-loss' injuries and resulted in a player unable to take a full part in future soccer training or match due to physical complaints.(7) Illnesses, diseases and mental complaints were not considered as physical complaints, but were taken into account to calculate match and training exposure. Information about circumstances (training or match), mechanism of injury (contact or non-contact), location and type of injury was recorded. An injured player was considered injured until the club doctor cleared him for participation in full training or matches. Location and type of injury were monitored according to the classifications proposed by Fuller et al.(7). The location of injuries was classified according to the main groupings (head and neck, upper limbs, trunk, lower limbs) and categories (head/face, neck/cervical spine, shoulder/clavicula, upper arm, elbow, forearm, wrist, hand/finger/thumb, sternum/ribs/upper back, abdomen, lower back /pelvis /sacrum, hip/groin, thigh, knee, lower leg/Achilles tendon, ankle, foot/toe). Type of injury was classified according to the main groupings (fracture and bone stress, joint and ligament, muscle and tendon, contusions, laceration and skin lesion, central/peripheral nervous system, other) and categories (fracture, other bone injuries, dislocation/subluxation, sprain/ligament injury, lesion of meniscus or cartilage, muscle rupture/tear/strain/cramps, tendon injury/rupture/tendinosis/bursitis, haematoma/contusion/bruise, abrasion, laceration, concussion, nerve injury, dental injuries, other injuries).

Injury severity was defined as the number of days that had elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection. Injuries were classified into 4 categories of severity according to the length of absence from full training sessions and matches(11): slight (1-3 days), minor (4-7 days), moderate (8-28 days) and major (more than 28 days), including the day of injury. The duration of training sessions (in the gym and on the field of play) and matches (hours) were monitored for each player. Match exposure was defined as play between teams from different clubs. Training exposure corresponded to team-based and individual physical activities under the control or guidance of the team's coaching or fitness staff that are aimed at maintaining or improving players' football skills or physical condition. Injury rate was calculated as all injuries per 1000 h of soccer (training + matches), injuries per 1000 h of training and injuries per 1000 h of matches.

Statistical analysis

Results are expressed as means ± standard deviations (mean ± SD). The normality distribution of the data was checked with the Shapiro-Wilk test. Paired Student's t-test was used to compare workload during pre-season and workload during in-season, as well as weekly workloads within the three weeks before each injury and the mean weekly workload. The magnitude of differences was also expressed as standardized mean difference (Cohen effect sizes, ES). The criteria to interpret the magnitude of the ES were as follows: 0.0 – 0.1 trivial, very small, 0.1 – 0.3 small, 0.3 – 0.5 moderate, 0.5 – 0.7 large, 0.7 – 0.9 very large, >0.9 almost perfect, >1 perfect.(12) The relationship between workloads and incidence of injury was analyzed using a Pearson product moment correlations. The correlation coefficients were interpreted in accordance with the scale of magnitude proposed by Hopkins (www.sportsci.org/ressources/stats): $r<0.1$ is trivial; $0.1\leq r<0.3$ is small; $0.3\leq r<0.5$ is moderate; $0.5\leq r<0.7$ is large; $0.7\leq r<0.9$ is very large; $0.9\leq r<1$ is nearly perfect. Fisher's Exact test was used to compare non-contact injury incidence between training and match, and between pre-season and in-season. For injury incidence and workload, the 95% confidence intervals (CI) were also calculated. Statistical significance was set at $p<0.05$

Results

Exposure to training and match

In total, the 92 players were exposed to 20741 hours of training and 3713 hours of matches during the season.

Total injury and injury rate

A total of 180 non-contact injuries in matches and training were reported, which corresponded to an overall non-contact injury incidence of 7.4 per 1000 hours of exposure (95% CI: 6.3 to 8.4). Non-contact injury incidence during training (4.2 per 1000 hours of exposure, 95% CI: 3.4 to 5.1) was significantly lower ($p<0.001$) than non-contact injury incidence during match (24.8 per 1000 hours of exposure, 95% CI: 19.7 to 29.8). The overall non-contact injury incidence during pre-season (6.7 per 1000 hours of exposure, 95% CI: 4.1 to 9.3) was not significantly different from the overall non-contact injury incidence during in-season (7.8 per 1000 hours of exposure, 95% CI: 6.6 to 9.0). The training non-contact injury incidence during pre-season (5.9 per 1000 hours of exposure, 95% CI: 3.4 to 8.4) was not significantly different from the training non-contact injury incidence during in-season (3.9 per 1000 hours of exposure, 95% CI: 3.0 to 4.8). The match non-contact injury incidence during pre-season (14.8 per 1000 hours of exposure, 95% CI: 0.3 to 29.2) was not significantly different from the match non-contact injury incidence during in-season (25.6 per 1000 hours of exposure, 95% CI: 20.2 to 30.9). Non-contact injuries severity are presented in Table 1. Main groupings and categories for the location and for the type of non-contact injuries are presented in Tables 2 and 3, respectively.

Table 1. Non-contact injury severity

Injury severity	**(n)**
Slight	53
Minor	44
Moderate	60
Major	23

Table 2. Main groupings and categories for the location of non-contact injuries.

Head and Neck	**Total**
Head, face	0
Neck, cervical spine	8
Upper limbs	
Shoulder, clavicula	0
Upper arm	0
Elbow	0
Forearm	0
Wrist	0
Hand, finger	0
Trunk	
Sternum, ribs, upper back	0
Abdomen	1
Lower back, pelvis, sacrum	5
Lower limbs	
Hip, groin	42
Thigh	64
Knee	24
Lower leg, Achilles tendon	14
Ankle	18
Foot, toe	4

Table 3. Main groupings and categories for the specific type of non-contact injuries.

Fracture and bone stress	
Fracture	1
Other bone injuries	0
Joint (non-bone) and ligament	
Dislocation, subluxation	0
Sprain, ligament injury	45
Lesion of meniscus or cartilage	6
Muscle and tendon	
Muscle rupture, tear, strain, cramps	109
Tendon injury, rupture, tendinosis, bursitis	17
Contusions	
Haematoma, contusion, bruise	N/A
Laceration and skin lesion	
Abrasion	N/A
Laceration	N/A
Central, peripheral nervous system	
Concussion	N/A
Nerve injury	0
Other	
Dental injuries	0
Other injuries	2

Workload

The total workload on the full season was 82396±41153 au (range: 10013 to 172246 au), which it corresponded to 2356±905 au (range: 90 to 10000 au) per week and 469±214 au per session (range: 202 to 829 au). The weekly workload during the full season is shown in Fig. 1. The workload per session (376±163 au, 95% CI: 340 to 412), as well as the weekly workload (3200±1754 au, 95% CI: 2814 to 3586) during pre-season, were significantly higher ($p<0.001$; ES=1.9 and 2.1, respectively) than the workload per session (257±104 au, 95% CI: 234 to 279) and the weekly workload (1770±763 au, 95% CI: 1611 to 1930) during in-season.

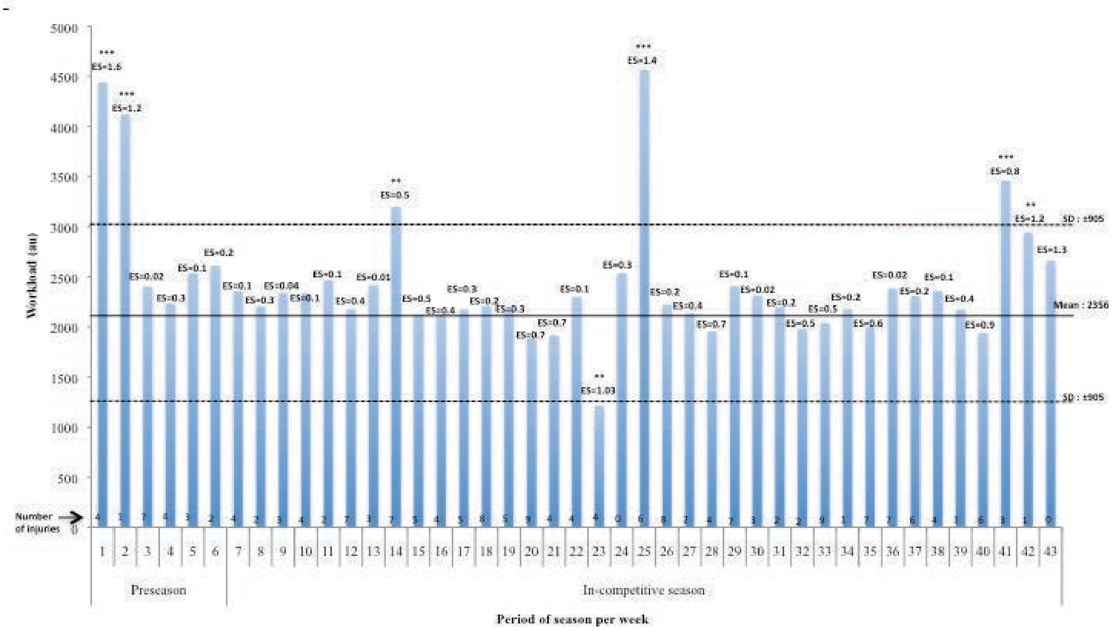

Figure 1. The weekly workload throughout the 2012/13 season and number of injuries in incurred during each week.

Relationships between workload and injuries

The overall incidences of injury for the full season, for the pre-season and the in-season were not significantly related (trivial to small correlations) to the total workload, the workload per session or the weekly workload (Table 4). Similarly, the training and the match incidences of injury for the full season, for the pre-season and the in-season were not significantly related (trivial to small correlations) to the total workload, the workload per session or the weekly workload (Table 4).

Table 4. Relationships between workload and incidence of non-contact injuries

		Overall incidence of injury	**Training incidence of injury**	**Match incidence of injury**
Full Season	**Total workload**	r=-0.08 (p=0.48)	r=-0.09 (p=0.41)	r=-0.06 (p=0.59)
	Workload per session	r=-0.05 (p=0.63)	r=-0.04 (p=0.71)	r=0.07 (p=0.50)
	Weekly workload	r=-0.09 (p=0.38)	r=-0.11 (p=0.32)	r=-0.06 (p=0.59)
Pre-Season	**Total workload**	r=-0.05 (p=0.61)	r=-0.08 (p=0.49)	r=0.11 (p=0.32)
	Workload per session	r=-0.06 (p=0.62)	r=-0.07 (p=0.51)	r=0.11 (p=0.33)
	Weekly workload	r=-0.03 (p=0.80)	r=-0.02 (p=0.79)	r=0.06 (p=0.60)
In-Season	**Total workload**	r=-0.08 (p=0.44)	r=-0.01 (p=0.94)	r=-0.11 (p=0.31)
	Workload per session	r=-0.06 (p=0.57)	r=-0.03 (p=0.86)	r=-0.13 (p=0.28)
	Weekly workload	r=-0.06 (p=0.61)	r=-0.02 (p=0.92)	r=-0.12 (p=0.29)

The weekly workload recorded the week before each injury (2442±969 au, 95% CI: 2282 to 2613) was significantly higher ($p<0.001$; ES=0.5) than the ‘usual’ weekly workload (2039±788 au, 95% CI: 1908 to 2178). The weekly workload recorded two weeks before each injury (2610±1272 au, 95%CI: 2380 to 2840) was significantly higher ($p<0.001$; ES=0.5) than the ‘usual’ weekly workload (2042±810 au, 95%CI: 1883 to 2163). The weekly workload recorded three weeks before each injury (2502±1125 au, 95%CI: 2289 to 2724) was significantly higher ($p<0.001$; ES=0.5) than the ‘usual’ weekly workload (2057±830 au, 95%CI: 1902 to 2223).

Discussion

The purpose of the present study was to investigate the relation between workload and the incidence of non-contact injuries in elite European soccer players. The incidence of non-contact injuries overall, in training and in matches during the full season, pre-season and in-season was not affected by the total workload, nor the workload per session or the weekly workload. However, the weekly workload recorded up to 3 weeks prior each injury was significantly higher ($p<0.001$, large effect sizes) than the 'usual' weekly workload.

Some studies have already shown that the workload is related to non-contact injuries in rugby league players(8,9) and Australian Rules Footballers.(2) These studies typically support a relation between the total workload and non-contact injury. Gabbett et al.(9) found the risk of non-contact, soft tissue injuries to be higher when players experienced a specific weekly workload threshold. During pre season, a workload of between 3000 to 5000 au meant that players were 50-89% more likely to sustain an injury. During the in-season, this threshold was injury likelihood was increased was lower between 1700 to 3000 au. Another study in Rugby League players(8) found that total workload was significantly ($p<0.01$) related to non-contact field injuries. In Australian Rules Footballers,(2) the accumulated load during the 3 weeks prior to an injury was highly specific to non-contact injury. In contrast to these studies, we did not find any relation between the total workload, the total workload per session nor for the total weekly load at any time point for the full season, pre-season or in-season.

Instead, the present study revealed that the weekly workloads recorded the week, two and three weeks before each injury were largely higher ($p<0.001$; $ES=0.8$) than the 'usual' weekly workload. So, an increase in the weekly workload greater than the normal weekly workload for a player could lead to the occurrence of a non-contact injury. Specifically, a 20% greater than normal workload in the 1 week leading to the injury was related with non-contact injury occurrence. Two weeks out from an injury a 28% higher workload than the normal weekly load was significantly related to injury. Finally, 3 weeks prior to occurrence of a non-contact injury a 22% higher workload than the players' normal load was related with injury. The results of the present study suggest that the workload of elite soccer players may be a risk factor for non-contact injury and that careful, individual monitoring of the changes in workload compared to the players 'usual' load may be an useful tool to identify players who may be at increased risk of non-contact injury.

The evolution of the workload over 1 full season shown in figure 1 highlights that as expected a higher workload is seen during the pre-season period (weeks 1 and 2) where training is usually focused on improving the physical capabilities of players. Additionally, there is a spike in workload in week 24 which corresponds to the week following the mid-season winter break. It is not known what training the teams involved in this study performed during this week but it could be postulated that this week was treated as a mini pre-season. Future research should verify this evolution and determine the overall training program of professional teams throughout a full season in order to further understand periods of the season with higher workloads.

Conclusion

Increases in the weekly workload of elite soccer players above their 'usual' workload may constitute a risk factor for non-contact injury in the players studied in the present study. At least one full season may be required to determine players' 'normal' workloads and to be able to identify when they are out-with their norm. The present results suggest that individual monitoring of players' weekly workloads is recommended in an attempt to reduce non-contact injury in the elite soccer population.

Future research needs to be conducted with larger sample sizes and over longer periods of time in order to further validate workload as a risk factor in this population. It would be interesting also to study the combined relation between player workload using the RPE method (internal workload) and measures of external workload variables such as running loads measured via GPS and accelerometer technology. Such an approach has shown a relation with non-contact injury risk in elite Australian Rules footballer.(2) This could further enhance our understanding of workload and non-contact injury risk in elite soccer players.

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4° Application d'un programme de prévention des blessures

4.1 Étude 5 : Effet d'un programme de prévention des blessures chez les joueurs de football professionnel engagés dans une compétition Européenne.

Introduction

Injuries in elite professional soccer teams are a major concern as they affect player health and performance and club economy. In terms of health, injuries impair the players' ability to work during the treatment period, they can increase the risk of re-injury at the same anatomical site as well as the risk of injury to a different body part and also affect long-term health: 47% of professional soccer players were forced to retire because of an injury and 32% were medically diagnosed as suffering from osteoarthritis in at least one of the lower limb joints.[8] Regarding performance, a lower injury incidence has been shown to be strongly correlated ($r=0.93$, $p<0.01$) with a team's final league ranking.[10] Additionally, a lower injury burden ($p=0.043$) and higher match availability ($p=0.048$) were associated with success in the UEFA Champions League or Europa League.[15] From a financial perspective, professional clubs continue to pay high salaries while players are unavailable through injury as well as costs associated with medical fees.

Soccer is associated with a high injury rate: an elite level player can expect to sustain on average 2.0 injuries per season.[11] Four main injury types have been identified as the most frequently sustained: hamstring (12%), adductor strains (9%), ankle sprains (7%) and knee sprains (5%).[11]

Elite players belonging to teams competing in European competitions can play in more than 50 matches per season comprising domestic league matches, league and national cup matches, and UEFA Champions League/Europa League matches. This schedule requires certain players to play 2 matches per week over several weeks. Research has shown that the injury rate was over 6 times higher in a Champions League team when players play 2 matches per week compared to when they play only 1 match per week (25.6/1000 versus 4.1/1000 hours of exposure).[9] Bengtsson et al.[3] confirmed these results with a study involving 27 professional teams over 11 seasons. Total injury rates and muscle injury rates were significantly increased in league matches when the recovery time was lower or equal to 4 days compared with matches where the recovery time was higher or equal to 6 days.

Although some injury prevention programs are effective in reducing the injury rate,[1.25.27] there has been no study, to the authors' knowledge, investigating the effects of an injury prevention program in players regularly playing 2 matches per week at the highest level and competing in the European competition. The purpose of the present study was to investigate the effects of an injury prevention program, targeting the most common injuries, on the injury rates in a top-level team participating in the UEFA Europa League.

Methods

Subjects

Injuries were monitored during two seasons (2008/2009, 2009/2010) in 37 professional soccer players playing for the same top-level team. The inclusion criteria were as follows: to provide written informed consent, to start and to complete the season with the first team and to fully complete the injury prevention program during the intervention season when they were able to do so. One player during the intervention season was excluded, as he did not want to follow the injury prevention program. For the season 2008/2009, 28 players were involved (age: 23.7±4.1 yr; height: 182.4±7.2 cm; body mass: 79.5±6.7 kg, on the 1st July 2008), and 27 players during the season 2009/2010 (age: 24.0±3.6 yr; height: 181.4±6.5 cm; body mass: 77.6±6.5 kg, on the 1st July 2009). Eighteen players were involved during the entire 2 seasons. This study was made with the agreement of the ethical committee in biomedical research and the recommendation of the Helsinki declaration.

During the season 2008/2009, the team played 50 matches: 38 League matches, 4 National Cup matches, 1 League Cup matches and 7 friendly matches. The team played 11 matches separated by at most 4 days, and 39 matches separated by at least 5 days. During the season 2009/2010, the team played 61 matches: 38 League matches, 14 Europa League matches, 1 National Cup match, 2 League Cup matches and 6 friendly matches. The team played 27 matches separated by at most 4 days, and 34 matches separated by at least 5 days. Among all of the players involved in the study, 14 played from 1 to 8 international matches per season. These international matches were taken into account in the injury rates. In addition, the matches played by some professional players when training and competing in the reserve team were also taken into account in the injury rates.

Experimental Approach to the Problem

The season 2008/2009 represented the control season where no injury prevention program was performed. The season 2009/2010 represented the experimental season in which an injury prevention program was implemented. The 3 technical coaches, medical doctor and the 3 physiotherapists remained the same during these two seasons. The only change was the fitness coach. During the two seasons, the typical week consisted of 7 training sessions when playing one match per week and 4 training sessions when playing two matches per week. Table 1 presents the duration and the level of intensity of the training sessions for a typical week when playing one or two matches per week. Global intensity of the session was described using a subjective scale from 0 (rest) to 10 (maximal) proposed by Foster et al.[13]

Table 1: Duration and level of intensity of the training sessions for a typical week when playing one or two matches per week.

Day	**One match a week**	**Two matches a week**
Saturday	Match	Match
Sunday	Rest	Duration: 0.75 hour Intensity: Level 2
Monday	Duration: 1 hour Intensity: Level 3	Duration: 1 hour Intensity: Level 4
Tuesday	*Morning* Duration: 1.5 hours Intensity: Level 8 *Afternoon* Strength: Lower body Duration: 1 hour Intensity: Level 4	Duration: 1 hour Intensity: Level 3
Wednesday	*Morning* Duration: 1.5 hours Intensity: Level 6 *Afternoon* Strength: Upper body Duration: 1 hour Intensity: Level 4	Match
Thursday	Duration: 1 hour Intensity: Level 2	Duration: 0.75 hour Intensity: Level 2
Friday	Duration: 1 hour Intensity: Level 4	Duration: 1 hour Intensity: Level 3
Saturday	Match	Match

Procedures

The injury prevention program consisted of 3 exercise modalities: (1) eccentric exercise, specifically, the Nordic hamstring exercise, good morning/single leg deadlift and adductor eccentric exercise on a Pilates reformer, (2) proprioceptive exercises involving static and dynamic balance and (3) core stability consisting of prone, side and reverse bridge. Video examples of the injury prevention exercises are available in the online version of this article. The Nordic hamstring (Appendix D.1.) is a partner exercise. The player starts in a kneeling position, with his torso from the knees upward held rigid and straight. A training partner applies pressure to the athlete's heels/lower legs to ensure that the feet stay in contact with the ground throughout the movement. The athlete then attempts to resist a forward-falling motion using his hamstring muscles to maximize loading in the eccentric phase. The participants were asked to brake the forward fall for as long as possible using the hamstrings. The athletes were asked to use their arms and hands to buffer the fall, let the chest touch the surface, and immediately get back to the starting position by pushing with their hands to minimize loading in the concentric phase.[1,25] The single leg deadlift (Appendix D.2.) and Good morning (Appendix D.3.) were alternated between each session. The good morning exercise was initiated from 180° hip extension (upright position) with an Olympic bar of 20 kg rested on the superior aspect of the trapezius. Eccentric hip flexion was performed until the torso was parallel with the floor (approximately 90° hip flexion). Concentric hip extension completed the lift until the player returned to an upright position. The single leg deadlift was also initiated from an upright position (180° hip extension) with the player standing on one leg. Players held one dumbbell of 6 to 12 kg (according to the level) in each hand hanging at arms length. Eccentric hip flexion was performed until torso was parallel with the floor keeping the dumbbells close to the legs throughout the descent. Concentric hip extension completed the lift until the player returned to an upright position. Adductor eccentric exercise (Appendix D.4.) was performed on a Pilates reformer (Peak Pilates®, Venice, CA, 90291). Players started by standing on the Pilates reformer with one leg on the moveable portion, hips and knees straight and hands placed laterally on the trunk. The leg on moveable portion was abducted, so that the centre of gravity moves laterally as much as controllably possible. The leg is then adducted, sliding back to the starting position. This was done for both legs. Initially players started with one spring and progressed to no springs as the exercise became easier. The proprioceptive exercises differed according to the period of the season. During the preseason and 1st half of the competitive season (July to August and August to December, respectively) static proprioceptive exercises were performed on two types of surface: a cushioned sponge pad (Airex AG®, Switzerland, 5643) and a suspension swing apparatus. Static proprioception refers to exercise performed by players balancing on one leg at varying knee angles. Dynamic proprioceptive exercises were used during the 2nd period of the competitive season (January to May). These exercises included single leg jumping/hopping with controlled landings at different knee angles on various types of surfaces: sponge pads, balance pro trainer (BOSU®, Ohio, 44805) and trampoline (Appendix D.5.). The core stability exercises were static and consisted of the prone bridge (Appendix D.6.), side-bridge and supine bridge respectively. The prone bridge began with the player lying on his front and lifting his weight off the ground keeping his elbows and toes on the ground and the trunk in neutral alignment. The side bridge began with the player lying on his side and subsequently lifting his torso and legs off the ground keeping one elbow and both feet on the ground for support with the trunk in neutral spine alignment. The supine bridge began with the player lying on his back with legs straight, subsequently he lifted his torso and lower limbs from the ground using heels and forearms to support his weight (arms shoulder width apart and feet together). The trunk was aligned with the legs and the spine in neutral position. Table 2 details the specifics of the injury prevention program i.e. sets, repetitions, and durations of sets.

This program was performed 4 times per week during the pre-season period, then twice per week when one match per week was played and once per week when one match per week was played. When one match per week was played, the 2 sessions were performed 3 days after the match and 2 days before the next match. When two matches per week were played, the session was performed 2 days before the midweek match. The injury prevention program and the objectives were presented to the players. Each exercise was taught and supervised by the same fitness coach or physiotherapist throughout the full season. The compliance in this program was recorded and displayed after each session. The injury prevention program was performed before the football session and lasted between 20 and 30 min.

Table 2: Specifics of the injury prevention program

			Nordic hamstring exercise	Single leg deadlift/good morning	Adductor eccentric exercise	Core stability	Proprioceptive exercises
Pre-season	Week 1	Sets	1	1	1	1	1
		Reps	6	8	8	N/A	N/A
		Time	N/A	N/A	N/A	45 s	3 min
	Week 2	Sets	1	1	1	1	1
		Reps	8	10	10	N/A	N/A
		Time	N/A	N/A	N/A	1 min	5 min
	Week 3	Sets	2	2	2	2	2
		Reps	6-10	8-10	8-10	N/A	N/A
		Time	N/A	N/A	N/A	45 s to 1 min	3 to 5 min
	Week 4	Sets	3	3	3	2	2
		Reps	8	10	10	N/A	N/A
		Time	N/A	N/A	N/A	1 min	5 min
1 match per week		Sets	1 to 2	1 to 2	1 to 2	1 to 2	1 to 2
		Reps	8 to 10	10	10	N/A	N/A
		Time	N/A	N/A	N/A	1 min	3 to 5 min
2 matches per week		Sets	1	1	1	1	1
		Reps	8	10	10	N/A	N/A
		Time	N/A	N/A	N/A	1 min	3 min

Injury definition, classification, severity and injury rate

Injury data collected corresponded to “time-loss” injuries that resulted in a player being unable to take a full part in future soccer training or match due to physical complaints.[14] Illnesses, diseases and mental complaints were not considered as physical complaints, but were taken into account to calculate match and training exposure. Information about circumstances (training or match), mechanism of injury (traumatic or overuse), location, type, recurrent injury, time-lost due to injury and the number of matches missed was recorded. The same club doctor diagnosed all injuries and an injured player was considered injured until the club doctor cleared him for participation in full training or matches. Location and type of injury were monitored according to the classifications proposed by Fuller et al.[14] The location of injuries was classified according to the main groupings (head and neck, upper limbs, trunk, lower limbs) and categories (head/face, neck/cervical spine, shoulder/clavicula, upper arm, elbow, forearm, wrist, hand/finger/thumb, sternum/ribs/upper back, abdomen, lower back/pelvis/sacrum, hip/groin, thigh, knee, lower leg/Achilles tendon, ankle, foot/toe). Type of injury was classified according to the main groupings (fracture and bone stress, joint and ligament, muscle and tendon, contusions, laceration and skin lesion, central/peripheral nervous system, other) and categories (fracture, other bone injuries, dislocation/subluxation, sprain/ligament injury, lesion of meniscus or cartilage, muscle rupture/tear/strain/cramps, tendon injury/rupture/tendinosis/bursitis, haematoma/contusion/bruise, abrasion, laceration, concussion, nerve injury, dental injuries, other injuries). Injury severity was defined as the number of days that had elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection. Injuries were classified into 4 categories of severity according to the length of absence from full training sessions and matches[9]: slight (1-3 days), minor (4-7 days), moderate (8-28 days) and major (more than 28 days), including the day of injury. A recurrent injury was defined as an injury of the same type and at the same site as a previous injury and which occurred after a player's return to full participation from the previous injury. A recurrent injury was defined "early", "late" and "delayed" when it was occurring within 2 months, 2 to 12 months and more than 12 months, respectively. The duration of training sessions (in the gym and on the field of play) and matches (hours) were monitored for each player. Match exposure was defined as play between teams from different clubs. Training exposure corresponded to team-based and individual physical activities under the control or guidance of the team's coaching. Injury rate was calculated as all injuries/1000 h of soccer (training + matches), injuries/1000 h of training and injuries/1000 h of matches.

Statistical analyses

Overall injury rates, as well as training, match muscle and sprain injury rates, were reported as the number of injuries per 1000 player hours. Absolute and relative data concerning exposure, injury severity, re-injury, mechanism of injury, main groupings and categories for the location and for the type of injuries were calculated. Results concerning the number of injuries per player and per season were expressed as means ± standard deviations. Fisher's Exact test was used to compare injury rates (number of injuries per 1000 h of exposure) between control and experimental seasons. Odds ratios (OR) and 95% confidence intervals (CI) were also calculated. Significance level was set at $p<0.05$.

Results

Exposure to training and match

During the control season, the overall exposure (training and match) was 10463.8 hours, the training exposure was 9638.8 hours and the match exposure was 825 hours. During the experimental season, the overall exposure (training and match) was 9396.8 hours, the training exposure was 8390.3 hours and the match exposure was 1006.5 hours.

Effect of the injury prevention program

During the control season, a total of 135 injuries and a mean 4.6±2.5 injuries per player (range: 1 to 11 per player) in matches and training. In total, players who suffered injuries were not available for 1153 days (means ± SD: 8.5±18.9 days; range: 1 to 195 days). During the experimental season, a total of 76 injuries and a mean 2.6±1.8 injuries per player (range: 0 to 6 per player) in matches and training. In total, players who suffered injuries were not available for 615 days (means ± SD: 8.1±16.2 days; range: 1 to 92 days).

The overall injury rate for the control season (12.9 injuries per 1000 hours of exposure; 95% CI: 10.7 to 15.1) was significantly higher (p=0.0014; OR=1.60; 95% CI: 1.20 to 2.12) than the overall injury rate for the experimental season (8.1 injuries per 1000 hours of exposure; 95% CI: 6.3 to 9.9). The injury rate during training for the control season (6.9 injuries per 1000 hours of exposure; 95% CI: 5.3 to 8.6) was significantly higher (p=0.002; OR=2.01; 95% CI: 1.30 to 3.11) than the injury rate during training for the experimental condition (3.5 injuries per 1000 hours of exposure; 95% CI: 2.2 to 4.7). The injury rate during matches for the control season (82.4 injuries per 1000 hours of exposure; 95% CI: 62.8 to 102.0) was significantly higher (p=0.0037; OR=1.77; 95% CI: 1.20 to 2.59) than the injury rate during matches for the experimental condition (46.7 injuries per 1000 hours of exposure; 95% CI: 33.3 to 60.1).

Injury severity, re-injury and mechanism of injury according to the condition (control season versus experimental season) are presented in Table 3. Main groupings and categories for the location and for the type of injuries according to the condition (control season versus experimental season) are presented in Tables 4 and 5, respectively.

Table 3: Injury severity, re-injury and mechanism of injury classified according to the condition (control season versus experimental season).

	Control season	Experimental season
Injury severity (n):		
- Slight	62	44
- Minor	32	21
- Moderate	35	6
- Major	6	5
Re-injury (n):		
- Early	12	5
- Late	3	1
- Delayed	2	0
Mechanism of injury (n):		
- Traumatic	37	39
- Overuse	98	37

Table 4: Main groupings and categories for the location of injuries according to the condition (control season versus experimental season).

	Control season	Experimental season
Head and neck:		
- head/face	3	0
- neck/cervical spine	0	1
Upper limbs:		
- shoulder/clavicula	1	0
- upper arm	0	0
- elbow	0	0
- forearm	0	0
- wrist	0	0
- hand/finger	2	0
Trunk:		
- sternum/ribs/upper back	1	3
- abdomen	5	1
- lower back/pelvis/sacrum	6	5
Lower limbs:		
- hip/groin	21	11
- thigh	35	17
- knee	30	12
- lower leg/Achilles tendon	4	7
- ankle	18	13
- foot/toe	9	6

Table 5: Main groupings and categories for the type of injuries to the condition (control season versus experimental season).

	Control season	Experimental season
Fracture and bone stress:		
- fracture	2	1
- other bone injuries	6	1
Joint (non-bone) and ligament:		
- dislocation/subluxation	0	0
- sprain/ligament injury	35	13
- lesion of meniscus or cartilage	9	4
Muscle and tendon:		
- muscle rupture/tear/strain/cramps	49	23
- tendon injury/rupture/tendinosis/bursitis	13	5
Contusions:		
- haematoma/contusion/bruise	19	28
Laceration and skin lesion:		
- abrasion	1	0
- laceration	1	1
Central/peripheral nervous system		
- concussion	0	0
- nerve injury	0	0
Other		
- dental injuries	0	0
- other injuries	0	0

Muscle injury rate for the control season (4.7 injuries per 1000 hours of exposure; 95% CI: 3.4 to 6.0) was significantly higher (p=0.0128; OR=1.91; 95% CI: 1.17 to 3.14) than the overall injury rate for the experimental season (2.5 injuries per 1000 hours of exposure; 95% CI: 1.5 to 3.5). Sprain injury rate for the control season (3.3 injuries per 1000 hours of exposure; 95% CI: 2.2 to 4.5) was significantly higher (p=0.0078; OR=2.42; 95% CI: 1.28 to 4.57) than the overall injury rate for the experimental season (1.4 injuries per 1000 hours of exposure; 95% CI: 0.6 to 2.1).

Discussion

The purpose of the present study was to investigate the effects of an injury prevention program, targeting the most common injuries, on the injury rates in a professional team participating in European competition. The overall injury rate was significantly reduced by 37.2% (p=0.0014; OR=1.60; 95% CI: 1.20 to 2.12) during the season where the injury prevention program was implemented. The implementation of the injury prevention program during the experimental season also led to a significant decrease in match (-43.3%), training (-49.5%), muscle (-46.8%) and sprain (-57.6%) injury rates. In addition, the time-loss injuries were reduced by 46.7% during the intervention season.

The main originality of this study was the implementation of an injury prevention program in a top-level team, regularly playing 2 matches per week at the highest level and competing in European competition (61 matches during the experimental season including 27 matches separated by at most 4 days). Injuries are of particular concern during periods of 2 matches per week as the injury risk is significantly increased.[3,9] According to the common belief, it is difficult to implement an injury prevention program when 2 matches are played per week because the recovery time is short (lower or equal to 4 days) and the priority is to optimise recovery.[9] This belief may be due to the possibility that implementing an injury prevention program during a congested period can lead to an increase in the training load thereby delaying the recovery process and increasing injury rate. However, as done here, implementing an injury prevention program during the pre-season period will accustom players to eccentric exercises and therefore reduce the muscle damage induced by these exercises during the in-season. In addition, the reduction of repetitions when two matches per week were played should have contributed to maintaining the muscle adaptations, as well as minimizing the risk induced by muscle damage before playing the second soccer match.

The multifaceted injury prevention program implemented in the present study consisted of 3 main exercise modalities: (1) eccentric exercise, (2) proprioceptive exercises and (3) core stability.

Eccentric exercise is recommended to prevent muscle injuries and is argued to prevent injury by improving the muscles' ability to absorb more energy before failing.[21] In response to eccentric exercise, the optimum length of peak tension will occur at longer lengths.[4] There is strong evidence in the research literature for the beneficial effect of hamstring eccentric exercises as to prevent hamstring strain injury in professional soccer players.[1,2,25] In professional soccer players specifically, eccentric training of the hamstring muscles has been shown to significantly increase ($p<0.05$) the optimum length of these muscles.[5] Exercises where the adductor muscle is working eccentrically are also important to consider in injury prevention, as this resembles situations where the muscle-tendinous structures are at the highest risk of injury.[26] A similar adductor eccentric exercise with the same movement principle (sliding abduction/adduction) as the one used in the present study has been shown to effectively target muscle activity of the adductor longus muscle.[26] The implementation of these eccentric exercises could explain the decrease of muscle injury rate (-46.8%) following the injury prevention program.

The inclusion of proprioceptive exercises could explain the decrease of sprain injury rate (-57.6%). A beneficial effect of proprioceptive type training in isolation has been shown on ankle[23,28,29] and knee injuries.[6,16] Although we did not measure any outcomes of the present exercises other than on injury rates, it could be postulated that the proprioceptive exercises improved the contraction patterns and muscle strength related to enhanced ankle and knee stability. In a systematic review, Zech et al.[31] reported that proprioceptive and neuromuscular interventions after ankle and knee joint injuries can be effective for the prevention of recurrent injuries and the improvement of joint functionality. Although not

measured, it could be hypothesised that the proprioceptive exercises included in the injury prevention program enhance joint stability, proprioceptive and neuromuscular abilities.
Although the literature is often conflicting regarding the role of core exercises in injury prevention, there is some evidence to suggest that core deficiencies may be a risk factor in the athletic population for lower extremity injury in general,[22] knee,[30] low back pain[7] and hip, groin and thigh injuries in professional Australian Rules footballers.[17] The effects of the core stability training component may have allowed players to achieve improved dynamic trunk control, transfer and control of forces and motion to the distal segments of the kinetic chain.[18]

An important part of any intervention is the compliance required to achieve the expected results.[12,20] Poor compliance with an injury prevention program can reduce the effect of the program on successfully reducing injuries. In the present study, we placed a major emphasis on compliance, and educational sessions were performed with the squad at the start of the preseason and during the in-season to explain the interest to perform the injury prevention program. Only one player did not comply with the injury prevention program and was excluded from the study. It is likely that the high compliance from the players helped to maximise the effects on the injury rates during the intervention season. An interesting direction for future research could be the investigation of whether a ‘placebo effect’ exists in players performing an injury prevention program e.g. believers versus non-believers and if this affects compliance and quality of execution of injury prevention exercises and programs.

There are some limitations to our study. Firstly, 10 players left the club after the control season, and 9 new players came in the intervention season. Therefore, eighteen players were involved in the two seasons. This is a common methodological limitation in studies assessing the effects of injury prevention intervention in professional soccer teams.[1,24] However, this is the reality at the top level of professional football and our purpose was to determine the effects of injury prevention in ‘real-world’ circumstances. Secondly, the injury prevention program was made up of several exercises, which makes difficult to attribute the isolated effect of one exercise on the global decrease of the injury rate. The combination of the exercises could lead to larger adaptations and to improve the effect of the injury prevention program; in addition, it is realistic to the practical setting. Thirdly, the number of matches played was not equally distributed during the two seasons. The number of matches played was greater during the intervention period (61) than during the control season (50); and consequently the training volume was lower during the control season (9635 hours) than during the experimental season (8390 hours). However, as injury rate is higher during matches than training,[9,11] one could expect an increase in injuries during a season where more matches were played, but this was not the case. Fourthly, potential intrinsic risk factors were not included in the analyses. For example, injuries are also linked with some psychological factors such as life event stress, somatic trait anxiety, mistrust and ineffective coping.[19] Further injury prevention programs should include an intervention program targeting these modifiable factors.

To our knowledge, the present study is the first to demonstrate beneficial effects of a multifaceted injury prevention program using eccentric, proprioceptive and core stability exercise modalities on reducing the absolute number of time-loss injuries, overall injuries, specifically muscle strains, joint sprains and re-injuries as well as total, training and match injury incidence in a top-level European soccer team competing in the UEFA Europa League. It is also the first study showing that an injury prevention program can be successfully implemented even when playing two matches per week to reduce injuries. High compliance to the program by the players is likely to have helped to maximise the effects.

Practical application

The present study provides detailed information on how to develop and implement an injury prevention program into the overall training plan of an elite football team. These principles and methods can be applied to other team sports in an attempt to successfully reduce injuries.

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5° Conclusion

5.1 Synthèse

La principale question posée dans cette thèse était ‘Est-il possible de réduire les blessures sans contact au plus haut niveau du football professionnel ?’. Tout en répondant à cette question, cette thèse avait aussi pour but 1) d’analyser la relation entre les choix des praticiens et les recommandations publiées dans la littérature scientifique dans le domaine de la prévention des blessures, 2) d’identifier et d’évaluer les facteurs impliqués dans les blessures sans contact et 3) de mettre en place un programme d’exercices préventifs visant à réduire les blessures sans contact.

Dans cette thèse, la première étape du processus était d’étudier la relation entre la science et les applications pratiques concernant la prévention des blessures dans le football professionnel. Une enquête a été réalisée, puis envoyée auprès des départements médicaux et scientifiques de clubs de football professionnels pour identifier les principaux facteurs de risques de blessures, les tests de risques de blessures et les stratégies de prévention.

L’enquête a été envoyée à 90 clubs de première division à travers le monde dont 44 ont répondu. Les principaux résultats de cette enquête ont montré qu’il y avait une grande hétérogénéité au sein des département médicaux et scientifiques des clubs professionnels dans la perception et les pratiques concernant les facteurs de risque, les tests et les stratégies préventives mises en place. Pour ces 3 domaines, les 3 points les plus importants étaient les suivants (par ordre d’importance) : - Pour les facteurs de risque : 1er : les antécédents de blessures, 2ème : la fatigue, 3ème: les déséquilibres musculaires. - Pour les tests de risque de blessures : 1er : l’analyse fonctionnelle, 2ème : les questionnaires, 3ème : la dynamométrie isocinétique. - Pour les exercices de prévention : 1er : les exercices excentriques, 2ème : les exercices d’équilibres et de proprioception, 3ème : les exercices excentriques des ischio-jambiers.

La deuxième étape du procédé visant à étudier la relation entre la science et la pratique était de réévaluer de manière systématique ces principales perceptions et pratiques. La revue systématique évalue la qualité méthodologique de chaque article concernant les 3 principaux facteurs de risques, tests et stratégies préventives. Pour analyser la qualité méthodologique, une grille d'évaluation validée était utilisée (Downs et Black, 1998) et était associée à une grille de recommandations basée sur les niveaux d'évidences scientifiques (Harbour et Miller, 2001). Au total, 40 articles ont été retenus pour l'évaluation de la qualité méthodologique. La revue systématique a révélé que certains clubs s'appuyaient sur des recommandations scientifiques élevées comme les antécédents de blessures, les exercices excentriques des ischio-jambiers et les exercices d'équilibre et de proprioception pour prévenir les entorses de cheville. Cependant, les niveaux d'évidences scientifiques et les niveaux de recommandations de la plupart des perceptions et pratiques comme la fatigue, les déséquilibres musculaires, les mouvements fonctionnels, les questionnaires, les exercices excentriques autres que les ischio-jambiers et les exercices de proprioception pour prévenir les entorses au genou sont faibles.

Le second objectif de cette thèse était d'identifier et d'évaluer les facteurs impliqués dans les blessures sans contact. La première étape était d'élaborer un test facile et rapide à mettre en œuvre pour détecter les risques de lésions musculaires des ischio-jambiers. Ce test se devait d'être reproductible et sensible pour détecter de réels changements dans la force musculaire. L'objectif était de trouver un test simple et pertinent pouvant être utilisé facilement dans la pratique. Par conséquent, il a été décidé dans cette thèse d'élaborer un test simple et pratique en se basant sur un test présenté dans la littérature scientifique pour identifier les risques de lésions musculaires au niveau des ischio-jambiers (Schache et al., 2010). Ce test, composé de contractions isométriques de 3 secondes des muscles postérieurs des membres inférieurs à 90° et 30° de flexion du genou pour chaque membre, a été reconnu comme présentant un faible risque de blessures à cause des contractions isométriques et comme étant le plus adapté pour mesurer la force des muscles postérieurs des membres inférieurs (incluant les ischio-jambiers) durant la période de récupération suivant un match. Ce test a montré une bonne reproductibilité pour la jambe dominante à 90° (CV=4,3%, CCI=0,95), la jambe non dominante à 90° (CV=5,4%, CCI=0,95), la jambe dominante à 30° (CV=6.3%, CCI=0,93) et la jambe non dominante à 30° (CV=4,8%, CCI=0,86). La sensibilité de ce test a également été évaluée comme suffisement sensible pour détecter une baisse de la force isométrique des muscles postérieurs des membres inférieurs induite par des matchs de compétition à chaque angle du genou et pour les deux jambes, dominante et non dominante. Une baisse significative de la force isométrique ($p>0.01$, ES>1) pour la jambe dominante (-15% à 30° et -16% à 90°) et pour la jambe non dominante (-11% à 30° et -13% à 90°) était observée immédiatement après le match.

L'étape suivante dans cette thèse était de d'étudier la relation entre la charge de travail interne et l'incidence des blessures sans contact. Dans cette étude, les données de charge interne et de blessures ont été collectées chez 92 joueurs de 4 équipes de football de très haut niveau, évoluant dans les deux compétitions européennes que sont la Ligue des Champions et l'Europa League. Il a été montré que l'incidence globale des blessures sans contact n'était pas corrélée à la charge de travail totale, à la charge de travail par séance et à la charge de travail hebdomadaire. Cependant, il a été trouvé que la charge de travail de la semaine qui précédait chaque blessure était significativement plus élevée (+20%, $p<0.001$) que la charge de travail hebdomadaire moyenne de la saison. De même, la charge de travail de la 2ème semaine et de la 3ème semaine qui précédaient chaque blessure était significativement plus élevée (+28% et +22%, respectivement ; $p<0.001$) que la charge de travail hebdomadaire moyenne de la saison. Ces résultats montrent que la charge de travail est un facteur à prendre en considération dans la prévention du risque de survenue des blessures sans contact chez les joueurs de football professionnel.

Le 3ème objectif consistait en l'application d'un programme d'exercices de prévention des blessures basé sur des évidences scientifiques élevées à acceptables. La principale originalité de cette intervention était la mise en place d'un programme de prévention dans une équipe de très haut niveau, qui participe à une compétition européenne. La prévention des blessures est un enjeu important dans les équipes de très haut niveau puisqu'elles sont fréquemment engagées dans des périodes durant lesquelles 2 matchs par semaine sont joués. Durant ces périodes, le risque de blessure augmente (Bengtsson et al., 2013 ; Dupont et al., 2010). Selon les praticiens, il est difficile de mettre en place un programme de prévention des blessures quand 2 matchs par semaine sont joués, puisque la période de récupération est courte et la priorité est d'optimiser la récupération. Cette représentation est peut être liée à la possibilité qu'un programme de prévention des blessures lors de cette période augmenterait la charge d'entraînement et donc, retarderait les processus de récupération. Cependant, lorsque les joueurs sont familiarisés aux exercices excentriques pendant la période de préparation, cela réduit les dommages musculaires induits par ces exercices durant la période de compétition. De plus, la réduction du nombre de répétitions lorsque 2 matchs par semaine sont joués devrait maintenir les adaptations musculaires tout en minimisant le risque de blessures. Le programme de prévention élaboré dans cette étude était composé de 3 modalités d'exercices: (1) les exercices excentriques, (2) les exercices proprioceptifs et (3) les exercices d'équilibre. Ce programme a permis de réduire de manière significative l'incidence globale des blessures (8.1 blessures/1000h vs 12.9/1000h), l'incidence des blessures à l'entraînement (3.5/1000h vs 6.9/1000h), l'incidence des blessures en match (46.7/1000h vs 82.4/1000h), l'incidence des blessures musculaires (2.5/1000h vs 4.7/1000h) ainsi que l'incidence des entorses de cheville (1.4/1000h vs 3.3/1000h). Ces résultats montrent que le programme de prévention des blessures est efficace dans le football de très haut niveau, même lorsque 2 matchs par semaine sont joués.

En conclusion, cette thèse a permis d'étudier la relation qui existe actuellement entre les sciences et la pratique. Le procédé consistant à valider ou à réfuter les considérations et les techniques utilisées dans la pratique a été réalisé au moyen d'une revue systématique des considérations et pratiques du football professionnel de très haut niveau. En outre, cette thèse a mis en évidence certaines nouvelles stratégies dans la détection des risques de blessure sans contact. Tout d'abord, un test simple et pratique pour mesurer la force des muscles postérieurs des membres inférieurs a été élaboré pour que les praticiens puissent l'utiliser. Ensuite, l'augmentation de la charge de travail des joueurs de football professionnels au-dessus des moyennes de la charge de travail sur la saison a été identifiée comme un facteur à prendre en considération dans la prévention du risque de blessures sans contact chez les joueurs de football professionnel. Enfin, il a été démontré qu'un programme de prévention des blessures visant les facteurs de risques de blessures peut être mis en place avec succès chez des équipes jouant régulièrement 2 matchs par semaine.

5.2 Limites

Alors que l'un des objectifs de cette thèse était de maximiser la qualité et la rigueur scientifique des études menées, plusieurs limites doivent être soulignées.

L'étude envoyée aux clubs de première division à travers le monde présente plusieurs limites ; les clubs des différents championnats n'étaient pas représentés de manière égale, il est donc difficile de comparer les différences culturelles selon les championnats et certains championnats majeurs ne sont pas représentés, comme par exemple, l'Allemagne, le Portugal, le Brésil. De plus, il y a des différences de professionnalisme importantes entre les clubs, dans lesquelles les ressources (par exemple, les équipements et la taille du staff) varient et influencent les pratiques des équipes. Enfin, le taux de réponse au questionnaire peut être considéré comme faible (47%). Ce faible taux de réponse peut être expliqué par de nombreuses raisons ; (1) les clubs ne réalisent pas de tests de risque de blessures et/ou de programme de prévention et ne souhaitent donc pas remplir le questionnaire, (2) ils n'ont pas le temps de le remplir, (3) ils ne croient pas au fait de lier sciences et pratique en utilisant une approche basée sur les évidences scientifiques et incorporant des connaissances et découvertes issues de la littérature scientifique, (4) ils estiment que la nature des informations demandées est trop sensible pour être dévoilée. Un nombre de clubs sondés plus important ou un taux de réponse à l'enquête plus élevé aurait permis d'obtenir des résultats encore plus significatifs. Toutefois, d'après nos connaissances, il s'agit de l'enquête la plus complète réalisée à ce jour concernant les pratiques liées à la prévention des blessures chez les footballeurs professionnels de très haut niveau.

Dans l'étude dont le but était de vérifier les effets d'un programme de prévention des blessures chez des footballeurs de très haut niveau, plusieurs limites sont présentes. Tout d'abord, même si des essais aléatoires contrôlés montrent le plus haut niveau d'évidence scientifique (Harbour et Miller, 2001), dans la pratique, ils peuvent être remis en cause d'un point de vue éthique. Premièrement et principalement, l'objectif dans les clubs professionnels est de gagner les matchs et donc de s'assurer que les meilleurs joueurs soient disponibles pour jouer et donc que leur santé à court et à long terme est protégée. La prescription d'un programme d'intervention à un groupe et pas à un autre n'est pas réalisable. Le meilleur compromis était alors d'utiliser une saison contrôle où aucun programme de prévention n'était réalisé et de mettre en place un programme de prévention durant une saison expérimentale. De plus, 10 joueurs ont quitté le club après la saison contrôle et 9 joueurs sont arrivés lors de la saison expérimentale. Dix-huit joueurs étaient donc impliqués sur les deux saisons. Il s'agit d'une limite méthodologique classique dans les études cherchant à évaluer une intervention favorisant la prévention des blessures dans les équipes professionnelles de football (Owen et al., 2013 ; Arnasson et al., 2008). Cependant, il s'agit de la réalité des équipes de très haut niveau et l'objectif était de déterminer les effets de la prévention des blessures dans les conditions réelles du terrain. De plus, le programme de prévention des blessures était composé de plusieurs exercices, ce qui a pour conséquence de rendre difficile l'attribution des effets de chaque exercice de manière isolée sur la réduction de l'incidence des blessures, toutefois, la combinaison des exercices pourrait permettre des adaptations plus larges et pourrait permettre d'améliorer les effets du programme de prévention des blessures. De plus, ceci est plus proche des réalités du terrain puisque les programmes d'entraînement de football globaux sont réalisés de manière multi-dimensionnels. Les matchs joués n'étaient également pas distribués de manière égale lors des deux saisons. Le nombre de matchs étaient plus importants durant la saison expérimentale (61) que durant la saison « contrôle » (50) ; ainsi, le volume d'entraînement était plus important lors de la saison contrôle (9635 heures) que lors de la saison expérimentale (8390 heures). Toutefois, les calculs d'incidence de blessures prenaient cette augmentation d'exposition en compte. Enfin, les facteurs de risque intrinsèques n'étaient pas pris en compte dans les analyses. Par exemple, les blessures sont également liées à certains facteurs psychologiques comme les évènements de la vie pouvant créer du stress, une anxiété trait, un manque de confiance (Ivarsson & Johnson, 2010).

En vérifiant la fiabilité et la sensibilité des tests de la force isométrique des muscles postérieurs des membres inférieurs, certaines limites sont également à avancer. La contribution précise et l'activation de nombreux muscles ayant participé à la production totale de force durant le test n'a pas été évaluée. La flexion de genou peut également être influencée par d'autres muscles qui traversent l'articulation du genou comme le gastrocnémien. Il est également possible que l'activation des extenseurs de la hanche comme le grand glutéal et le grand adducteur contribuent à la force globale isométrique générée. Dans les études futures, l'utilisation de l'électromyographie de manière à enregistrer l'activité des ischio-jambiers internes et externes durant le test pourrait améliorer la valeur de ce test.

L'étude sur la relation entre la charge de travail et l'incidence des blessures comporte également des limites. Les données provenaient de 4 clubs de football jouant les compétitions européennes et mérite d'être prise en compte dans l'extrapolation des données. Les séances d'entraînement (contenu, volume, intensité) n'étaient pas calibrées dans chaque équipe. Le nombre de matchs n'était pas le même dans chaque équipe puisqu'il dépendait de la qualification dans les différentes coupes. Les séances de prévention de blessures n'étaient pas harmonisées entre les différents clubs. Les caractéristiques de la population, et plus spécifiquement les facteurs de risque intrinsèque des joueurs (âge, antécédents de blessures, etc.) n'étaient pas pris en compte dans l'analyse.

5.3 Perspectives

Bien que la présente thèse ait fourni des réponses et des solutions aux questions posées et aux problèmes réellement rencontrés en pratique, elle a également ouvert la voie à plusieurs pistes de recherches futures.

Plusieurs perceptions et pratiques mises en place, révélées dans de l'enquête, ne sont pas actuellement validées ou réfutées par la recherche comme la fatigue, les déséquilibres musculaires, les mouvements fonctionnels, les questionnaires, les exercices excentriques autres que les ischio-jambiers et les exercices de proprioception pour prévenir les entorses au genou.

Pour le test isométrique évaluant la force des muscles postérieurs des membres inférieurs suite à un match chez des footballeurs professionnels de haut niveau, il serait intéressant d'étudier la localisation anatomique des muscles impliqués et l'intensité des contractions. La cinétique de récupération de la force des muscles postérieurs des membres inférieurs pourrait être également étudiée. Il serait également intéressant de déterminer l'origine de la fatigue (centrale ou périphérique) qui explique les mécanismes par lesquels ces muscles subissent la fatigue. Il est également nécessaire de conduire une étude longitudinale avec un nombre important d'équipes de football professionnelles pour déterminer si ce test peut identifier les joueurs à risque de blessure des muscles postérieurs des membres inférieurs.

Pour la charge d'entraînement, il est nécessaire de valider ce facteur de risque chez les joueurs professionnels jouant moins souvent (1 match par semaine) avec des charges d'entraînement plus importantes au travers des études impliquant un échantillon large et sur plusieurs saisons. Il serait alors intéressant d'étudier la relation combinée entre la charge interne d'un joueur utilisant la perception de l'effort et les valeurs de charge de travail externe comme la course via des GPS et des accéléromètres. Une telle approche a montré une relation avec les blessures sans contact chez des joueurs de football australien (Colby et al., 2014). Cela permettrait d'améliorer notre compréhension de la charge de travail en lien avec le risque de blessure sans contact chez le footballeur professionnel de haut.

Enfin, même s'il a été démontré dans la présente thèse qu'un programme de prévention des blessures réduisait l'incidence des blessures dans une équipe de football professionnel jouant régulièrement deux matches par semaine, il serait intéressant de déterminer les effets spécifiques de différents exercices sur les changements potentiels relatifs à l'exercice comme la force excentrique, l'angle optimal, l'équilibre et l'activation centrale. Cela permettrait de déterminer les contributions spécifiques de différents exercices et de fournir des explications et/ou des mécanismes sous jacents.

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7° Annexes

Annexe A.

The survey administered to Medical and Sport Science departments of professional football teams from various premier leagues (Study I)

SURVEY – Non-contact injury risk factors and prevention

The purpose of this survey is to determine current practices and perceptions within the medical department belonging to elite European football teams in regards to injury risk and injury prevention. The global results of the survey could be published in congress, courses and scientific articles. Individual responses filled will be anonymous.

Please tick, □ Agree □ Do not agree

Objectives:
1) To determine the staff involved in the injury prevention
2) To establish the most commonly perceived risk factors for non-contact injuries
3) To identify the perceived effectiveness of injury prevention exercises

Name and position: Club:

Phone number: Email:

Date: Number of players:

Level: □ First Team □ Reserve and Youth

Concerning the Season 2012/13, please complete the following questions;

1° Staff

1.1 Can you specify the position of the persons involved in the injury prevention program (design and application)?

Position	Number of persons

1.2 For each of these persons involved in the injury prevention program, can you specify their level of qualification?

Position	Level of qualification

1.3 For each of these persons, can you specify their role in the injury prevention (test/design/application)?

Position	Design	Test	Application

<u>2° Non-contact injury risk factors</u>

2.1 On a scale from 1 (not important) to 4 (very important), can you specify the following as risk factors for non-contact injuries;

- Previous injury		- Movement efficiency	
- Age		- Psychological factors (e.g. stress, anxiety)	
- Fatigue		- Pitch surface	
-Anatomy/morphology		- Fitness	
- Growth period		Blood markers (e.g. creatine kinase, uric acid)	
- Genetics		- Footwear	
- Strength imbalance		- Hydration	
- Strength endurance		- Diet	
- Sleep			
- Flexibility			

Other, please specify:
……………………………………………………………………………………………..
……………………………………………………………………………………………..
……………………………………………………………………………………………..
……………………………………………………………………………………………..

3° Testing

3.1 When do you test the players for injury risk?
□ Pre season □ In season □ Post season
□ Other, please specify:
………………………………………………………………………………………..
………………………………………………………………………………………..
………………………………………………………………………………………..

3.2 Which tests to identify injury risk did you implement this season?
□ Isokinetics □ Questionnaire □ Functional Movement Screening
□ Other, please specify:
………………………………………………………………………………………..
………………………………………………………………………………………..
………………………………………………………………………………………..
………………………………………………………………………………………..

3.3 Which materials do you use?
………………………………………………………………………………………..
………………………………………………………………………………………..
………………………………………………………………………………………..
………………………………………………………………………………………..
………………………………………………………………………………………..

4° Injury prevention

4.1 Do you believe injury prevention program is of benefit?
□ Yes □ No

4.2 Do your players perform an injury prevention program?
□ Yes □ No

4.3 How often do you implement the injury prevention program?
- During pre-season:
□ 1X/month □ 2X/month □ 1X/week □ 2X/week
□ Other frequency:…………………………………………..

- During in-season
□ 1X/month □ 2X/month □ 1X/week □ 2X/week
□ Other frequency:…………………………………………..

- If you implement at least 1X/ week during in-season (one match per week):
□ 1X/week □ 2X/week □ 3X/week □ 4X/week
□ 5X/week

- If you implement at least 1X/ week during in-season (two matches per week):
□ 1X/week □ 2X/week □ 3X/week □ 4X/week
□ 5X/week

4.4 Do you prescribe an injury prevention program?

□ globally □ individually □ both

4.5 Can you tick the exercises you have included in your injury prevention program:

- Stretching			- Flywheel training		
- Balance exercise			- Pilates		
- Core			- Other eccentric		
- Isokinetics					
- Nordic hamstring exercise					

If you use some other exercises, can you specify them?

…………………………………………………………………………………………..
…………………………………………………………………………………………..
…………………………………………………………………………………………..
…………………………………………………………………………………………..

4.6 In order of importance, can you specify the 5 exercises the most effective in your program?

Position	**Exercise**
1	
2	
3	
4	
5	

4.7 What is the recovery duration afforded between injury prevention program and:

□ a game: ……………………….

□ a lower body strength session: ……………………….

□ another injury prevention program: ……………………….

Annexe B. Individual scoring sheets for methodological quality assessment of top 3 risk factors, tests and preventative strategies. (Study II)

B.1. Individual and overall quality score and corresponding level of scientific evidence for previous injury as a risk factor for injury

Study name	**Question number**														**Quality score (%)**	**Level of evidence**
	1	**2**	**3**	**5**	**6**	**7**	**10**	**11**	**12**	**18**	**20**	**21**	**22**	**25**		
Bennell et al. 1998	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Hagglund et al. 2013	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Fousekis et al. 2011	1	1	1	0	1	1	1	1	1	1	1	1	0	1	80	2++
Engebretsen et al. 2010a	1	1	1	2	1	1	1	1	1	1	1	1	0	1	93	2++
Engebretsen et al. 2010b	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Engebretsen et al. 2010c	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Engebretsen et al. 2010d	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Gabbe et al. 2010	1	1	1	2	1	1	0	1	1	1	1	1	1	1	93	2++
Gabbe et al. 2006	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Koulouris et al. 2007	1	1	1	1	1	1	1	1	1	1	1	1	1	1	93	2++
Walden et al. 2006	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Hagglund et al. 2006	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Arnason et al. 2004	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Orchard et al. 2001	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Verrall et al. 2001	1	1	1	2	1	1	1	1	1	1	1	1	0	1	93	2++

B.2. Individual and overall quality score and corresponding level of scientific evidence for fatigue as a risk factor for injury

Study name	Question number														Quality score (%)	Level of evidence
	1	2	3	5	6	7	10	11	12	18	20	21	22	25		
Zvijac et al. 2013	1	1	1	1	1	1	1	1	1	1	1	1	1	1	93	2++
Carling et al.a 2010	1	1	1	0	1	1	1	1	1	1	1	1	1	0	80	2++

B.3. Individual and overall quality score and corresponding level of scientific evidence for muscle imbalance as a risk factor for injury

Study name	Question number														Quality score (%)	Level of evidence
	1	2	3	5	6	7	10	11	12	18	20	21	22	25		
Zvijack et al. 2013	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Fousekis et al. 2012	1	1	1	1	1	1	1	1	1	1	1	1	0	1	87	2++
Fousekis et al. 2011	1	1	1	0	1	1	1	1	1	1	1	1	0	1	80	2++
Henderson et al. 2010	1	1	1	2	1	1	0	1	1	1	1	1	0	1	87	2++
Croisier et al. 2008	1	1	1	1	1	1	1	1	1	0	1	1	1	1	87	2++
O'Connor 2004	1	1	1	1	1	1	1	1	1	1	1	1	0	0	80	2++
Dauty et al. 2003	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Cameron et al. 2003	1	1	1	0	1	1	1	1	1	1	1	1	0	1	80	2++
Bennell et al. 1998	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Orchard et al. 1997	1	1	1	2	1	1	1	1	1	1	1	1	1	1	73	2+

B.4. Individual and overall quality score and corresponding level of scientific evidence for functional movement screen as a testing tool to identify injury risk

Study name	Question number														Quality score (%)	Level of evidence
	1	2	3	5	6	7	10	11	12	18	20	21	22	25		
Kiesel et al. 2013	1	1	0	2	1	1	0	1	1	1	1	1	0	0	73	2+
Kiesel et al. 2007	1	1	1	1	1	1	1	0	0	1	1	1	1	0	73	2+

B.5. Individual and overall quality score and corresponding level of scientific evidence for Questionnaire as a testing tool to identify injury risk

Study name	**Question number**														**Quality score (%)**	**Level of evidence**
	1	**2**	**3**	**5**	**6**	**7**	**10**	**11**	**12**	**18**	**20**	**21**	**22**	**25**		
Ivarsson & Johnsson, 2010	1	1	1	0	1	0	1	1	1	1	1	1	1	0	73	2+
Devantier, 2011	1	1	1	1	1	1	1	1	1	1	1	1	1	0	87	2++
Engebretsen et al.2010a	1	1	1	2	1	1	1	1	1	1	1	1	0	1	93	2++
Engebretsen et al.2010b	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Engebretsen et al.2010c	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Engebretsen et al.2010d	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++

B.6. Individual and overall quality score and corresponding level of scientific evidence for isokinetic testing as a testing tool to identify injury risk

Study name	**Question number**														**Quality score (%)**	**Level of evidence**
	1	**2**	**3**	**5**	**6**	**7**	**10**	**11**	**12**	**18**	**20**	**21**	**22**	**25**		
Fousekis et al. 2012	1	1	1	1	1	1	1	1	1	1	1	1	0	1	87	2++
Fousekis et al. 2011	1	1	1	0	1	1	1	1	1	1	1	1	0	1	80	2++
Henderson et al. 2010	1	1	1	2	1	1	0	1	1	1	1	1	0	1	87	2++
Croisier et al. 2008	1	1	1	1	1	1	1	1	1	0	1	1	1	1	87	2++
Cameron et al. 2003	1	1	1	0	1	1	1	1	1	1	1	1	0	1	80	2++
Bennell et al. 1998	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++
Orchard, 1997	1	1	1	2	1	1	1	1	1	1	1	1	1	1	100	2++

B.7. Individual and overall quality score and corresponding level of scientific evidence for eccentric exercise as an exercise to prevent injury

Study name	**Question number**																										**Quality Score (%)**	**Level of Evidence**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**		
Petersen et al. (2011)	1	1	1	1	2	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	5	88	1++
Holmich et al. 2010	1	1	1	1	2	1	1	0	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	5	88	1++
Arnason et al. (2008)	1	1	1	1	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	1	0	0	0	0	0	5	56	2+
Croisier et al. (2008)	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	0	0	0	1	1	5	75	2+
Fredberg et al. 2008	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	0	0	1	5	78	1++
Brooks et al. (2006)	1	1	1	1	0	1	1	0	0	1	1	1	1	0	0	1	0	1	0	1	0	0	1	0	0	5	59	2+
Gabbe et al. (2006)	1	1	1	1	2	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	0	1	1	1	5	84	1++
Askling et al. (2003)	1	1	1	1	2	1	1	1	0	0	1	1	1	0	0	1	0	1	1	1	1	0	1	0	0	5	72	1+
Croisier et al. (2002)	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0		34	2-

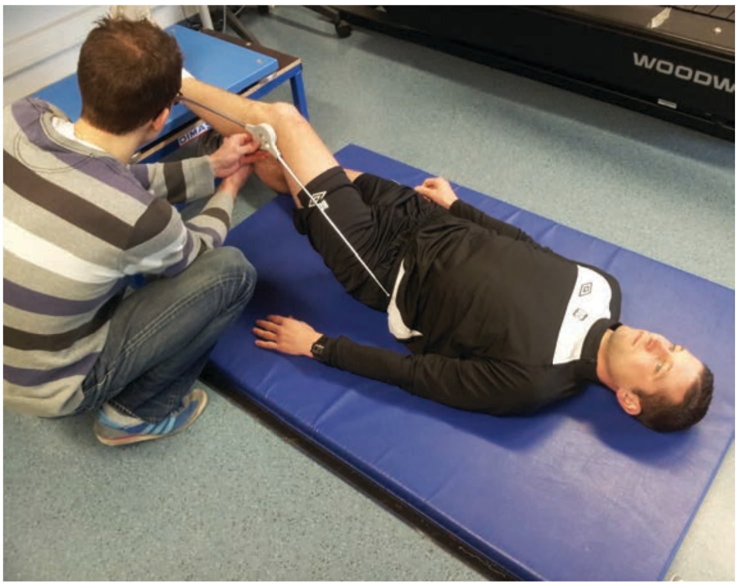
B.8. Individual and overall quality score and corresponding level of scientific evidence for balance/proprioception exercise as an exercise to prevent injury

Study name	Question number																									Quality Score	Level of
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18	19	20	21	22	23	24	25	26	27	(%)	Evidence
Mohammadi et al. 2007	1	1	1	1	0	1	1	0	0	1	1	1	1	0	0	0	1	0	0	1	0	1	1	0	0	5	59	1+
Carraffa et al. 1996	1	1	1	1	0	1	0	0	0	1	1	1	1	0	0	1	0	0	0	1	1	0	0	0	0	5	53	2+
Tropp et al. 1985	1	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1	0	0	1	5	63	1+

Annexe C. Figures demonstrating the positon of the isometric posterior lower limb muscle force (Study III)

C.1. Subject performing test of isometric posterior lower limb muscle force at 90°

C.2. Testing position of isometric posterior lower limb muscle force at 30°

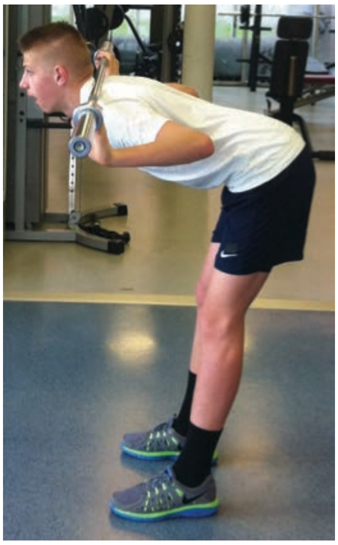


Annexe D. Figures demonstrating the exercises used in the multi-faceted injury prevention program (Study V)

D.1. Nordic hamstring exercise targeting the hamstring muscles

D.2. Single leg stiff-legged deadlift (SLDL) targeting the hamstring muscles

D.3. Good morning exercise targeting the hamstring muscles



D.4. Adductor eccentric emphasized exercise targeting the adductor muscles

D.5. An example of a dynamic balance/proprioception exercise station (targeting ankle and knee joints

D.6. Prone bridge targeting the ‘core’ muscles