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Injury prediction in veteran football players using the Functional Movement Screen™

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ABSTRACT
The Functional Movement Screen™ (FMS™) is aimed at assessing fundamental movements and is often used to identify players' injury risk. The purpose of this study was to determine whether the FMS™ can be used to predict injuries in veteran footballers (aged > 32 years). Eighteen veteran football teams (n = 238) were recruited and prospectively followed for 9 months. The players (44 ± 7 years; 178 ± 7 cm, 84 ± 11 kg) performed the FMS™ at the start of the study period. Players' exposure hours and injuries were recorded. The difference of FMS™ overall score between injured and uninjured players was not significant (11.7 ± 2.9 vs 12.2 ± 2.8 points; Mann-Whitney U-test P = 0.17). Players scoring <10 (score < 1 standard deviation [SD]) below the mean) had a significantly higher injury incidence (z-statistics P < 0.05) compared to an intermediate reference group (mean ± 1 SD; scores of 10–14). No lower injury incidence for players with scores of >14 (score > 1 SD above the mean) was found. Further analyses of potential risk factors suggest higher age, lower body mass and a longer football career to be risk factors for injuries. The findings of this study suggest that the suitability of the FMS™ for injury prediction in veteran footballers is limited.

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Soccer; prevention; assessment; risk factor; senior; FMS; recreational football

Introduction

Musculoskeletal injuries are a major concern not only in elite but also in amateur football players (Fuller, Junge, & Dvorak, 2012; Junge & Dvorak, 2004). For instance, Junge et al. (2011) examined injury incidences in Swiss amateur players. Male senior players (age was not specified) incurred between 4.9–6.1 injuries per 1000 training hours and 18.4 and 22.7 injuries per 1000 match hours, numbers which are similar to injury rates in professional players (Ekstrand, Hagglund, Kristenson, Magnusson, & Walden, 2013). Football injuries often cause absence from competition, which can compromise team performance. However, depending on the severity of the injury and on job requirements, they might also cause medical costs and absence from work. Data from the Netherlands (approximately 17 million inhabitants) illustrate the impact of football injuries: the estimated direct and indirect costs due to sport injuries are €1.3 billion per year based on a total of 3.6 million injuries, whereby 19% of all sport injuries are football injuries (van Beijsterveldt et al., 2011). Therefore, injury prevention seems to be of major importance not only for the individual player but also for the society as a whole in an economical sense.

According to van Mechelen, Hlobil, and Kemper (1992), the identification of injury risk factors is a crucial step for the implementation of successful prevention measures. For instance, decreased muscle strength and strength imbalances (Opar, Williams, & Shield, 2012), higher age and previous injury (Arnason et al., 2004) have been linked to an increased injury risk. Faulty functional movement patterns have also been discussed as an injury risk factor (Cook, Burton, & Hoogenboom, 2006a, 2006b; McCall et al., 2014). Although there is no consistent definition for a so-called functional movement in the scientific literature, Cook et al. (2006a) refer to an "integrated, functional approach, incorporating the principles of proprioceptive neuromuscular facilitation (PNF), muscle synergy, and motor learning" instead of the "traditional and isolated" approach. Over the last few years, the Functional Movement Screen™ (FMS™) (Cook et al., 2006a, 2006b) has gained increasing interest amongst practitioners. A survey by McCall et al. (2014) revealed that the FMS™ is used as a screening tool for injury risk in 66% of the 44 professional football clubs included in this study.

The FMS™ consists of seven test items (deep squat, hurdle step, in-line lunge, shoulder mobility, trunk stability push-up, active straight leg raise and rotary stability). It assesses the movement quality for each item on a 4-point Likert scale (0–3 points). The maximum attainable overall score is therefore 21 points. The FMS™ aims to assess basic locomotor and stabilising movements while maintaining postural control along the kinetic chain in a standardised manner (Cook et al., 2006a). Cook et al. (2006a) and Cook et al. (2006b) claim to consider general neuromuscular coordination, trunk strength, movement symmetry, as well as static and dynamic flexibility and stability during fundamental movements frequently needed in

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sports. For example, the squat is considered a movement common in various sports. Cook et al. (2006a) suggest that the squat position is the "ready position" and is required for most power movements involving the lower extremities. Consequently, the "deep squat" item could potentially assess the ability to perform this movement properly.

Several studies have indicated that a low FMS™ score is linked to a higher injury risk. The first published study of the FMS™ in 2007 was conducted by Kiesel, Plisky, and Voight (2007) within professional American football and comprised one season (approximately 4.5 months). The study results showed that an overall score of 14 points or less predicted serious injuries (≥3 weeks duration) with a specificity of 0.91 and a sensitivity of 0.54. In a similar vein, Chorba, Chorba, Bouillon, Overmyer, and Landis (2010) confirmed this cut-off point of 14 (specificity: 0.74 and sensitivity: 0.58) in female collegiate athletes participating in football, volleyball and basketball. Chorba et al. (2010) also followed the athletes for one season. Peate, Bates, Lunda, Francis, and Bellamy (2007) investigated firefighters during a 12-month period. "Failing" the FMS™ was defined as a score below 16 and was associated with a 1.7-fold increased injury risk. The injury predictive ability of the FMS™ in firefighters was confirmed by Butler et al. (2013); however in this study the cut-off point for an increased injury risk was ≤14.

In contrast to these studies, other researchers have detected poor associations or conflicting results with regard to the FMS™ overall score and injury risk. O'Connor, Deuster, Davis, Pappas, and Knapik (2011) and Lisman, O'Connor, Deuster, and Knapik (2012) reported that injury risk was higher for candidates with low (≤14) and very high (≥18) scores as compared to intermediate scores (15–17). Warren, Smith, and Chimera (2015) did not find any association of FMS™ overall score and injury risk in male college athletes. Research with competitive male runners revealed poor predictability of the FMS™ overall score for running injuries (Hotta et al., 2015). Recently, a large study by Bushman et al. (2015) examining 2476 physically active male soldiers aged 18–57 years found a low predictive value of the FMS™ overall score and injuries, although the results were statistically significant. The results of this study led to the author's conclusion that the FMS™ should not be implemented as injury risk screen in this population. In summary, the available research indicates that the FMS™ might have the potential to predict injuries; however, this quality may depend upon the sports or populations involved and requires further research.

A large number of football players continue playing at an older age. That refers to training and competition alike, and organised recreational veteran football competitions are established in many countries worldwide. In Germany, the minimum age required to qualify as a veteran football player is 30 or 32 years, depending upon the region's football association (there is no such upper age limit which restricts players from playing). Veteran football players in Germany represent approximately one-third of all registered players or approximately 1.8 million players (Woll & Dugandzic, 2007). As higher age has been described as a potential risk factor for football injuries (Arnason et al., 2004), injury prevention may be especially important in this age group.

Despite the frequent use of the FMS™ in various sports, there is a lack of research addressing its injury predictive ability in football. Since movement patterns assessed in the FMS™ seem relevant in football, it appears worthwhile to investigate this further. If players at an increased injury risk can be identified, subsequent preventive measures could be implemented in due time and thus future injuries might be avoided. The purpose of this study was to investigate the predictive validity of the FMS™ together with potential further risk factors for football injuries in veteran footballers. The study was designed as a prospective cohort study. Injury and exposure data were collected over one full season (nine months). All participants performed the FMS™ at the beginning of the study period. It was hypothesised that the FMS™ would be able to predict injuries in veteran football players.

Methods

Participants

For recruiting purposes we firstly introduced our study at a public regional veteran football event. Subsequently, we contacted each club with an organised veteran football team in the Saarland county by letter, email and/or phone. This was done in collaboration with the county's football association (Saarländischer Fußballverband, SFV). Inclusion criteria were that the teams regularly compete in league or friendly matches against other clubs and conduct regular weekly training sessions. With regard to the county's rules for veteran players the minimum age was 32 years. There was no upper age limit. The first 20 teams which agreed to participate and fulfilled the inclusion criteria were included in the study. Each participant received written and verbal study information and gave his written informed consent. Due to incomplete data reporting two teams had to be excluded from the analysis. Therefore, results refer to 18 teams. Anthropometrics and further characteristics of the participants are presented in Tables 1 and 2. The study was approved by the local ethics

Table 1. Characteristics of participants (n = 238).

	Mean	SD	Min	Max
Age (years)	44	7	32	69
Height (cm)	178	7	164	196
Body mass (kg)	84	11	58	118
BMI (kg/m^2)	26.4	2.8	20.7	36.1
FMS™ (overall score)	12.1	2.8	3	19
FMS™ dysbalances (number)[a]	1.3	1.0	0	4
Football experience (years)	31	11	2	60

[a]Items displaying a side-to-side difference.

Table 2. Football-specific participants characteristics (n = 238).

	n	%
Playing position		
Goalkeeper	10	4.2
Defender	64	26.9
Midfielder	77	32.4
Striker	30	12.6
Undefined	28	11.8
Injury history (football related)		
Previous major injury	187	78.6
Acute neuromusculoskeletal complaints (without time loss)	109	45.8

committee (Ärztekammer of Saarland, Saarbrücken, Germany) and was registered at ClinicalTrials.gov with the identifier NCT01993056.

Injury data collection

Injuries and exposure hours were recorded according to the consensus statement on injury definitions and data collection procedures in studies of football injuries (Fuller et al., 2006). In this regard, "any physical complaint sustained by a player that result from a football match or football training" was considered an injury. In the present study, only injuries that led to a time loss ("results in a player being unable to take fully part in future football training and match play") were taken into account. This definition was chosen because non-time-loss injuries occur frequently in this population. Approximately 46% of all players declared to suffer from musculoskeletal complaints without time loss at the beginning of the study (Table 2). Non-time-loss injuries would thus imply a less discriminating definition of injury. Furthermore, it is difficult to receive a comprehensive record of minor injuries (Hagglund, Walden, Bahr, & Ekstrand, 2005). "All injuries" and "Non-contact injuries" (no contact with another player or other object) were analysed separately. One player per team (the "team advisor") recorded exposure time (in minutes) from each player for each football session. In case of an injury, the player had to complete a standardised injury form (Fuller et al., 2006). The injury data were collected via paper- or computer-based systems. The designated team advisor transferred the data to the researchers. Data were then checked for comprehensiveness and completeness. If additional information was required, the players were contacted by telephone, email, or personally.

FMS™ assessment

Six FMS™ experienced sport scientists conducted the FMS™ during training sessions in the first four weeks of the study period. The original test kit (Functional Movements Systems, Inc., Chatham, USA) was used. Verbal instructions were based on those provided by the company (functionalmovement.com, 2014) but translated into German.

As stated, the FMS™ consists of seven test items assessing dynamic mobility as well as stability on a 4-point Likert scale (0–3 points). Therefore, the maximum composite score is 21 points. The exercise test items are deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability (Table 3). In general, the given score is "zero" if the player experiences pain during the test. The score "one" indicates that someone is unable to perform the test. A score of two is attributed if the player is able to perform the movement, but compensation appears. "Three" stands for perfect test execution. Three tests (shoulder mobility, trunk stability push-up and rotary stability) include clearing tests. They ask for pain only and are graded as a pass (no pain during the test) or fail (pain during the test). If a participant fails the clearing test, the score is automatically zero, regardless of the score achieved in the original test. Five tests (hurdle step, in-line lunge, shoulder mobility, active straight leg raise and rotary stability) assess right and left sides, respectively. Thereby, the lower score is counted towards the final overall score. For further explanations and detailed grading criteria for each test item, the reader can refer to the original papers (Cook et al., 2006a, 2006b).

Table 3. The seven test items of the FMS™ (Cook et al., 2006a, 2006b; Frost et al., 2012).

	Description
1. Deep squat	A dowel is placed over the head, arms are outstretched and the player is asked to squat as low as possible.
2. Hurdle step	The player has to step over a hurdle that is placed directly in front him; a dowel is placed across the shoulders.
3. In-line lunge	A dowel is placed at the bodies' back side (contacting head, back and sacrum, the player has to perform a split squat).
4. Shoulder mobility	The player attempts to touch his fists behind the back.
Clearing test	The player places his hand on the opposite shoulder and then attempts to point the elbow upward.
5. Active straight leg raise	The player has to actively raise one leg as high as possible while lying supine with the head touching the ground.
6. Trunk stability push-up	The player has to actively raise one leg as high as possible while lying supine with the head touching the ground.
Clearing test	The player has to perform a press-up in the push-up position (spinal extension).
7. Rotary stability	The player has to assume a quadruped position and attempts to touch his knee and elbow, first on knee and elbow of the same side of the body and then on the opposite sides.
Clearing test	At first, the player has to assume a quadruped position, then rocking back and touching the buttocks to the heels and the chest to the thighs. The hands have to remain in front of the body reaching out as far as possible.

Several studies have shown that the FMS™ provides relatively objective and reliable data (Gribble, Brigle, Pietrosimone, Pfile, & Webster, 2012; Onate et al., 2012; Shultz, Anderson, Matheson, Marcello, & Besier, 2013), even if the raters were not experienced (Minick et al., 2010; Smith, Chimera, Wright, & Warren, 2012; Teyhen et al., 2012). It could therefore be assumed that the FMS™ scores in our study are accurate, although it should be acknowledged six sport scientists conducted the tests. All sports scientists were educated and experienced in movement analysis. Prior to the study, the orthopaedic surgeon as part of the author team trained all six raters within several meetings. In order to guarantee objective and reliable scores, agreements and discrepancies were discussed during the practice trials. Here, university students and employees served as volunteers. After the practice trials the six sport scientists visited the team at the agreed time to ensure an efficient assessment of the whole team (1–4 raters per visit). If included players did not attend this initial training session, another visit was scheduled.

Statistics

Data were analysed using SPSS Statistics version 19 (SPSS, Inc., Chicago, Illinois, USA) and Excel 2007 (Microsoft, Inc., Redmond, USA). Anthropometric data were reported as mean and standard deviation (SD). Receiver operating curves were used for detecting cut-off scores with maximal sensitivity and specificity. As we did not presume interval-scaled data, Mann-Whitney U-tests were applied to compare FMS™ scores of injured with uninjured players. Remaining parameters were analysed with *t*-tests for independent measures. Additionally, effect sizes (Cohen's *d*) were calculated. Based on previous research using adult male amateur football players (van Beijsterveldt et al., 2012), we estimated that 50% of our participants would sustain at least one injury during the season. Given a statistical power of 0.95, a total sample size of $n = 220$ was needed to detect a moderate effect ($d = 0.5$) of the FMS™ overall score between injured and uninjured players (G*Power Version 3.1.9.2., Kiel, Germany).

According to Bahr and Holme (2003), the FMS™ and further potential risk factors were taken as categorical variables by classifying players into three groups. Injury incidence rate ratios (IRR) and corresponding confidence intervals (95% CI) were calculated for groups including players with low values (>1 SD below the mean, <10 points, LOW) and high values (>1 SD above the mean, >14 points, HIGH) (Bahr & Holme, 2003). Subsequently, injury incidences (injuries per 1000 h) of the HIGH and LOW groups were compared with the intermediate group (≤1 SD above/below the mean, 10–14 points, INTERMEDIATE) that served as a reference group. Rate ratios and 95% CIs, and z-statistics were used for inter-group comparisons. Likewise, injury incidences in single test items were compared between participants with low (0–1 points) and high (2–3) scores in the respective test item. To examine the relationship between potential risk factors and injuries, a Cox proportional hazard regression analysis was conducted with total exposure time (hours) to first injury during the study serving as the main variable. Univariate analyses were used to identify potential risk factors independently. For all tests, $P < 0.05$ was considered significant.

Results

Mean overall FMS™ scores of the participants are presented in Table 1. The distributions of the FMS™ composite scores and single item scores are shown in Figures 1 and 2. The mean football exposure time was 28.4 ± 14.2 h per player during the nine months. Receiver operating characteristic curves did not reveal significant results. This occurred whether overall injuries (area under the curve [95% CI]: 0.56 [0.47–0.64], $P = 0.17$) or non-contact injuries (area under the curve [95% CI]: 0.55 [0.46–0.64], $P = 0.30$) were taken into account.

Comparisons of injured and uninjured players revealed a significant age difference (Table 4). Players with an FMS™ score of <10 points (LOW) had a significantly higher injury incidence (considering all injuries) compared to the reference group (INTERMEDIATE, Table 5). The comparison of participants with low (0–1 points) and high (2–3) scores in the active straight leg raise revealed a significant higher injury incidence in players achieving a low score (Table 6). However, none of the variables reached statistical significance in the univariate Cox regression analyses (Table 7).

Participants who suffered from a recurrent injury during the study ($n = 189$) had a longer football career when compared to those without ($n = 20$) (31 ± 11 vs 38 ± 8 years, $P = 0.009$). The same applied to participants with a previous football-related injury ($n = 185$) compared to those without ($n = 24$) (24 ± 14 vs 32 ± 11 years, $P = 0.009$).

Discussion

The main finding of the present study was that only very low FMS™ overall scores (<10 points) were associated with an increased injury risk in veteran football players. The injury incidence was 1.9-fold higher compared to intermediate overall scores (10–14 points). This could indicate that the FMS™ is able to identify players with an increased injury risk. However, a score <10 points equals a mean single item score below 1.3 points; thus it might only identify players with very poor fundamental movement ability. The FMS™ seems to lack the discriminative power to identify those amongst higher scores.

This finding is partly in contrast to other investigations that revealed higher cut-off scores of 14 (Butler et al., 2013; Chorba et al., 2010; Kiesel et al., 2007; Lisman et al., 2012) or 16 points

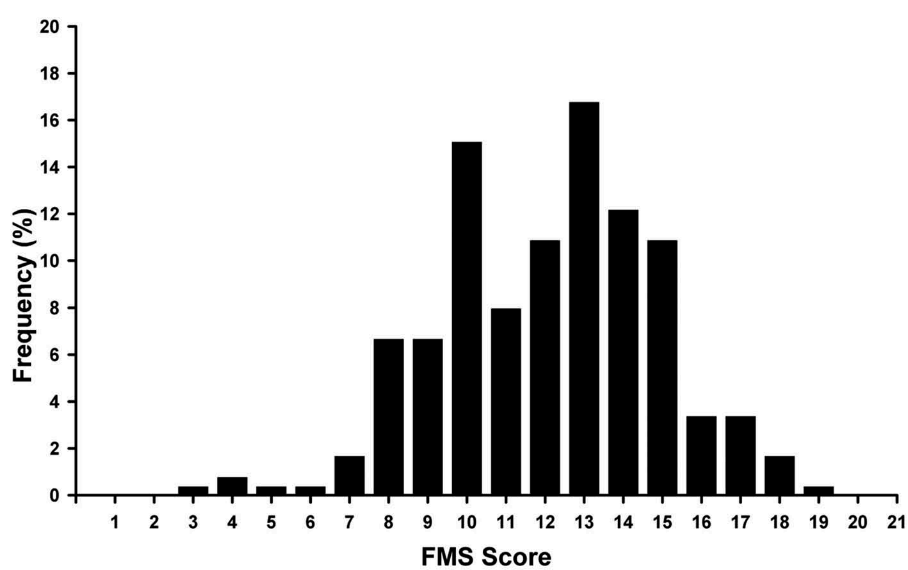

Figure 1. Frequencies of FMS™ overall scores.

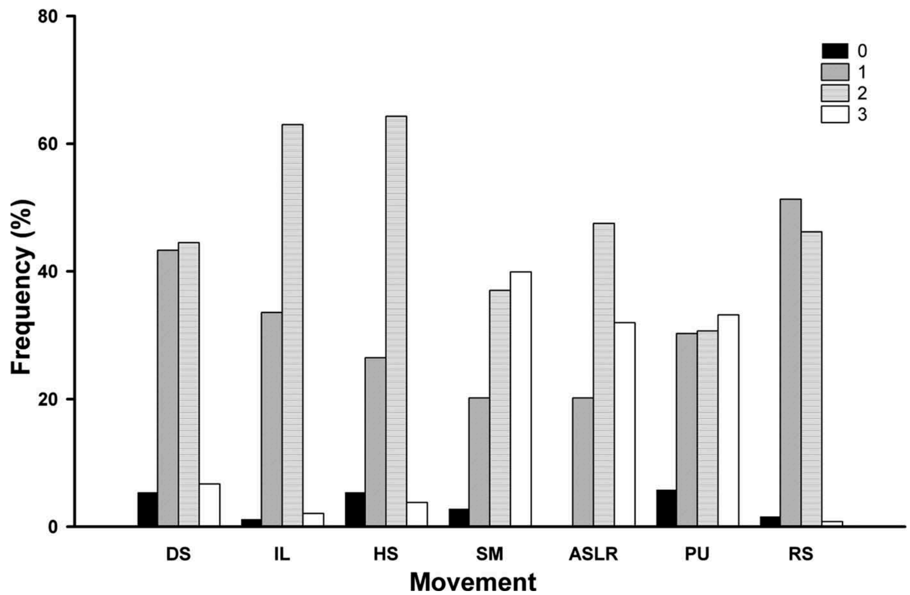

Figure 2. Frequencies of individual FMS™ item scores. DS: deep squat, IL: in-line lunge, HS: hurdle step, SM: shoulder mobility, ASLR: active straight leg raise, PU: trunk stability push-up, RS: rotary stability.

Table 4. Comparisons of injured and uninjured players during the study. Data as mean (SD).

	All injuries				Non-contact injuries			
	Injured (*n* = 67)	Uninjured (*n* = 167)	*P* value	Effect size	Injured (*n* = 47)	Non-injured (*n* = 191)	*P* value	Effect size
FMS™ (overall score)[a]	11.7 (2.9)	12.2 (2.8)	0.17	0.18	11.6 (3.0)	12.2 (2.8)	0.29	0.21
Age (years)[b]	46 (7)	44 (7)	0.04	−0.29	45 (7)	44 (7)	0.19	−0.14
Body mass (kg)[b]	83 (11)	85 (11)	0.28	0.18	84 (12)	84 (11)	0.79	0.00
Height (cm)[b]	188 (7)	188 (7)	1.00	0.00	180 (7)	178 (6)	0.21	−0.32
BMI (kg/m^2)[b]	26.0 (2.4)	26.6 (2.9)	0.14	0.22	25.9 (2.5)	26.6 (2.8)	0.16	0.26
Training time (h)[b]	20.4 (10.0)	18.8 (10.9)	0.29	−0.15	20.4 (10.2)	18.9 (10.8)	0.40	−0.14
Match time (h)[b]	9.2 (5.0)	9.2 (5.5)	0.98	0.00	9.0 (5.0)	9.2 (5.5)	0.83	0.04
Total exposure (h)[b]	29.6 (12.9)	27.6 (14.7)	0.43	−0.14	29.4 (13.0)	28.2 (14.5)	0.59	−0.08
Training to match ratio[b]	3.0 (2.8)	2.9 (5.8)	0.97	−0.02	3.1 (3.1)	2.9 (5.5)	0.84	−0.04
Football experience (years)[b]	34 (11)	31 (12)	0.08	−0.26	34 (10)	31 (11)	0.06	−0.28

Comparisons done by Mann–Withney (a) and *t*-test for independent samples (b).

Table 5. Comparisons of groups separated by potential risk factor values (LOW vs INTERMEDIATE and HIGH vs INTERMEDIATE).

	All injuries (IRR)		Non-contact injuries (IRR)	
	LOW vs INTERMEDIATE	HIGH vs INTERMEDIATE	LOW vs INTERMEDIATE	HIGH vs INTERMEDIATE
FMS™ (overall score)	1.86 (1.13–3.08)*	1.07 (0.62–1.86)	1.69 (0.89–3.21)	0.77 (0.35–1.67)
Age (years)	0.88 (0.45–1.71)	0.99 (0.47–1.69)	0.93 (0.39–2.20)	1.29 (0.62–2.66)
Body mass (kg)	2.20 (1.33–3.62)*	1.51 (0.86–2.65)	2.16 (1.13–4.14)*	1.57 (0.77–3.22)
Height (cm)	1.15 (0.65–2.04)	1.45 (0.85–2.46)	0.82 (0.37–1.85)	1.23 (0.61–2.47)
BMI (kg/m^2)	1.41 (0.83–2.38)	0.65 (0.32–1.31)	1.10 (0.53–2.27)	0.57 (0.22–1.44)
Football experience (years)	0.37 (0.17–0.81)*	1.13 (0.64–1.99)	0.51 (0.20–1.31)	1.89 (0.99–3.63)

Players were classified into three groups for each risk factor: IRR and corresponding confidence intervals (95% CI) were calculated for groups including players with low values (>1 SD below the mean and high values (>1 SD above the mean). Displayed IRRs are calculated with the intermediate group as reference group. Mean ± SD for risk factors were: FMS™: 12.1 ± 2.8; Age: 44.1 ± 7.2; Body mass: 84.4 ± 11.4; Height: 178 ± 7; BMI: 26.4 ± 2.8; Football experience: 31.4 ± 11.3. Significant results (P < 0.05) are marked with "*".

Table 6. Injury IRR of players with single FMS™ item values of 0–1 ("low") versus 2–3 ("high").

	All injuries	Non-contact injuries
Deep squat	1.09 (0.72–1.65)	1.42 (0.83–2.45)
Hurdle step	1.26 (0.81–1.94)	1.56 (0.90–2.69)
In-line lunge	1.20 (0.76–1.89)	1.52 (0.87–2.66)
Shoulder mobility	1.19 (0.74–1.90)	0.93 (0.49–1.76)
Active straight leg raise	1.65 (1.05–2.59)*	1.21 (0.65–2.26)
Trunk stability push-up	1.39 (0.91–2.12)	1.11 (0.64–1.93)
Rotary stability	0.75 (0.49–1.15)	1.00 (0.58–1.71)

Injury IRR and corresponding confidence intervals (95% CI).
Significant results (P < 0.05) are marked with "*".

(Peate et al., 2007) discriminating between participants with high and low injury risk. However, the aforementioned studies investigated different populations with different physical qualities to participants from the current study. Kiesel et al. (2007) examined professional American football players, Chorba et al. (2010) various female college athletes, Lisman et al. (2012) a military cohort, and Peate et al. (2007) and Butler et al. (2013) firefighters. Obviously, professional American football players differ vastly from veteran football players both with regard to the general physical strain of the different sports as well as the

Table 7. Cox proportional hazard regression analyses.

	Variable	Hazard ratio	95% Confidence interval	*P* value
All injuries	FMS™ (overall score)	0.93	0.85–1.01	0.08
	FMS™ dysbalances (number)[a]	1.14	0.89–1.47	0.29
	Age (years)	1.03	0.97–1.06	0.09
	Body mass (kg)	0.99	0.97–1.01	0.27
	Height (cm)	1.00	0.96–1.04	0.95
	BMI (kg/m^2)	0.93	0.85–1.03	0.15
	Training to match ratio	1.00	0.96–1.05	0.92
	Football experience (years)	1.02	1.00–1.05	0.07
Non-contact injuries	FMS™ (overall score)	0.92	0.83–1.02	0.12
	FMS™ dysbalances (number)[a]	1.09	0.81–1.47	0.57
	Age (years)	1.02	0.98–1.06	0.25
	Body mass (kg)	0.99	0.97–1.02	0.71
	Height (cm)	1.02	0.98–1.07	0.30
	BMI (kg/m^2)	0.92	0.82–1.04	0.17
	Training to match ratio	1.01	0.96–1.05	0.84
	Football experience (years)	1.03	1.00–1.06	0.051

[a]Items displaying a side-to-side difference.
The main variable was total exposure time (hours). Univariate analyses were conducted to identify potential risk factors (continuous variables). $P > 0.05$ was considered significant.

sports-specific movements required within each sport. The same principle is true for occupational studies, which involve the military or firefighting personnel. Indeed, the physiological demands in these jobs across numerous domains (i.e., movement efficiency, lifting and pushing) and training regimes make it difficult to compare with the demands of recreational veteran football.

Lisman et al. (2012) reported another interesting result. They not only found a cut-off point of 14, they also revealed that the injury risk was increased in participants scoring ≥18 points compared to those scoring between 15 and 17 points. The underlying reason for this phenomenon is not obvious, but this finding somewhat confirms our finding that the FMS™ lacks discriminatory power with regard to higher scores. Due to the low number of players with high scores in our study (Figure 1), an analysis of players with scores of ≥18 was not possible. However, this inconsistency has to be clarified in future studies, since it would substantially compromise the suitability of the FMS™ in practice. Altogether, our results, in conjunction with those from other studies, seem to indicate that the predictive value of the FMS™ might be limited and that it seems to differ substantially between different population and sports.

FMS™ scoring system

Since only very low FMS™ overall scores were shown to be injury predictive, the FMS™ seems to lack discriminatory power. The scoring system might be responsible for this. As previously described, studies testing the objectivity and reliability of the FMS™ have demonstrated that scoring the FMS™ is consistent even amongst less experienced assessors (Gribble et al., 2012; Minick et al., 2010; Onate et al., 2012; Shultz et al., 2013; Smith et al., 2012; Teyhen et al., 2012). Therefore, it does not seem to be an issue due to assessors' rating that could contribute to the lack of discriminatory power. From a practical perspective, this is a major advantage as raters with extensive experience are often rare. However, as shown in Figure 2, a score of "2 points" is most frequently assigned. It represents a wider range as compared to "1" and "3". A score of "1" is only given if somebody is unable to conduct the exercise. The "3" only if the exercise is performed in perfect quality. Each other option is subsumed under "2". This leads to the assumption that the scoring system may not be discriminative enough.

Using a more detailed scoring system could possibly address this issue. Frost, Beach, Callaghan, and McGill (2012) and Lockie, Jalilvand, Jordan, Callaghan, and Jeffriess (2015) used a 100-point scale. Frost et al. (2012) detected a higher number of FMS™ score changes after a training intervention as compared to the standard scoring method. This indicates a potentially higher sensitivity for differences. However, with regard to using the FMS™ in conjunction with the assessment of athletic performance (multidirectional speed and jump tests) (Lockie et al., 2015), the 100-point scale was not able to identify athletes with movement deficiencies that were related to decreased athletic performance. Furthermore, from a practical point of view the latter scale complicates the scoring system by far. Beach, Frost, and Callaghan (2014) and Lockie et al. (2015) were also required to use videos to score the movements retrospectively. Although potentially worthy of further investigation, no research has been conducted so far regarding the prediction of injury risk using this 100-point scale.

FMS™ and performance

Cook et al. (2006a, 2006b) claim to assess common movements in multiple sports with the FMS™; however there is no scientific evidence for this. Several studies have previously investigated the relationship between FMS™ and athletic performance, such as performance in linear sprint-, agility-, jump-, strength- or sport-specific indicators (Lockie et al., 2015, 2015; Okada, Huxel, & Nesser, 2011; Parchmann & McBride, 2011). The aforementioned parameters are commonly used in a football setting aiming to assess the players' general performance level. Each of the studies found only poor or no relationships between the performance in the FMS™ and the results in performance tests.

At first glance, these findings suggest that the FMS™ may not represent common athletic movements. However, athletic performance tests such as sprint, agility or jump tests assess quantitative outcome measures such as time or height. They do not assess movement quality. Therefore, results in athletic performance tests and movement quality tests represent different dimensions and lacking correlations between them should not lead to the assumption that the FMS™ is not a valid measurement of movement quality. Moreover, it is noteworthy that Cook et al. (2006a, 2006b) did not claim to capture or predict performance with the FMS™. Limited functional movement quality may indeed affect performance. Athletes might also be able to compensate poor movement patterns resulting in similar performance test results as athletes showing good movement quality (Cook et al., 2006a, 2006b). Nonetheless, it is widely assumed that poor movements are likely to predispose athletes to injuries (Cook et al., 2006a). Despite this, the present study and previous research rather suggest a limited injury predictive value of the FMS™ specifically. As mentioned before, there is no scientific evidence for an association of movements assessed by the FMS™ and football-specific movements, as it is assumed by Cook et al. (2006a, 2006b) and many practitioners working in professional football (McCall et al., 2014). Biomechanical and kinematic studies should aim to clarify this in the future.

Further injury risk factors

The present study revealed significant age differences between injured and uninjured players (Table 4). Arnason et al. (2004) investigated elite football players from Iceland and revealed that the odds ratio of sustaining an injury during one season was 1.1 per year of age. It is noteworthy that Arnason et al. (2004) used elite players aged 16–38 years, whereas our sample included recreational players aged 32–69 years, which limits a direct comparison. In contrast, Dvorak et al. (2000) did not report any age differences between injured and uninjured players in a sample of football players from the Czech Republic including eight different age- and skill-level groups. They investigated a full season; however, the mean age was also considerably lower (19.0 years) than in our study. Our study is the first one examining age as potential injury risk factor in recreational veteran football players. The findings suggest that injury prevention measures become more important with increasing age.

In the present study, a longer football career was associated with a higher overall injury incidence (Table 5). Naturally, the length of the football career is directly correlated with one person's age and consequently with the number of injuries, which makes it difficult to distinguish the effects. However, injuries sustained as a young football player are likely to increase the injury risk at present, since a "previous injury" is a well-established risk factor for subsequent and recurrent injuries (Arnason et al., 2004). Previous injuries as a potential risk factor were not taken into account in this study for several reasons. We collected previous injuries retrospectively; therefore, a recall bias is very likely. Junge and Dvorak (2000) compared injury incidences of prospectively collected data (weekly follow-up) with data from retrospective questionnaires after one year from the same football players. The authors found that only approximately one-third of moderate and one-half of the severe injuries were reported retrospectively. These results may indicate a substantial bias in our study sample, in particular because participants were asked about injuries in their whole football career and not just the previous year (Junge & Dvorak, 2000).

Table 5 suggests that lower body mass is a risk factor for sustaining an injury. This finding has not been reported in football before. Arnason et al. (2004) and Dvorak et al. (2000) did not find such an association in elite and competitive players. An association between lower body mass and more injuries was reported in elite Australian football players (Verrall et al., 2007). However, Verrall et al. (2007) stated that reasons for this association remained unclear. Yard and Comstock (2011) found that undermass high school athletes sustained more fractures when comparing to normal weight athletes. In contrast, an increased body mass has previously been linked to an increased risk of sustaining lateral ankle sprains (Gribble et al., 2015), knee injuries (Yard & Comstock, 2011) or osteoarthritis (Zheng & Chen, 2015). It seems plausible that there are sport-specific reasons responsible for these results. A lower body mass is possibly disadvantageous in tackling situations frequently occurring in football. However, lower body mass remained a significant risk factor in non-contact injuries as well (Table 5). Since body mass can be an indicator for muscle mass, some participant's muscular fitness might have not been adequate for football-specific demands. However, this remains highly speculative, since body composition was not determined in the present study.

Methodological considerations

When comparing the results of the present study with other research some issues have to be considered. The manner in which the term "injury" is defined is of great importance, especially when comparing previous studies (Brooks & Fuller, 2006). For instance, Kiesel et al. (2007) only took injuries into account that lasted at least three weeks, thus lowering the number of injuries. In contrast to this, Peate et al. (2007) considered "any injury". Chorba et al. (2010), O'Connor et al. (2011) and Lisman et al. (2012) chose another option. They included "medical attention injuries" only in the analysis. In an attempt to control how the injuries were defined and thus investigated, the present study used standardised definitions according to a consensus paper for injury studies in football (Fuller et al., 2006). Calculating injury incidences (injuries per 1000 football hours) so as to include the exposure time is strongly recommended and regarded as the gold standard in injury reporting (Fuller et al., 2006). The analysis of the present study is also based on methodological and statistical considerations from Bahr and Holme (2003). Bahr and Holme (2003) stressed the importance of the use of correct statistical measures. Neither receiver operating characteristic curves as used by Kiesel et al. (2007), nor linear and logistic regressions as used by Peate et al. (2007) take the time under risk (exposure) into account. The exposure time in elite athletes may be relatively equal (they usually follow a similar training schedule), however is quite different amongst veteran football players, possibly leading to bias. As recommended by Bahr and Holme (2003), a Cox regression analysis was consequently applied in the present study as it considers the exposure time. However, this is only true up until when the first injury of the study period occurs. This may explain the different results between separate analysis methods of the present study such as that there were significantly different IRR but no significant results in the Cox regression.

Limitations

There are further injury predictive variables that have not been considered in the analysis, for example activities outside of football. There might well be interrelations between injury risk, FMS™ score and the participation in football and/or further activities. However, quantification of further activities would have provided several problems. In terms of the involved physiological and musculoskeletal demands, every sport has its unique profile. Further activities might influence FMS™ score and injury risk in either a negative or a positive way, depending of the specific character of the activity. Therefore, we chose not to include further activities in the analysis. The major focus of our study was to investigate the injury predictive value of the FMS™ in football. Further variables were only taken into account to improve our understanding about injury risk and to seek for further simple variables that might improve the predictive value of the FMS™ in a practical setting.

The use of video recording to analyse the FMS™ movements might have led to more accurate scoring. Nowadays, various media devices could be used (e.g., filming on a mobile phone). This could improve the accuracy of scoring especially if numerous joints have to be observed at the same time due to the complexity of the test or in case of differing scores. However, the initial test protocol did not use video-based scoring. Moreover, the instruction is "when in doubt score it low" (Cook et al., 2006a, 2006b). The need for standardisation of the angle from which videos would be recorded is also an example that has to be considered when using video-based scoring. Standardisation issues as well as the retrospective analysis might interfere with the practicability of the test. Our purpose of the study was to investigate the original test protocol, as it offers an easy, quick and low-cost screening tool.

Conclusions

Our findings suggest that the usefulness of the FMS™ in veteran football players for injury prediction is limited. Only very low overall scores (<10 points) were associated with a 1.9-fold higher injury incidence. However, a higher score could not discriminate between injured and non-injured players. The FMS™ might therefore link only major movement deficiencies (equivalent to very low scores) and injury risk. Practitioners may consider this when using the FMS™. This unsatisfactory efficacy could be due to the screen's lack of football specificity or due to its scoring system that might not be discriminative enough.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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