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Does changing the Functional Movement Screen composite score threshold influence injury risk estimation in junior Australian football players?

Emma Moore [a], Joel T. Fuller [b], Steve Milanese [c], Stephen C Jones[c], Alex Townsley[c], Matthew Lynagh[c] and Samuel Chalmers [a,d]

[a]Alliance for Research in Exercise, Nutrition and Activity (ARENA), Allied Health and Human Performance, University of South Australia, Adelaide, Australia; [b]Faculty of Medicine, Health and Human Sciences, Macquarie University, Sydney, Australia; [c]Allied Health and Human Performance, University of South Australia, Adelaide, Australia; [d]Exercise and Sport Science, Faculty of Medicine and Health, The University of Sydney, Sydney, Australia

ABSTRACT
This study aimed to identify whether a revised lower Functional Movement Screen (FMS) composite score threshold would be associated with a greater injury risk for junior athletes than the common threshold of≤14. This prospective cohort study included tracking of 809 elite junior male Australian football players for injuries that resulted in a missed game. All athletes completed pre-season FMS testing and a 12-month self-reported retrospective injury questionnaire. Analyses examined the relationship between composite score thresholds of≤14, ≤13, and≤12 and the risk of injury. The relationship between prospective injury and the common composite threshold score of ≤ 14 was dependent on the presence of a recent injury history (relative risk [RR] = 1.45, $p = 0.004$) in comparison to no recent injury history (RR = 0.98, $p = 0.887$). Scoring≤12 in the presence of a recent injury history had the greatest diagnostic accuracy but only a trivial increase in injury risk (RR = 1.59, $p = 0.001$, sensitivity = 0.35, specificity = 0.80, negative and positive likelihood ratios = 0.81 and 1.75). Whilst some small statistical relationships existed between prospective injury and the FMS composite score thresholds, all three thresholds were not associated with a clinically meaningful relationship with prospective injury and were no more effective than retrospective injury for determining athletes at risk of injury.

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Athlete screening; injury risk estimation; junior athletes; Functional Movement Screen; Australian rules footballers

Introduction

Movement screening provides a means for assessing athletic movement quality across a range of fundamental movement patterns (Gamble, 2014). A common goal of movement screening is to identify movement pattern limitations (Cook et al., 2006a) that could contribute to an increased risk of injury (Gamble, 2014). The Functional Movement Screen (FMS) is one such popular system that is designed to assess fundamental movement patterns and detect dysfunctional, asymmetrical, and painful movements that could contribute to the development of a range of injuries (Cook et al., 2006a).

Kiesel, Plisky & Voight (K. Kiesel et al., 2007) completed an early study using a small sample of players ($n = 46$) from a single professional American football team. The authors identified an FMS composite threshold of ≤ 14 (out of a possible 21) as the threshold best suited to estimating serious injury risk (odds ratio [OR] = 11.67) (K. Kiesel et al., 2007). The authors suggested the≤14 threshold identified players with dysfunctional movement patterns and this interpretation has since been commonly adopted by FMS clinicians and researchers (Chalmers et al., 2017; Duke et al., 2017; Garrison et al., 2015). A systematic review found conflicting evidence across 18 studies for using the FMS composite score to determine injury risk in athlete populations (R. W. Moran et al., 2017), concluding that there was not sufficient support for the use of the screen as an injury risk estimator in a sporting context. A more recent review based on 29 studies found small and moderate links between low FMS composite score and increased injury risk in some, but not all sports (Moore et al., 2019). Whilst the general consensus across the literature is that the composite score threshold of ≤ 14 is either broadly not related, or only related to a small and potentially not clinically meaningful extent, with injury risk in athlete populations, it is worth acknowledging that most studies supporting the threshold include adult athlete populations (Moore et al., 2019; R. W. Moran et al., 2017).

Research involving other movement screens suggests that junior Australian football (Australian Rules football) players appear less competent at fundamental movement patterns than their senior counterparts (Woods et al., 2016). Furthermore, elite junior soccer players' (and likely other similar sporting populations) fundamental movement quality improves as their biological age increases, with a greater percentage of junior soccer players achieving an FMS score above 14 after the positive effects of reaching the most accelerated period of growth (Portas et al., 2016). However, the overall percentage of the eldest junior athletes (aged between 17 and 18 years [y]) that were able to score above the composite score threshold of 14 remained low (approximately 50%) in the same study (Portas et al., 2016). This observation is similar to

CONTACT Samuel Chalmers samuel.chalmers@unisa.edu.au Alliance for Research in Exercise, Nutrition and Activity (ARENA), Allied Health and Human Performance, University of South Australia, Adelaide, Australia

a previous FMS study (Fuller et al., 2017), where only 40% of junior (mean age 17 y) Australian footballers scored above 14. Between-study comparisons in junior athletes have demonstrated a tendency for lower mean FMS composite scores (Bardenett et al., 2015; Chalmers et al., 2017), with one junior study finding a mean composite score as low as 12 (Rusling et al., 2015). In comparison, adult studies regularly report mean composite scores above 15 (Dorrel et al., 2015; K. B. Kiesel et al., 2014; Smith & Hanlon, 2017). Additionally, a recent meta-analysis found that a threshold of ≤ 14 was not associated with a significant increase in injury risk across eight studies involving junior athletes (Moore et al., 2019). This finding might relate to a lack of relationship between injury and composite score. Alternatively, it could be that the concept of an "at-risk" threshold still holds relevancy, but the lower average distribution of composite scores that are typically achieved by junior athletes heightens the likelihood of false-positive diagnoses if a threshold of ≤ 14 is used. Bardenett et al (Bardenett et al., 2015), reported that changing the composite score threshold from≤14 to≤13, ≤12, or ≤ 11 did not meaningfully change the relationship between movement quality and injury in a small study (Sample $n = 167$; injuries $n = 39$). However, small and mixed-sport studies suffer from statistical power issues and challenges with the heterogeneity of typical movement patterns between sports.

In light of these findings, there is a need to explore whether a different composite score threshold is related to injury in junior athletes. Therefore, the primary aim of this study was to determine if lower FMS composite score thresholds (≤13 and≤12) are associated with increased risk of injury in junior athletes. It was hypothesised that a revised FMS composite score threshold (i.e., lower than the common threshold of≤14) would be related to injury risk. Reducing the threshold by two points was supported by between-study comparisons that report the typical FMS composite score can often be approximately two points lower in junior (Bardenett et al., 2015; Chalmers et al., 2017; Garrison et al., 2015; Portas et al., 2016; Rusling et al., 2015) vs senior (Duke et al., 2017; K. B. Kiesel et al., 2014; K. Kiesel et al., 2007; S. Moran et al., 2017; Tee et al., 2016) sporting groups.

Methods & materials

Study overview

This study was a prospective cohort study completed across four seasons of Australian Football (2015–2018). Athletes were tested during the pre-season phase (February), one month prior to the start of each season. Subsequently, athletes were monitored during the 18-round regular season (March to September) to identify injuries that required missing at least one game.

Participants

Eligibility criteria for inclusion in the study were (1) registered with one of the eight elite junior under 18 (U18) clubs in South Australia, (2) attendance at the annual pre-season fitness testing combine, (3) free from injury at the time of testing, (4) had their injury status prospectively monitored throughout a competitive season, and (5) provided (including parent or guardian if player is < 18 y) written informed consent to participate. A total of 1,026 athlete observations were eligible (inclusive of duplicate players across multiple seasons). Whilst the majority of players competed in the competition for only one year, some talented players were selected from an earlier age and therefore competed across two seasons. In that instance, only data from the second season (i.e., most senior season) was included for players who competed in multiple seasons. This avoided double counting of participants and associated statistical issues caused by dependence across some but not all observations. After removal of duplicate participant observations, 809 male athletes were included in the study (age: 17.4 ± 0.6 y, height: 181.6 ± 7.2 cm, body mass: 75.5 ± 8.4 kg). Based on the 809 available athletes, an expected injury rate of~35% in this cohort (Chalmers et al., 2018), and having 25% of players below the revised FMS thresholds, we could detect an OR as small as 1.6 with 80% statistical power and 5% Type 1 error rate. Ethics approval was given by the local institution's ethics committee (Approval Number #33950).

Movement screening

Athletes underwent a non-standardised warm-up conducted by their respective club fitness coach prior to testing, as dictated by the organisational structure of the event. The FMS consists of seven sub-tests with detailed descriptors of each test published previously (Cook et al., 2006a, 2006b). In brief, the sub-tests include the deep squat, the hurdle step, the in-line lunge, shoulder mobility, trunk stability push-up, active straight leg raise, and rotary trunk stability. Three sub-tests (shoulder mobility, trunk stability push-up and rotary stability) included an accompanying pain clearing test: the impingement clearing test, press-up clearing test, and posterior rocking clearing test. Five of the seven sub-tests were completed on both sides of the body: the hurdle step, the in-line lunge, shoulder mobility, active straight leg raise, and rotary trunk stability. Participants were given instructions and a brief demonstration of each sub-test but were not coached through the movement during the assessment. Each sub-test was scored on a scale of 0–3 according to the established criteria where 0 represents the athlete reporting pain and 3 represents the athlete completing the movement in line with the criteria (Cook et al., 2006a, 2006b). The lowest score from sub-tests completed on both sides of the body was considered the overall score for each sub-test. Scores from the seven sub-tests were compiled to provide a composite score out of 21. The FMS was performed using standard FMS test kits (Functional Movement Systems Inc, Virginia USA). Each tester was a qualified physiotherapist, exercise physiologist, or strength and conditioning coach that had completed the Level 1 FMS training course. Each tester was responsible for 1–2 sub-tests throughout each testing day for a given year, with players rotating between testers. Not all testers were able to complete every season of data collection. The FMS has been shown to have good intra-rater and inter-rater reliability (Cuchna et al. 2016).

Injury surveillance

For the purpose of this study, an injury was defined as "a trauma or medical condition which caused a player to miss a competitive regular season game", which aligned with current methodological practice in the league (Scase et al., 2012). The definition aligns with the inclusion of either moderate (8–28 days) or severe (>28 days) injuries in accordance to the consensus statement on injury surveillance in soccer (football) (C. Fuller et al., 2006). The inclusion of all-cause injuries is consistent with the majority of studies within the FMS literature and a previous meta-analysis has showed little difference in the relationship between the composite score and all-cause vs non-contact injury categorisation (Moore et al., 2019). Therefore, an all-cause injury definition was utilised given the multifactorial nature of FMS testing and injuries in football. A missed game injury definition was used as there was no specific data available for hours of exposure; in addition, this definition is considered the most accurate and reliable of all injury definitions used in sport (Orchard & Hoskins, 2007), which is particularly important in junior Australian football leagues which typically do not have the required level of medical support to track minor injuries. Prospective injury surveillance was undertaken across the 18-round regular season of the U18 competition between 2015 and 2018. The injury status and competition playing involvement of all players enrolled in the study was tracked by the Development Manager of each of the eight clubs using a standardised player movement report. If a player was categorised as missing a game due to injury, club medical staff (usually a physiotherapist) submitted a standardised injury report form to a centralised database. Each player was only able to contribute one injury (i.e., the first injury sustained during the season), but given the narrow injury definition, most injured players did not suffer multiple independent injuries.

At the time of FMS testing, each athlete was asked a yes or no question that stated "During the previous football season, did you miss any football games due to an injury sustained playing football or performing exercise for the purpose of improving or maintaining physical fitness?". Each retrospective season contained either a total of 18 or 20 regular season games that could potentially be missed. This injury data were defined as *retrospective* injuries that were used to account for the increased injury risk that is typically observed for players with previous injuries (Orchard, 2001).

Statistical analysis

Mean and standard deviation composite FMS scores were calculated for the whole population. FMS score and injury status were analysed using Receiver Operator Characteristic (ROC) analysis to determine if there was an optimal threshold composite score for identifying elite junior Australian football players at increased risk of injury. The ROC curves were created by plotting the true positive rate (sensitivity) against the false positive rate (1 – specificity) for different FMS composite score thresholds. The effect sizes of Area Under the Curve (AUC) were considered no effect (≤0.50), poor (0.51–0.70), good (0.71–0.90), excellent (0.91–0.99), and perfect (1.00) (Greiner et al., 2000).

Previous injury history was also considered in combination with FMS composite score threshold to determine the injury risk. Binary logistic regression analysis was utilised to determine whether the combination of retrospective injury status and FMS composite score improved the predictions of injury risk. Separate analyses were performed for potential FMS composite thresholds of≤12, ≤13, and≤14 combined with retrospective injury data.

Sets of risk groups that produced significant odds ratios were further analysed using 2×2 contingency tables. The contingency tables dichotomised those who got injured and those who did not, as well as those who were classified as at risk (below composite score combined with/without retrospective injury) and those who were classified as not at risk (above composite score with no retrospective injury) from the binary logistic regression. Relative risk (RR), likelihood ratios (LR), sensitivity, and specificity were the 2×2 contingency table outcome variables used. Effect sizes for RR were considered trivial (0.84–1.19), small (0.53–0.83 and 1.20–1.89), moderate (0.34–0.52 and 1.90–2.99), and large (<0.34 and>3.00) (Hopkins,2002). Effect sizes for positive LR were considered small and rarely important (1–2), small but sometimes important (2–5), moderate (5–10), and large and often conclusive (>10) (Fritz & Wainner, 2001). Effect sizes for negative LR were considered small and rarely important (0.5–1), small and sometimes important (0.2–0.5), moderate (0.1–0.2), and large and often conclusive (<0.1) (Fritz & Wainner, 2001). Data was analysed using SPSS© (v22.0, NY, USA). Confidence intervals were set at 95% and results were considered statistically significant if $p \leq 0.05$.

Results

Injury profile

There was a total of 296 injuries with a mean severity of 3.3 games missed per injury. Injury body location details were provided for 262 (88.5%) of injuries and these were categorised into seven injury regions: head/neck ($n = 29$), arm/shoulder/elbow ($n = 37$), forearm/wrist/hand ($n = 18$), trunk/back ($n = 30$), hip/groin/thigh ($n = 49$), knee ($n = 27$), shin/ankle/foot ($n = 72$).

Injury history

Risk assessment was performed for self-reported 12-month retrospective injury history and its association with prospective injury risk. The presence of retrospective injury was linked with a small effect (RR = 1.5 [1.2–1.8]; $p<0.001$) on prospective injury risk.

Movement screening and injury risk

Figure 1 shows the spread of FMS composite scores out of 21 for the study population over the entirety of the study. The mean FMS score of the population was 13.8 ± 2.5.

Table 1 shows a summary of the binary logistic regression analysis for injury risk. Due to the similarities of ORs for many of these thresholds, no optimal threshold could be identified from this analysis (Table 1). Table 2 shows the outcome of the 2×2

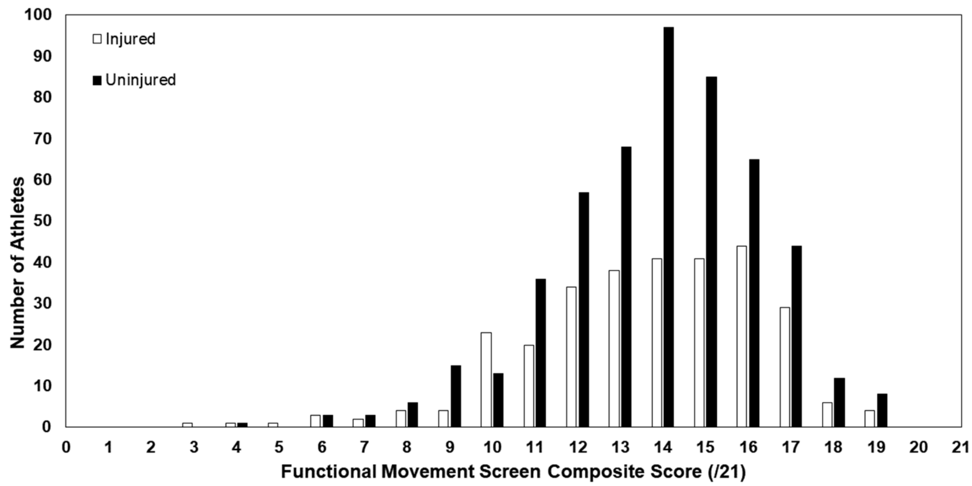

Figure 1. Spread of Functional Movement Screen composite scores for the study population stratified by injury status.

Table 1. Summary of binary logistic regression for injury risk estimation.

Predictor Variable	Odds Ratio [95%CI]	p-value	Descriptor
>12, No RI	REF		
>12, RI	2.05 [1.45–2.90]	<0.001*	Small
≤12, No RI	1.52 [0.97–2.38]	0.068	Small
≤12, RI	2.11 [1.36–3.28]	0.001*	Small
>13, No RI	REF		
>13, RI	1.92 [1.31–2.82]	0.001*	Small
≤13, No RI	1.26 [0.83–1.89]	0.276	Trivial
≤13, RI	2.16 [1.44–3.24]	<0.001*	Small
>14, No RI	REF		
>14, RI	1.86 [1.19–2.92]	0.007*	Small
≤14, No RI	1.00 [0.66–1.50]	0.999	Trivial
≤14, RI	1.89 [1.25–2.86]	0.003*	Small

* denotes significance ($p < 0.05$).
CI – Confidence Interval; RI – Retrospective Injury.

contingency tables. Scoring at or below each threshold, with or without controlling for the effect of a recent retrospective injury, was not associated with a meaningful increase in risk compared to the risk associated with retrospective injury alone (Table 2). There was no optimal threshold based on the combined interpretation of RR, likelihood ratios, sensitivity, and specificity (Table 2). The RR for all thresholds was considered either "small" or "trivial" and no threshold resulted in the likelihood ratios being considered greater than "small and rarely important" (Table 2). The ROC curve analysis for injury showed that no composite score threshold maximised sensitivity and specificity. The AUC for injury was poor (0.52 [0.47–0.56]; $p = 0.426$).

Discussion

This study aimed to identify whether a revised lower FMS composite threshold was associated with a meaningfully greater serious injury risk for elite junior Australian football players in comparison to the common threshold of≤14. Whilst there were some small statistical relationships between serious injury and composite score thresholds, there was no threshold that optimised the statistical and clinically meaningful relationship with prospective injury in comparison to the others. This study is the largest investigating the relationship between different FMS composite score thresholds and prospective injury risk in a sporting population ($n = 809$) and was powered to detect a *small* odds ratio. The use of a single sport cohort rather than the commonly used mixed sports cohorts in FMS research helps reduce the influence of between-sport variability of movement demands and injury profile. However, the results of the current study are still likely to be relevant (to some extent) to the similar sporting codes of soccer and rugby.

It is well established that retrospective injury is an unmodifiable intrinsic risk factor for prospective injury due to potential changes in area functionality and biomechanics (Cook et al., 2006a; Orchard, 2001), therefore it was important to determine if this was a risk factor for prospective injury risk in the current study. Retrospective injury alone was associated with a small increase in prospective injury risk. Due to the consistent effect of previous injury upon risk of future injury risk in Australian footballers (Gabbe et al., 2010; Orchard, 2001), the factoring of retrospective injury (albeit self-reported) status is a particular strength of the current study.

There was a limited increase in injury risk associated with scoring at and below any FMS composite score threshold and injury, regardless of whether retrospective injury status was included or not. This finding was expected for the≤14 threshold as only 42% of the current population were capable of scoring>14, which increased the likelihood of false positives. Bahr (2016) (Bahr, 2016) highlights the main challenge with injury screening tests is the substantial overlap between groups of

Table 2. Relative risk assessment for various FMS composite score thresholds for prospective injury.

Threshold	Relative Risk [95%CI]	Descriptor	χ^2 (p-value)	Sens	Spec	+LR	-LR
>12, No RI	REF						
RI Alone	1.58 [1.29–1.94]	Small	20.096 (<0.001)*	0.62	0.55	1.40	0.68
≤12 Alone	1.47 [1.16–1.85]	Small	10.540 (0.001)*	0.50	0.64	1.39	0.78
>12, RI	1.57 [1.26–1.95]	Small	16.009 (<0.001)*	0.53	0.64	1.47	0.73
≤12, No RI	1.31 [0.98–1.76]	Small	3.129 (0.077)	0.34	0.77	1.48	0.86
≤12, RI	1.59 [1.22–2.08]	Small	10.918 (0.001)*	0.35	0.80	1.75	0.81
>13, No RI	REF						
RI Alone	1.55 [1.25–1.92]	Small	16.676 (<0.001)*	0.66	0.50	1.32	0.68
≤13 Alone	1.37 [1.09–1.72]	Small	7.605 (0.006)*	0.62	0.50	1.24	0.76
>13, RI	1.50 [1.18–1.92]	Small	10.605 (0.001)*	0.51	0.64	1.42	0.76
≤13, No RI	1.13 [0.85–1.50]	Trivial	0.746 (0.388)	0.41	0.64	1.14	0.92
≤13, RI	1.60 [1.25–2.06]	Small	13.579 (<0.001)*	0.48	0.70	1.60	0.74
>14, No RI	REF						
RI Alone	1.45 [1.14–1.86]	Small	10.002 (0.002)*	0.73	0.40	1.22	0.67
≤14 Alone	1.19 [0.93–1.52]	Trivial	2.019 (0.155)	0.75	0.30	1.07	0.83
>14, RI	1.45 [1.10–1.92]	Small	6.902 (0.009)*	0.53	0.61	1.36	0.77
≤14, No RI	0.98 [0.74–1.30]	Trivial	0.020 (0.887)	0.57	0.42	0.98	1.02
≤14, RI	1.45 [1.12–1.89]	Small	8.170 (0.004)*	0.61	0.53	1.30	0.73

* denotes significance ($p < 0.05$).
CI, Confidence Interval; RI, Retrospective Injury; +LR, Positive Likelihood Ratio; -LR, Negative Likelihood Ratio; Sens, Sensitivity; Spec, Specificity.

players across scale scores, which is evident in the injured vs uninjured players across the composite score spectrum in Figure 1. The complex nature of injury risk factors also limits the potential strength of any isolated movement screening tool analysis (Verhagen et al., 2018). However, we initially expected that lowering the FMS scoring threshold from≤14 to ≤ 13 or≤12 would potentially eliminate some false positives, improve diagnostic ability, and result in a stronger association with injury risk. This was not the case in our study, and when these results are taken with previous research (Bardenett et al., 2015; Martin et al., 2017), albeit if some small statistical relationships exist, suggests that there is not a consistent clinically meaningful relationship between injury risk and FMS composite score in junior athletes, regardless of scoring threshold. This questions the proposed utility of the FMS as an injury risk screening tool in junior athletes.

Whilst it is plausible that a broader injury definition capturing less serious injuries could influence the outcomes of the current study, existing evidence from a meta-analysis by Moore et al (Moore et al., 2019), suggests that the definition has minimal effect on the consistency between the FMS and injury risk. Concurrently, a narrower definition (as used in this study) improves the reliability of injury reporting (Orchard & Hoskins, 2007), especially considering the inherent variability between the diagnosis and management of injuries between league-wide teams. It is also plausible that, irrespective of injury definition, the relationship between the composite score and injury is limited by some sub-tests (e.g., shoulder mobility) having limited relevance or transferability to the most common high risk injury contexts in Australian football.

The primary limitation of the study was that FMS screening was completed prior to the commencement of the 6-month competitive season. It is not clear whether FMS scores obtained at this early pre-season stage are representative of player movement capacity throughout the in-season. Multiple FMS testing periods throughout the season may be needed to account for the temporality of injury risk (Verhagen et al., 2018), where factors such as training load, fatigue, ground and weather conditions, and movement dysfunctions may change over time (Hrysomallis, 2013). Indeed, previous rugby-based FMS research found that FMS composite scores and their relationship to prospective injury changed as the season progressed (Duke et al., 2017), which provides some support for the concept of repeat in-season movement screening.

Conclusion

Whilst some small statistical relationships existed between prospective injury and the FMS composite score thresholds of≤12, ≤13, and≤14, all three thresholds were not associated with a clinically meaningful relationship with prospective injury and were no more effective than retrospective injury for determining athletes at risk of injury. Therefore, practitioners should use caution when inferring injury risk from FMS testing.

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ORCID

Emma Moore http://orcid.org/0000-0002-1752-4228
Joel T. Fuller http://orcid.org/0000-0002-0997-4878
Steve Milanese http://orcid.org/0000-0002-6470-3296
Samuel Chalmers http://orcid.org/0000-0003-1901-6910

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