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Association of the Functional Movement Screen™ with match-injury burden in men's community rugby union.

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Ethics approval Research Ethics Approval Committee for Health, University of Bath.

Abstract

Evidence supporting the use of Functional Movement Screen (FMS$^{™}$) to identify athletes' risk of injury is equivocal. Furthermore, few studies account for exposure to risk during analysis. This study investigated the association of FMS$^{™}$ performance with incidence and burden of match-injuries in adult community rugby players. 277 players performed the FMS$^{™}$ during pre-season and in-season time-loss injuries and match exposure were recorded. The associations between FMS$^{™}$ score, pain, and movement-pattern asymmetries with match-injury incidence (≥8days time-loss/1000hours), severe match-injury incidence (>28days time-loss/1000hours), and match-injury burden (total time-loss days/1000hours for ≥8days match-injuries) were analysed using Poisson regression. Multivariate analysis indicated players with pain and movement-pattern asymmetry during pre-season had 2.9 times higher severe match-injury incidence (RR, 90%CI=2.9, 0.9-9.7) and match-injury burden (RR, 90%CI=2.9, 1.3–6.6). Players with a typically low FMS^{TM} score (mean – 1SD threshold) were estimated to have a 50% greater match-injury burden compared to players with a typically high FMS^{TM} score (mean + 1SD threshold) as match-injury burden was 10% lower per 1-unit increase in FMS$^{™}$ score. As the strongest association with injury outcome was found for players with pain and asymmetry, when implementing the FMS$^{™}$ it is advisable to prioritise these players for further assessment and subsequent treatment.

Introduction

In men's community rugby union, one player receives an injury causing them to miss at least one game every three team games (Roberts, Trewartha, England, Shaddick, & Stokes, 2013). On average, each of these injuries requires 7.6 weeks out of competition in order to recover (Roberts et al., 2013). However, injury risk factors in men's community rugby are poorly understood with the exception of previous injury, which has consistently been identified as a risk factor for further injury (Chalmers, Samaranayaka, Gulliver, & McNoe, 2012; Quarrie et al., 2001). As such, more information is needed to inform injury reduction strategies.

One approach to understanding the likelihood of a player getting injured is to conduct screening. However, comprehensive screening such as the medical screening protocol developed for the Australian College of Sports Physicians (Brukner, White, Shawdon and Holzer, 2004) can be too costly, too time consuming and may require practitioner expertise that is not available within community clubs. A simple and quick-to-perform movement control assessment has the potential to be of great benefit to community teams. Compared with comprehensive athlete screening protocols, the Functional Movement Screen™ (FMS™) is more economical to administer and can be performed by individuals with basic FMS™ training (Cook, Burton, & Hoogenboom, 2006a, 2006b). The FMS™ comprises seven movement patterns that assess individuals' strength, balance and range of motion and are combined with three movements that screen for pain (Cook et al., 2006a, 2006b). The primary function of the FMS™ is to identify areas of movement deficiency in individuals, but it has also been used to predict injury in a range of athletic populations, with conflicting results concerning the relationship of the FMS™ scores with injury. The FMS™ was not associated with injury in runners (Hotta et al., 2015), mixed sports (including cross-country, football, soccer, swimming, tennis, and volleyball) high school athletes (Bardenett et al., 2015), mixed sports (including basketball, football, volleyball, track and Field, swimming, soccer, golf and tennis) NCAA division 1 athletes (Warren, Smith, & Chimera, 2015), or professional soccer players (Zalai, Panics, Bobak, Csaki, & Hamar, 2015). However, associations of FMS™ with injury have been identified in collision based sports, including American football (Kiesel, Butler, & Plisky, 2014; Kiesel, Plisky, & Voight, 2007) and rugby union (Duke, Martin, & Gaul, 2017; Tee, Klingbiel, Collins, Lambert, & Coopoo, 2016). In American Football, FMS™ score (Kiesel et al., 2007) and presence of movement-pattern asymmetry (Kiesel et al., 2014) were associated with a higher likelihood of injury. In elite rugby union, movement competency (Duke et al., 2017; Tee et al., 2016) and sub-test scores (Tee et al., 2016) were associated with increased likelihood of injury, but movement-pattern asymmetry and likelihood of injury were poorly associated (Duke, et al., 2017).

One of the most important risk factors for rugby injury is the amount of time players are exposed to risk (Williams et al., 2017) yet no study described above accounted for exposure. Only a few sports-based FMS™ studies have accounted for players’ exposure during analysis (Chalmers et al., 2018; Chalmers et al., 2017; Hammes, Aus der Fünten, Bizzini, & Meyer, 2016). In veteran football players, Hammes et al. (2016) reported no clear association between FMS™ score and playing time until first injury. In junior Australian Football players, Chalmers et al. (2017) also reported no association between FMS™ score and injury. However, the presence of one or more asymmetries was associated with 1.9 times higher likelihood of injury in junior Australian Football players, escalating to 2.8 times likelihood of injury where players had 2 or more asymmetries (Chalmers et al., 2017). Following a direct replication of the Australian Football study design, the results originally presented in 2017 could not be replicated, and asymmetry during FMS™ testing was not associated with a significant increase in prospective injury in the replication dataset (Chalmers et al., 2018). As such, asymmetry should be considered when analysing the association between FMS™ performance and rugby injury.

This study investigated FMS™ performance (including the influence of movement asymmetry and pain), while accounting for individual player match exposure, the association with time-loss match-injury outcomes of 8 days or greater, and what FMS™ score was associated with the greatest difference in match-injury burden for a men's community rugby population.

Methods.

This study was designed as a prospective observational cohort study. All participants performed the FMS™ at the beginning of the study period after which match-injury and exposure data were collected over a competitive rugby season.

Participants

Participants were recruited from the community rugby playing population in England. A similar population has previously been categorised into three sub-groups as Semi-professional (Rugby Football Union (RFU) levels 3-4; highest level of English community rugby), Amateur (RFU levels 5-6) and Recreational (RFU levels 7-9) (Roberts et al., 2013). An inclusion criteria was that participating clubs had to have a recognised qualified sports therapist, osteopath, chiropractor, physiotherapist, or doctor to record injuries. At the time of recruitment, participants were injury free (self-reported) and all were considered by the coaching team to be eligible and under consideration to play in the club's 1st team for the forthcoming season. In total, 23 clubs (men's senior squad only) were recruited (Figure 1), from which 433 players volunteered to participate.

****FIGURE 1 NEAR HERE****

Ethical approval and consent

Participating clubs were provided with study information and full instructions for testing procedures prior to the testing session taking place, which was then disseminated to all players who provided written informed consent at the start of the testing session. Ethics approval was granted by the University of Bath, Research Ethics Approval Committee for Health (EP 12/13 58).

Examiners

Fourteen people acted as raters during the testing period, attending participating clubs in groups of 4. All raters had a sports science background and included undergraduate students, post graduate students, and academic staff. Rater training was received from a certified FMS™ trainer and five of the raters had over 12-months experience using FMS™ prior to this study. No formal reliability study was performed as part of the present study, though raters with similar and varied backgrounds have previously been shown to have good intra-rater (interclass correlation coefficient (ICC), 95% confidence interval (CI), = 0.81, 0.69-0.92) and inter-rater reliability (ICC, 95% CI, = 0.81, 0.70-0.92) when delivering the FMS™ (Bonazza, Smuin, Onks, Silvis, & Dhawan, 2017).

Procedures

FMS™ data were collected during pre-season (between July and September 2013) at each club. After an introduction to the testing procedures by the research team leader, participants signed informed consent forms. Participants' self-reported primary playing position and age (years) and the research team recorded height (m) (Leicester Height Measure, Seca, UK) and mass (kg) (SC-240 body composition monitor, Tanita, USA). Participants' movement control, pain and movement pattern asymmetry were then assessed using the FMS™ in an indoor area within the club.

Functional Movement Screen™

Participants wore shorts, T-shirts, their normal trainers and were divided into four even groups with one researcher completing the entire FMS™ screen with each group. Participants were not allowed to complete a warm-up or to perform preparatory stretching prior to testing. The FMS™ was conducted using the standard method (Cook et al., 2006a, 2006b). For each movement pattern component, a central demonstration with standard verbal instructions was provided by the research team leader to ensure that all participants received the same information prior to screening. Participants were not aware of the scoring system. Each component was repeated up to three times by participants and the best scores recorded. Component movement scores were recorded in real-time by the raters who were able to change their viewing position. FMS™ components were scored on an ordinal scale (0-3), where 'zero' is given if the participant experiences pain during the test, through to a score of 'three' for perfect test execution. For bilateral movement patterns (inline lunge, rotational stability, shoulder mobility, active straight leg raise and hurdle step) scores were recorded for both right and left sides. Asymmetry was present if the movement scores for the left and right sides differed by one point or more. Where a difference in score was recorded for a bilateral movement pattern, the lower score for was used when the overall FMS™ score was calculated. A player's FMS™ score was calculated according to standardised criteria (Cook et al., 2006a, 2006b).

Match exposure

For every 1st team match of the 2013-14 rugby season, participating clubs recorded individual player match exposure using a standardised form. Match exposure was recorded as 20, 40, 60 or 80 minutes.

Player injury

Injury management staff at participating clubs completed and returned injury forms. Any injury incurred during a first team match resulting in an absence from participation in full training or match play for 8 days or more from the day of the injury was defined as a "time-loss" match-injury (Fuller et al., 2007). The date on which the injured player was fit for game selection (whether or not they actually played on that date) was recorded as the return to play date. Injury severity was calculated as the number of days elapsed between the date of injury and 'return to play' date.

For all time-loss injuries, information was recorded for the anatomical site, injury type, injury event, treatment, time of injury during match and severity using a standard report form. Injury diagnoses were recorded using the Orchard Sports Injury Classification System version 8 (Rae, Britt, Orchard, & Finch, 2005) by the injury management staff. Only injuries incurred during match play were recorded and therefore absences from match play due to illness or injuries incurred through any other activity (including rugby training) were excluded.

Statistical Analysis

Data analysis was performed using SPSS (Version 22 for Windows, Armonk, NY. IMB Corp). Descriptive characteristics for player demographics were reported as mean ± standard deviation (SD). Mean FMS™ scores were compared according to players' injury status ('injured' = any player suffering a time-loss injury during the season, or 'non-injured' = no time-loss injury during the season).

Injury incidence rates (IIRs) were reported per 1000 player match-hours and severity recorded as the number of days absence from full training or match play. Match-injury burden was reported as total time-lost (days) per 1000 player match-hours. The sum of match-injuries and sum of total match exposure was used to calculate incidence of overall (≥8days time-loss) and severe match-injuries (>28days time-loss). Effect sizes (ES) were quantified and considered as trivial (≤0.2), small (>0.2-0.6), moderate (>0.6- 1.2), large (>1.2-2.0) and very large (>2.0-4.0) (Batterham and Hopkins, 2006). A General Estimating Equation (GEE) was used to determine associations between FMS™ score, asymmetry, pain and injury count. Multivariate analyses were undertaken and over-dispersion was controlled for using a Pearson chi-square scaling parameter (McCullagh and Nedler, 1989). Regression analysis was offset for exposure (hours) and was adjusted for club (cluster), playing level stratification (semi-professional; amateur; recreational) and player (random effects). Analysis was performed for any match-injury (≥8days time-loss), severe match-injury (>28days time-loss) and match-injury burden (time-lost days) for all ≥8days time-loss injuries. Results are presented as rate ratio (RR) with 90% confidence intervals (90%CI) and interpreted using clinical-magnitude based inference (Hopkins and Batterham, 2016). Threshold values for unlikely/harmful (25) and most/very unlikely (5) were used to derive the odds ratio for making mechanical inference (Hopkins and Batterham, 2016).

Results

Descriptive summary

Due to factors including club withdrawal from the study, individual players never playing for the 1st team or otherwise returning incomplete data, time-loss injury and individual match exposure data were reported for 277 (64%) of the initial 433 players who were screened. For the 277 players included within the analysis, FMS™ and anthropometric characteristics are presented in table 1.

****TABLE 1 NEAR HERE****

For the 277 players the median FMS™ score was 14 (mean ± standard deviation (SD) = 14.1±2.6), 28% of all players reported pain and 72% of all players displayed asymmetry on ≥1 of the FMS™ movement patterns. Twenty-three percent of all players displayed both movement-pattern asymmetry and reported pain, while 23% of all players displayed neither asymmetry nor reported pain when completing FMS™ screening. Both movement-pattern asymmetry and pain were most commonly reported for the shoulder mobility movement pattern.

Of the 277 players, 57 (21%) players sustained 74 acute match-injuries across 4359 player match-hours (equivalent to 218 team-games) (Table 2). No recurrent or gradual onset injuries were reported. Overall match-injury incidence (≥8days time-loss) was 17.0 (90%CI=14.0–20.6) injuries/1000 player match-hours. Of the 57 injured players, 30 players accumulated 35 severe (>28days time-loss) match-injuries with an incidence of 8.0 (90%CI=6.1–10.6) severe match-injuries/1000 player match-hours. For all ≥8days time-loss match-injuries the match-injury burden was 655 (90%CI=541-792) days/1000 player match-hours. Contact (n = 57) and non-contact injuries (n = 9) accounted for 77% and 12% of match-injuries, respectively, while no event was reported for 8 (11%) match-injuries.

****TABLE 2 NEAR HERE****

The greatest match-injury burden was associated with injuries involving the knee (127.3 days/1000 player match-hours), ankle (84.2 days/1000 player match-hours) and the shoulder (70.7days/1000 player match-hours; table 3), while the match-injury types associated with the greatest match-injury burden were ligament tears/sprains (163.6 days/1000 player match-hours), muscle tears/strains (92.0 days/1000 player match-hours) and fractures (76.6 days/1000 player match hours; table 4).

****TABLE 3 NEAR HERE****

****TABLE 4 NEAR HERE****

Association of FMS™ score with injury outcomes

The distribution of FMS™ scores for these 277 players, stratified by injury status is displayed in Figure 2. Difference in mean FMS™ score between players with any match-injury (14.0 ± 2.7) and non-injured players (14.1 ± 2.6) was trivial (Figure 2; Effect size (ES), 90% CI= -0.04, -0.27–0.19). The difference in mean FMS™ score between players who sustained a severe match-injury (13.5 ± 2.6) and non-injured players (14.1 ± 2.6) was also trivial (Figure 2; ES, 90% CI= -0.22, -0.53 – 0.09).

****FIGURE 2 NEAR HERE****

Poisson regression analysis indicated the association of FMS™ score and injury incidence was trivial for overall match-injury (RR, 90%CI=0.96, 0.90-1.02) and severe match-injury (RR, 90%CI=0.92, 0.84-1.01) (Figure 4). A 1-unit increase in FMS™ score was associated with a possibly beneficial 10% lower match-injury burden (RR, 90%CI=0.90, 0.83-0.97). Rate ratio analysis was used to determine the FMS™ score associated with the greatest difference in match-injury burden (Figure 3). Players scoring ≥16 (31%) compared with <16 on the FMS™ demonstrated the greatest difference in all match-injury outcomes including a very likely beneficial 59% lower match-injury burden (RR, 90%CI=0.41, 0.22-0.76), a likely beneficial 51% lower severe match-injury incidence (RR, 90%CI=0.49, 0.24-

1.02) and a likely beneficial 30% lower overall match-injury incidence (RR, 90%CI=0.70, 0.47-1.05).

FIGURE 3 NEAR HERE

Association of pain and asymmetry with injury

Multivariate Poisson regression analysis indicated that the presence of any movement pattern asymmetry was associated with a very likely harmful 2.5 times higher severe match-injury incidence (RR, 90%CI=2.5, 1.0–6.2) and very likely harmful 2.4 times higher match-injury burden (RR, 90%CI=2.4, 1.4–4.3) (Figure 4) compared with players with no movement pattern asymmetry, adjusted for FMS^{TM} score. The presence of pain was associated with a likely harmful 1.8 times higher match-injury burden (RR, 90%CI = 1.8, 1.0–3.2) compared with players who did not report pain during movement pattern testing, adjusted for FMS^{TM} score.

FIGURE 4 NEAR HERE

Players displaying asymmetry without pain (n=136, 49%) were associated with a likely harmful 2.3 times higher incidence of severe match-injury (RR, 90%CI=2.3, 0.8-6.5) and likely harmful 2.2 times higher match-injury burden (RR, 90%CI=2.2, 1.1-4.4) compared with the control group (Figure 5), adjusted for FMS^{TM} score. Players presenting both asymmetry and pain (n=65, 23%) were associated with a likely harmful 2.9 times higher incidence of severe match-injury (RR, 90%CI=2.9, 0.9-9.7) and a very likely harmful 2.9 times higher match-injury burden (RR, 90%CI=2.9, 1.3–6.6) compared with the control group, adjusted for FMS^{TM} score.

FIGURE 5 NEAR HERE

Discussion

This study investigated whether the Functional Movement Screen^{TM} score, pain and/or asymmetry determined prospectively during FMS^{TM} testing were associated with time-loss match-injury outcomes in men's community rugby players. Better movement control, indicated by a higher FMS^{TM} score, was associated with less time lost to injury, where a 1-point increase in FMS^{TM} score was associated with a 10% lower match-injury burden. Controlling for FMS^{TM} score, the presence of both pain and movement asymmetry were associated with an approximately 3-fold increase in severe match-injury incidence and match-injury burden. While players with an FMS^{TM} score of ≥13 demonstrated a clearly beneficial lower match-injury burden compared to players scoring <13, the greatest difference in all injury outcomes was found for players scoring ≥16 compares to players scoring <16.

This study was the first to investigate FMS^{TM} and injury burden and used Poisson linear regression offset for player match exposure to analyse players risk of injury. As a measure of movement competency, a 1-point increase in FMS^{TM} performance was associated with a 10% lower injury burden, which implies that players with better movement patterns lose less time to injury than players with deficient movement patterns. However, no meaningful association between FMS™ score and overall match-injury incidence (≥8-days time-loss) or severe match-injury (>28-days time-loss) was found. The lack of association between FMS™ score and match-injury incidence may be due to the many random events and player to player contacts that occur during rugby match play, which makes predicting 'who' gets injured challenging. Previous researchers have likened the ability of the FMS™ to predict 'who' will get injured to flipping a coin (Dorrel, Long, Shaffer and Myer, 2018). Yet better movement competency was associated with lower match-injury burden for which there is no clear and obvious rationale. A possible explanation is that players with better movement competency (higher FMS™ scores) are able to achieve and better maintain 'optimal' body positions during contact events such as the tackle, ruck and maul compared with players with poor movement competency (lower FMS™ scores). For example, improved lower-limb alignment during a tackle situation may reduce forced knee valgus when under the sudden external load experienced by the tackler, resulting in a lower match-injury burden. Hopkins, Marshall, Batterham, & Hanin (2009) recommend making inferences by comparing the effect of different levels of continuous predictors i.e., comparing the injury burden for players with typically low (mean-SD) to typically high (mean+SD) scores. In this study, the mean FMS™ score for all players was 14.1 (SD = 2.6). A 2SD improvement in players' FMS™ score thus approximates to 50% lower match-injury burden based on this relationship. A similar result was reported for veteran soccer players where players with a 'low' FMS™ score (FMS™ <10) had 1.9 times the injury incidence compared to those with an 'intermediate' FMS™ score (FMS™=10-14) (Hammes et al., 2016). These results support the notion that better movement competency (higher FMS™ score) is associated with lower injury outcomes. As FMS™ scores have been demonstrated to be modifiable by implementing movement control interventions (Kiesel et al., 2011), clubs may be advised to maximise players movement competency by intervention post screening. Improving players movement competency should be considered by clubs as even moderate reductions in injury burden may have worthwhile effects on competition outcomes (Williams et al., 2016).

In the present study, the presence of ≥1 asymmetry was associated with 2.2 times the overall injury burden (664 vs 291 days/1000 player match-hours) and 2.3 times the incidence of severe injury (8.6 vs 3.7 injuries/1000 player match-hours) when adjusted for FMS™ score. When assessing sports injury risk, recommended methods of analysis include Cox regression, frailty modelling (Finch and Marshall, 2016) and linear regression (Bahr and Holme, 2003) where the forms of analysis account for individual player exposure to the risk (participation in the sport). While the present study used Poisson linear regression, two previous studies of contact sports have used Cox regression in their research of FMS™ and injury outcome. In Australian Rules Football, junior players with ≥1 movement asymmetry were associated with 1.9 times the likelihood of injury (any trauma or medical condition resulting in match time-loss) compared with players with no asymmetry, which increased to 2.8 times the likelihood of injury for players with ≥2 movement pattern asymmetries (Chalmers et al., 2017). In addition, players that displayed both pain and asymmetry had a 1.6 times likelihood of time-loss injury (Chalmers et al., 2017). However, these results have not yet proven to be replicable in junior Australian Rules Football (Chalmers et al., 2018). In the present study, players that demonstrated both pain and asymmetry had a likely harmful 2.9 times higher incidence of severe injury and very likely harmful 2.9 times higher injury burden for players displaying both pain and asymmetry when adjusted for FMS™ score. What is not apparent when conducting the FMS™ is why asymmetry or pain is present. Possible reasons could be related to hand and leg dominance, poor training practice or previous injury. Clubs using the FMS™ may be advised to triage players displaying asymmetry or pain for further investigation by a registered medical practitioner, such as a physiotherapist, to identify the underlying cause, for which a corrective exercise programme may be developed. Priority for such referral should be granted to players who display asymmetry and also report pain as these players were associated with a greater risk of injury than asymmetry alone.

Most sports screening tests measure using a continuous scale and must be translated to a dichotomous outcome (Bahr, 2017). In the present study, rate ratio analysis was used to determine whether a FMS™ score would maximise the difference in injury outcomes. Players (31%) that scored ≥16 on the FMS™ had beneficially lower injury outcomes, including overall injury incidence (12.4 v 18.9 injuries / 1000 player match hours), severe injury incidence (4.6 v 9.5 injuries / 1000 player match-hours) and injury burden (325 v 794 days / 1000 player match-hours) compared to players scoring <16. Similar scores have been proposed by studies in different populations including intercollegiate athletics (FMS™ ≤17; Weise, Boone, Mattacola, McKeon and Uhl, 2014), physically active students (FMS™ <17; Letafatkar, Hadadnezhad, Shojaedin and Mohammadi, 2014) and National Collegiate Athletic Association Division II athletes (FMS ≤15; Dorrel et al., 2018). However, a score of ≥16 contrasts with other FMS^{TM} literature where a score of FMS^{TM} ≤14 has commonly been proposed as an injury predictive value (Kiesel et al., 2007; Chorba et al., 2010; Butler et al., 2013; Lisman et al., 2013). These previous studies did not account for participants' exposure when identifying their injury predictive values using receiver operator characteristic analysis (Keisel et al., 2007, Butler et al., 2013) and otherwise adopted the cut-off score of FMS^{TM} ≤14 based on previous research (Chorba et al., 2010; Lisman et al., 2013). While a score of ≥16 is higher than the commonly proposed score of >14, no previous literature has considered injury burden, used Poisson regression analysis, nor accounted for players match exposure with similar resolution, which likely effected these results. Overall, the better a player's movement competency, the lower the overall injury risk where a target score of FMS^{TM} ≥16 should be employed to maximise the injury risk benefit.

No study has measured players' FMS™ scores and used the results to produce an exercise intervention demonstrated to be effective in reducing the injury risk of athletes. Many variables affect FMS™ scores which are player specific, possibly requiring an individualised approach to each player's pre-habilitation intervention. The FMS^{TM} total score does not represent a unidimensional construct (Kazman, Galecki, Lisman, Deuster and O'Connor, 2014), in that two players can have the same FMS^{TM} score but achieve it with considerably different movement competencies. As such, a uniform solution to improve movement competency is not possible to prescribe based on total FMS^{TM} score alone. During follow-up assessment of players highlighted as at 'higher risk', therapists must focus on the players specific movement deficiencies before providing a treatment/intervention. Based on the proportion of players in the present study with low FMS™ scores, pain and/or asymmetry, if community club therapists started screening during pre-season, it is unlikely that the follow-up assessments necessary to determine each player's dysfunction and subsequent treatment would be complete until early into the competitive season, where the risk of injury is highest (Garraway and Macleod, 1995; Quarrie et al., 2001; Roberts et al., 2013). Rather than using FMS™ in isolation, clubs are advised to administer movement competency injury prevention programmes to all players during training, as such interventions have reduced injury in rugby (Attwood, Roberts, Trewartha, England, & Stokes, 2017; Hislop et al., 2017), football (Emery and Meeuwisse, 2010; Gilchrist et al., 2008; Soligard et al., 2010), basketball (Longo et al., 2012) and handball (Andersson, Bahr, Clarsen, & Myklebust, 2016; Olsen, Myklebust, Engebretsen, Holme, & Bahr, 2005). By implementing club wide movement control programmes such as Activate (Attwood, Roberts, Trewartha, England, & Stokes, 2017; Hislop et al., 2017) clubs would already be implementing a recommended player welfare strategy while adequate time is allocated to facilitate FMS™ screening and subsequent player follow-up to develop individualised programmes for 'higher risk' players. The implementation of Activate, FMS™ screening and subsequent player specific corrective treatment may have a combined and beneficial effect on player welfare and thus maximise the injury reduction benefit for limited resources available to community rugby teams.

Strengths and Limitations of the Study

Strengths of the study include the large sample of players followed throughout a season and the inclusion of individual players match exposure during analysis, as has been recommended when investigating injury risk factors (Bahr and Holme, 2003). This was also the first study to apply Poisson regression analysis, while accounting for playing level, which has previously been associated with significant differences in injury incidence (Roberts et al., 2013). There were some limitations to this study. Injury reporting was limited to match-injuries with a severity of ≥8-days rather than 1-day. This injury definition excluded all training injuries and any match injuries <8-days time-loss from the analysis, which do account for a small proportion of the overall injury burden. This approach was thought to be appropriate as it negated the need to report injury and exposure data for a squad of players at every training session, thus helping to maintain clubs' involvement in the study. As described in the methods, no formal reliability study was performed to determine agreement between assessors. The analysis performed throughout this study, was not powered for, and does not account for the type of injuries sustained which could influence the associations reported, due to the low count per injury type / site. As such, type and site of injury were limited to descriptive analysis only. Further investigation into the relationship between injury severity, injury burden, FMS™ score and specific injury types, such as anterior cruciate injury or hamstring injury as two examples, is recommended to affirm the association between the burden of specific injuries and movement competency screened using the FMS™.

Using the Functional Movement Screen™ to assess movement competency during pre-season may help practitioners to identify players at greater risk of match injury. Players movement competency should be maximised by practitioners, since a 1-point change in

FMS™ score was associated with a 10% lower match-injury burden, resulting in a 50% lower match-injury burden when comparing players with typically low to typically high FMS™ scores. However, if screening started at the beginning of pre-season, some players may not receive corrective treatment until the early in-season period, due to the time required to conduct FMS™ screening, to follow-up and develop interventions for players identified as ‘high risk’. As movement control programmes such as ‘Activate’ reduce rugby players injury burden, rugby clubs should implement Activate club-wide while screening is conducted in order to help maximise the welfare of their players. Following screening, players with the lowest FMS™ scores should be prioritised, particularly those with low FMS™ scores that report pain and display asymmetrical movements, as the combined presence of these factors was associated with the greatest injury risk.

Tables and Figures

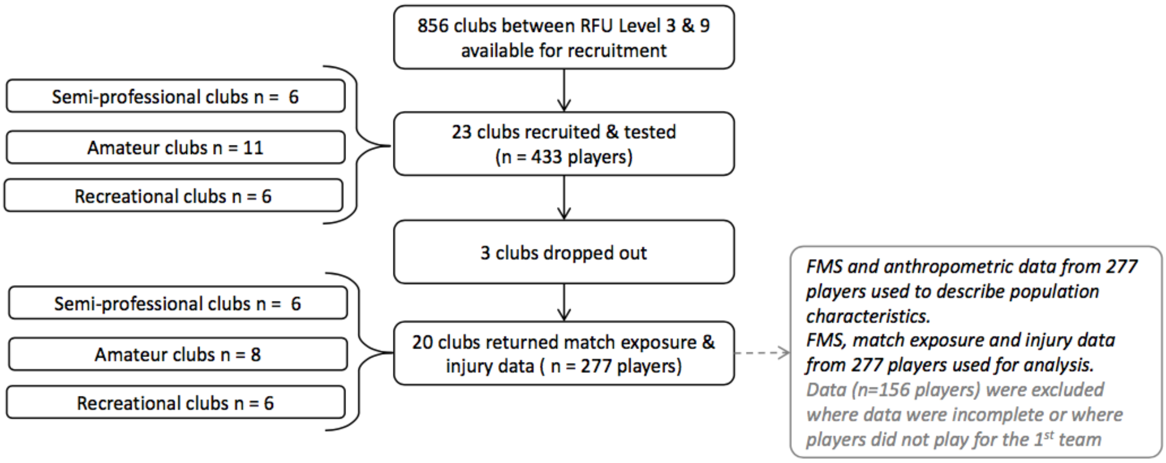

Figure 1. Overview of the reach of the study, including the number of clubs that participated, dropped-out, and volume of data used for analysis.

Table 1. FMS^{TM} and anthropometric characteristics of 277 players, organised by playing level stratification.

Playing level	Clubs (n)	Players (n)	FMS score mean (SD)	Age (years) mean (SD)	Height (cm) mean (SD)	Mass (kg) mean (SD)	BMI (kg/m^2) mean (SD)
Semi-professional	6	85	14.2 (2.9)	23.7 (3.8)	182.2 (6.5)	95.7 (13.1)	28.8 (3.2)
Recreational	8	108	14.2 (2.4)	25.3 (4.2)	181.2 (6.6)	95.7 (13.1)	29.2 (3.7)
Amateur	6	84	13.8 (2.5)	25.4 (5.3)	178.7 (6.5)	91.2 (12.7)	28.6 (4.0)
Total	20	277	14.1 (2.6)	24.8 (4.4)	180.7 (6.5)	94.2 (13.0)	28.9 (3.6)

Table 2. A summary of the nature and number of injuries including match-injury incidence and match-injury burden organised by playing level stratification.

	Injury count (n)	Contact injuries n(%)	Non-contact injuries n(%)	Unknown event injuries n(%)	Exposure (hours)	Incidence per 1000 player match-hours (90% CI)	Time lost (days)	Burden per 1000 player match-hours (90% CI)
Semi-professional	25	16 (64)	3 (12)	6 (24)	1272	19.7 (13.3-29.1)	781	614 (572-659)
Amateur	27	22 (81)	5 (19)	0	1683	16.0 (11.0-23.4)	1217	723 (684-765)
Recreational	22	15 (68)	6 (27)	1 (5)	1404	15.7 (10.3-23.8)	855	609 (570-651)

*Percentages for contact and non-contact injuries do not sum to 100% where injury event details weren't fully reported.

Table 3. The injury sites with greatest burden for all groups, arranged in descending order of match-injury burden.

	Injury count (n)	Contact injuries n(%)	Non-contact injuries n(%)	Unknown event injuries n(%)	Exposure (hours)	Incidence per 1000 player match-hours (90% CI)	Time lost (days)	Burden per 1000 player match-hours (90% CI)
Semi-professional	25	16 (64)	3 (12)	6 (24)	1272	19.7 (13.3-29.1)	781	614 (572-659)
Amateur	27	22 (81)	5 (19)	0	1683	16.0 (11.0-23.4)	1217	723 (684-765)
Recreational	22	15 (68)	6 (27)	1 (5)	1404	15.7 (10.3-23.8)	855	609 (570-651)

*Percentages for contact and non-contact injuries do not sum to 100% where injury event details weren't fully reported.

Table 4. The injury types with greatest burden for all groups, arranged in descending order of match-injury burden.

Injury type	n	Time-lost (days)	Exposure (hours)	Incidence per 1000 player match-hours (90% CI)	Mean severity days (90% CI)	Burden per 1000 player match-hours (90% CI)
Ligament tear/strain	15	713	4359	3.4 (2.3-5.3)	48 (31-73)	164 (107-250)
Muscle tear/sprain	15	401	4359	3.4 (2.3-5.3)	27 (18-41)	92 (60-140)
Fracture	7	334	4359	1.6 (0.9-3.0)	48 (26-89)	77 (41-142)
Nerve injury	7	217	4359	1.6 (0.9-3.0)	31 (17-58)	50 (27-93)
Tendon injury	5	212	4359	1.1 (0.6-2.4)	42 (20-88)	49 (23-101)

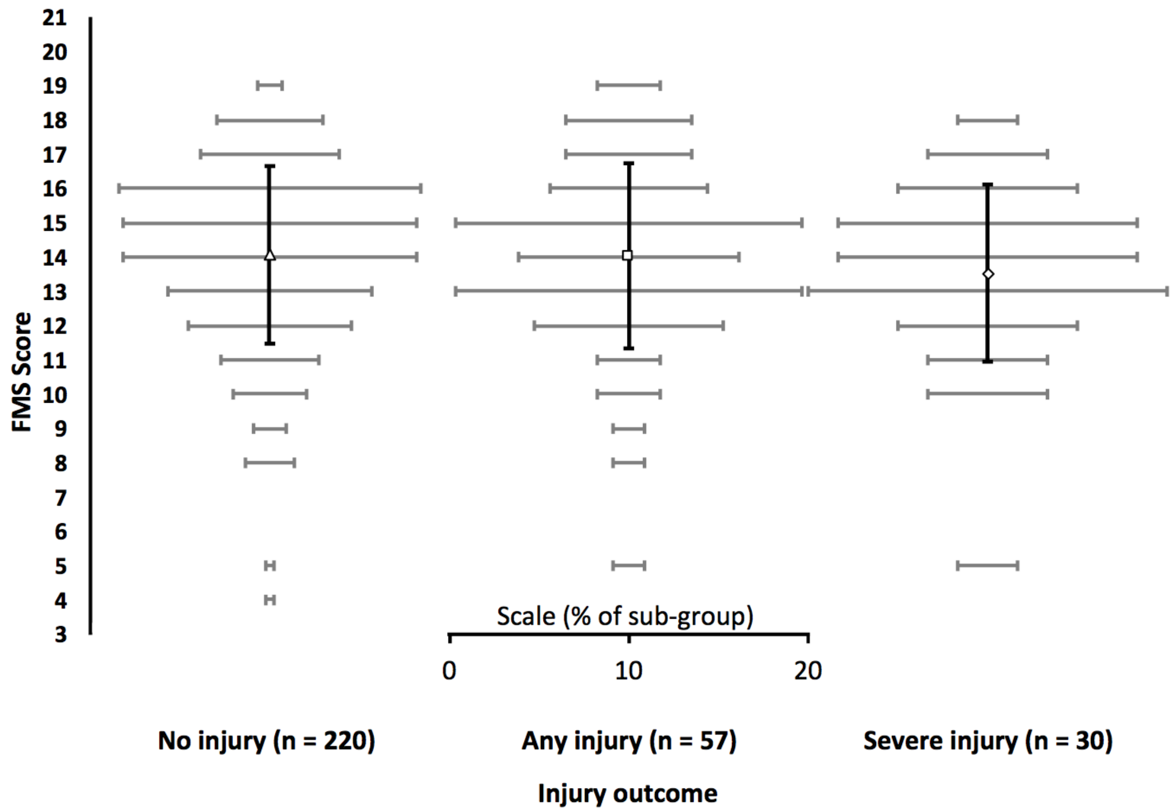

Figure 2. FMS™ scores stratified by injury definition; no injury, any injury (≥8 days), and severe injury (>28 days). Horizontal error bars represent frequency of FMS™ scores, vertical error bars represent mean and 90% confidence limits.

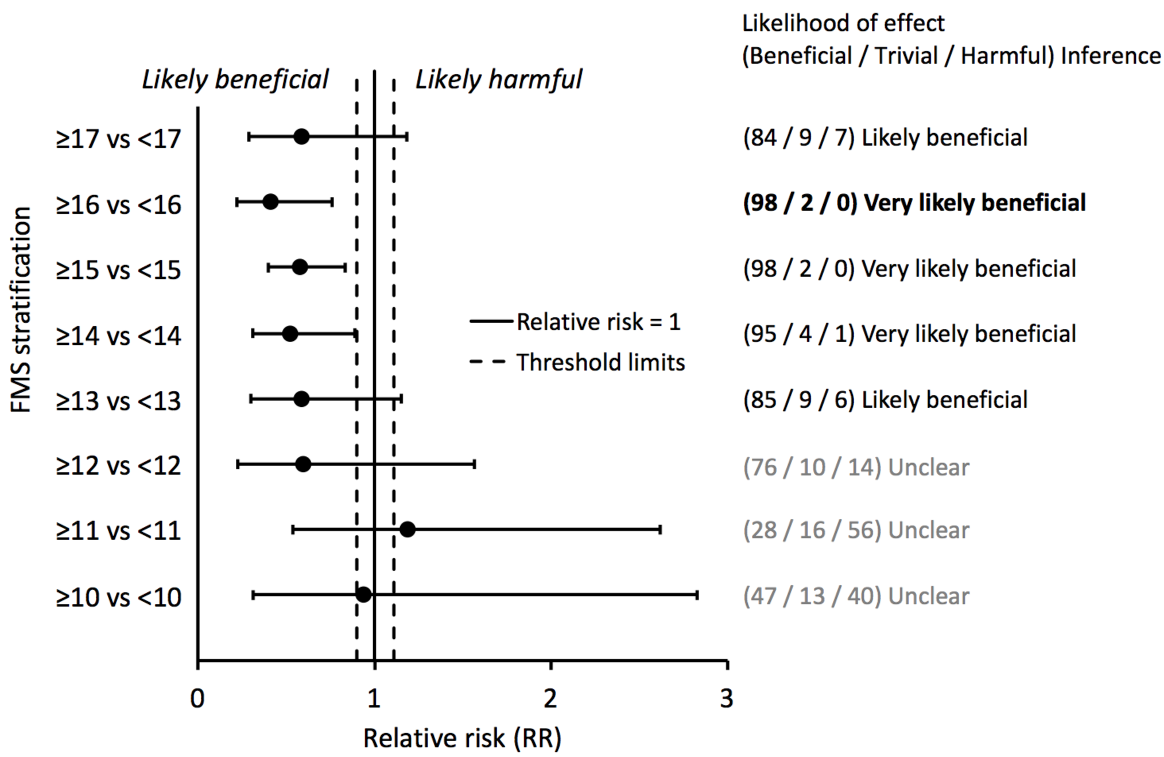

Figure 3. Forest plot comparing match-injury burden (days/1000 player match-hours) by FMS™ score stratification. The right side of the figure displays the likelihood of effect. FMS™ scores at and above which resulted in a lower injury burden with a high likelihood of effect are highlighted in bold (right column).

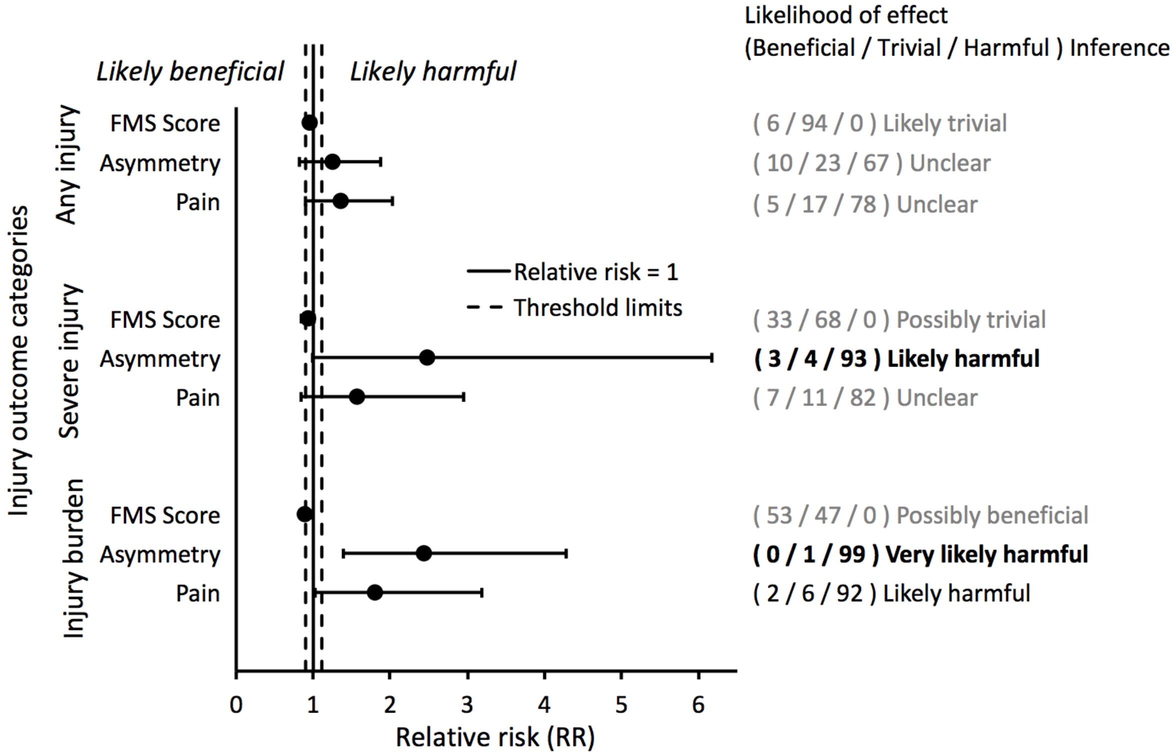

Figure 4. Forest plot displaying univariate results for relative risk of players with higher FMS™ score (continuous) compared to lower FMS™ score; players displaying any asymmetry compared to players with no asymmetry; and players reporting pain to players not reporting pain. The largest effects are highlighted in bold.

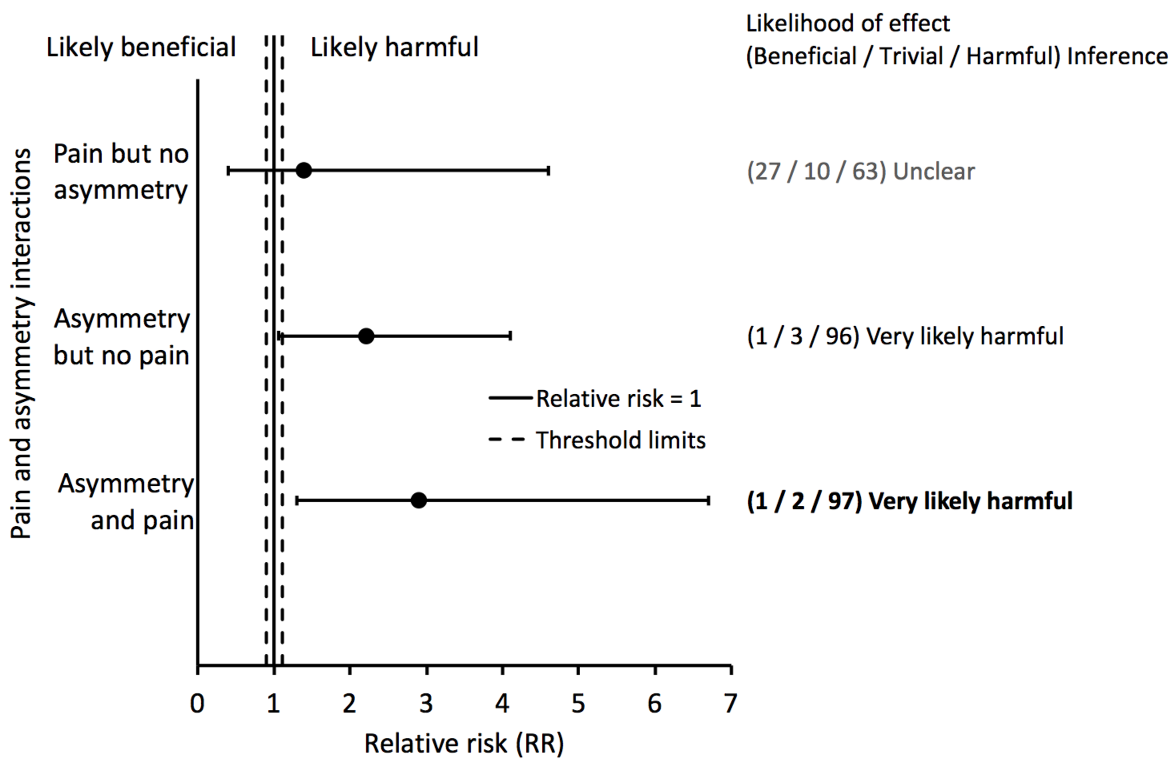

Figure 5. Forest plot displaying the interaction effects of pain and asymmetry on match-injury burden (days/1000 player match-hours) compared baseline (no asymmetry, no pain). The largest effects are highlighted in bold.

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