**A Preliminary Study Investigating Functional Movement Screen Test Scores in Novice and Advanced Female Show Jumping Riders**

Lewis, Victoria; Bicanardi, Thelma; Douglas, Jenni; Dumbell, Lucy

*Published in:*
Journal of physical fitness, medicine and treatment in sport

*Publication date:*
2019

# A Preliminary Study Investigating Functional Movement Screen Test Scores in Novice and Advanced Female Show Jumping Riders

Victoria Lewis*, Thelma Bicanardi, Jenni Douglas and Lucy Dumbell

*Equestrian Performance Research and Knowledge Exchange Arena, Hartpury University, GL19 3BE, United Kingdom*

Corresponding author: Victoria.lewis@hartpury.ac.uk

## Abstract

*The functional movement screen (FMS) is an easily administered and non-invasive tool to identify areas of weakness and asymmetry during specific exercises. FMS is a common method of athlete screening in many sports and is used to ascertain injury risk, but has to be used within an equestrian population. The aim of this study was establish FMS scores for Novice and Advanced Female Show Jumping Riders, to inform a normative data set of FMS scores in horse riders in the future.*

*Twenty-two female show jumping horse riders (mean age 21.5 yrs.). Twelve riders competing at 80cm and below were the 'novice' group and ten riders in the 'advanced' group competing at 125cm, were assessed based on their performance on a 7-point FMS (deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability and rotary stability). The mean composite FMS scores (± s.d.) for the novice rider group was 12.08 ± 2.7 and for the advanced riders was 14.08 ± 1.77. There was a statistical significant difference in median FMS composite scores between the novice show jumping rider and advanced show jumping rider groups (Mann-Whitney U test, p=0.004). One hundred percent of novice show jumping riders and 50% of advanced show jumping riders scored ≤14, indicating that a novice rider is 2 times (O.R.) more likely to be at increased risk of injury compared to advanced riders.*

*Advanced show jumping riders scored higher than novice riders but both groups scored lower than seen in other sports suggesting some show jumping riders may be at risk of injury. Riders' FMS scores demonstrated asymmetric movement patterns potentially limiting left lateral movement. Asymmetry has a potential impact on equestrian performance, limiting riders' ability to apply the correct cues to the horse. The findings of such screening could inform the development of ancillary training programmes to correct asymmetry pattern and target injury prevention.*

**Keywords: Show Jumping, equestrian, functional movement screen, injury, asymmetry**

## Introduction

Functional movement is the ability to produce and maintain a balance between mobility and stability along the kinetic chain while performing fundamental patterns with accuracy and efficiency (Chorba et al., 2010), Muscular strength, flexibility, endurance, coordination, balance, and movement efficiency are components necessary to achieve functional movement which is integral to performance and sport-related skills. Effective performance in Equestrian sports is reliant on the rider maintaining balance and posture in order to be able to administer predictable cues (aids) to the horse. The rider aims to maintain a straight line through the ear-shoulder-hip-heel, with the pelvis in the neutral position and a controlled upright trunk position adapting to the movement of the horse (Guire *et al.*, 2017; Hobbs *et al.*, 2014; Nevison *et al.*, 2013; Douglas *et al.*, 2012; Lovett *et al.*, 2005). The Olympic discipline of show jumping requires the horse and rider to negotiate a course of 12-20 knock able fences. The activity of jumping requires the rider to alter or adjust their position by adopting a forward seat in order to cope with the increased mechanical forces involved. During jumping, the rider closes the hip and thigh angle and moves the trunk into a more forward position. In order to maintain their balance through the jumping phase the rider's weight is absorbed by the legs, as opposed to pelvis and legs as seen in the regular riding position (Nankervis, *et al.* 2015; Douglas, *et al.* 2012; Patterson, *et al.,* 2010). This adjustment in position requires a great deal of control of the body segments, as the rider has to deal with acceleration forces from the horse particularly on landing (Patterson, *et al.,* 2010). If the rider is unable to maintain the desirable position then they are less likely to be able to control their body movements, administer repeatable predictable cues to the horse and are increased risk of losing their balance or causing undesirable behaviours in the horse.

Physical screening of athletes is commonplace in many sports to identify areas of weakness or functional insufficiencies. Screening can inform coaches and physiotherapists to actualize their interventions to enhance performance and prevent injuries. The British Equestrian Federation's Long Term Participant Development model suggests that riders' body alignment and functional stability patterns should be regularly tested, yet a standardised, quantitative and valid measure has yet to be fully investigated within this population.

The Functional Movement Screen (FMS) is a simple measure to identify asymmetry in a person's basic functional movements. It was designed to assess muscle flexibility, strength, imbalances and general movement proficiency using a range of performance tests. It also identifies deficits related to proprioception, mobilisation, stabilisation and pain within the prescribed movement patterns (Cook *et al*., 2006). It is a screening process growing in popularity due to it being a rapid, non-invasive measure to identify potential injury risk (Cook *et al*., 2006). The screen consists of seven different functional movements that assess trunk and core strength and stability, neuromuscular coordination, asymmetry in movement, flexibility, acceleration, deceleration, and dynamic flexibility (Peate *et al*., 2007). The FMS measures the quality of the movement based on specific criteria that allow the evaluator to use quantitative values for the movement on a scale of 0–3. The FMS focusses on the efficiency of movement patterns rather than the quantity of repetitions performed. It has been used as a tool for injury prevention (Kiesel *et al*., 2007; Kiesel *et al*., 2011) and composite scores of 14 or below has proven to be a valid indicator of injury risk among elite athletes. Research also indicates that the FMS demonstrates moderate-to-excellent inter- and intra-rater agreement for most of the assessment protocols (Leeder *et al.*, 2013; Shiltz *et al.*, 2013).

Lewis *et al. (*2019) used the FMS to test female colligate riders and established a mean compostite score of 14.15 ± 1.9, suggesting that this population maybe be at risk of an injury. Riders are at risk of acute injuries whilst handling horses, as a result of falling off the horse when riding (Whitlock, 1999; Sorli, 2000; Moss *et al.*, 2002) and is considered one of the most dangerous sports with a hospital rate of 49 hospital visits for every 1000 hours of riding (Sorli, 2005). Long term injuries resulting in chronic pain is seen in 76-100% of riders (Kraft *et al.*, 2007; Lewis, 2017; Lewis *et al.*, 2018) therefore the use of a screen tool to identify poor functional movement that may result in injury such the FMS may be useful in the equestrian population. Although equestrian sports science is an emerging field, evidence-based data on discipline-specific screening are still limited in the equestrian population. Therefore, the aim of this study is to establish FMS scores for novice show jumping riders compared to advance show jumping riders.

## Methods

*Participants*

Twenty-two female show jumping riders took part in this study (mean age 21.5 yrs.). The participant criteria were riders competing at 80cm and below will integrate the 'novice group' and riders competing at 125cm and above will integrate the 'advanced group'. Participants were a convenience sample of volunteers that met the inclusion criteria. Inclusion criteria required all participants to be at least eighteen years of age, injury free and not experiencing pain at the start of the protocol. The experimental protocols received Institutional Ethics Committee Approval and informed written consent was obtained from all participants.

*Testing Procedures*

Riders were familiarized with the test protocols using verbal guidelines and visual demonstrations, which allowed for some cueing and ensured riders, were aware of the requirements of each movement task. All participants were advised to report for testing rested (i.e. having performed no strenuous exercise in the preceding 24 hours), hydrated and at least 3 hours following the consumption of a light carbohydrate based meal (Winter *et al.,* 2007). Participants were required to perform the procedures with no prior warm up or physical activity, to increase the validity of the results.

*Functional Movement Screen*

Participants were screened using the seven point functional movement screening protocol described by Cook *et al.* (2006) and Kiesel *et al.* (2007). Each participant performed 7 different functional movements:

'1) the deep squat which assesses bilateral, symmetrical, and functional mobility of the hips, knees and ankles, 2) the hurdle step which examines the body's stride mechanics during the asymmetrical pattern of a stepping motion, 3) the in-line lunge which assesses hip and trunk mobility and stability, quadriceps flexibility, and ankle and knee stability, 4) shoulder mobility which assesses bilateral shoulder range of motion, scapular mobility, and thoracic spine extension 5) the active straight leg raise which determines active hamstring and gastroc-soleus flexibility while maintaining a stable pelvis, 6) the trunk stability push-up which examines trunk stability while a symmetrical upper-extremity motion is performed, and 7) the rotary stability test which assesses multi-plane trunk stability while the upper and lower extremities are in combined motion' (Kiesel *et al.* 2007, p.148).

After each movement, a score was given to the movement based on specific FMS criteria by a qualified sports therapist. A score of 3 indicated that the movement was completed both pain-free and without compensation. A score of 2 indicated that the movement was completed pain-free but with some level of compensation or aid, and a score of 1 indicated that the participant could not perform the movement. A score of 0 was assigned to a movement that induced self-reported pain. When a FMS is performed, 5 of the 7 tests (hurdle step, shoulder mobility, active straight leg raise, in-line lunge, and rotary stability) tests are scored independently on the right and left sides of the body, whilst the other two the deep squat and the trunk stability push up test are symmetrical tests. Participants were given three trials of each movement pattern, with each trial being scored by the same researcher real time on a 0-3 point scale. Based upon the relationship between neuromuscular asymmetry and injury risk, the FMS scoring system highlights asymmetry and takes the lowest score of the three as the overall score for that movement (Beckham, 2010). After the 7 different movements were evaluated, a cumulative score out of 21 was recorded, as per the method described by Cooke *et al.* (2006) where 0 is very low and 21 is the highest score possible .

*Statistical Analyses*

Descriptive statistics were used to report scores and percentages within data. Odds ratios were utilized to assess risk of injury based on mean composite FMS scores. Due to the ordinal FMS scoring system a non-parametric Mann Whitney- U statistic was used to test for difference between novice rider and advanced rider groups. An alpha value was set at $p<0.05$ (confidence interval 95%) throughout unless otherwise stated. Data were analysed using SPSS for Windows version 24.

**Results**

The mean composite FMS scores (± SD) for the novice group was 12.08 ± 2.7; and for the advanced show jumping rider group was 14.08 ± 1.77 (Figure 1). There was a significant difference for FMS composite scores between the novice group (12.08 ± 2.7) and advanced (14.08 ± 1.77) groups (Mann-Whitney U test, p=0.004). One hundred percent of novice riders and 50% of advanced riders scored ≤14, indicating a risk of injury (Table 1) with an odds ratio of 2:1 in novice riders: advanced riders. A novice rider is two times more likely to be at risk of an injury based on their composite FMS score.

Table 1. A comparison of Functional Movement Screening composite scores for a group of novice show jump riders compared to a group of advanced show jump riders

| | **Number of Participants (n)** | **Mean composite score** | **Range of scores** | **Number of scores ≤ 14** | **Number of scores >14** | **Odds ratio** |
|---|---|---|---|---|---|---|
| **Novice Rider** | 12 | 12.08 | 18-14 | 12(100%) | 0 (0%) | Ad Rider: Nov rider 2 : 1 |
| **Advanced Rider** | 10 | 14.80 | 11-19 | 95(50%) | 5 (50%) | |

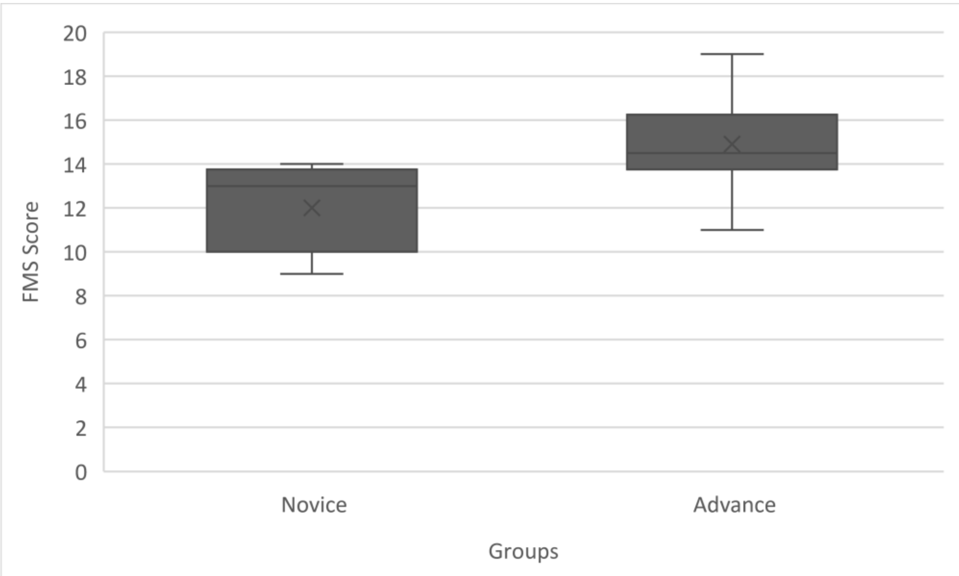


Figure 1: Cumulative functional movement scores for the Novice and Advanced show jumping riders

FMS for individual exercises (Figure 2) showed no significant difference between the two groups except Hurdle Step Left leg (p=0.032), Shoulder Mobility Right arm (p=0.004) No significant difference was seen in absolute asymmetry between riders and non-riders (Mann-Whitney U test, n=23, all p>0.05).

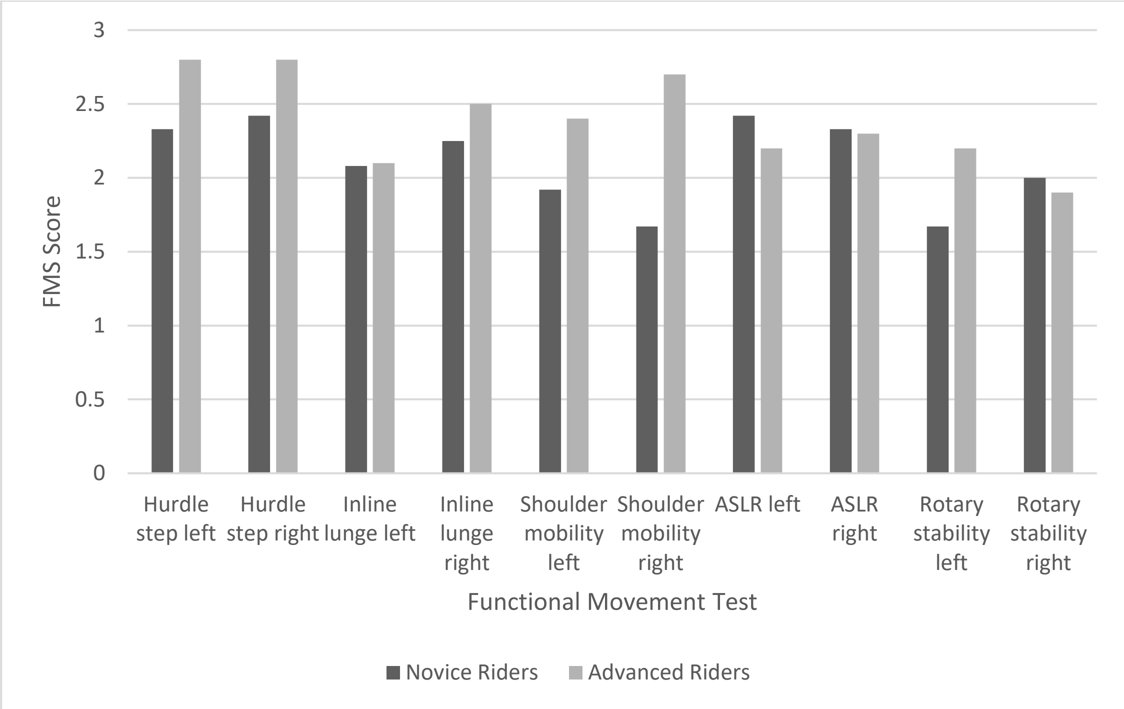


Figure 2. Mean left and right scores for functional movement screen.

## Discussion

The purpose of this study was to determine FMS scores in a sub-population of female show jumpers based upon reports of a high prevalence of pain, (Kraft, 2007; Lewis, 2018), and asymmetry (Symes and Ellis, 2009; Hobbs *et al.*, 2014) within horse riders.

FMS test results have been described in many other populations, including distance runners (Loudon *et al.*, 2014), professional football players (Kiesel, 2011), young and active populations (Schneiders *et al.*, 2011), and military personnel (Lisman *et al.* 2013). It is pertinent to establish FMS patterns specific to individual groups of athletes to understand how sports specific demands may influence movement patterns. In this study composite scores for novice show jumping riders was 12.08 ± 2.7; and for the advanced show jumping riders was 14.08 ± 1.77. This is lower than what has been established for all other populations found in current literature (Loudon 2015; McCall *et al.*, 2014; Schnieders *et al.*, 2013; Perry, 2013; Lisman *et al.* 2013; Kiesel, 2011), including colligate horse riders (Lewis et al., 2019) where a score of 14.12 was found. Based on the composite scores in the current study novice show jumping riders double their risk of an injury compared to advanced show jumping riders. Whilst the differential FMS score of 14 indicates a general predisposition to increase injury risk, it would be interesting to identify whether there was a clear relationship between FMS score and injury during show jumping.

Horse riding is regarded as one of the most dangerous sports due to the high numbers of injuries (Ekberg et al., 2011) and this may explain the low composite scores. However, research concludes that riders are at risk of acute injuries whilst handling horses or as a result of falling off the horse when riding

(Whitlock, 1999; Sorli, 2000; Moss *et al.*, 2002) there is no evidence to suggest these acute injuries are as result of poor functional movement patterns. The hospitalisation rate for equestrian activity is 49 hospital visits for every 1000 hours of riding (Sorli, 2005). Ball *et al*., (2009) identified that over half of riders that had been hospitalized due to an acute riding injury, experienced chronic physical difficulties following their accident including chronic pain, weakness, decreased balance, headaches, limited use of limbs which may affect functional movement. Overuse injuries can be caused by the repetitive movement patterns experienced during riding and the repetitive of riding and nature of tasks required to care for horses e.g. mucking out. Horse-riders have been reported as frequently having an asymmetric posture (Symes and Ellis, 2009; Hobbs *et al*., 2014), which may explain the low functional movement scores seen in the show jumping riders. As such they are at risk of spinal instability, contributing to overuse injury and inevitably leading to back pain (Al-Eisa *et al*., 2006; Symes and Ellis, 2009; Lewis, 2017; Lewis *et al*., 2018). One of the most prevalent areas of pain in the riding population is back pain (BP), with a reported prevalence of 86% - 100% compared to 33% in non-riders (Lewis et al., 2018; Lewis and Kennerly, 2017; Kraft 2009). No rider in the current study was unable to complete any of the tests due to serve pain (producing a score of 0), low or moderate levels of pain, which may have an influence on the movement pattern was not recorded in this study but the relationship between pain and functional movement is worthy of further research.

Within the individual tests the shoulder mobility hurdle step and inline lunge test demonstrate high variability, and individuals differed within the novice group and when compared to the advanced rider group. The advanced participants in this study scored greater scores in the right shoulder mobility test than novice riders. The shoulder mobility test examines shoulder range of motion, scapular motion and thoracic spine mobility. This trend was also seen in the study of Lewis *et al* (2019) and Schneiders *et al.* (2013). The in-line lunge assesses bilateral stability and mobility of the trunk, hips, knees and ankles. It challenges the body's trunk and lower extremities to resist rotation and lateral flexion to ensure appropriate alignment in all three planes. Alexander (2014) points out that trunk rotation to the right was a common postural characteristic in riders and that trunk rotation asymmetry deviates pressure away from the central position in the saddle producing uneven weight through the pelvis. Asymmetric performance in the hurdle step and in-line lunge can be a result of many factors such as hip limitations of either legs, adductor and abductor tightness or weakness or limitations in the thoracolumbar spine. It is important to further investigate the cause in each individual rider, but a trend for this movement scoring asymmetric is apparent in riders. Increased iliac crest height to the right has been reported (Hobbs *et al.*, 2014) and authors had suggested that the causal factor may be greater muscle stiffness and development on the right side would limit lateral bending to the left. Symes and Ellis (2009) also report this right hip limitation and blocking of movement to the left during actual riding. Hobbs et al., (2014) evaluated symmetry whist riding and showed riders with a greater number of years' experience, or competing at a higher level, showed significantly greater postural asymmetries than those with less experience but off horse FMS scores were lower in the novice scores compared to advanced riders in this study, so further evaluation of riding asymmetry and FMS asymmetry is needed.

Athletes often utilize compensatory movement patterns to achieve performance. However, these inefficient movement strategies may reinforce poor biomechanical movement patterns during typical activities, resulting in injury (Chorba et al., 2010). Injury and pain can result in poor performance, time off, retirement and severe injuries seen in equestrian sports, often have life changing consequences (Lewis *et al*., 2018). It is important to be able to identify riders at risk of injury through screening mechanisms so that preventative measures such as strength and conditioning programmes, ergonomics, and training practices can be utilized. Research has demonstrated the importance and contributions of core stability in producing efficient trunk and limb movement allowing for the generation, transfer, and control of forces or energy during integrated kinetic chain activities. During whole-body movement, the core muscle groups (i.e., transversus abdominis, multifidus, rectus abdominis, and oblique abdominals) are activated before any limb movements. Highlighting the importance of these core muscles in functional movement. This core stability is also key to the rider position as the rider requires stabilization and isometric contraction of the back and core muscles (Terada *et al.*, 2004; Terada, 2004), damage to these muscle groups caused by repetitive strain can result in chronic LBP (Shepard, 1997). Poor endurance of the hip extensor muscle (*Gluteus maximus*) and hip abductors (*Gluteus medius*) has also been previously noted in individuals suffering with LBP (Nadler, 2000; Kankaanpaa *et al*., 1998; McGill, 1997). This suggests that weakness in these muscle groups in connection with LBP may have an impact on the rider maintaining a correct position (Lewis and Kennerly, 2017; Lewis et al. 2018). Thus, a strength and conditioning programme focused on developing the 'core' could improve the FMS scores in a show jumping riders, reducing injury risk, in turn improve the riders' position (Hampson & Randle, 2015) and ultimately show jumping performance.

*Limitations*

The sample was convenience based and a small sample of twenty-two female show jumping riders that were eligible to participate within this study recruited. Additional training load were not accounted for within this study but could be considered in future studies. The current study has established and corroborated reports that riders have asymmetric movement patterns, and future research should consider exploring the role of the FMS as a screening tool in horse riders.

## Conclusion

This study highlights that composite FMS scores found in a small purposeful sample of show jumping riders indicate a higher risk of injury in novice show jumping riders compared to advanced show jumping riders. However, the composite FMS scores were lower than reported in other sports and collegiate aged riders, suggesting some show jumping riders may be at risk of injury. The FMS scores showed that riders scored differently across the tests demonstrating asymmetric movement patterns potentially limiting left lateral movement patterns. Limited left lateral movement patterns have been observed in riders in other studies. Asymmetry has an impact on equestrian performance and given the duration of a rider's career, which may span four decades, highlights the importance of regular functional movement screening to the individual rider. Such findings can be used to develop individual axillary training programmes to improve functional movement and targeted injury prevention. Further research to establish normative scores for other horse riding populations based on discipline, level and age could inform the development of future training to minimise the risk of asymmetry and injury.

## Acknowledgements

The authors would like to thank all the participants for their time and to the staff at the Margaret Giffin Rider Performance Centre, Hartpury.

## References.

1. Al-Elisa, E., Egan, D., Deluzio, K. and Wassersug, R., 2006. Effects of pelvic skeletal asymmetry on trunk movement three-dimensional analysis in healthy individuals versus patients with mechanical low back pain. *Spine* 31 (3): E71-E79.
2. Al-Elisa, E., Egan, D., Deluzio, K. and Wassersug, R., 2006. Effects of pelvic asymmetry and low back pain on trunk kinematics during sitting: a comparison with standing. *Spine* 31 (5): E135-E143.
3. Alexander, J., Hobs, S-J., May, K., Northrop, A. and Brigden, C., 2015. Postural characteristics of female dressage riders using 3D motion analysis and the effects of an athletic taping technique: a randomised control trial. *Physical Therapy in Sport* 16: 154-161.
4. Ball, C.G., Ball, J.E., Kirkpatrick, A.W. and Mulloy, R.H., 2007. Equestrian injuries: incidence, injury patterns, and risk factors for 10 years of major traumatic injuries. *The American Journal of Surgery* 193 (5): 636-640
5. Beckham, S.G. and Harper, H., 2010. Functional training: Fad or here to stay? *American College of Sport Medicine Health Fitness Journal* 14: 24-30.
6. British Equestrian Federation, 2018. *Long term participant development for equestrian riders, drivers and vaulters*. British Equestrian Federation: Warwickshire. http://www.bef.co.uk/repository/downloads/Riders/RiderDevelopment/LTPD2013v5.pdf accessed 10/07/18.

7. Cook, G., Burton, L., and Hoogenboom, B., 2006. Pre-Participation Screening: The Use of Fundamental Movements as an Assessment of Function – Part 1. *North American Journal of Sports Physical Therapy* 1 (2): 62–72.
8. Cook, G., Burton, L., and Hoogenboom, B., 2006. Pre-Participation Screening: The Use of Fundamental Movements as an Assessment of Function – Part 2. *North American Journal of Sports Physical Therapy* 2006 August; 1 (3): 132-139.
9. Chorba RS, Chorba DJ, Bouillon LE, Overmyer CA, Landis JA. Use of a functional movement screening tool to determine injury risk in female collegiate athletes. *N Am J Sports Phys Ther*. 2010;5(2):47–54.
10. Douglas, J.D., Price, M. and Peters, D.M., 2012. A Systemic Review of Physical Fitness, Physiological Demands and Biomechanical Performance in Equestrian Athletes. *Comparative Exercise Physiology* 8 (1), pp. 53-62.
11. Guire, R., Mathie, H., Fisher, M. and Fisher, D., 2017. Riders' perception of symmetrical pressure on their ischial tuberosities and rein contact tension whilst sitting on a static object. *Comparative Exercise Physiology* 13 (1): 7-12.
12. Hampson, A & Randle, H., (2015) The influence of an 8-week rider core fitness program on the equine back at sitting trot, International Journal of Performance Analysis in Sport, 15:3, 1145-1159, DOI: 10.1080/24748668.2015.11868858
13. Hobbs, S.J., Baxter, J., Broom, L., Rossell, L., D., Sinclair, J., Clayton, H.M., 2014. Posture, Flexibility and Grip Strength in Horse Riders. *Journal of Human Kinetics* 42: 113-125.
14. Kiesel, K., Pilsky, P. and Voight, M., 2007. Can serious injury in professional football be predicted by a preseason functional movement screen? *North American Journal of Sports Physical Therapy* 2: 147-158.
15. Kiesel, K., Plisky, P.J. and Butler, R., 2011. Functional movement test scores improve following a standardized off- season intervention program in professional football players. *Scandinavian Journal of Medicine and Science in Sports* 21 (2): 287-292.
16. Kraft, C. Urban, N. Ilg, A., Wallny, T.M. Scharfstädt, M. Jäger, M. Pennekamp, P., 2007. Influence of the riding discipline and riding intensity on the incidence of back pain in competitive horseback riders, *Sportverletz Sportschaden* 21 (1): 29–33.
17. Leeder, J., Horsley, I. and Herrington, L., 2013. The inter-rater reliability of the functional movement screen within an athletic population using untrained raters. *Journal of Strength and Conditioning Research* 30 (9): 2591-2599.
18. Lewis, V. and Kennerley, R., 2017. A preliminary study to investigate the prevelance of pain in elite dressage riders during competition in the United Kingdom. *Journal of Comparative Exercise Physiology* 13 (4): 259-263.
19. Lewis, V. and Baldwin, K., 2018. A preliminary study to investigate the prevalence of pain in international event riders during competition, in the United Kingdom. *Journal of comparative Exercise Physiology* 14 (3): 173-181.
20. Lisman, P., O'Connor, F.G., Deuster, P. A., and Knapik, J. J., 2013. Functional movement screen and aerobic fitness predict injuries in military training. *Medicine and Science in Sport and Exercise* 45 (4): 636-643.
21. Loudon, JK, Parkerson-Mitchell, AJ, Hildebrand, LD, and Teague, C., 2014. Functional movement screen scores in a group of running athletes. *Journal of Strength and Conditioning Research* 28 (4): 909–913.
22. Lovett, T. Hodson-Tole, E. and Nankervis, K., 2005. A preliminary investigation of rider position during walk, trot and canter. *Equine and Comparative Exercise Physiology* 2 (2): 71-76.
*23.* McCall, A., Carling, C., Nedelec, M., Davison, M., Le Gall, F., Berthoin, S. and Dupont, G., 2014. Risk factors, testing and preventative strategies for non-contact injuries in professional football: current perceptions and practices of 44 teams from various premier leagues. *British Journal of Sports Medicine* 48: 1352-1357.
24. Moss, P.A., Wan, A. and Whitlock, M.R., 2002. A changing pattern of injuries to horse riders. *Emergency Medicine Journal* 19 (5): 412-414**.**
25. Nadler, S.F., Wu, K.D., Galski, T. and Feinberg, J. H., 1998. Lower back pain in college

athletes: A prospective study correlating lower extremity overuse or acquired ligamentus laxity with lower back pain. *Spine* 23 (7): 818-833.

26. Nankervis, K., Dumbell, L., Herbert, L., Winfield, J., Guire, R. and Launder, E., 2015. A comparison of the position of elite and non-elite riders during competitive show jumping. *Comparative Exercise Physiology 11* (2): 119-125.
27. O'Connor, F.G., Deuster, P.A., Davis, J., Pappas, C.G. & Knapik, J.J., 2011. Functional movement screening: Predicting injuries in officer candidates. *Medicine & Science in Sport and Exercise* 43: 2224-2230.
28. Patterson, M., Doyle, J., Cahill, E., Caulfield, B. Persson, U.M., 2010. Quanitifying show jumping horse rider expertise using IMUs. In: Proceedings of the Annual International Conference of IEE Engeneeing in Medicine and Biological Society 2010: 684-687.
29. Peate, W.F., Bates, G., Francis, S. and Bellamy, K., 2007. Core strength: A new model for injury prediction and prevention. *Journal of Occupational Medicine and Toxicology* 2 : 3.
30. Perry, F. and Koehle, M., 2013. Normative data for the functional movement screen in middle-aged adults. *The Journal of Strength and Conditioning Research* 27 (2): 458-462.
31. Schneiders, A.G., Davidsson, A., Horman, E. and Sullivan, S.J., 2011. Functional movement screen normative values in a young, active population. *The International Journal of Sports Physical Therapy* 6 (2): 75-82.
32. Shiltz, R., Anderson, S., Matheson, G., Marcello, B. and Besier, T., 2013. Test-retest and interrater reliability of the functional movement screen. *Journal of Athletic Training* 48 (3): 331-336.
33. Sorli, J.M., 2000. Equestrian injuries: a five year review of hospital admissions in British Columbia, Canada. *Injury Prevention* 6 (1): 59-61.
34. Symes, D. and Ellis, R., 2009. A preliminary study into rider asymmetry within equitation. *The Veterinary Journal* 181: 34-37.
35. Whitlock, M.R., 1999. Injuries to riders in the cross-country phase of eventing: The importance of protective equipment. *British Journal of Sports Medicine 33*: 212–214.
36. Winter, E.M., Jones, A.M. Davidson, R.C.R., Bromley, P.D. and Mercer, T.H. Eds, 2007. *Sport and Exercise Physiology Testing Guidelines: Volume I – Sport Testing.* Routledge, London & New York.