FUNCTIONAL MOVEMENT SCREENING AS A PREDICTOR OF INJURY IN HIGHLY TRAINED FEMALE'S MARTIAL ARTS ATHLETES

Zenati Yacine[1-3], Benbernou Othmane[1-3], Belkadi Adel[1-3], Sebbane Mohamed[2-3], Benchehida Aabdelkader[1-3], Cherara Lalia[1-3]

[1)] Laboratory of Optimizing Research Programmes on Physical and Sports Activities, Institute of Physical Education and Sport, University of Abdelhamid Ibn Badis - Mostaganem, 27000 Algeria
[2)] Laboratory of Applied Sciences to Human Movement. Institute of Physical Education and Sport ,University of Abdelhamid Ibn Badis - Mostaganem, 27000 Algeria
[3)] Training-University Research Projects (PRFU N° J00L03UN270120190002 Agreement: January 2019), 16000 Algeria

STRESZCZENIA / ABSTRACTS

Objective. This research examines the emerging role of FMS™ in the context of predicting lower extremity injury in females University athletes. The secondary purpose of this study is to investigate the differences between FMS performance comparisons between three martial arts sports to establish baseline comparisons.
Method. Forty-seven university female athletes were recruited for this study, The data collected was separated into three groups based on their sports discipline (judo N=17 age: 19±4, wrestling N=15 age: 18±5, karate N=15 age: 19±3), Independent t-tests were performed on each group with significance being set at P<0.05 to determine difference in FMS™ scores between injured and non injured athletes during the successive competitive seasons. One-way analyses of variances were used to determine if there was a significant difference between sports, 'body parts injured' groups, and 'mechanisms of injury' groups.
Results. One-way analysis of variance revealed no statistically significant difference between the two (ankle, knee) injury groups, and non-injury group ($F_{2,54}$= 2.34; p=0.106). There was no statistical difference between the pre-season FMS™ scores of the injured and non-injured groups (t47 = -1.68; P=.100; d=0.52; 95%CI: -0.11, 1.15). Finally, strong evidence of FMS score was found when comparing the three sports with one-way ANOVAs (F=5.83, df= 2, 54, p=0.005).
Conclusion. One of the more significant findings to emerge from this study is that FMS™ has emerged as a powerful tool for identifying lower extremity injury in female athletes. Further investigation and experimentation into FMS™ are strongly recommended before implementing them into a pre-participation physical examination (PPE) for combat sports. What is now needed is a cross-national study involving other sports.
Keywords: functional movement screen, injury, prevention, female, athletes.

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INTRODUCTION

The Functional Movement Screen, used as a predictor of injury, has received increased attention across a number of disciplines in recent years. Recently, researchers have shown an increased interest in the Functional Movement Screen [1] utilising several performance-based and movement competency-based tests [2,3] for the purpose of identifying deficits in neuromuscular ability associated with elevated injury risk. To prepare an athlete for the wide variety of activities needed to participate in their sport [2], the Functional Movement Screen (FMS) is a movement competency based test in widespread clinical use [4,5] and has also attracted considerable research attention [6,7]. The FMS is a battery of seven movement tasks and three additional clearing tests, assessed by visual observation using standardised criteria [2,8]. Reviews report acceptable intra-rater and inter-rater reliability for composite FMS scores [9,10]; however, other properties are less well established with the use of FMS as an injury prevention screening tool, a particular area of current debate [5].

Recent research has evaluated risk factors that contribute to overall injury rates [11]. The potential to screen athletes for risk of injury during a pre-participation physical examination (PPE) could enhance our understanding about future athletes performances [12]. The FMS™ testing incorporates risk factors for Voluntary strength, proprioception, postural sway, and range of motion [13] in an attempt to identify individuals at risk in athletic populations [2] Also the FMS™ may be useful for recognising deficiency in certain movements and could be useful to implement training programmes to prevent sport injury movements used in specific sports [14,15]

No previous study has investigated this screening tool focusing specifically on women's sports [16]. This indicates a need to understand the various perceptions of FMS™ tests that exist among Algerian female's sports, [18] Research shows that women's team sports are at high risk for athletically related lower extremity injuries.

Several studies have assessed the reliability and the values for the summed composite FMS score in a variety of samples [19,20], but no research has been conducted to see if these scores can predict injury prospectively in female's combat sports.

Participation in sports has increased dramatically [21] predominantly in females [22]. This increase in females participating in sports has brought on an understandable increase in the number of injuries being seen in female athletes [23]. Due to this increase in female injuries [24], a national focus in predicting and preventing injury to the female athlete has arisen [25].

PPE screening has been used routinely in an attempt to identify those conditions that may place an athlete at increased risk and affect safe participation in organised sports. [26,27,28], it may be possible to implement a prevention program to reduce the risk of injury in that specific case [29,30,31].

Being able to understand the injury risk factors specifically associated with females is a major element in identifying at risk females [25]. By understanding the specific aspects of their biomechanics, alignment, intrinsic/extrinsic factors, and neuromuscular activity, it is possible to then be able to work on actual injury incidence; thus preventing the injury [32]. It is one factor to be able to acknowledge the actual fact that female athletes are injured more than their male counterparts [33], or that there are multiple reasons for these injuries and "at risk" athletes, however it's a totally different side to truly be able to distinguish and establish the athletes [34] who are destined for injury [35]. It's not merely one essential or alien issue, or muscle imbalance, or inflexibility that predisposes Associate in Nursing a contestant to injury, rather a combination of factors. This paper can review the literature associated with parts of injury prediction and prevention.

The studies enclosed beneath the heading of Functional Movement Screen demonstrate the high degree of reliability, validity and sheer practicality of the FMS™ [36] once it involves clinical incorporation into athletics, and therefore the prospects of being a tool to help clinicians and coaches [38,39] in predicting, and so preventing injuries to athletes [40]. While considering these promising results, none of these studies have implemented the FMS™ as a screening tool for female athletes despite consistently higher injury rates in this group [41,42], but further research still needs to be conducted in order to further the validity to the great claims being made in association with the FMS™ [43,44,45]. However, no studies have determined a mean value for Algerian females Martial Arts sports.

HYPOTHESIS

H1: Throughout the regular competitive season for female judo, wrestling, and karate athletes that suffer lower extremity acute injuries will have a lower composite FMS™ score through the PPE than those athletes without any extremity injury.

H2: The PPE FMS™ scores of judo female athletes will be higher than female wrestling and karate athletes.

Purpose: The primary aim of this study was to examine the emerging role of FMS™ in the context of predicting lower extremity injury in female judo, wrestling, and karate athletes at the Algerian sports university. The secondary aim of this study was to compare factors of injury mechanism and specific sport on FMS™ PPE scores.

MATERIALS AND METHODS

PARTICIPANTS

Forty-seven university female athletes were recruited for this study after receiving a comprehensive explanation of the procedure; the data collected was separated into three groups based on their sports practice (Table 1). The study was planned according to the Helsinki Declaration [46] and was approved by the scientific institute of sports ethics committee. Based on the accuracy results of a self-reported questionnaire [47], no subject had been treated with any medication or physiotherapy from severe injury during the first three months. Female athletes that did not perform the pre-participation physical tests due to an earlier or existing injury were excluded from participation in the study.

Tab. 1

Baseline Characteristics of Participants.

	Participants (N=47)		
Measure	Judo (*N*=17*)*	wrestling (*N*=15)	karate (*N*=15)
Age (Mean ± SD)	19±3	18±5	19±3
Height, cm (Mean ± SD)	164.0±5.47	158.0±3.72	166.0±5.2
Weight, kg (Mean ± SD)	63.0±4.56	61.1±2.26	61.0±1.33
Year of practice (Mean ± SD)	9.2 ± 2.1	8.1 ± 3.2	7.5 ± 4.3
Total Injured Athletes (*N)*	07	06	04
Total Injured Athletes (%)	14.90%	12.77%	8.51%
Total Uninjured Athletes (*N)*	10	09	11
Total Injured Athletes (%)	21.27	19.03	23.03

PROCEDURES

Anthropometric data from each participant was completed by the coaching staff, which regularly performed these measurements as part of their evaluation routine. Body mass and height were respectively obtained from a Connected Scales 700 (Geonaute, France) and a Stadiometer HM200P Portstad Portable (Charder, USA). The subjects involved in the study were evaluated on the FMS™ using the standard 0-3 ordinal system (Table 2). The FMS included a deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability test. The FMS™ testing incorporated risk factors for balance, strength, range of motion, flexibility, and proprioception to help predict injury in athletic populations [48,49]. Each test is done 3 times and the best performance is recorded. The total score out of 21 is considered, the injury analysis records were tracked throughout the season with the help of the university training staff reviewing medical records. An injury form was completed after each session, where exposure was considered one athlete per training or competition. Thus, analysis of injury risk, based on preseason FPT measures, for a homogeneous sample of athletes is warranted.

Tab. 2

Scoring Criteria for Each Component of the Functional Movement Screen [49].

Description	**FMS™ score**
Ability to correctly complete the movement without any predefined compensations	3
Performing the movement with any one of component specific compensations	2
Inability to perform the movement	1
Presence of pain during any portion of the movement	0

STUDY DESIGN

First, this study utilised a prospective cohort design. A prospective cohort design reduces the risk of bias that can occur when utilising other epidemiologic study designs [50]. Pre-season performance on the FMS™ tool was obtained from the female judo, wrestling, and karate athletes. During the season, daily exposure rates for practices and competitions were recorded. Any incident that resulted in the athlete not being able to continue to participate in a competition or practice or that kept the athlete from participating in physical activities the following day were counted as injuries. Specific details related to the injury, as well as preventative measures (taping, bracing, etc) were recorded, and at the conclusion of the season, the scores on the FMS were compared with the injury information. Correlations, related effects, and global results were taken from the information related to sports, injury rates and specific prediction testing.

STATISTICAL ANALYSES

The FMS™ composite scores (which is the lowest cumulative score from a bilateral comparison of all 7 of the tests), and independent t-tests were performed on each group with significance being set at $P<0.05$ to determine the difference in FMS™ scores between injured and non injured athletes during the successive competitive seasons (H: 1), Separate one-way ANOVA models were used to determine if there was a statistical difference in FMS scores between different sports (Judo, wrestling, karate) (H:2); a Tukey's post hoc test was applied. Statistical analysis was performed using SPSS software (version 22) and Significance levels were set at $p \leq 0.05$. To determine the magnitude of the differences in means, effect sizes

between groups were produced using Cohen's d, utilising the pooled standard deviations, along with the 95% confidence interval around the effect size point measures. The interpretation of Cohen's d was: small <.03; moderate 0.05; large > 0.08.

RESULTS

Tab. 3

Injured vs. Non-Injured FMS comparison.

	FMS composite ±SD
Injured Group (*n*=17)	15.38±1.72
Non-injured Group (*n*=30)	15.41±1.43

Of the 47 participants, 17 (36.17%) suffered a recorded acute lower extremity injury that resulted in removal from participation for at least one full training or competition. The results will be presented in the order of the stated hypotheses.

There was no statistical difference between the pre-season FMS™ scores of the injured

And the non-injured groups (t_{47} =-1.93; P=.100; d=0.52; 95%CI: -0.11, 1.15) (Table 03)

Tab. 4

Descriptive statistics of FMS performance from three groups from different athletic groups (mean ± SD).

Sports	**FMS Total mean ± SD**
Judo	16.36±1.75
Wrestling	13.86±1.77
Karate	16.41±1.56

Tab. 5

Effect Size and Confidence Interval between Sports.

	Effect Size	95% Confidence Interval
Judo vs. Wrestling *	1.00	0.32, 1.55
Karate vs. Wrestling **	0.71	0.19, 1.64
Judo vs. Karate	0.96	-0.32, 1.38

* Judo athletes had a statistically significant higher FMS™ score than Wrestlers
** Karate athletes had a statistically significant higher FMS™ score than Wrestlers.

When comparing the three sports, one-way ANOVA revealed statistical significance between judo and wrestling, between karate and wrestling, but not between judo and karate. The one-way analysis was statistically significant for comparing differences between the three sports (F=5.83, df= 2, 54, p=0.005). The Tukey's post hoc testing demonstrate that the differences existed between Judo (16.36±1.75,n=17) and wrestling athletes (13.86±1.77, n=15), (d=1.00; 95% CI: 0.32, 1.55), as well as between the karate (16.41±1.56, n=15) and wrestling athletes (d=0.71; 95% CI: 0.19, 1.64); but not between the judo and karate athletes (d=0.96; 95% CI: -0.32, 1.38) showed in the (Table 5).

DISCUSSION

This study set out with the aim of assessing the importance of the FMS™, also if it could predict lower extremity injury in female Judo, wrestling and karate athletes. The recent research utilised a specific comparisons between the two different groups (injured or non-injured athletes), as well as between subgroups determined by the specific body part injured, and the sport the athlete belonged to. The current study found that the injured athletes had a lower mean composite FMS™ score as compared to the non-injured athletes, but it was not found to be statistically significant. Though the scores were not statistically significant between the groups, These results reflect those of [49] who also found that, there was a cutoff score found that maximised sensitivity

and specificity by using an ROC curve for analysis. Our study cutoff found the score 15.38 on the composite FMS™ score. Using odds ratios and calculations this came out to mean that if an athlete scored less than 15.38 on the FMS™ they were 3.5 times more likely to have suffered a lower extremity injury as compared to those athletes who scored above a 15.38 on the FMS™.

When examining the difference in the FMS™ scores of the ankle vs. knee vs. non-injured groups, there was no statistically significant difference found. These statistically insignificant results may have been due to the nature of the sports, or to the fact that there were a low number of injuries observed during this competition season. This finding broadly supports the work of other studies on FMS™ [33,45,51,52]. However, those that suffered an ankle injury had the lowest pre-season FMS score, with effect sizes that were large when compared to the No Injury groups and the Knee Injury groups. It is interesting to note that there was almost no difference in the mean scores of the Knee Injury group and No Injury Group. Perhaps the FMS is able to screen more effectively for ankle injuries [49]. At the knee it is possible to make corrections and compensatory movements both at the hip and ankle joint [53], but at the distal end of the kinetic chain there is less room for adjustment at the ankle joint. However, with a low number of injuries observed, it is difficult to make that a definitive conclusion [54].

Similarly, there were no statistically significant differences between the Contact Injury, Non-Contact Injury and No Injury groups [55]. Supporting this conclusion were very low effect sizes. It seems that the FMS is not effective to use to predict the general mechanism of injury to the ankle or knee [56,57]. Most of the movement patterns are performed in the sagittal plane, which may explain the lack of difference in injury mechanism. The exercises used throughout the FMS™ screening are primarily performed in the sagittal plane [58-60], and in athletics most movements are multiplanar. Additionally, the tasks in the FMS are performed relatively slowly. Perhaps other screening tools that emphasise other planes of movement and a faster pace of movement will be able to differentiate contact vs. non-contact injuries more effectively, similarly to the study [56].

For the comparison between the FMS™ scores and injuries of the different sports (judo, wrestling, and karate) there were statistical differences found between karate and judo athletes [56,58] as well as between wrestling and judo athletes, but not between karate and wrestling female athletes. These differences in the FMS™ scores of the different sport-specific athletes could be due to the nature of the training involved with each sport [54], or the focus of their weightlifting and conditioning programs that would have altered their scores. This finding from the study could be considered valuable in the future in regards to the way that certain "prevention" or "treatment" programmes are designed in order to prevent injury to those athletes with a lower composite score. If it is found and widely accepted that specific sports training is beneficial in raising an athlete's FMS™ score [60], then it is conceivable that other sports may alter their pre-season conditioning to mimic another's in order to minimise injury [51].

Perhaps the most important finding to come out of the study is the finding of a cutoff score that could be used for predictive models. Using the ROC curve and related calculations, the cutoff score is found by maximising the sensitivity and specificity of the test. As represented by the 2x2 contingency table, the goal is to maximise the number of true positives and false negatives; when the FMS™ score identifies that someone is at risk of an injury, and an athlete that actually suffers an injury throughout the season, it adds further legitimacy to the FMS™ predictive model. In this particular study there were 30 true positives out of 47 total athletes, and 17 total injuries. For 17 of the 30 injuries to be "predicted" by the FMS™ is a step in the right direction to modifying and potentially using the FMS™ tool as part of a pre-participation examination in order to screen for "at risk" athletes.

The cutoff score found in this study was 16.5 on the composite FMS™ score. Other studies have reported cutoff scores of their own. [61] reported a cutoff score of 14 for prediction of injury among Brazilian jiu-jitsu athletes. The cutoff score found in this study is not consistent with study [56], but may be attributed to some fairly substantial differences between the studies. The most obvious difference between the two studies is the level of competition and skill at which the athletes compete. Del Vecchio worked with professional Brazilian jiu-jitsu athletes whereas our research was conducted with Brazilian jiu-jitsu athletes female judo, karate, and wrestling athletes. The differences in athletic abilities, training and sport demands may have influenced the result and cut-off score in both studies. Another potential difference could be the gender of athlete being tested. Females are considered to have many biomechanical differences when compared to their male counterparts, and to potentially already be at risk due to gender differences, so when comparing males to females it may actually be an unfair comparison [1]. Yet another discrepancy between the studies could be their definition of "injury." The [55] article classifies an injury only once an athlete had been placed on the injured reserve for at least 3 weeks [4]. Our investigation categorised injury as any acute lower extremity issue that held an athlete out for one or more exposures to competition or practice.

CONCLUSION

This research study demonstrated that the FMS™ shows a true potential to work as an effective and efficient predictive model of lower extremity injury in division I collegiate female athletics. More research is still necessary before implementing the FMS™ into a PPE for athletics, but due to the low cost and its simplicity to implement, it should be considered by clinicians and researchers in the future.

LIMITATIONS

The main limitation in this study is that only female athletes were tested. In an ideal study there would be a variety of athletes tested; various sports, multi-gender, various ages. Females have been shown to have a higher risk of injury in specific sports as opposed to their male counterparts, so to have only tested females could have skewed the results in regard to a cutoff score that could be used across the board in all sports when screening during a pre-participation physical exam.

Another limitation could have been the number of athletes tested in comparison to the number of injuries observed. In order to obtain very widely accepted results, a large amount of data is needed, and a large amount of

injuries must be seen. While this study may not fulfil those requirements, it adds to a larger body of research that will hopefully lead in that direction. Also in dealing with the injuries observed, only two were contact injuries so this study is not very comparable to studies done in the past that looked at Judo specifically, which involved an increase in contact injuries as compared to this study.

To make the results more generalisable, future research should consider the inclusion of males and females, as well as including as many different sports as possible as opposed to the "high risk" female sports used throughout this study. In addition to including males and females in the study, differences among sports and their risk of contact vs. noncontact injuries should be considered. Regardless of the capability of the FMS™ as a predictive model for injury, it would be hard to assume that a lower score on the FMS™ predisposed an athlete for a contact injury that no one could truly predict.

A final limitation that should be considered from the study is the inclusion of multiple examiners during the baseline FMS™ testing. It has been shown that the tool has a high interrater reliability when performed by clinicians with the proper training; however there is always room for error when having multiple raters assessing the athletes [55]/.

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REFERENCES

1. Hegedus EJ, McDonough S, Bleakley C, Cook CE, Baxter GD. Clinician-friendly lower extremity physical performance measures in athletes: a systematic review of measurement properties and correlation with injury, part 1. The tests for knee function including the hop tests. Br J Sports Med. mai 2015;49(10):642-8;
2. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function - part 1. North Am J Sports Phys Ther NAJSPT. mai 2006;1(2):62-72;
3. Whatman C, Hing W, Hume P. Physiotherapist agreement when visually rating movement quality during lower extremity functional screening tests. Phys Ther Sport Off J Assoc Chart Physiother Sports Med. mai 2012;13(2):87-96;
4. McCall A, Carling C, Davison M, Nedelec M, Le Gall F, Berthoin S, et al. Injury risk factors, screening tests and preventative strategies: a systematic review of the evidence that underpins the perceptions and practices of 44 football (soccer) teams from various premier leagues. Br J Sports Med. mai 2015;49(9):583-9;
5. Wright AA, Stern B, Hegedus EJ, Tarara DT, Taylor JB, Dischiavi SL. Potential limitations of the functional movement screen: a clinical commentary. Br J Sports Med. juill 2016;50(13):770-1;
6. Bonazza NA, Smuin D, Onks CA, Silvis ML, Dhawan A. Reliability, Validity, and Injury Predictive Value of the Functional Movement Screen: A Systematic Review and Meta-analysis. Am J Sports Med. 2017;45(3):725-32;
7. Moran RW, Schneiders AG, Major KM, Sullivan SJ. How reliable are Functional Movement Screening scores? A systematic review of rater reliability. Br J Sports Med. mai 2016;50(9):527-36;
8. Cook G, Burton L, Hoogenboom BJ, Voight M. Functional movement screening: the use of fundamental movements as an assessment of function-part 2. Int J Sports Phys Ther. août 2014;9(4):549-63;
9. Bonazza NA, Smuin D, Onks CA, Silvis ML, Dhawan A. Reliability, Validity, and Injury Predictive Value of the Functional Movement Screen: A Systematic Review and Meta-analysis. Am J Sports Med. 2017;45(3):725-32;
10. Cuchna JW, Hoch MC, Hoch JM. The interrater and intrarater reliability of the functional movement screen: A systematic review with meta-analysis. Phys Ther Sport Off J Assoc Chart Physiother Sports Med. mai 2016;19:57-65;
11. Kiesel K, Plisky PJ, Voight ML. Can Serious Injury in Professional Football be Predicted by a Preseason Functional Movement Screen? North Am J Sports Phys Ther NAJSPT. août 2007;2(3):147-58;
12. Sanders B, Blackburn TA, Boucher B. Preprticipation screening - the sports physical therapy perspetive. Int J Sports Phys Ther. avr 2013;8(2):180-93;
13. de Noronha M, Refshauge KM, Herbert RD, Kilbreath SL. Do voluntary strength, proprioception, range of motion, or postural sway predict occurrence of lateral ankle sprain? Br J Sports Med [Internet]. oct 2006;40(10):824-8. Disponible sur: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2465053/;
14. Bardenett SM, Micca JJ, DeNoyelles JT, Miller SD, Jenk DT, Brooks GS. Functional movement screening normative values and validity in high school athletes can the FMS™ be used as a predictor of injury? Int J Sports Phys Ther. juin 2015;10(3):303-8;
15. Gribble PA, Hertel J, Denegar CR. Chronic ankle instability and fatigue create proximal joint alterations during performance of the Star Excursion Balance Test. Int J Sports Med. mars 2007;28(3):236-42;
16. Academy USS. Movement Competency Screen Predicts Performance in Female Military Academy Recruits [Internet]. The Sport Journal. 2018 [cité 19 janv 2019]. Disponible sur: https://thesportjournal.org/article/movement-competency-screen-predicts-performance-in-female-military-academy-recruits/;
17. Belkadi A, Othman B, Mohamed S, Abdelhafid L, M BH, Gleyse J. Contribution to the Identification of the Professional Skills Profile of Coaches in the Algerian Sport Judo System. Int J Sports Sci. 2015;5(4):145-50;
18. Powell JW, Barber-Foss KD. Sex-related injury patterns among selected high school sports. Am J Sports Med. juin 2000;28(3):385-91;
19. Bonazza NA, Smuin D, Onks CA, Silvis ML, Dhawan A. Reliability, Validity, and Injury Predictive Value of the Functional Movement Screen: A Systematic Review and Meta-analysis. Am J Sports Med. 2017;45(3):725-32;
20. Moran RW, Schneiders AG, Major KM, Sullivan SJ. How reliable are Functional Movement Screening scores? A systematic review of rater reliability. Br J Sports Med. mai 2016;50(9):527-36;
21. Ireland ML. The female ACL: why is it more prone to injury? Orthop Clin. 1 oct 2002;33(4):637-51;
22. Strandbu Å, Bakken A, Sletten MA. Exploring the minority–majority gap in sport participation: different patterns for boys and girls? Sport Soc. 15 nov 2017;0(0):1-19;
23. Launay F. Sports-related overuse injuries in children. Orthop Traumatol Surg Res. 1 févr 2015;101(1, Supplement):S139-47;
24. Belkadi A, Benchehida A, Benbernou O, Sebbane M. Competencies and training needs and its impact on determining the professional skills of Algerian elite coaches. 2019;
25. Voskanian N. ACL Injury prevention in female athletes: review of the literature and practical considerations in implementing an ACL prevention program. Curr Rev Musculoskelet Med. 15 févr 2013;6(2):158-63;
26. Carek PJ, Mainous A. The preparticipation physical examination for athletics: a systematic review of current recommendations. BMJ [Internet]. 19 nov 2003 [cité 25 févr 2019];327(7418):E170-3. Disponible sur: https://www.bmj.com/content/327/7418/E170;
27. Conley KM, Bolin DJ, Carek PJ, Konin JG, Neal TL, Violette D. National Athletic Trainers' Association Position Statement: Preparticipation Physical Examinations and Disqualifying Conditions. J Athl Train [Internet]. 2014;49(1):102-20. Disponible sur: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3917287/;
28. Sanders B, Blackburn TA, Boucher B. Preparticipation screening - the sports physical therapy perspetive. Int J Sports Phys Ther [Internet]. avr 2013;8(2):180-93. Disponible sur: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3625797/;
29. Bird SP, Markwick WJ. Musculoskeletal screening and functional testing: considerations for basketball athletes. Int J Sports Phys Ther. oct 2016;11(5):784-802;

30. Lin CY, Casey E, Herman DC, Katz N, Tenforde AS. Sex Differences in Common Sports Injuries. PM&R. 1 oct 2018;10(10):1073-82;
31. Sallis RE, Jones K, Sunshine S, Smith G, Simon L. Comparing sports injuries in men and women. Int J Sports Med. août 2001;22(6):420-3;
32. Bahr R, Krosshaug T. Understanding injury mechanisms: a key component of preventing injuries in sport. Br J Sports Med. 1 juin 2005;39(6):324-9;
33. Ivković A, Franić M, Bojanić I, Pećina M. Overuse Injuries in Female Athletes. Croat Med J. déc 2007;48(6):767-78;
34. del B, Abdelkader B, Alia C, Othman B, Mohamed S, Houcin A. The Effect of High-Intensity Exercise on Changes of Blood Concentration Components in Algerian National Judo Athletes. Acta Fac Educ Phys Univ Comen. 2019;59(2):148-60;
35. Young K, White P, McTeer W. Body talk: Male athletes reflect on sport, injury, and pain. Sociol Sport J. 1994;11(2):175-94;
36. Ryan D. Normative values of functional competence, speed and lower body power for youth football players at different stages of biological maturity. Waterford Institute of Technology; 2016;
37. Adel B, Othman B, Mohamed S, Benkazdali M, Gleyse J. Contribution to the identification of the professional skills profile of coaches in the Algerian sport judo system. Int J Sport Stud. 2015;5(7):770-7;
38. Berria M, Belkdi A, Kasmi B, Seghir NE. Study of LDH adaptations associated with the development of Speed endurance in basketball players U19. 3 sept 2018 [cité 29 mai 2020]; Disponible sur: http://e-biblio.univ-mosta.dz/handle/123456789/7504;
39. Chrara L, Raoui RA, Belkadi A, Hocine A, Benbernou O. Effects of caloric restriction on anthropometrical and specific performance in highly-trained university judo athletes. Arab J Nutr Exerc AJNE. 2018;105-18;
40. Dijkstra HP, Pollock N, Chakraverty R, Alonso JM. Managing the health of the elite athlete: a new integrated performance health management and coaching model. Br J Sports Med. avr 2014;48(7):523-31;
41. 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. North Am J Sports Phys Ther NAJSPT. juin 2010;5(2):47-54;
42. Moran RW, Schneiders AG, Mason J, Sullivan SJ. Do Functional Movement Screen (FMS) composite scores predict subsequent injury? A systematic review with meta-analysis. Br J Sports Med. déc 2017;51(23):1661-9;
43. Gnacinski SL, Cornell DJ, Meyer BB, Arvinen-Barrow M, Earl-Boehm JE. Functional Movement Screen Factorial Validity and Measurement Invariance Across Sex Among Collegiate Student-Athletes. J Strength Cond Res. déc 2016;30(12):3388-95;
44. Kiesel K, Rhodes T, Mueller J, Waninger A, Butler R. Development of a screening protocol to identify individuals with dysfuncional breathing. Int J Sports Phys Ther. oct 2017;12(5):774-86;
45. Letafatkar A, Hadadnezhad M, Shojaedin S, Mohamadi E. Relationship between functional movement screening score and history of injury. Int J Sports Phys Ther. févr 2014;9(1):21-7;
46. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA. 27 nov 2013;310(20):2191-4;
47. Lalia C, Ali AR, Adel B, Asli H, Othman B. Effects of caloric restriction on anthropometrical and specific performance in highly-trained university judo athletes. Phys Educ Stud. 2019;23(1):30-6;
48. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function - part 2. North Am J Sports Phys Ther NAJSPT. août 2006;1(3):132-9;
49. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function - part 1. North Am J Sports Phys Ther NAJSPT. mai 2006;1(2):62-72;
50. Bonita R, Beaglehole R, Kjellström T. Basic epidemiology. World Health Organization; 2006;
51. Brumitt J, Mattocks A, Loew J, Lentz P. Preseason Functional Performance Test Measures are Associated with Injury in Female Collegiate Volleyball Players. J Sport Rehabil. 2019;1-20;
52. Dorrel BS, Long T, Shaffer S, Myer GD. Evaluation of the Functional Movement Screen as an Injury Prediction Tool Among Active Adult Populations: A Systematic Review and Meta-analysis. Sports Health. déc 2015;7(6):532-7;
53. Dill KE, Begalle RL, Frank BS, Zinder SM, Padua DA. Altered Knee and Ankle Kinematics During Squatting in Those With Limited Weight-Bearing–Lunge Ankle-Dorsiflexion Range of Motion. J Athl Train. 2014;49(6):723-32;
54. Frost DM, Beach TA, Callaghan JP, McGill SM. Using the Functional Movement Screen™ to evaluate the effectiveness of training. J Strength Cond Res. 2012;26(6):1620-30;
55. Shultz R, Anderson SC, Matheson GO, Marcello B, Besier T. Test-retest and interrater reliability of the functional movement screen. J Athl Train. 2013;48(3):331-6;
56. Boguszewski D, Buda M, Adamczyk JG, Białoszewski D. Relationship between functional limitations of the locomotor system and performance in judo. Pol J Sport Tour. 2017;24(3):145-9;
57. 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. North Am J Sports Phys Ther NAJSPT. 2010;5(2):47;
58. Boguszewski D, Jakubowska KJ, Adamczyk JG, Białoszewski D. The assessment of movement patterns of children practicing karate using the Functional Movement Screen test. J Combat Sports Martial Arts. 2015;6(1):21-6;
59. Li Y, Wang X, Chen X, Dai B. Exploratory factor analysis of the functional movement screen in elite athletes. J Sports Sci. 2015;33(11):1166-72;
60. Nadler SF, Malanga GA, Feinberg JH, Rubanni M, Moley P, Foye P. Functional performance deficits in athletes with previous lower extremity injury. Clin J Sport Med Off J Can Acad Sport Med. mars 2002;12(2): 73-8;
61. Del Vecchio FB, Gondim DF, Arruda ACP. Functional Movement Screening performance of Brazilian jiu-jitsu athletes from Brazil: differences considering practice time and combat style. J Strength Cond Res. 2016;30(8):2341-7;