Integrated Health Research Journal (IHRJ)

The Official Journal of the
**College of Health and Allied Sciences**
**University of Cape Coast, Ghana**

RESEARCH ARTICLE

# Effect of 16 Weeks of Core and Strength Training on Incidence of Injury Occurrence and FMS Score of Ghanaian University Basketball Athletes

Eric Opoku-Antwi[1] and Josephine Adjubi Kwakye[1]

[1] College of Health and Allied sciences, School of Allied Health sciences, Department of Sport and Exercise sciences

## Abstract

**Background:** The purpose of this study is to determine if FMS scores can predict the prevalence of injury occurrence after 16 weeks of core training and strength training in a Ghanaian University basketball athlete.

**Materials and methods:** Ninety (90) athletes aged 18-25 years participated in the study. Athletes were randomly stratified into two groups (n=45) and participated in 16 weeks of core training and 16 weeks of strength training respectively. All athletes received questionnaires and FMS scores before and after training was recorded.

**Results:** Of the 90 athletes, ankle and knee were the most vulnerable parts of basketball athletes to injuries. Compared with pre-training, athletes' incidence of injury was reduced after training. When the FMS score was 14.5, the value of Sensitivity-(1-Specificity) is the largest. In addition, FMS scores could only take integers, so FMS=14 was the best critical value for predicting the risk of injury by FMS score whether it was before or after training. Fifty (50) basketball athletes had an FMS score of ≤14 before training and 40 had FMS scores >14. After training, 15 basketball athletes had an FMS score of ≤14 and 75 had FMS scores >14. There was a significant increase in FMS scores single and total scores after training compared with pre-training.

**Conclusion:** FMS score can effectively predict the injury risk of basketball players. Increasing strength and core training can effectively prevent basketball players from injury and improve FMS score.

**Keywords:** FMS score, Basketball players, Injury, Core, Strength, Training

**Citation:** Opoku-Antwi, E., and Kwakye, J. A. (2023) Effect of 16 Weeks of Core and Strength Training on Incidence of Injury Occurrence and FMS Score of Ghanaian University Basketball Athletes. Integrated Health Research Journal 1(2), 17-23. https://doi.org/10.47963/ihrj.v1i2.1370
**Received** 15th July, 2023; **Accepted** 30th October, 2023; **Published** 31st December, 2023


## Introduction

Functional Movement Screen (FMS), developed by Gray Cook and Lee Burton, was designed as a systematic screening guide to assist health and wellness professionals in identifying poor fundamental movement patterns in patients and clients [1]. The movements of the FMS have been specifically designed to stress an individual's functional movement limits so that one's range of motion, dynamic stabilization, and balance deficits are been exposed [2-4]. The FMS consists of seven fundamental movement patterns that include the deep squat, the hurdle step, the in-line lunge, the shoulder mobility test, the active straight-leg raise, the trunk stability push-up, and the rotary stability tests [5]. Each movement of the FMS is scored on a four-point scale of 3, 2, 1, or 0 with a total composite score (FMSTM) of 0 to 21 points possible [6]. The FMSTM as a screening tool for exposing injury risk associated with movements has a vital role in injury prevention, through the detection of pain during movement patterns [7]. Several studies have examined FMS score and prediction of injury [5,8-11]. Researchers have reported that those with lower FMS scores are more likely to become injured or already have a history of injury [12,13].

In competitive athletes, the association between FMS and injury has been observed [14]. An FMS composite score of 14 as a threshold for predicting injury has been identified in volleyball players, college female basketball, and professional American football players [15,16]. Kiesel et al [16] studied professional football players (n=46) and found that those with a score of less than or equal to 14 had a much greater chance of serious injury during their competitive season. Research focusing on female collegiate soccer, volleyball, and basketball players (n=38) also found that a lower score on the FMS was associated with injury [15]. In this study population, 69% of the injuries sustained were by participants who scored a 14 or less.

As sport participation has continually increased over time, the risk of incurring a musculoskeletal injury has also increased [17]. According to Teyhen et al [6], "More than 10,000 Americans seek medical treatment for sports, recreational activity, and exercise-related injuries on a daily basis". Pre-participation screenings therefore act as a preventative measure to assist with reducing the risks of injuries as it has been used in different sport [2]. Studies by [18] shows that FMS has been used to assess and reduce the risk of injury among marine officers, and among fire fighters following 8 weeks training program, an enhanced functional movement reduced time injury by 62% compared with historical injury rates [19]. For performance improvement and injury prevention, training involving strength and conditioning as well as corrective exercises are often implemented [7].

Based on current research available, it was unknown if Functional Movement Screen following core and strength training could predict the prevalent risk of injury in basketball among athletes' competing at the university level in Ghana. More research on a threshold FMS score for endurance and contact sports is still needed. Sports such as basketball where contact and overused injuries are more common and needs further research regarding use of the FMS [5,16] is of importance. Thus, the purpose of this study is to determine if FMS scores can predict the prevalence of injury occurrence after 16 weeks of core and strength training and to identify FMS predictive value for injury in Ghanaian University Basketball athletes.

# Materials and Methods

### 2.1. Participants

The study employed a quasi-experimental, separate-sample pre-test/post-test research design. This study involved a total of 90 Ghanaian university basketball team athletes between the ages of 18-25 years. A random sampling method using the FMS was used to select participants. Basketball athletes were randomly stratified into two groups (n=45) with a deficiency on the FMS scale and underwent 16 weeks of core training in one group and 16 weeks of strength training in another group. The study excluded 1) athletes who had sustained an injury 30 days or less prior to FMS testing which will prevent them from participating in strength and conditioning, practice, competition, 2) if they have had recent surgical intervention that will limit their participation in sport due to physician restriction. A pre and post basketball injury questionnaires produced by Shanghai Sport Institute were distributed to all participating athletes in both groups.

### 2.3. Research method

Before and after the experiment, the students were uniformly investigated, the basic situation of the 90 students was understood and questionnaires were distributed. The contents of the questionnaire include: height, weight, age, and years of basketball. Ten (10) expects in the field of basketball were employed to evaluate the validity of the structure, content and overall validity of the questionnaire. Five grades of indicators were selected to evaluate the questionnaire (a) perfect (b) perfect (c) perfect (d) imperfect (e) imperfect. Following the preliminary review, the experts put forward an insightful commentary. To ensure the validity of the questionnaire, the author incorporates the advice of the experts and further enhances and revises the questions. The questionnaire for this study had high levels of recognition from ten experts for their overall validity, structure and content. While 60% believes it is the most perfect, 40% believes it is perfect. This study reliability test adopted the retesting method. Before the official questionnaire was distributed, using a survey sample, this study pre-tested fifty (50) ordinary college basketball fans. The correlation coefficient of the two measurement scores of the questionnaire before and after the first filling of the scale was 0.993.

The FMS test consists of three exclusive tests and seven basic action mode tests which effectively test subjects' basic abilities such as overall motion control, body stability, flexibility, balance and proprioception. The seven basic action mode tests are deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability. The three exclusive test actions include deep squat, hurdle step and shoulder mobility. Athletes do not warm up before the test starts. The scoring criteria were divided into four grades. 0 points: pain in any part of the test; 1 point: subjects cannot complete the whole action or maintain the starting posture; 2 points: subjects can complete the whole action, but the quality of completion is not high; 3 points: subjects can complete the action with high quality. The total score of the seven basic movements was 21 points and 14 points are passing lines. The higher the score, the better the quality of the athletes' functional movements and the lower the risk of injury in training or competition. If pain occurred in the exclusive test, the excluded action scored 0. For hurdle step, in-line lunge, shoulder mobility, active straight leg raises and rotary stability, these movements were tested on both sides of the body where the final score of the basic movements is the lower score in the two-side test. The test is performed three times and scored according to the specific scoring criteria and recorded.

The Strength training included; 1) Wall squats, 30 seconds; 2) Overhead squats, 30 seconds; 3) Wall squats, 30 seconds; 4) Squat with in heel raise, 30 seconds; 5) Overhead squats, 30 seconds. 3 sets/time, 4 times/week. The Core training included; 1) Bicycle crunch, 20 reps; 2) Crunch on stability ball, 20 reps; 3) Long lever crunch, 20 reps; 4) Static plank with leg raise, 20 reps; 5) Side bridges, 20 reps. 3 sets/time, 4 times/week.

### 2.3. Statistical analysis

Data was entered using Epidata 3.1, a database was created, and IBM Statistical Package for Social Sciences (SPSS) 17.0 software was used to analyze the data obtained. The measurement data was described by

mean ± standard deviation, and the count data was described by percentage. Paired sample t-test was used to determine statistically significant differences in FMS scores. A receiver operator characteristic (ROC) curve was used to plot sensitivity verses 1-specificity to determine the best critical value (cut-off) score. A table was developed to divide athletes with injury sites >1 and those with injury

Table 1. Incidence of Athletic Injury in Basketball Athletes before and after Training

| Injury site | Participants | | Incidence (%) | |
|---|---|---|---|---|
| | Before Training | After Training | Before Training | After Training |
| Finger | 12 | 2 | 13.33 | 2.22 |
| Wrist | 6 | 0 | 6.67 | 0 |
| Elbow joint | 8 | 3 | 8.89 | 3.33 |
| Shoulder joint | 6 | 4 | 6.67 | 4.44 |
| Back & spine | 14 | 4 | 15.56 | 4.44 |
| Knee joint | 17 | 9 | 18.89 | 10 |
| Ankle joint | 28 | 9 | 31.11 | 10 |

Table 2. Area under the curve (ROC curve) before the training and after training

| | AUC | SD | P-value | 95%CI Lower | 95%CI Upper |
|---|---|---|---|---|---|
| Before Training | 0.818 | 0.043 | <0.001 | 0.734 | 0.903 |
| After Training | 0.802 | 0.056 | <0.001 | 0.693 | 0.911 |

sites ≤ 1, as well as those who were above and below the critical value (cut-off) score of the FMS. Chi-square test was used to determine any significant difference in the occurrence of injury between basketball athletes with FMS score ≤ 14 and FMS score > 14. The statistical significance for all statistical tests was set at $p<0.05$. The FMS score predicted the effectiveness of basketball players' sports injuries by sensitivity, specificity and index.

**2.4. Ethical consideration**

The study was approved by the University of Cape Coast's Institutional Review Board (UCC). All participants were able to withdraw from the study without repercussions and were not be forced to participate. Prior to the study, a written informed consent form was issued to the participants and they were briefed about the confidentiality of the study, test procedures, purpose, benefit and risks involved in the study.

# Results

As shown in Table 1, before the training, the incidence of ankle injury in basketball athletes before training was 31.11%, the incidence of knee injury was 18.89%, and the incidence of back and spine injury was 15.56%. In addition, the incidence of finger, elbow, wrist and shoulder injuries were 13.33%, 8.89%, 6.67%and 6.67%, respectively.

Also as shown in Table 1, after the training, the incidence of knee and ankle injury in basketball athletes both were 10%, and the incidence of shoulder and back& spine injury were 4.44%. In addition, the incidence of finger, elbow, wrist injuries were 2.22%, 3.33% and 0, respectively.

As shown in Figure 1 and Table 2, when the injury risk of basketball athletes was predicted by FMS score, the area under the ROC curve was 0.818 [95%CI (0.734-0.903)] before training, the area under the ROC curve was 0.802 [95% CI (0.639-0.911)] after training, which had certain predictive value. When the FMS score was 14.5 as shown in Table 3, the value of Sensitivity-(1-Specificity) is the largest. In addition, FMS scores could only take 79 integers, so FMS=14 was the best critical value for predicting the risk of injury by FMS score whether it was before or after training.

As shown in Table 4, before training, there were 50 basketball athletes with an FMS score of ≤14, of which 24 athletes had injury sites >1, 26 athletes had injury

sites ≤1, and 40 basketball athletes had FMS scores >14. Among them, there were 8 athletes with a lesion of >1 and 32 with a lesion of ≤1. After chi-square analysis, there was a significant difference in the occurrence of injury between basketball athletes with FMS score ≤ 14 and FMS score > 14 ($\chi2=7.603$, $P=0.006$). From Table 5, after training, there were 15 basketball athletes with an FMS score of ≤14, of which 5 athletes had injury sites >1, 10 athletes had injury sites ≤1, and 75 basketball athletes had FMS scores >14. Among them, there were 1 athlete with a lesion of >1 and 74 with a lesion of ≤1. After chi-square analysis, there was a significant difference in the occurrence of injury between basketball athletes with FMS score ≤ 14 and FMS score > 14 ($\chi2=20.571$, $P=0.006$).

Table 3. The log-log plot of ROC for predicting the risk of injury by FMS score

| | FMS | Sensitivity | 1-Specificity |
|---|---|---|---|
| Before Training | 7.0000 | 1.000 | 1.000 |
| | 8.5000 | 1.000 | 0.983 |
| | 9.5000 | 1.000 | 0.966 |
| | 10.5000 | 1.000 | 0.915 |
| | 11.5000 | 1.000 | 0.864 |
| | 12.5000 | 1.000 | 0.627 |
| | 13.5000 | 0.935 | 0.441 |
| | 14.5000 | 0.774 | 0.271 |
| | 15.5000 | 0.516 | 0.169 |
| | 16.5000 | 0.258 | 0.068 |
| | 17.5000 | 0.194 | 0.000 |
| | 18.5000 | 0.065 | 0.000 |
| | 20.0000 | 0.000 | 0.000 |
| After training | 11.0000 | 1.000 | 1.000 |
| | 12.5000 | 1.000 | 0.920 |
| | 13.5000 | 1.000 | 0.680 |
| | 14.5000 | 0.985 | 0.440 |
| | 15.5000 | 0.815 | 0.400 |
| | 16.5000 | 0.692 | 0.360 |
| | 17.5000 | 0.538 | 0.160 |
| | 18.5000 | 0.338 | 0.080 |
| | 19.5000 | 0.138 | 0.000 |
| | 21.0000 | 0.000 | 0.000 |

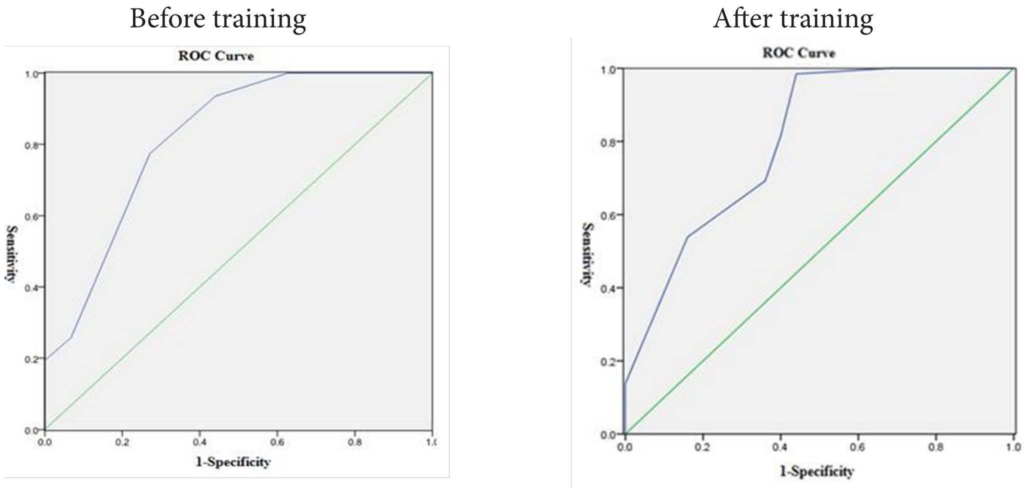


Figure 1: The ROC curve before the training and after training

As shown in Table 6, the average scores of deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability of 90 basketball athletes before training were 1.98, 1.86, 2.00, 2.00, 1.96, 2.32 and 2.03, respectively, and the average score of FMS was 14.14; the average scores of deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability of 90 basketball athletes after training were 2.40, 2.30, 2.52, 2.44, 2.39, 2.44 and 2.32, respectively, and the average score of FMS was 16.82. There were significant differences between FMS single and total scores before and after training (P<0.05).

Table 4. Comparison of the Actual Number of Injured Athletes and the Number of Injured Athletes Judged by the Critical Value of 14 before Training

| **FMS scoring** | **Number of athletes with injury sites>1** | **Number of athletes with injury sites≤1** | **Total** |
|---|---|---|---|
| ≤14 points | 24 | 26 | 50 |
| >14 points | 8 | 32 | 40 |
| Total | 32 | 58 | 90 |

Table 5. Comparison of the Actual Number of Injured Athletes and the Number of Injured Athletes Judged by the Critical Value of 14 after Training

| **FMS scoring** | **Number of athletes with injury sites>1** | **Number of athletes with injury sites≤1** | **Total** |
|---|---|---|---|
| ≤14 points | 5 | 10 | 15 |
| >14 points | 1 | 74 | 75 |
| Total | 6 | 84 | 90 |

## Discussion

The FMS test is one of the most frequently utilized methods that researchers use to evaluate the risk of injuries in sport [20]. Accordingly, this study was designed to determine if, after 16 weeks of core and strength training, FMS score can predict the frequency of injuries in addition to finding the FMS predictive value for injury in Ghanaian university basketball players.

Table 6. FMS Scoring of Athletes before and after Training

| **Item** | **Before Training** | **After training** |
|---|---|---|
| Deep Squat | 1.98±0.89 | 2.40±0.65* |
| Hurdle Step | 1.86±0.77 | 2.30±0.74* |
| In-line lunge | 2.00±0.95 | 2.52±0.58* |
| Shoulder Mobility | 2.00±0.75 | 2.44±0.58* |
| Active Straight Leg Raise | 1.96±0.73 | 2.39±0.59* |
| Trunk Stability Push-Up | 2.32±0.68 | 2.44±0.66* |
| Rotary Stability | 2.03±0.64 | 2.32±0.56* |
| Total | 14.14±2.23 | 16.82±2.17* |
| Note: Compared with pre-training, *P<0.05. | | |

The major findings of this study showed that 16 weeks of strength and core training help athletes recover from injury and significantly improve their FMS scores. In addition, an FMS score of 14 was the most accurate critical value for estimating the likelihood of injury based on FMS score, whether it occurred before training or after training.

Zhang [21] used the method of questionnaire to investigate the injury status and causes of 386 college students who often participated in basketball. The results of the study showed that, total prevalence of sports injuries was 60.88%. The location of sports injuries was fingers, ankles, knees, fingers, waist and back, thighs. The common types of injuries were joint sprain, muscle strain and soft tissue injury. The causes of injuries were inappropriate preparatory activities, violation of competition rules, technical errors, poor venue and excessive exercise load. Chen [22] conducted an epidemiological survey on 367 athletes (211 men and 156 women) who participated in the 2006-2007 CBA and WCBA professional leagues. The results showed that the morbidity rate reached 72.75% in the six-month race, 74.41% in males and 70.51% in females; lumbar muscle strain (12.3%), ankle ligament injury (9.42%) and knee meniscus injury (8.64%) ranked among the top three injury categories; the incidence of injury was knee joint injury (34.55%), lumbar injury (21.2%) and ankle injury (16.75%). The age group with high incidence of injury was 23-26 years old. Studies by Feng [23] used questionnaire to investigate the injuries of NBA professional athletes

Through the analysis of the statistics of professional basketball matches in the quarter of 2013-2014, it can be seen that among the injured parts of NBA professional athletes, the proportion of hand and finger is the smallest, only 1%; while the proportion of knee joint injuries is the largest, 23.8% followed by ankle injuries accounting for 23.8%. Ye et al [24] analyzed the injuries of national men's and women's basketball athletes who participated in the training from 2006 to 2007. The results showed that the incidence of knee (22%), ankle (15.3%) and waist (16%) injuries was higher. The injury was mainly caused by the special position characteristics of basketball athletes.

In the Ghana University basketball athletes, the incidences of ankle injury and knee injury were 31.11%, 18.89% before training and both 10.00% after training. The result of this study is consistent with the studies of other researches. This showed that ankle and knee are the most vulnerable parts of basketball athletes which is similar to other research studies. This was mainly because basketball requires regular running, and in the process of basketball players' knees rarely appear upright state, which will increase. The incidence of lumbar and spinal injuries was 15.56%, suggesting that the injuries in the core of the body should not be neglected. In addition, the incidence of finger, elbow, wrist and shoulder injuries were 13.33%, 8.89%, 6.67% and 6.67%, respectively. After 16 weeks of training, the injury rate of basketball athletes in all parts was significantly lower than that before training, indicating that strength training and core training can help athletes recover from injury.

Kiesel et al. [16] first proposed the "threshold" of FMS injury risk. Kiesel et al tested 46 rugby athletes and monitored them during the 4.5-month season by using the ROC Subject Work Characteristic Curve. It was found that the injury risk of athletes whose test score was less than or equal to 14 was much higher than that of athletes whose test score was greater than 14.

Li, et al. [25] studied 33 ice hockey athletes' injury and functional movement screening, and found that the FMS score of ice hockey athletes was 13.12, which was lower than the recognized 14-point threshold, indicating that the potential injury risk of athletes was higher [16].

Gao et al. [26], discussed the application value of FMS in the risk assessment of sports injury of rugby athletes in China. They took active national and provincial rugby athletes as subjects, collected data by standard FMS test, and tracked and investigated non-contact injury of rugby athletes. They evaluated the value of relevant indicators of FMS test to assess the risk of sports injury and determined the best cut-off point of total score of FMS by using statistical methods such as ROC curve and OR. The area under the curve is 0.780, and the best cut-off point for the total score of FMS is 13.5. Chi-square test showed that the prevalence of positive group (the total score of FMS is less than the corresponding cut-off point) was significantly higher than that of negative group (the total score of FMS is greater than the corresponding cut-off point). It shows that in rugby athletes, the total score of FMS has a strong correlation with non-contact sports injury and can be used as an index for risk assessment of non-contact sports injury [26]. Wang et al. [27] selected 45 main shooting 97 athletes of our country as the test subjects to carry out FMS function test. After data analysis, it was found that the area under ROC curve calculation curve was 0.745 and the difference was statistically significant, indicating that the total score of FMS test had evaluation value for shooting athletes' injuries. Through Youden index, the cut-off point is determined to be 15 points. Its sensitivity is 0.750, specificity is 0.609, pre-test probability is 0.410, post-test probability is 0.571, and the total score of FMS is less than 15. The proportion of possible injuries of athletes will increase from 41% to 57.1%. This shows that this new test method has good predictive ability for shooters.

This study also confirmed by ROC curve method that the area under the curve of FMS score predicting basketball athletes' injury risk is more than 0.7, which shows that FMS score method has certain value. Both before training and after training judging the sensitivity and specificity in Table 3, when the FMS score is 14.5, the sensitivity - (1- specificity) reaches the maximum. However, the FMS scores are all integers, so the optimal threshold value is 14, which is consistent with the results of most researchers. We further compared the injuries of basketball athletes whose FMS score was less than 14 and whose FMS score was more than 14 as shown in Table 4 and 5. We found that the injuries of basketball athletes whose FMS score was less than 14 were obviously more than those of basketball athletes whose FMS score was more than 14. This proves that FMS score has certain value in predicting the risk of sports injuries of basketball athletes and is worth popularizing. The potential damage risk of different projects and groups cannot be judged simply by referring to the conclusions of previous studies at home and abroad as the "gold standard", but should be adjusted according to the research conclusions in the field of practice.

The functional movement screen (FMS) was created as a pre-season and pre-participation examination [28]. Lin et al. [29] selected 16 table tennis students (2.5 years of special sports) from the Institute of Physical Education of Yangtze University as the research subjects for functional action screening. The results showed that the average score of FMS for college table tennis students was 15.86, with the average score of 2.71 for squatting, 1.86 for hurdling step, 2.43 for squatting in straight line, 2.71 for shoulder flexibility, 2.00 for active leg lifting, 2.29 for trunk stability push-ups and 1.86 for body rotation stability. Studies by Zhao et al. [30] selected 77 athletes from 6 teams in Xi'an to participate in FMS screening. The results of the study showed that the mean FMS score was 14.76 in this screening, and the number of people who scored high scores during screening was small. Most athletes scored between 14 and 18, and the mean value of the body stability of the trunk was the highest. The stability of the push-up mode has the lowest mean value, and some athletes have differences in the left and right-side limb. Some athletes had pain during screening and there was sports injury. No linear relationship between the athlete's age, training period and FMS scores and the 7 action patterns was observed. In this study, the average scores of deep squats, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability of 90 basketball athletes before training were 1.98, 1.86, 2.00, 2.00, 1.96, 2.32 and 2.03, respectively, and the average score of total FMS score was 14.14. This score is moderate, which is close to that reported by Zhao et al. [30], but it also suggests that basketball athletes have a certain risk of injury. However, there was significant improvement in FMS scores after training compared with pre-training as shown in Table 6.

# Conclusion

This research study demonstrated that the ankle and the knee are the most vulnerable parts of basketball athletes, and the injuries in the core of the body, such as lumbar and spinal also should not be neglected. An FMS score of 14 was the best value for effectively predicting the injury risk of basketball players and this provides a reference value for screening university basketball athletes before participation. Strength training and core training can effectively prevent basketball players from injury and improve FMS score.

### Conflict of Interest

The authors state no conflict of interest.

### Author contribution.

Dr Opoku-Antwi conducted a literature search, read every reference, evaluated every article and exported the data. The paper was initially written by JAK, and then it was edited by both authors. The final manuscript was reviewed and approved by all authors.

# Reference


[1] Shojaedin, S. S., Letafatkar, A., Hadadnezhad, M., & Dehkhoda, M. R. (2014). Relationship between functional movement screening score and history of injury and identifying the predictive value of the FMS for injury. International Journal of Injury Control and Safety Promotion, 21(4), 355–360. https://doi.org/10.1080/17457300.2013.833942

[2] Cook, G., Burton, L., & Hogenboom, B. (2006a). The use of fundamental movements as an assessment of function – part I. North American Journal of Sports Physical Therapy, 2, 62–72.

[3] Cook, G., Burton, L., & Hoogenboom, B. (2006b). Pre-participation screening: The use of fundamental movement as an assessment of function – part 2. North American Journal of Sports Physical Therapy, 1(3), 132–139

[4] Narducci, E., Waltz, A., Gorski, K., Leppla, L., & Donaldson, M. (2011). The clinical utility of functional performance tests within one year post ACL reconstruction: A systematic review. International Journal of Sports Physical Therapy, 6 (4), 333–342

[5] Cook, G., Burton, L., Kiesel, K., et al. (2010). Movement: functional movement systems: screening, assessment, and corrective strategies[M]. Aptos, CA: On Target Publications

[6] Teyhen, D. S., Shaffer, S. W., Lorenson, C. L., et al. (2012). The functional movement screen: a reliability study. J Ortho Sports Phys Ther, 42(6): 530-540.

[7] Dexter, R., Renggli, C., May, J., & Larkins, L. (2020). The Effects of Strength and Conditioning on Functional Movement ScreenTM Scores in Secondary School Basketball. Journal of Sports Medicine and Allied Health Sciences: Official Journal of the Ohio Athletic Trainers' Association, 5(3). https://doi.org/10.25035/jsmahs.05.03.05

[8] Warren, M., Lininger, M. R., Chimera, N. J., Smith, C. A., & Lininger, M. R. (2018). Utility of FMS to understand injury incidence in sports : current perspectives Utility of FMS to understand injury incidence in sports : current perspectives. https://doi.org/10.2147/OAJSM.S149139

[9] Asgari, M., Alizadeh, S., Sendt, A., & Jaitner, T. (2021). Evaluation of the Functional Movement Screen ( FMS ) in Identifying Active Females Who are Prone to Injury . A Systematic Review. Sports Medicine - Open. https://doi.org/10.1186/s40798-021-00380-0

[10] Dossa, K., Cashman, G., Howitt, S., West, B., & Murray, N. (2014). Can injury in major junior hockey players be predicted by a pre-season functional movement screen - A prospective cohort study. The Journal of the Canadian Chiropractic Association, 58, 421–427.

[11] Moran, R., Schneiders, A., Mason, J., & Sullivan, S. J. (2017). Do Functional Movement Screen (FMS) composite scores predict subsequent injury? A systematic review with meta-analysis. British Journal of Sports Medicine, 51. https://doi.org/10.1136/bjsports-2016-096938

[12] Smith, P.D., Hanlon, M.P. (2017). Assessing the Effectiveness of the Functional Movement Screen in Predicting Noncontact Injury Rates in Soccer Players. Strength Cond Res, 31(12): 3327-3332. https://doi.org/10.1519/JSC.0000000000001757l

[13] Dossa, K., Cashman, G., Howitt, S., West, B., Murray, N. (2014). Can injury in major junior hockey players be predicted by a pre-season functional movement screen–a prospective cohort study. J Can Chiropr Assoc, 58(4): 421

[14] Warren, M., Smith, C. A., & Chimera, N. J. (2015). Association of the functional movement screen with injuries in division I athletes. Journal of Sport Rehabilitation, 24(2), 163–170. https://doi.org/10.1123/jsr.2013-0141

[15] Chorba, R. S., Chorba, D. J., Bouillon, L. E., Overmyer, C. A., & Landis, J. A. (2010). Use of a functional movement screening tool to determine injury risk in female collegiate athletes. North American Journal of Sports Physical Therapy : NAJSPT, 5(2), 47–54.

[16] Kiesel, K., Plisky, P.J., & Voight, M.L. (2007). Can serious injury in professional football be predicted by a preseason functional movement screen? North American Journal of Sports Physical Therapy, 2(3), 147–158

[17] Minick, K., Kiesel, K., Burton, L., et al. (2010). Interrater reliability of the functional movement screen. Journal of Strength & Conditioning Research, 24(2): 479-486.

[18] O'Connor, F.G., Deuster, P.A., Davis, J., Pappas, C.G., & Knapik, J.J. (2011). Functional movement screening:

Predicting injuries in officer candidates. Med Sci Sports Exerc, 43: 2224-2230

[19] Peate, W.F., Bates, G., Lunda, K., Francis, S., & Bellamy, K. (2007). Core strength: A new model for injury prediction and prevention. Journal of Occupational Medicine and Toxicology, 2, 3

[20] Wu, H., & Zhang, X. D. (2016). Ruan H. Research progress of functional test methods for predicting athletes' waist and lower limb injury[J]. Chinese Journal of Rehabilitation Medicine, 31 (3): 354-357. [210]

[21] Zhang, X. D. (2005). Analysis of the regularity and causes of College Students' basketball injury[J]. School Health in China, 1: 31-32

[22] Cohen, Z. X. (2007). Prevention and treatment of sports injuries of professional basketball players[D]. Beijing: General Hospital of the Chinese People's Liberation Army

[23] Feng, X. M. (2017). Analysis of injury status and defensive measures in basketball[J]. Journal of Xi'an Academy of Arts and Sciences (Natural Science Edition), 20 (5): 125-128

[24] Ye, R. B., Zhang, M., Wang, Q., et al. (2008). Investigation and analysis of sports injuries of elite basketball players in national team[J]. Chinese Journal of Sports Medicine, 27 (6): 752-753 https://doi.org/10.4103/njcp.njcp_145_16

[25] Li, S. L., Nie, Z. C., Zhu, B. F. et al. The correlation between functional movement screening and injury of ice hockey players[J]. Ice and Snow Sports, 39 (4): 29-34.

[26] Gao, X. T., Xu. H., Huang, P., et al. (2017). Study on the application of functional motor test to assess the injury risk of Chinese rugby players. Chinese Journal of Sports Medicine, 36 (5): 410-415

[27] Wang. J. S., Luo, X. B., Yan, H. L. (2016). Analysis of the correlation between injuries and functional movement screening of national shooting team athletes. Journal of Capital Institute of Physical Education, 28(4): 352-355, 379.

[28] Kuzuhara, K., Shibata, M., Iguchi, J., & Uchida, R. (2018). Functional Movements in Japanese Mini-Basketball Players. Journal of Human Kinetics, 61(1), 53–62. https://doi.org/10.1515/hukin-2017-0128

[29] Lin, X. L., Zhang, Y. T., Li, M., et al. (2017). Functional movement screening analysis of table tennis students in colleges and universities. Sports Science and Technology, 38 (2): 162-164.

[30] Zhao, J. G. (2016). Xi'an city high-performance male basketball player functional action screening (FMS) research. Xi'an Institute of Physical Education