Assessment of the functional movement screen and injuries in gymnasts

Mercedes Vernetta-Santana[1,2], Alicia Salas-Morillas[2,3], Jesús López-Bedoya[1,2]

[1]Departamento de Educación Física y Deporte. Facultad de Ciencias del Deporte. Universidad de Granada. [2]Grupo de Investigación Análisis y evaluación de la actividad físico-deportiva CTS 171. [3]Departamento de Danza Acrobática y Circense. Instituto Universitario Alicia Alonso. Universidad Rey Juan Carlos. Madrid.

doi: 10.18176/archmeddeporte.00085

Received: 22/10/2021
Accepted: 25/03/2022

Summary

Objective: To identify possible differences in movement quality through the functional movement screen (FMS) between injured and non-injured adolescent acrobatic gymnasts in the last season.
Method: descriptive, comparative, cross-sectional study involving 20 adolescent female gymnasts divided into two groups, one composed of 9 gymnasts who had suffered an injury in the last season (14,7±1,56) and the other composed of 11 gymnasts who had not suffered any injury (13,9±2,25). The FMS battery was used, consisting of seven tests: deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability in push-ups, trunk rotational stability.
Results: Of the nine gymnasts who had sustained an injury, 66.6% were located in the lower limb, ankles and knees. The results of the total functional assessment of FMS using the Mann Whitney U statistic for independent samples showed no statistically significant differences between groups (Z = -.393; p > 0.05), with the average range of FMS being similar in both cases (10.05 and 11.06 in injured and non-injured gymnasts respectively). It also showed the absence of significant differences in each of the tests of the battery, and no relationship was found through Spearman's R statistic, between the overall FMS score and the group of injured gymnasts.
Conclusion: The results of the FMS total score were slightly higher in gymnasts who were not injured last season, as well as slightly better in all the lower body tests, hence the FMS can be used as a preventive programmed to detect possible deficiencies.

Key words:
Functional movement. Functional movement screen. Motor competence. Acrobatic gymnastics. Sports injuries.

Evaluación del *functional movement screen* y lesiones en gimnastas

Resumen

Objetivo: Identificar posibles diferencias en la calidad de movimiento a través del *functional movement screen* (FMS) entre gimnastas adolescentes de acrobática lesionadas o no lesionadas en la última temporada.
Método: Estudio descriptivo, comparativo y transversal donde participaron 20 mujeres adolescentes divididas en dos grupos, uno compuesto por 9 gimnastas que habían sufrido alguna lesión en la última temporada (14,7±1,56) y otro por 11 gimnastas que no habían sufrido ninguna (13,9±2,25). Se usó la batería FMS, compuesta por siete pruebas: sentadilla profunda, paso de valla, estocada en línea, movilidad de hombro, elevación activa de la pierna recta, estabilidad del tronco en flexiones, estabilidad rotatoria del tronco.
Resultados: De las nueve gimnastas que habían sufrido alguna lesión, 66,6% se localizaron en el miembro inferior, tobillos y rodillas. Los resultados de la valoración funcional total del FMS mediante el estadístico U de Mann Whitney, para muestras independientes no mostró diferencias estadísticamente significativas entre grupos (Z = -,393; p > 0,05), siendo el rango promedio de FMS similar en ambos casos (10,05 y 11,06 en gimnastas lesionadas y no lesionadas respectivamente). Igualmente arrojó la ausencia de diferencias significativas en cada una de las pruebas de la batería, no encontrándose ninguna relación a través del estadístico R de Spearman, entre la puntuación global del FMS y el grupo de gimnastas lesionadas.
Conclusión: Los resultados de la puntuación total del FMS fueron mayores en las gimnastas que no sufrieron lesión en la temporada pasada, así como ligeramente mejores en todas las pruebas del tren inferior. Sin embargo, estas diferencias no fueron significativas. No existió ninguna relación entre la puntuación total del FMS y el grupo de gimnastas lesionadas.

Palabras clave:
Movimiento funcional. Functional movement screen. Competencia motriz. Gimnasia acrobática. Lesiones deportivas.

Correspondence: Alicia Salas
E-mail: aliciasalasmorillas@gmail.com

Introduction

Acrobatic gymnastics (AG) is a gymnastic discipline which joined the International Gymnastics Federation in 1999 and is now consolidated as an international competitive sport. It is essentially a highly cooperative sport in which the gymnasts perform a conjunction of technical movement and body movements set to music[1].

The morphological profile for this discipline depends on the role played by each gymnast. The smaller, younger, more agile ones are called 'tops' and they perform elements of balance, flexibility or air jumps. The 'bases' are those who support these elements or perform propulsions and receptions of them[1,2]. The competitive categories exclusive to women are pairs and groups of three.

The risk of injury in these gymnasts is increasing due to the extremely difficult motor skills involved in and great technical demands of the discipline[3]. The most frequently reported injuries are in the lower limbs, the most affected areas being the ankle and knee. The injuries mostly consist of tendon and ligament injuries[3–8].

Specifically, in female gymnasts who perform this discipline, the injuries most reported are in the lower limbs, with an emphasis on sprains, followed by contractures and strains, which tend to be mild to moderate in terms of severity and occur during training[3]. Although these gymnasts are fundamentally concerned about injury for the sake of their own health, being an extremely cooperative sport in all its modalities, injury to an acrobatic gymnast would also necessarily have an impact on their partners' performance in the sport and could mean pulling out of competitions.

Of all the evaluation tests which aim to reduce the risk of injury in athletes, Bennett *et al*.[9] maintain that the *Functional Movement Screen* (FMS) is becoming a key tool. It is a standardised evaluation method through which movement quality can be categorised in a systematic, reproducible, reliable and valid way. It serves to assess fundamental movement patterns, motor control and movement quality, and allows us to establish profiles and comparisons between athletes of the same or different disciplines[10,11].

It consists of seven specific movement tests related to stability, mobility and balance which can detect the existence or not of possible bilateral imbalances in each body segment involved[12,13], making it a potential predictor of injuries[14]. The tests are simple, do not require much time and space, require little material and their reliability is excellent according to the meta-analysis carried out by Bonazza *et al*.[15].

Although there exist controversies about its ability to predict injury[16], several studies with judokas and CrossFit athletes[17,18] have reported its power as a key information tool for coaches so they can intervene in their athletes' development or check if they have recovered properly following injury[19].

Therefore, performing a functional evaluation with the FMS on a group of adolescent gymnasts who had an injury the previous season may allow us to analyse if they are more likely to suffer further injuries or check if they have recovered properly.

The fact that the FMS offers the chance to evaluate core instability, neuromuscular control, joint mobility and muscle imbalances allows us to obtain valuable data on the deficits that these gymnasts may have so we can address them better in the future with adequate rehabilitation programmes aimed at reducing the likelihood of recurrence. The most noteworthy limitations of this instrument in relation to the most frequent injuries in acrobatic gymnasts are its inability to detect injuries in the ankle area (an area extremely prone to injury in the discipline) and the issue which exists regarding the shoulder test, because although the bilateral information from the test can provide functional guidelines of interest, it can also breed controversy as the score obtained may mean a risk of injury or it may mean greater development of muscle mass in the area[20].

To date, we are only aware of the use of the FMS in one study conducted in AG, but it only describes movement quality in a sample of gymnasts who did acrobatics compared to others who did not20. Hence, our objective was to use the FMS to identify possible differences in movement quality between adolescent acrobatic gymnasts who had been injured the previous season and others who had not.

Material and method

Participants

Descriptive cross-sectional, comparative study with the voluntary participation of 20 female gymnasts between 12 and 17 years of age (age= 14.3±1.97 years; weight= 50.4±8.98 kg; height= 1.59±.09; BMI= 19.53±1.78 kg/m^2), all members of the same AG club in Granada. The participants had experience in the discipline of 3±1 years and trained at national competitive level 3 to 4 days a week for an average of 3±1 hours per session. Of the total sample, 9 had suffered an injury the previous season (one top and eight bases). The inclusion criteria were: adolescent females, federated acrobatic gymnasts, who attended training regularly, national level competitors; and as exclusion criteria: some type of current injury preventing them from performing the FMS at the time of the evaluation. Before starting the study, all the parents or legal guardians of the gymnasts signed an informed consent where the objective of this research and the procedure to be used was described. The study respected the principles of the Declaration of Helsinki and was approved by the Ethics Committee at the University of Granada (number 1.011).

Instrument and materials

To analyse the movement quality variable, the test used was the FMS created by Gray Cook and Lee Burton in 1998, whose three fundamental objectives are: to evaluate basic movement patterns, detect asymmetries and assess motor control[21].

The FMS consists of seven tests: deep squat, hurdle step, inline lunge, shoulder mobility, active straight-leg raise, torso stability push-up and torso rotary stability. The following materials were used to evaluate the different tests: a 1.22 m dowel, two 0.61 m dowels, a 2x6 cm wooden

plank, a rigid measuring rod and two high-definition cameras with 4K recording technology to record the execution of the exercises.

For the injuries variable, a self-record sheet was handed out with questions about the existence of injuries (type, severity and when they occurred: training or competition) during the preparatory and competition period from October to June 2020/2021.

Finally, weight and height were used to calculate BMI. Weight was determined with a TEFAL digital scale with an accuracy of 0.05 kg and height was measured with a SECA 220 height rod with an accuracy of 1 mm. The two measurements were entered into the formula weight (kg)/height $(m)^2$ to arrive at the BMI (kg/m^2).

Procedure

First, informed consent was obtained from the club to which the gymnasts belonged and the confidentiality of the results was emphasized.

The evaluation procedure was carried out at the beginning of the season during a training session after a day of rest. First, they were given a self-record questionnaire with questions about the existence or not of injuries in the previous season. According to the data obtained, the gymnasts were divided into two groups depending on whether or not they had had an injury the previous season (in the last eight months), corresponding to the preparatory and competition period. Before starting, all the participants were informed about the evaluation procedures. The evaluations were carried out individually, carrying out each of the tests that make up the FMS three times. All the gymnasts followed the same order of tests and the guidelines established by Cook[22] to minimise any possible bias or negative effect on the tests.

Both sides (left and right) were evaluated in all the tests except the deep squat and torso stability push-up. The participants performed a small dynamic warm-up before completing the FMS tests. They were given verbal instructions for each exercise following the description guidelines proposed by Cook[22] and each participant had three opportunities for correct execution.

The maximum score which can be obtained in the FMS is 21 points, three points being the maximum score per exercise. Three points were awarded if the gymnast was able to perform the movement without needing to apply any compensations, two points if she managed to perform the movement applying one or more compensations, one point if she could not complete the exercise and zero if she experienced pain, regardless of whether she could complete the exercise. In the bilateral tests, the lower score of the two was taken to calculate the total FMS score[12].

When the subject earns the maximum score in the screen, it can be concluded that they have highly developed movement patterns with no limitations on basic movements. If they get between 15 and 20 points, it is understood that they need to improve some weaknesses found, but in general have an acceptable level of movement patterns. Finally, if a subject's score is 14 or lower, the subject's situation is a cause for concern or he/she is at risk of suffering an injury[23,24].

Two different planes of movement (front and side) were digitally recorded when the tests were performed by each participant and these were analysed jointly by two evaluators with previous experience in the use of the FMS[25].

All the gymnasts had sufficient functional capacity to perform each of the tests and were active, with optimal sports performance within their competitive modality (pairs or groups of three) at the time of recording.

Statistical analysis

Statistical analysis was conducted using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). The descriptive data for each of the FMS tests are shown with the mean and standard deviation. The frequency and percentage values of all tests were also calculated, differentiating the body side in the bilateral tests. Since the variables presented a non-normal distribution, the Mann-Whitney U test was used to check the FMS scores based on whether or not injuries had been suffered in the previous season. The value of statistically significant difference between groups (injured and uninjured) was shown whenever $p < 0.05$. Finally, correlational analysis was performed using Spearman's rho to see whether the overall FMS score was related to injury or non-injury in AG.

Results

As seen in Table 1, the injuries were mostly ligament injuries (n=7). Meanwhile, six injuries (66.6%) were located in the lower limbs, the knee (n=2) and ankle (n=4) being the most affected areas. Focusing on these areas, the injured structures were the posterior cruciate ligament in the knee (n=1) and the external lateral ligament of the ankle (n=4). It is noteworthy that most of the injuries occurred in the dominant segment (n=6).

All the injuries occurred during training (n=9) and none in competition. In terms of severity, most of the injuries were mild and moderate, meaning the subject could not engage in sporting activity for one week or less in 44.4% of the cases and between 9 and 20 days for the other 44.4%.

Table 2 shows the descriptive statistics (mean and standard deviation) and the differences in the scores obtained in each of the FMS tests by the two groups (uninjured and injured). No significant differences were observed in terms of the performance obtained in each of the evaluation tests carried out by the gymnasts belonging to the two groups evaluated.

Table 3 shows the frequency and percentage obtained in the different tests. The great majority of the members of both groups got the maximum score of 3 in all the tests. The score was never zero for any of the gymnasts. The test with the lowest score was shoulder mobility, which was worse in the non-injured than it was in the injured, although without a significant difference.

Table 4 classifies the sample based on the total score obtained in the FMS. As can be seen, all the gymnasts displayed an acceptable level of movement quality.

The Mann-Whitney U statistic for independent samples showed an absence of statistically significant differences between the two groups (Z = -.393; p >0.05), with the mean rank of the FMS similar in both cases (10.05 and 11.06 in injured and uninjured gymnasts, respectively). Finally, Spearman's rho statistic did not show a statistically significant positive relationship between the variables *overall FMS score and presence of injuries.*

Table 1. Type of injuries, body region, location, severity and time of injury.

Type of injuries	Gymnasts injured (n=9)
Torn ligament	1 (11.1)
Sprains	6 (66.6)
Fissures and fractures	1 (11.1)
Others	1 (11.1)
Body region	
Upper limb	3 (33.3)
Trunk	-
Lower limb	6 (66.6)
Location	
Knee	2 (22.2)
Ankle	4 (44.4)
Waist	1 (11.1)
Forearm	1 (11.1)
Hand	1 (11.1)
Severity	
Mild	4 (44.4)
Moderate	4 (44.4)
Severe	1 (11.1)
Time of injury	
Training	9 (100.0)
Competition	-

Discussion

The injuries in the group of gymnasts injured the previous season chiefly affected the lower limbs, particularly knees and ankles, and were mainly ligament injuries. These data confirm the results obtained by different authors studying young acrobatic gymnasts[3,4,6]. 100% of the injuries occurred during training and most were mild or moderate, putting the subjects out of sports action for no more than three weeks, during which time they were active and the injury did not excessively impact their training. These data are in line with the results found by Vernetta *et al*., Purnell *et al.*, and Caine and Vernetta *et al.*[3,6,20,26].

Regarding the movement quality data, it is worth highlighting acceptable FMS test levels in the entire sample, there being practically the same movement quality in the non-injured gymnasts and no statistically significant difference between the two groups in the overall FMS score or each test taken independently. However, the values obtained in the tests related to core stability, balance and neuromuscular control (hurdle step, inline lunge and squat) show that the group which had had an injury the previous season got a slightly lower score.

In our study, it should be noted that none of the gymnasts obtained a total FMS score less than or equal to 14, which indicates that, according to Cook *et al.* [22], neither of the groups had a greater risk of injury. Most of the gymnasts in both groups obtained scores between 18 and 20 points, corresponding to an acceptable level, these results being consistent with

Table 2. Comparison of the scores obtained in the different tests in the FMS according to the presence or not of injuries.

FMS test	Not injured (n=11)	Injured (n=9)	p
Deep squat	2.91±.302	2.78±.441	0.441
Hurdle step (right)	3.00±0.0	2.89±.333	0.269
Hurdle step (left)	3.00±.0.0	2.89±.333	0.269
Inline lunge (right)	2.91±.302	2.78±.441	0.425
Inline lunge (left)	2.91±.302	2.89±.333	0.884
Shoulder mobility (right)	2.09±944	2.33±.707	0.596
Shoulder mobility (left)	2.09±539	1.89±.782	0.489
Active straight-leg raise (right)	3±.0	3±.0	1
Active straight-leg raise (left)	3±.0	3±.0	1
Trunk stability push-up	2.55±.522	2.67±.5	0.592
Torso rotary stability (right)	2.64±.674	2.89±.333	0.354
Torso rotary stability (left)	2.73±.647	2.78±.441	0.913
Total FMS score	19 ±1.26	18.89±1.61	0.710

*p < 0.005. **p < 0.001

Table 3. Frequency and percentage of each score in the different tests in the FMS obtained by the sample.

Test	Not injured N=11				Injured N=9			
	0	1	2	3	0	1	2	3
Deep Squat	-	-	1 (9.1)	10 (90.9)	-	-	2 (22.2)	7 (77.8)
Hurdle step (right)	-	-	-	11 (100)	-	-	1 (11.1)	8 (88.9)
Hurdle step (left)	-	-	-	11 (100)	-	-	1 (11.1)	8 (88.9)
Inline lunge (right)	-	-	1 (9.1)	10 (90.9)	-	-	1 (11.1)	8 (88.9)
Inline lunge (left)	-	-	1 (9.1)	10 (90.9)	-	-	1 (11.1)	8 (88.9)
Shoulder mobility (right)	-	4 (36.4)	2 (18.2)	5 (45.4)	-	1 (11.1)	4 (44.4)	4 (44.4)
Shoulder mobility (left)	-	1 (9.1)	8 (72.7)	2 (18.2)	-	3 (33.3)	5 (44.4)	2 (22.2)
Active straight-leg raise (right)	-	-		11 (100.0)	-	-	-	9 (100.0)
Active straight-leg raise (left)	-	-		11 (100.0)	-	-	-	9 (100.0)
Trunk stability push-up	-	-	5 (45.5)	6 (54.5)	-	-	3 (33.3)	6 (66.7)
Torso rotary stability (right)	-	1 (9.1)	2 (18.2)	8 (72.7)	-	-	1 (11.1)	8 (88.9
Torso rotary stability (left)	-	1 (9.1)	1 (9.1)	9 (81.8)	-	-	2 (22.2)	7 (77.8)

Table 4. Frequency and percentage of the total score obtained in the FMS in all gymnasts divided according to the presence or not of injuries.

FMS score	Not injured N (%)	Injured N (%)
≤ 17	1 (9.1)	1 (11.1)
18-20	8 (72.8)	8 (88.8)
21	2 (18.2)	0 (0)

those found in the studies by Vernetta *et al*., Gil-Lopez *et al.* and Vernetta *et al*. [20,27,28] in adolescents engaged in sports such as judo, basketball and AG, possibly due to the relationship between motor performance in basic movement patterns and organised physical activities[29]. Taking into account these scores, it can be assumed that the training to which the different athletes in the above studies are subjected has a significant effect on the most optimal FMS results[20,30].

It should be noted that none of the gymnasts injured in the previous season obtained the maximum score of 21 points, which was achieved by two gymnasts from the non-injured group.

Regarding the results obtained in each of the tests, it can be observed that the scores are very similar in the two groups, except in those tests which involve the lower body (deep squat, right/left hurdle step and right/left inline lunge), where the injured gymnasts got worse scores, albeit without statistically significant differences. This may in part be due to the fact that most injuries in these gymnasts were located in the lower limbs, with the ankle and knee being the most affected areas. Specifically, considering that 22.2% of the injuries were in the ankle and 44.4% in the knee, the slightly worse scores in the hurdle step and inline lunge tests, which require knee, hip and ankle stability, according to Cook *et al*.[22], could be to do with a small fault detected in these gymnasts in relation to the ability to maintain stability in their lower limbs. In this regard, Nadler *et al.*[31] recommend balanced mobility and stability work centring on the foot, ankle, knee and hip joints to avoid imbalances and possible injurious states in large chain exercises.

Regarding joint mobility, the two groups obtained the maximum score of 3 points in the leg raise test on both sides, results which should be expected due to the importance of the flexibility of the coxofemoral joint in gymnastic sports[32], coinciding with the maximum scores obtained in acrobatic gymnasts assessed using the FMS[20].

As for possible asymmetries in the five bilateral tests, in general the gymnasts in both groups got very similar scores on both sides in all the tests, except shoulder mobility, where slight asymmetries were observed in those gymnasts who had been injured, with lower scores on the left side. In these gymnasts, this could be justified by the fact that they were all right-handed, since as Arango[33] indicates, athletes have a natural tendency to reach higher amplitudes of movement with the dominant limb due to repetition. In the specific case of AG, gymnasts often perform specific technically very difficult movements with only one arm. Therefore, it is essential to raise awareness among coaches to encourage work on flexibility with the same intensity in both upper limbs and avoid decompensations which could, in the long term, manifest themselves in the form of injury.

Finally, no relationship was found between the overall FMS score and previous injuries. Since Cook *et al.*[12] published the FMS, there have been several controversies about its use as a tool for identifying the risk of injury. Several studies have found a clear association between FMS scores and the occurrence of injuries and significant differences between injured and non-injured subjects in overall FMS scores[14,34-36]. Other studies, however, have not found such differences or association, as was the case in the results of our study[18,37–39].

Perhaps the differences not found between the two groups in this study could be due to the lack of a larger sample. As indicated by Alemany *et al.*[25], several studies carried out these days use small samples that are not statistically representative, which leads to a lack of association between the risk of injury and the FMS. Another point could be the criterion chosen to determine the group of injured subjects, because they were gymnasts who had recovered from injuries suffered the previous season. Additionally, the demanding neuromuscular training that these gymnasts receive, acrobatic gymnastics being a sport that requires a very high level of technical execution, may have influenced the very acceptable FMS scores obtained in the two groups[20,40]. Future studies should investigate the ability of the FMS to identify the risk of injury in a larger sample using prospective designs or retrospectively by evaluating gymnasts recently injured prior to the FMS evaluation or who are even in the recovery phase, as long as evaluation is possible and convenient. Likewise, it seems essential to observe the compensations used in the execution of each FMS test.

Finally, with regard to BMI, it should be noted that the majority of the gymnasts (75%) were classified as normal weight, thus obtaining a healthy BMI, with only a low percentage of gymnasts with grade I thinness (20%) and a single gymnast with grade III thinness according to the indicators proposed by Cole *et al.*[41].

The chief limitations of this study lie in the small size of the sample, which means that the results cannot be generalised to the rest of young gymnasts in this discipline.

Conclusions

In view of the above, we can conclude that the results of the total FMS score were slightly higher in those gymnasts who had not suffered injury the previous season. These gymnasts scored better in all the tests except trunk stability in push-ups and torso rotary stability on both sides. These differences, however, were not significant. Likewise, there was no relationship between the total FMS score and the group of injured gymnasts.

Practical applications

As a practical application, this series of tests is valid to establish the functional profile of these gymnasts. It could, therefore, be used as a basic tool for their coaches at the beginning of the season, since it would allow them to identify limitations in certain movement patterns in their gymnasts, design exercises which can correct those deficits individually and reduce in part the risk of possible injuries[41]. Additionally, the five bilateral tests in the FMS can provide information which may be valid in order to programme training aimed at achieving symmetry between limbs and reducing possible future injuries. Finally, it can be used to monitor fitness after an injury and define the appropriate time for gymnasts to return to training, especially in the case of knee injuries[42].

Conflict of interest

The authors do not declare a conflict of interest.

Bibliography

1. Vernetta M, López-Bedoya J, Gutiérrez A. La creatividad de la gimnasia acrobática. In: *Creatividad y deporte Consideraciones teóricas e investigaciones breves*. Sevilla: Wanceulen.; 2008. p. 133–56.
2. Taboada Y, Vernetta M , Gutiérrez-Sánchez A. Anthropometric profile in different event categories of acrobatic gymnastics. *J Hum Kinet*. 2017;57:169–79.
3. Vernetta M, Montosa I, López-Bedoya J. Lesiones en jóvenes gimnastas femeninas de acrobática de la élite nacional. *Rev Iberoam ciencias la Act Física y el Deport*. 2018;8:71–84.
4. Grapton X, Lion A, Gauchard GC, Barrault D PP. Specific injuries induced by the practice of trampoline, tumbling and acrobatic gymnastics. *Knee Surg Sports Traumatol Arthrosc*. 2013;21:494–9.
5. Martins Ú, Cunha J, França L, Amaro J, Gomes J & Branco CA. I was an acrobat. Am i in pain?. *Br J Sports Med*. 2017;51:357–8.
6. Purnell M, Shirley D, Nicholson I & Adams R. Acrobatic gymnastics injury: occurrence, site and training risk factors. *Phys Ther*. 2010;11:40–6.
7. Rego F, Reis M, OR. Lesõesem ginastas portugueses de competição das modalidades de trampolins, ginástica acrobática, ginástica artística e ginástica rítmica na época 2005/2006. *Rev Port Fisioter no Desporto*. 2007;21:21–7.
8. Vernetta-Santana M, Ariza-Vargas L, Martínez-Patiño MJ , López-Bedoya J. Injury profile in elite acrobatic gymnasts compared by gender. *J Hum Sport Exerc*. 2021;
9. Bennett H, Arnold J, Martin M, Norton K, Davison K. A randomised controlled trial of movement quality-focused exercise versus traditional resistance exercise for improving movement quality and physical performance in trained adults. *J Sports Sci*. 2019;37:2806–17.
10. Fernández-Pino JA, Figueroa-Contreras DE, Garcés-Mondría FI, Montalva-Purcell B, Olivares N, Alonso R. *Calidad de movimiento evaluado a través del Test FMS en* estudiantes de primer año de la carrera de Educación Física durante el año 2016. Doctoral dissertation, Universidad Andrés Bello. 2017.
11. Villalobos-Samaniego C, Rivera-Sosa JM, Ramos-Jimenez A, Cervantes-Borunda MS, Lopez-Alonzo SJ, Hernandez-Torres RP. Métodos de evaluación del equilibrio estático y dinámico en niños de 8 a 12 años. *RETOS*. 2020;37:793-801.
12. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function - part 1. *N Am J Sport Phys Ther*. 2006;1:62.
13. Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function - part 2. *N Am J Sport Phys Ther*. 2006;1:132–9.

14. Kiesel K, Plisky PJ VM. Can serious injury in professional football be predicted by a preseason functional movement screen? *N Am J Sport Phys Ther.* 2007;2:147–58.
15. 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;45:725–32.
16. Bunn PDS, Rodrigues AI, Bezerra da Silva E. The association between the functional movement screen outcome and the incidence of musculoskeletal injuries: A systematic review with meta-analysis. *Phys Ther Sport Off J Assoc Chart Physiother Sport Med.* 2019;35:146–58.
17. Gil-López MI, García-Hurtado M y Hernández-García R. Valoración funcional básica del judoka: Un estudio piloto. *Rev Artes Marciales Asiáticas*. 2018;1:20–2.
18. Hernández-García R, Rodríguez-Díaz L, Molina-Torres, G y Torres-Luque G. Efectos de un programa de actividad física con el método pilates sobre la funcionalidad de mujeres embarazadas. Estudio piloto. *Rev Iberoam Ciencias la Act Física y el Deport*. 2018;7:40–52.
19. Li Y, Wang X, Chen X, Dai B. Exploratory factor analysis of the functional movement screen in elite athletes. *J Sports Sci.* 2015;33:1166–72.
20. Vernetta M, Salas A, Peláez-Barrios EM , López-Bedoya J. Calidad de movimiento en adolescentes practicantes y no practicantes de Gimnasia Acrobática mediante la batería Funtional Movement Screen. *Retos.* 2021;41:879–86.
21. Dorrel BS, Long T, Shaffer S, Myer GD. Evaluation of the functional movement screen as an injury prediction tool among active adult populations. *Sports Health.* 2015;7:53–9.
22. Cook G. Movement: Functional movement systems: Screening, assessment, corrective strategies. Book Baby. 2010.
23. Troule S, CD. Application of functional test to the detection of asymmetries in soccer players. *J Sport Heal Res.* 2016;8:53–64.
24. de Orbe Moreno M, Salas Morillas A, Vernetta Santana M. Evaluación de la calidad de movimiento en escolares mediante el Functional Movement Screen: una revisión. *Sport Sci J Sch Sport Phys Educ Psychomot.* 2021;7:199–217.
25. Alemany J, Bushman T, Grier T, Anderson M, Canham-Chervak M, North W, *et al.* Functional movement screen: Pain versus composite score and injury risk. *J Sci Med Sport.* 2017;20:S40–4.
26. Caine D NL. Gymnastics injuries. *Med Sport Scl.* 2005;48:18–58.
27. Gil-López M, Sanchez-De la Vieja C, Hernández-García R. Perfil funcional básico de los jóvenes del programa nacional de tecnificación en bádminton. *JUMP.* 2021;3:1–9.
28. Vernetta M, De Orbe M, Salas A. Práctica extraescolar del baloncesto y calidad de movimiento en chicas adolescentes. *Rev Iberoam Ciencias la Act Física y el Deport.* 2020;9:75–93.
29. Holfelder B, Schott N. Relationship of fundamental movement skills and physical activity in children and adolescents: A systematic review. *Sport Exerc Perform Psycho.* 2014;15:382–91.
30. Peate WF, Bates G, Lunda K, Francis S, Bellamy K. Core strength: a new model for injury prediction and prevention. *J Occup Med Toxicol..* 2007;2:1–9.
31. Nadler SF, Malanga GA, Feinberg JH, Prybicien M, Stitik TP, DePrince M. Relationship between hip muscle imbalance and occurrence of low back pain in collegiate athletes: a prospective study. *Am J Phys Med Rehabil.* 2001;80:572–7.
32. Sands WA, McNeal JR, Stone MH RE, JM. Flexibility enhancement with vibration: acute and long-term. *Med Sci Sport Exerc.* 2006;38:720–5.
33. Arango LZ. El uso de ambas manos posibilita un desarrollo mayor. P*ediatr Rev Colomb Pediatr.* 2003;38.
34. Chang WD, Lu CC. Sport-Specific Functional tests and related sport injury risk and occurrences in junior basketball and soccer athletes. *Biomed Res Int.* 2020;
35. Rowe K. Using the Functional Movement Screen® and Y-balance test to predict injury in division iii volleyball players. Masters of education in human movement, sport, and leisure studies graduate projects. 2020. 84.
36. Syafei M, Budi DR, Listiandi AD, Festiawan R, Kusnandar K, Nurcahyo PJ, Qohhar W. Functional movement screening: an early detection of the student injury risk in sport class. *J Pendidik Jasm dan Olahraga*. 2020;5:182–91.
37. Bardenett SM, Micca JJ, DeNoyelles JT, Miller SD, Jenk DT, Brooks GS. Functional movement screen normative values and validity in high school athletes: can the fmstm be used as a predictor of injury? *Int J Sports Phys Ther.* 2015;10:303.
38. Rusling C, Edwards K, Bhattacharya A, Reed A, Irwin S, Boles A HL. The functional movement screening tool does not predict injury in football. *Prog Orthop Sci*. 2015;1:1.
39. Smith PD, Hanlon MP. Assessing the effectiveness of the functional movement screen in predicting noncontact injury rates in soccer players. *J Strength Cond Res.* 2017;31:3327–3322.
40. Portas MD, Parkin G, Roberts J, Batterham AM. Maturational effecton Functional Movement Screen™ score in adolescent soccer players. *J SciMed Sport.* 2016;19:854–8.
41. Miller JM, Susa KJ. Functional movement screen scores in a group of division IA athletes. *J Sports Med Phys Fitness*. 2018;
42. Davies GJ, McCarty E, Provencher M, Manske RC. ACL Return to sport guidelines and criteria. *Curr Rev Musculoskelet Med.* 2017;10:307–14.