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The Functional Movement Screen's Relation to Young Tennis Players' Injury Severity

La relación de la Evaluación Funcional del Movimiento con las lesiones de los jóvenes jugadores de tenis

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Abstract

This study aimed to explore the relationship between functional movement screen (FMS) scores and injury severity in young tennis players. Additionally, we investigated the effect of the characteristics of the training programme on injury severity. During the annual testing and screening, we assessed 181 tennis players aged between 12 and 18. The Functional Movement Screen was used to measure multiple movement factors, to detect deficits in gross movement quality, to identify movement asymmetries, and to predict general musculoskeletal injury risk. The cohorts' mean composite FMS score was 16.02 ± 1.98. Players scored higher in shoulder mobility and active straight leg raise, while the lower scores were obtained in the deep squat and rotary stability. We found that the FMS composite scores were higher for players who had not been injured and lower for players who had not trained or competed for >4 weeks due to injury. There was a significant association between the FMS composite score and injury severity. Namely, the group of players who had been injured for >4 weeks, reached the lower average FMS score (14.95). It was found that more hours of tennis practice per week increased, significantly, the injury severity, while more hours of fitness and conditioning practise decreased significantly the injury risk for the 6-months following the FMS testing.

Key words: tennis; FMS screening; fitness; conditioning.

Resumen

El objetivo de este estudio fue explorar la relación entre las puntuaciones de las Pruebas de Movimiento Funcional (FMS) y la severidad de las lesiones en jóvenes jugadores de tenis. Además, se investigó el efecto de las características del programa de entrenamiento sobre la severidad de la lesión. Durante las pruebas y exámenes anuales evaluamos a 181 jugadores de tenis de entre 12 y 18 años de edad. La FMS se utilizó para medir múltiples factores de movimiento, para detectar deficiencias en la calidad del movimiento amplio, para identificar asimetrías de movimiento y para predecir el riesgo general de sufrir lesiones músculo esqueléticas. La puntuación promedio del FMS compuesto del grupo fue de 16,02 ± 1,98. Los jugadores obtuvieron una puntuación más alta en la movilidad de los hombros y en el levantamiento activo de la pierna estirada, mientras que las puntuaciones más bajas se dieron en la sentadilla profunda y la estabilidad rotatoria. Se ha constatado que los jugadores que no se habían lesionado obtuvieron puntuaciones compuestas de la FMS mayores, mientras que las más bajas las obtuvieron los jugadores que no habían entrenado o competido durante más de 4 semanas debido a una lesión. Se encontró una asociación significativa entre la puntuación compuesta de la FMS y la duración de la lesión. Concretamente el grupo de jugadores que había estado lesionados durante más de 4 semanas alcanzaron la puntuación media de FMS menor (14,95). Los jugadores que participaron en más entrenamientos y sesiones de preparación física se ausentaron con menos frecuencia de los entrenamientos y torneos.

Palabras clave: tenis; examen FMS; fitness; preparación física.

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Introduction

Tennis is becoming increasingly competitive in junior categories. Over 12,000 players compete in ITF tournaments that are included in the world junior ranking of boys and girls U18 (International Tennis Federation, 2018). A little over 2,000 juniors manage to collect ranking points and make it on to the world ranking list. This statistic explains the higher number of competitions players are involved in, which also increases the number, volume, and intensity of training, thereby posing a higher risk of injury (Fett, Ulbricht, Wiewelhove, & Ferrauti, 2016). Frisch, Croisier, Urhausen, Seil, and Theisen (2009) found that a higher scope and intensity of training increases the possibility of injury or overload syndrome. Early detection and prevention of injury are therefore very important. The overall injury rate in tennis varies greatly from 0.04 injuries/1000 hours to 21.5 injuries/1000 hours of playing tennis, depending on the definition of injury (Pluim, Staal, Windler, & Jayantha, 2006). Lower limbs injury was the most common injury location for male players and torso injuries for female players. Muscle injuries were the most common type in both groups (Moreno-Pérez, Hernandez-Sanchez, Fernandez-Fernandez, Del Coso, & Vera-Garcia, 2018). Kibler and Safran (2005) stated that more an athlete participates in tennis and other sports training, higher is the injury frequency.

The purpose of diagnostic procedures is to focus on the development of particular dimensions that are required in subsequent phases of sports training. Musculoskeletal testing is a method for identifying players who are at risk of muscle strain injury (Fernandez-Fernandez, Ulbricht, & Ferrauti, 2014). It is based on static measurements and clinical examinations of joint integrity and range of motion. The United States Tennis Association uses 10 tests to assess tennis players. These tests reliably measure flexibility and the range of motion of all body joints. The Functional Movement Screen (FMS) is a relatively inexpensive and time-efficient tool for measuring multiple movement factors, with the goal of predicting the general risk of musculoskeletal conditions and injuries (Minick et al., 2010). FMS consists of seven fundamental movement tests. Based on previous research (Schneiders, Davidsson, Hörman, & Sullivan, 2011; Šimenko, 2012; Gribble, Brigle, Pietrosimone, Pfile, & Webster, 2013; Smith, Chimera, Wright, & Warren, 2013; Leeder, Horsley, & Herrington, 2016), FMS has proven to be a reliable tool for detecting deficits in gross movement quality and identifying movement asymmetries. A qualified assessor evaluates flexibility, stabilisation, and motor control for an individual movement test (Cook, Burton, & Hoogenboom, 2006; Cook et al., 2014). Previous studies have demonstrated moderate to good interrater and intrarater reliability of FMS (Onate et al., 2012; Garrison, Westrick, Johnson, & Benenson, 2015). FMS can help identify a typical adaptation in throwing shoulder among handball players (Slodownik, Ogonowska-Slodownik, & Morgulec-Adamowicz, 2017). Garrison et al. (2015) also found that if the FMS result was lower than 14, the risk of injury increased 15-fold. Garbenytė-Apolinskienė, Šiupšinskas, Salatkaitė, Gudas, & Radvila (2017) analysed young male and female basketball players and the composite FMS scores of both observed groups were higher than 14. Lockie et al. (2015) established that FMS has a limited ability to detect movement compensation that could impact athletic performance. The screen can be used to help design specific corrective exercises for athletes, that may minimize injury (Miller & Susa, 2018).

Fett et al. (2016) analysed the training characteristics of young tennis players. They found that total training volume and tennis training volume vary in three different quality groups of young tennis players. The highest quality group of tennis players demonstrated a significant relationship between total training volume and tennis ranking. At the same time, Lloyd and Oliver (2012) highlighted that physical fitness is an important area in young tennis players' long-term development. Reid and Schneiker (2007) added the need to develop core stability and flexibility that are, without a doubt, significant for injury prevention.

Previous studies associated with the FMS have typically addressed a smaller number of athletes from different sports. The rationality behind comparing FMS scores of athletes from different sports is questionable. For the purpose of this study, we therefore, designed a larger sample of participating young athletes who all had one sport in common – tennis. To our knowledge, no similar studies have thus far been conducted.

This study aimed to explore the relationship between functional movement screen scores and tennis players' injury severity in the six months prior to performing the tests. The hypothesis was that young tennis players with a lower FMS score had not trained and competed in a longer period of time. Additionally, we wished to investigate the effect of a player's age, the number of years spent playing tennis, and training programme characteristics on injury severity. Fuller et al. (2006) defined injury severity as the number of days that elapse between the date of injury and the date of the player's return to full participation in training and availability for competition.

Methodology

Participants

Members of national junior tennis teams in the U12, U14, U16, and U18 categories were assessed during annual testing and screening organised by the National Tennis Association. The study included a cohort of 181 players, more specifically 111 boys and 70 girls. The average age of the players was 14.6 ± 1.7 years, their average body height 171.3 cm ± 10.0, and their average body weight 59.6 kg ± 11.8. The study participants were classified into four groups based on injury severity. The first group included players without injuries, the second included players who had not trained or competed for 1 week (light injury), the third was comprised of players with up to a 4 week absence (moderate injury) and the fourth group was made up of players who had not trained or competed for more than 4 weeks (serious injury). Additional descriptive data of players' age, frequency, and duration of tennis and fitness & conditioning practises in each group are presented in Table 1.

Table 1. Descriptive data of players' age, frequency, and duration of tennis as well as fitness & conditioning practices in four different groups.

Group	1 - no injury		2 - light injury		3 - moderate injury		4 - serious injury	
N	34		79		46		22	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age	14.41	1.57	14.51	1.63	14.26	1.78	16.07	1.21
Years of playing tennis	8.79	2.10	8.46	2.30	8.30	2.41	11.45	1.56
No. of tennis practice sessions per week	4.74	1.58	4.48	1.58	4.50	1.63	6.45	2.22
Hours of tennis practice per week	9.32	2.76	9.78	3.80	9.66	3.84	14.73	3.12
No. of fitness & conditioning sessions per week	1.82	0.72	2.05	0.85	1.85	0.82	3.00	0.69
Hours of fitness & conditioning practice per week	1.95	0.86	2.21	1.02	1.98	0.94	3.73	1.32

The study was conducted in accordance with the ethical standards outlined in the 1964 Declaration of Helsinki, following the 6th revision of 2008. Participation was based on written applications submitted by clubs and coaches. Individual tennis players, their coaches, and parents received information about the study before the tests, and we obtained their signed consent before collecting data.

Procedures

Three certified FMS experts collected the FMS data in the laboratory for movement analysis at the Faculty of sport, University of Ljubljana. Each tennis player was assessed individually and given three trials for each of the seven sub-tests (active straight leg raise, deep squat, in-line lunge, hurdle step, shoulder mobility, rotary stability, and trunk stability push-up). Tests were scored on a 0-3 ordinal scale. An overall composite FMS score (FMS total) with a maximum value of 21 was calculated, and the participants were informed of their scores. The administration and scoring procedures were consistent with the standardised version of the FMS test developed by Cook et al. (2006). The FMS experts used a four-scale scoring criteria: a score of 0 was given if pain was reported during the movement; a score of 1 indicated failure to complete the movement or loss of balance during the movement; a score of 2 was given for the completion of the movement with compensation; and a score of 3 indicated performance of the movement without any compensation.

The FMS test was obtained in October 2017 before the start of training preparation. Injury data was collected using a medical history questionnaire to determine prior and current musculoskeletal injury in the six months following the FMS test. Tennis players, assisted by their coaches or parents, answered questions about their age, the number of years they had been playing tennis, their training programme characteristics, the location and type of injury they had sustained (e.g., sprain, contusion), and the severity of their injuries. To evaluate injury severity, we adjusted the Fuller scale (Fuller et al., 2006).

Statistical analysis

All statistical analyses were computed using the Statistical Package for the Social Sciences (Version 22.0; IBM Corporation, New York, USA). Parameters of the descriptive statistics (mean ± standard deviation) and verification of the normality of distribution using the Shapiro-Wilk test were calculated for all variables. ANOVA was used to detect differences between the four groups of tennis players, distributed according to the severity of their injury. The post hoc Bonferroni Test was conducted to indicate differences between the four groups of players (based on injury severity). A linear regression was used to assess the relationship between injury severity and players' age, years spent playing tennis, and training programme characteristics. Statistical significance for all tests was set at $P < 0.05$

Results

The Shapiro-Wilk test showed that the results for all variables were normally distributed. The results (mean and standard deviation) for the seven FMS variables for all subjects are presented in Table 2. The mean composite FMS score for the sample was 16.02 ± 1.98. Participants had the highest scores in shoulder mobility and active straight leg raise, while the lowest values were measured for the deep squat and rotary stability. In total, 181 young tennis players were screened with the FMS test. In the six months prior to these tests, 34 tennis players (18.8%) were not injured, 79 (43.6%) had not trained for 1 week due to injury (light injury), 46 (25.4%) had been absent from practice for up to 2 weeks (moderate injury) and 22 (12.2%) had been injured for 4 weeks or more (serious injury).

Table 2. Descriptive data (mean and standard deviation) for FMS variables

Variables	Mean	SD	Min	Max
FMS total	16.02	1.98	11	21
Active straight leg raise	2.49	0.54	1	3
Deep squat	1.93	0.54	1	3
In-line lunge	2.20	0.46	1	3
Hurdle step	2.35	0.50	1	3
Shoulder mobility	2.54	0.66	0	3
Rotary stability	2.05	0,28	1	3
Trunk stability push-up	2.48	0.97	0	3

The relationship between musculoskeletal injury and the FMS score (composite and movement patterns) is reported in Table 3. Results of the FMS composite score decrease in relation to our tennis player groups. On average, the highest values were achieved by tennis players without injuries and the lowest by those who had not trained or competed for 4 weeks or more due to injury. Further, in the FMS movement tests, the recorded values decreased in all FMS movement tests, except in the deep squat, in-line lunge, and rotary stability tests. There was a significant association between the FMS composite score and injury severity ($p < 0.05$). Moreover, in all FMS movement pattern tests, with the exception of rotary stability, we established a significant statistical association with the severity of an injury. The post hoc comparisons revealed that differences were significant in almost all variables between players without injuries and those who had not been training/competing for 1 week (except for rotary stability). In addition, most differences between groups were found in the variable active straight leg raise, while no differences were found in rotary stability.

Table 3. Association between FMS variables and injury severity, reflected in duration of absence from training and competitions.

Variables	Groups	N	Mean	SD	F	P value	Post Hoc
FMS total	1	34	18.26	0.45	27.25	0.00	a., d., e.
	2	79	15.61	1.86			a., f.
	3	46	15.11	1.58			d.
	4	22	14.95	2.10			e.
Active straight leg raise	1	34	2.79	0.41	13.10	0.00	a., d.
	2	79	2.44	0.55			a., b., f.
	3	46	2.20	0.50			b., c., d.
	4	22	2.18	0.39			c., f.
Deep squat	1	34	2.21	0.48	5.33	0.00	a., d.
	2	79	1.85	0.56			a.
	3	46	1.80	0.45			d.
	4	22	2.01	0.61			
In-line lunge	1	34	2.56	0.50	10.94	0.00	a., d.
	2	79	2.09	0.40			a.
	3	46	2.11	0.38			d.
	4	22	2.12	0.46			
Hurdle step	1	34	2.82	0.39	17.36	0.00	a., d., e.
	2	79	2.29	0.48			a.
	3	46	2.13	0.40			d.
	4	22	2.02	0.46			e.
Shoulder mobility	1	34	2.91	0.29	6.20	0.00	a., d., e.
	2	79	2.56	0.66			a.
	3	46	2.35	0.71			d.
	4	22	2.32	0.78			e.
Rotary stability	1	34	2.09	0.29	0.85	0.47	
	2	79	2.01	0.25			
	3	46	2.07	0.25			
	4	22	2.09	0.43			
Trunk stability push-up	1	34	2.85	0.36	4.09	0.01	a., e.
	2	79	2.38	0.81			a.
	3	46	2.50	0.78			
	4	22	2.23	0.92			e.

Significant main effect ($p < 0.05$); significant post hoc effects: a. 1 vs. 2; b. 2 vs. 3; c. 3 vs. 4; d. 1 vs, 3; e. 1 vs. 4; f. 2 vs. 4.

The results of linear regressions analysis show statistical significance association between injury severity and hours of tennis and fitness & condition practise per week (Table 4). Tennis players with a larger volume of tennis practice per week have higher chance of injury. On the contrary, a larger number of hours spent in fitness & conditioning statistically significantly lowers injury risk for the 6-months following FMS testing.

Table 4. Association of young tennis players' injury severity with their age, years playing tennis, and training programme characteristics.

Regression coefficient	R Square	Adjusted R Square	Sig.
0.44	0.19	0.18	0.00

Player's and training programme characteristics	Beta	Corr	Sig.
Age	0.13	0.19	0.17
Years of playing tennis	0.03	0.23	0.79
Hours of tennis practice per week	0.45	0.31	0.00*
Hours of fitness & conditioning practice per week	-0.35	-0.07	0.00*

* $p < 0.05$

Discussion

The first conclusion of this article is that there is a significant association between the total FMS score and the four tennis player groups which differed in injury severity. The FMS total score decreased relative to the injury severity and, in the group of tennis players who had been injured for more than 4 weeks, it reached a value of 14.95. This result is in line with the findings of a study by Garrison et al. (2015) which found that a total FMS score below 14 means a 15-time higher risk of injury. In that study, team-sport athletes assessed their past injury history. As in the present study, an injury was not determined based on a medical visit or documentation, but on an assessment of absence from training and competitions. A broad definition of injury may also allow the inclusion of injuries that may affect movement patterns, and which do not allow for optimal performance of training or competitive activities that last for less than 3 weeks. In our study, we used the same definition of injury as that applied by Kiesel, Plisky, and Voight (2007) who found a significant association between the FMS composite score and injury in professional football players. Athletes with dysfunctional fundamental movement patterns reflected in an FMS composite score below 14 had a greater chance of suffering serious injury, although the score cannot be used to establish a cause-effect relationship.

Similar to Chorba et al. (2010), we found that fundamental compensatory movement patterns can increase the risk of injury in tennis players. FMS composite values below 14 increase the risk of lower extremity injury in a competitive season four-fold. On the contrary, Dossa, Cashman, Howitt, West, and Murray (2014) found that a lower FMS score was not significantly associated with injury. Lower FMS composite scores (≤14) in major junior hockey players, measured before the start of a competitive season, did not predict the risk of injury throughout the season. Among the possible reasons for the non-significant association of FMS composite scores and injury, the authors mentioned a different method for determining injury severity. An injury was defined as an event that resulted in a hockey player not playing in one or more official games. Similarly, Warren, Smith, and Chimera (2014) found that the FMS composite score was not different between injured and non-injured college athletes from various sports (including nine tennis players). There was also no association found between FMS movement pattern asymmetry and injury. However, athletes who had an injury were significantly older and lighter. It is precisely this diversity of the athletes included in the study, from track-and-field, basketball, football, swimming, and others, that may explain the lack of visible differences in FMS scores between injured and non-injured athletes.

In our opinion, the different correlations between FMS results and injuries are a result of the great diversity in motion patterns occurring within different sports and of symmetrical (swimming, track and field, cross-country) or non-symmetrical loads (tennis, golf). In the present study, significant differences were presented in all FMS tests except for rotary stability. In rotary stability, an athlete in a four-point quadruped position had to perform a diagonal position with the shoulder and contralateral hip. In this study, tennis players who were not injured had the highest values for all measured tests, indicating a higher level of flexibility, stabilisation, and efficient motor control in an individual movement test. However, the results of this study can be interpreted more broadly because a larger number of junior tennis players of both genders was screened. Many authors (Chorba et al., 2010; Warren et al., 2014; Garrison et al., 2015) have searched for an association between the FMS composite score and injury occurrence or whether, based on the FMS test, one can predict the possibility of injury.

We were interested in the cause-effect relationship between injury severity and a player's age, number of years of playing the sport, volume of tennis training, along with fitness & conditioning practices per week. In our study, the amount of time spent in tennis training proved to be a significant factor affecting injury severity. Players with a serious injury were found to be older, they had been playing tennis longer, and had significantly more specialized tennis training. A greater volume of tennis training, which involves many repetitions of strokes, intense movements, and one-sided workloads on the upper part of the body, was also correlated with a greater risk of injury. Hjelm, Werner, and Renstrom (2012) found that playing tennis for more than 6 hours per week was one of the identified risk factors increasing the chance of back injury. In addition, one-sided movement (the dominant side of the body) or local strain (shoulder) create body asymmetries which also present a risk factor for injury occurrence. Several studies have reported that strength, flexibility, or performance asymmetries were associated with injury in adolescent and college athletes (Knapik, Bauman, Jones, Harris, & Vaughan, 1991; Zifchock, Davis, Higginson, McCaw, & Royer, 2008; Brumitt, Heiderscheit, Manske, Niemuth, & Rauh, 2013).

On the other hand, the number of hours of fitness and conditioning per week was shown to be a factor which significantly reduced the impact of injury occurrence and duration. An important part of fitness and conditioning programmes for tennis players includes preventing injuries. Due to the frequently one-sided physical strain, repetitive rotational movements, and dynamic movements with high amplitude, tennis players must perform activities that reduce or even eliminate the adverse effects of specific tennis training on a daily basis. In tennis, coaches' understanding of the relationship between injury and motor control is increasing. Motor control commonly refers to the selective activation of the deep musculature of the spine, abdomen, pelvis, hip, knee, and shoulder girdle. Reid, Quinn, and Crespo (2003) found that players who had injury prevention training as part of their training programme had fewer injuries during their long-term careers.

Limitations of the study

This study is not without its limitations which should be considered carefully when interpreting and applying its research findings. Since the dominant side of the body is distinctly more strained in tennis, in addition to the seven FMS tests, four measurements to test the level of asymmetry between the dominant and non-dominant sides of the body could also have been included. When analysing a player's injury, we did not receive information on its cause and location. As the tennis players came from various tennis clubs, we were unable to collect data about previous injuries, or the data was unreliable. At the same time, it would be very useful for the purpose of interpretation to know whether the injury was the first of its kind or a repeating one. Concerning the content of the fitness training, the study could benefit from information on the proportion of time dedicated to injury prevention. In addition to the number and scope of training sessions, it would be beneficial to collect data on the number of tournaments and matches played by tennis players in a certain part of the season.

Conclusion

The study results have an applied value because the selected training characteristic of "hours of fitness and conditioning practice per week" proved to be a factor that significantly reduced the impact on injury severity. This finding is an important fact for coaches working with tennis players, especially fitness coaches, and for tennis players themselves. The implementation of tennis-specific injury prevention training programmes (e.g., strength and flexibility) during the annual training and competitive season is required, as it may diminish the severity of injuries and enhance a player's performance.

Conflict of interest

The authors have declared no conflict of interest.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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