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The Association between the Injury Risks and the FMS among the Chinese High-Level Table Tennis Athletes

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Abstract: Objective: *The objective was to examine the association between the Chinese high-level table tennis players' FMS (Functional Movement Screen) scores and the potential risks of injury, and to evaluate which movement was closely associated with the injury risk of Chinese high-level table tennis players.****Design:*** *The ROC (receiver-operator characteristic) curve and discriminant formula was used to determine the relationship between the Chinese high-level table tennis athletes' score on the FMS and the likelihood of injury risk.****Set:*** *The testing sites are located in State General Administration of Sport's training centers.****Participants:****Eighty-one players consisting of nineteen males and sixty-two females were selected from Chinese table tennis national youth team and national excellent women's training team.* ***Main Outcome Measures:*** *Functional Movement Screen™ (FMS).****Results:*** *The potential risks of injury whose scores were less than 12.5 points were about 28.5 times higher than those of players who got the scores more than 12.5points. Discriminant formula had screened out four test movements with injury risks among the Chinese high-level table tennis players, namely deep squat, rotary stability, hurdle step, and active straight-leg-raise.****Conclusions:****The injury risk threshold and the discriminant analysis could be employed together to predict the potential risks of injury using the FMS.*

Keywords: *screening; table tennis, odds ratio; injury risk threshold, discriminant formula*

1. Introduction

As a comprehensive test, the functional movement screen (FMS) can assess the qualities of fundamental movement patterns to ascertain and classify the limitations, the compensation, the asymmetries of participants' movements, and screen the potential risks of injury effectively (Cook et al., 2006a, 2006b). Unlike other assessments, FMS accentuates the quality of movement patterns, rather than the total amount of the movements or repetitions. The qualities of movements can be measured by specific criteria using a scale from 0 to 3 points. The FMS consists of seven testing movements including deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push up, and rotary stability, including three clearing tests such as spinal flexion, spinal extension, and shoulder impingement (Cook etal, 2006a, 2006b; Cook et al., 2011; Perry et al, 2012; Teyhen et al, 2012). As a rapid, inexpensive, and easily administered reliable tool, which was invented by Gray Cook and Lee Burton in the 1990s, it bridges the gap between the medical tests and sport performances (Onate et al., 2012; Parenteau-Get al., 2014; Smith, Chimera, Wright, Warren, 2013; Teyhen et al., 2012).

Previous researchers have illustrated that FMS test possesses substantial interrater and intra-rater reliability (Gribble, et al., 2013; Gulgin et al., 2014; Onate et al., 2012; Parenteau-G et al., 2014; Shultzet al., 2013; Smith et al., 2013; Teyhen et al., 2012). Different testing methods such as surveillance in real-time and video recording were also deployed by assessors who had the plentiful clinical and FMS experience. In addition, these studies had experimented with various physically active population groups such as active-duty service members (Teyhenet al., 2012), physically active adults (Minick et al., 2010; Onateet al., 2012; Smith et al., 2013), athletes (Loudon, Parkerson-Mitchell, Hildebrand, & Teague, 2014; Shultz et al., 2013), and youth athletes or physically active children (Butler, 2012;Parenteau-G et al., 2014). Moreover, after reviewing systematically with meta-analysis,The FMS seems to be a reliable tool which can be utilized within clinicians' clinical practice (Jennifer W et al., 2016).

Other research reports have demonstrated that a score of less than or equal to 14 points on the FMS

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can predict the injury risk for professional football players. While Kiesel utilized receiver-operator characteristic to determine the cut score of 14 as predictive of injury in professional football players on the FMS (Kiesel et al,.2007). Chorba (Chorbaet al., 2010) also revealed that a score of less than 14 points on the FMS resulted in an approximate 4-fold increase in the risks of lower extremity injuries in female college football players, female volleyball players, and female college basketball players. O'Connor (O'Connoret al., 2011) found that when the score was less than or equal to 14 points on the FMS, limitations were generated to predict all traumatic or overuse musculoskeletal injuries in officer candidates (sensitivity: 0.45, specificity: 0.71). Similar to Kiesel, Butler used an ROC curve to illustrate an FMS score of less than or equal to 14 points between those at a greater risk for injury and those not in firefighters (Butler et al,2013). Peate (Peate et al., 2007) studied the correlations between FMS performance and the histories of prior injuries among 433 firefighters. After adjusting the ages of participants and dichotomizing to either passing scores above 16 points or failing scores below 16, the odds ratios of failing the FMS were 1.68 times higher in firefighters compared with previous histories of any injury.

However, up to now, there had been no studies described the use of FMS as a predictor of injury risks among table tennis players. All the Chinese high-level table tennis players build on high-intensity training every day, accompanying compensatory movement strategies for high performance. Although movement patterns may be reinforced by some movement strategies which sometimes turn out to be inefficient, repetitive micro traumas may lead to severe injuries or chronic pains, especially non-contact injuries over time (Cooket al., 2006a, 2006b). As a result, preventing table tennis–related injuries that frequently occur among the Chinese high-level table tennis players comes to the fore. Therefore, the fundamental purpose of this study was to explore the relationship between the Chinese high-level table tennis players' FMS scores and the potential risks of injury. Secondly, it was to identify which movement bears the strongest link with the injury risks of Chinese high-level table tennis players over the course of one competitive season.

2. Method

2.1. Experimental Approach to the Problem

The ROC curve was employed to examine the relationship between the Chinese high-level table tennis players' scores on the FMS and the potential risks of injury. Discriminant formula was applied to find out which movement on the FMS was closely associated with the injury risk of Chinese high-level table tennis players.

2.2. Participants

Eighty-one participants in total were tested before the competitive season (19 males, height=175.7±4.5cm, weight=65.7±6.8kg, training age=11.1±1.3 years, one world champion; three international champion; fourteen athletes Asian champion, and one national level of athletes;62 females, height=166.3±4.7cm, weight=60.3±4.7kg, training age=10.5±1.5 years, two world champion; international champion; twenty nine athletes, and twenty two national level of athletes. All participants were asked to restrain from any physical training for 24 hours before the test at the National Sports Training Centre. They were required to sign an informed consent and informed of the testing procedures. Ethical permission was reviewed and approved for this study by the Chinese Committee of Sport Science Research.

2.3. The Characteristics of Assessor

The experienced assessor had worked in the Chinese national table tennis team for more than 5 years, who was certificated as a table tennis strength and conditioning coach and FMS Level 1 specialist.

2.4. Procedures

The tests for table tennis players had been accomplished at the National Training Center before pre-season. Non-standardized warm-up exercises were organized by the strength and conditioning coach. All players completed the consent forms. The FMS was also explained to the players as described by Cook (Cook et al., 2006a, 2006b).

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While researchers utilized the scoring system as described by Cook (Cook et al., 2006a, 2006b), the FMS evaluated the quality of fundamental movement patterns by categorizing an individual's performance on the movement using 0 to 3 on an ordinal scale. A score of 3 was given if the subject performed the movement correctly without any compensation. A score of 2 was given if the subject was able to complete the movement but with some compensations to perform the fundamental movement. A score of 1 was given if the subject was unable to complete the movement pattern or unable to assume the position to perform the movement. If the participant feels pain, a score of 0 was marked, meanwhile the pain area must be noted. Each participant was tested by seven different movements in accordance with their performance. Five movements which were hurdle step, in-line lunge, shoulder mobility, active straight leg raise, and rotary stability were scored independently on both sides, and the tester recorded the lowest score for one movement. At last, a composite score was recorded. FMSTM, which can evaluate the quality of movements, include a measuring device, a measuring stick, and a hurdle. The best score of three times was recorded for the data analysis (Cooket al., 2006a).

Injuries that emerged in sport activities were recorded. The term of injury in the study is defined as follow: the following 4 conditions are satisfied; the participant due to sports injury is absent from one-week tactical training and physical training exercises during the training and matches within the team; the participant is absent from more than two games of super league or open tournament in the course of the competition season, which is caused by sports injury; the participant asks for help from the strength and conditioning coach and physical therapist; injuries are engendered by training or competition. The injury surveillance time for the study lasted about one full season, approximately half a year.

2.5. Statistical Analysis

Data were analyzed and summarized by SPSS 20.0. Descriptive statistics were used to summarize the data. Mean and standard deviation was computed for the composite scores, which is expressed as Mean ± SD. Moreover, ROC curve guarantees that cut-off score could maximize the specificity and the sensitivity. Using the data can help figure out which movement from the FMS is in tune best with the injury risks of Chinese high-level table tennis players (Kiesel et al., 2007). Discriminant analysis was also employed to screen out which movement was closely linked to the injury risks. All tests were used two- tailed tests, and the p-value was set at $p < 0.05$.

3. Results

Upon the analysis of the ROC curve (Figure 1) and the corresponding table of sensitivity and specificity values, we observed that a score of 12.5 maximized specificity and sensitivity of the test.

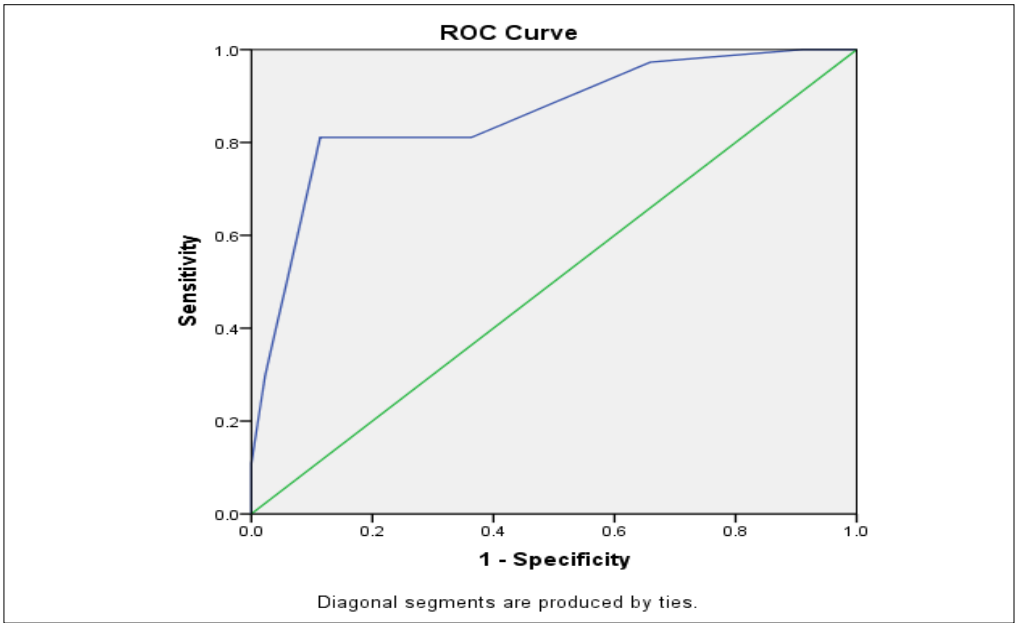

Figure 1. ROC curve for the composite scores and injury situation

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With a 95% confidence interval ranging from 0.775 to 0.943, the result of this study was 0.859. This cut-off score represents a sensitivity of 0.811 and a specificity of 0.886 (Table 1). Nevertheless, the mean score is 13.4±1.5. For participants who suffered an injury, the mean score is 12.0±1.2, while for those who were not injured, the mean score is 13.9±1.2. The mean score of participants who suffered an injury is significantly different from those who were not ($df = 79; t = 5.214; p<0.05$).

Table 1 Coordinates of the ROC curve

FMS scores	Sensitivity	1 –Specificity
9.0000	.000	.000
10.5000	.108	.000
11.5000	.297	.023
12.5000	.811	.114
13.5000	.811	.364
14.5000	.973	.659
15.5000	1.000	.909
17.0000	1.000	1.000

The odds ratio is 28.5 (CI 95= 8.451—96.108). It could be interpreted that when the Chinese high-level table tennis players' FMS scores are less than or equal to 12.5, they will experience a surge in injury risks at 28.5 times compared with those whose scores are higher than 12.5 prior to the start of the table tennis season (Table 2).

Table 2 Calculation of odds ratio

Subjects			Asymptotic 95% confidence interval	
			lower	Upper
5.00	Odds ratio score (>12.5 / .)	.a		
8.00	Odds ratio score (>12.5 / .)	.a		
30.00	Odds ratio score (<12.5 / .)	.a		
38.00	Odds ratio score (<12.5 / .)	.a		
Total	Odds ratio score (<12.5 / >12.5)	28.500	8.451	96.108
	Injury	4.929	2.588	9.386
	Healthy	.173	.076	.394
	Valid	81		

Based on the discriminant analysis, we found that four movements were most closely related to the injury: deep squat, hurdle step, rotary stability, and active straight leg raise. Table 3 revealed the coefficients and constants of discriminant formula (Table 3).

Healthy group=79.093+20.254X1+16.138X2+17.649X3+9.454X4

Injury group: Y=65.077+19.158X1+14.966X2+16.478X3+8.247X4

Table 3 Classification function coefficients

	Classification	
	Health	Injury
Rotary Stability	20.254	19.158
Active Straight Leg Raise	16.138	14.966
Hurdle Step	17.649	16.478
Deep Squat	9.454	8.247
Constant	-79.093	-65.077

Finally, the discriminant formula is as follows: X1 is the rotary stability score; X2 is the active straight leg raise score; X3 is the hurdle step score; X4 is the deep squat score. Table 4 illustrates

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the comparisons of the results of ROC and discriminant formula:

Table 4 Comparisons of results of ROC and discriminant formula

	16	15	14	13	12	11	10	Total
simultaneous error	0	1	6	0	4	1	0	12
simultaneous correct	4	11	13	8	19	7	3	65
ROC correct /discriminant error	0	0	0	3	1	0	0	4
discriminant correct /ROC error	0	0	0	0	0	0	0	0
Total	4	12	19	11	24	8	3	81

4. Discussion

The above findings indicated that the Chinese high-level table tennis players whose scores were less than 12.5 points would suffer a potential risk of injury, which was about 28.5 times higher than those with more than 12.5 points. Discriminant analysis had screened out four movements relevant to the injury risks of the Chinese high-level table tennis players: deep squat, rotary stability, hurdle step, and active straight leg raise. To the authors knowledge this was the first study that was involved with the application of Chinese national table tennis players and provides reference data on a miraculous cohort of high-level table tennis players for FMS.Because it not only figures out the ROC curve and injury risks threshold, but also the first time puts forward the discriminant formula for Chinese high-level table tennis players. Different from previous studies that pondered FMS as a whole, discriminant analysis is adopted creatively to find out the discriminant formula for Chinese high-level table tennis players, which has enriched and further encouraged the application of FMS.

To confirm whether the FMS could predict the injury risks, it is crucial to stress the test's ability to screen out the potential risks of injury in Chinese high-level table tennis players. High specificity enhances the test's ability to recognize when the injury will occur. So is the test's sensitivity. However, the reverse is true when a given diagnostic test has high sensitivity (Kiesel et al., 2007). Unlike other reported studies (Kiesel et al., 2007; Peate et al., 2007; O'Connor et al., 2011; Chorbaet al., 2010), the results demonstrate that an FMS score of 12.5 maximizes the specificity and sensitivity of the test in Chinese high-level table players (Table1). In contrast to former studies, in table 1 it could be seen that when the score was 14, the sensitivity of 0.973 scored better with the specificity only 0.341, which reflects that the possibility of screening out the potential risks of injury in this group is 97.3%, whereas the error rate of mistaking the healthy people as injured is 34.1%. When the score is 16, the sensitivity is very good. The correct rate of screening out the potential risks of injury is 100%, while the specificity of 0.091 is too low. However, no research on FMS in high-level table tennis players has been published currently. As a result, no comprehensive comparison could be made. Besides, the injury risk threshold of 12.5 is low. This study gets different injury risk thresholds under in accordance with several considerations that are different sports, different levels of athletes, and different amounts of samples. In particular, different definitions of injury may exert significant influences on results. Preceding studies varied when it came to the definitions of injury. Kiesel (Kiesel et al., 2007) defined an injury as three or more weeks of time absent from football. Chorba (Chorbaet al., 2010) defined an injury criteria :firstly the injury happens as a result of participating in organized training or competition; secondly the injury requires medical attention, or the player seeks advice from a certified athletic trainer or physician. Kiesel (Kiesel et al., 2007) only used absent of time without defining the essence in his study.

Nevertheless, Chorba and O'Connor (O'Connor et al., 2011; Chorbaet al., 2010) both specified that the injury results from trauma or overuse. We hope that a better definition of injury for table tennis players will assist in perfecting the interpretation of data. Chalmers (Chalmers et al., 2017) adopted the definition that an injury is a trauma or medical condition which contributes to a player missing a competitive match. While in this study, an injury is defined as follows. Firstly, Player is absent for two or more games. Secondly, the absence of skill and tactical training is more than one week. Thirdly, the table tennis players have asked advice from the national team's physical therapist. Finally, the injury

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occurs in the course of an organized practice or competition. The inability to train and compete that had a clear impact to high-level table tennis players, especially national table tennis players. A better definition of injury for Chinese high-level table tennis players should be attached great importance as inventors of the FMS hypothesized that repetitive microtrauma resulting from compensatory or poor movement patterns might give rise to chronic pain or musculoskeletal injury, even severe injury. However, this study reveals that a majority of recorded injuries in table tennis are non-contact injuries, which are different from those of hockey that are from slashing, collisions, hits, and puck impact (Khaled et al., 2014). This study denotes that the lower FMS could not predict the injury among junior hockey players. From this perspective, it may predict the injury risks in non-contact sports such as table tennis. For the contact sports like hockey, the FMS does not work to its advantages. Because of the few relevant studies, we recommend that future studies should apply the FMS and seek out the law in more sports.

Nevertheless, the majority of former studies considered the seven movements tested as a whole, using the composite score to predict the potential risks of injury (injury risk threshold). Indeed, it was found that the seven movements tested were not completely correlated with the injury risks in high-level table tennis players. In addition, the discriminant analysis, a kind of statistical analysis method used to determine the observation data of new samples, had been divided into several categories. The advantages of the discriminant formula were that it could take into account not only the prior probability but also the loss caused by the discriminant analysis. Finally, two discriminant formulas that functioned with a large value were obtained, and it was appropriate to check out which category the samples belonged to. Among four movements, three movements required testing on both the left and right sides. Active straight leg raise belongs to the mobility movement; rotary stability attaches to the stable movement; the hurdle step and deep squat pertain to the complete movement. The test consisted of the mobility movement, the stable movement, and the complete movement. It has been the first time to put forward the discriminant formula to apply in the FMS, which actually enriched and promoted the application of the FMS. Overall, the correct rate of the discriminant formula is 80.2%, and the error rate is 19.8%. In the healthy category of 44 healthy persons, 36 persons proved be healthy, while 8 were mistaken for the injury. Thus, the correct rate was 81.8%. In the injury category of 37 persons, 29 were correctly judged as injured, while eight were mistaken as healthy. Hence, the correct rate was 78.4%. Meanwhile, we also discovered that when the scores are 10 and 16, ROC and discriminant formula worked well. While the scores were 11 and 15, the judgment was also good with one mistake. When the score was 14, the error rate was 31.5%, and the judgment appeared to be general. For the score 12, there was no significant difference between ROC and discriminant formula, and the ROC was superior to the discriminant formula in 13 points (Table 4).

However, certain additional limitations should be spotted in this study. First, selection bias exists in the samples that mainly give priority to the Chinese female high-level table tennis players with barely 19 male players, for the author works in the Chinese female table tennis team. Specific groups should be targeted as the subjects for future research. Prepare the number of female and male group as much as possible. Second, on account of some participants winning acclaim as world champions, details of the injury are not open in this study. As a result, a deep analysis into the relationship between the movements and the injured region for Chinese high-level table tennis players could not be taken. Also, concerning the definition of injury, previous studies and the actual situation of table tennis players foster the definition of injury in this study. A unified definition of injury can be employed to explore the FMS for other groups.

5. Conclusion

The results of this study validate the hypothesis that the FMS is available to table tennis players so as to identify the players who are more likely to suffer an injury in the course of competition season. All the movements on the FMS were not applicable to table tennis players. Therefore, the injury risk threshold and discriminant analysis can collaborate as a common method to determine the potential risk of injury. Moreover, the FMS could be recognized as a pre-season screening instrument for injury prevention. A further study that should be explored practically to different sports and different groups to apply the FMS.

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