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Investigation of the accuracy of functional testing on predicting the severity of lower limb injuries of handball athletes

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Abstract

Purpose: The number of damages and severity of the injury has increased in recent years in handball. Recent studies have reported that functional testing before the season is associated with future injuries of athletes. However, the findings related to these studies are inconsistent. The current study aims to examine the accuracy of functional testing to predict the amount and severity of lower limb injuries of handball athletes in Tehran. **Method:** 80 people of handball players (men) of league clubs of Tehran in the age range of 20-30 years were purposefully selected. Next, functional testing, including the Y balance, single-leg jump, and Functional Movement Screen (FMS) was taken from them. The hours of exercise and competition for teams, along with the number of players' injuries, were

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recorded during the half-season of competitions. To predict the severity and incidence rate of the injury, the univariate curve estimation regression test was used. **Results:** The results of this test showed that among functional testing, only single-leg jump ($p= 0.035$) could predict the severity of the injury incidence, and none of the tests the incidence rate of the injury ($p> 0.05$). **Conclusions:** It can be said that only single-leg jump can predict the severity of weak injuries (less than 10 lost days), and screening tests of functional activities have a very limited application to identify the handball athletes at risk of the injury.

Keywords: Screening Tests, Functional Testing, Handball Injuries.

Introduction

Handball is one of the most popular sports fields worldwide, and it was entered from the 1972 Olympics in Munich into Olympic sports (Junge et al., 2004; Junge et al., 2006). Today, handball is played in 199 countries, and there are about 19 million players in 800000 teams around the world (Laver, 2015). It is a sport with high severity that is along with physical collisions among players. In Europe, after football, basketball, is one of the most popular sports (Myklebust et al., 1997; Piri et al., 2011). This sport is developing continuously in terms of the power, speed, and technique of players, and changes in rules and tactics are also observable. Since handball, in contrast to other sports such as basketball, does not have only limitations in terms of errors, but also the error has a component of the team tactic that causes the attack of the opposing team to be disrupted and is considered as a good defense, this, in itself, causes the severe fights among the players who want to stop the opposing players and prevent them from reaching the goal. In this sport, the professional players do about 70-100 plays per annum, due to participating in the league, world, continental, and Olympic games that this factor can cause high injury of players in this sports field (Langevoort et al., 2007; Laver et al., 2015).

In the past three Olympic games, handball has always been one of the superior sports fields in terms of injury rate. In the 2004 Olympics in Athens, handball with 114 injuries per 1000 hours, in 2008, after football, taekwondo, and hockey, and in 2012, after taekwondo, football, and BMX cycling has had the highest injuries; and in 2016 has been one of the 8 fields with the highest injury (Engebretsen et al. 2013; Junge et al., 2009; Junge et al., 2006; Soligard et al.. 2017). Most of the injured handball players have to distance themselves from the competition or exercise for more than a week (Nilson, 1988; Piri et al., 2011), and even in some cases, the injured one must leave the sports fields due to the injury. According to all these cases, it appears that handball injuries are a serious problem for players of this field (Langevoort et al., 2007; Piri et al., 2011). In professional sports teams, general medical evaluations and functional testing are used to identify athletes who are at risk before the season. In this regard, gathering the information resulting from the medical and physical examination of current and retired professional players of the

Netherlands football who had done the tests of circulatory, cardiovascular, musculoskeletal, and mental systems, Akturk et al. (2014) concluded that it must be added more and better tests to them to prevent from long-term diseases and injuries of tests (Akturk et al. 2014). Considering the costs and also the negative consequences related to sports injuries, most of the research is focused on injury prevention. One of the ways to prevent injury in the lower limb is to perform a screening assessment of lower limb injuries to identify people who may be at risk of injury. Several injury screening tests, which consist of one or more practical functions, Specifically, it was done to identify associations with the occurrence of lower limb injury (Gabriel et al. 2020).

Functional tests such as the Y balance test of lower limbs, FMS test of functional movements, and single-leg jump test have been examined for the prediction of the injury in different sports fields and on the various subjects (Azzam et al., 2015; Brumitt et al., 2013; Brumitt et al., 2015; Butler et al., 2013, Doosav et al., 2014; Gonell et al., 2015; Kiesel et al., 2007; Manske et al., 2013; Plisky et al., 2006; Smith et al., 2015). In most of the studies, lower limb injuries have been reported as the most common injury site in professional athletes (Morgan, 2001). A balance disorder is one of the risky factors for the increase in the incidence rate of injury in the lower limbs. Gonell et al. (2015) have reported that the Y balance test can be included in the form of physical tests prior to the season to recognize the athletes who are at risk of the injury (Gonell et al., 2015). Smith et al. (2015) found that asymmetry in anterior access more than 4 cm in both limbs is associated with increased risk of the injury, but they did not find a relation between the total score of this test and the injury (Smith et al., 2015).

Also, in the case of the pre-season FMS test, the reports indicate that a point less than 14 is associated with the increased risk of injuries which leads to time loss and absence from the exercise and next competition (Kiesel et al., 2007). Marques has also reported that young athletes of 14-20 years have a very important defect in overhead squat and trunk stability tests as well as the high prevalence of asymmetry between the right and left side of their body (Marques et al., 2017). Dok et al. (2017) used the FMS to predict the time loss due to injuring in the professional rugby athletes and concluded that the FMS could be considered as a suitable predictor of the time loss due

to injuring (Dok et al., 2017). But on the other hand, Moran, in his review, reported that there is not a relationship between the test score of FMS and prediction of the injury (Moran et al., 2017).

There are also inconsistent studies related to the predictor of the vulnerability of this test regarding the single-leg jump test. For example, Brumitt et al. have reported that athletic women with more than 10% asymmetry between two limbs in the single-leg jump score have four times more likely to face the risk of an ankle injury, but this test cannot predict the injuries of the back and lower limbs in university women athletes (Brumitt et al., 2013).

Asymmetry between limbs in the exercise, i.e., the difference between the limbs in terms of their functional ability (e.g., flexibility, the range of the motion power, and the control of the motion motor), is prevalent especially in athletes involved in one- as well as two-sided sports activities due to the dominant use of one limb over another. Such asymmetry, as noted by sports instructors and physicians, is associated with a decrease in sports function and an increase in the risk of non-contact injuries. In the field of prevention from injury without contact, injuries such as Anterior Cruciate Ligament (ACL) rupture, anterior knee pain (patellofemoral joint pain), and ankle sprains, the disorder in the function of nearby lower extremity joints such as the hip joint may be necessary. Compensation of a farther joint that is associated with the same motion chain in series compromises the entire function of lower limbs (Ioannis Konstantopoulos et al., 2021).

The descriptions above show that the mentioned tests enable to identification the of athletes who are prone to be injured. However, the opposing findings associated with these studies have led the instructors and physicians to hesitate about these tests or their composition for the athletes at risk of the injury. According to the pervasiveness of the handball and high severity and incidence rate of the injury, as well as the high treatment cost of injuries induced by handball and their impact on the decline of the players' athletic course and economical loss of athletic teams, it is necessary to be performed a perfect evaluation in order to investigate the musculoskeletal system aimed to predict the possibility of injury incidence. According to what was expressed, this research aimed to examine the accuracy of functional testing to predict the incidence rate and injury intensity of

handball players of Tehran league in the half-season of the first year of 2020-2021.

Method

The current research is a correlation study in terms of the method and a perspective and a longitudinal one in terms of the type of information collection. The statistical population of this research was all male handball players of Tehran clubs in the age group of 20 to 30 years. Among them, 80 people declared their readiness to participate in the research as a sample and available. 5 of them were removed from the research by the team doctor due to the failure to record the injury record, and finally 75 subjects participated in this research. The anthropometric characteristics of subjects consisted of the mean weight of 76.15±7.52, mean height of 180.18±5, mean age of 26.32±4.28, and mean BMI of 45.55±22.1. The total hours of the exercise and players' competition were registered on the specific hour registration form, and the injuries occurred during the season at the specific injury registration one by the physician of each team. These forms were collected weekly by the examiner. In this study, the injury was registered, which 1. have been occurred during the time of participation in the exercise or competition, and 2. required medical help (the medical team must examine the athlete's condition). Entry criteria include the age range of 20 to 30 years, membership in university teams, having regular handball training (at least three sessions per week), absence of injury and surgery in the lower limbs, and exclusion criteria during the research including the lack of consent of the athlete to continue cooperation, the lack of cooperation was appropriate for the athlete.

FMS testing

The FMS tests include 7 motion tests which enable to identify limitations and changes of normal movement patterns. These tests have been designed for interaction between the motion chain movement and necessary stability to perform the functional and essential motion patterns. In FMS testing, the person was gaining 3 points if he/she could do it correctly without compensated motions desired, 2 points if could do it with compensated motions, and one point if could not enable to do it without compensated motions. This collection includes overhead squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise (ASLR), trunk stability push-up, and

rotary stability tests (Budnar et al., 2013). This study aims to assess the functionality of training with FMS. The assessment of the closed kinetic chain (CKC) has been used for the patients' test (GALI et al., 2021).

Figure 1: FMS testing

Single-leg jump testing

This test is used to evaluate the function, especially in persons who are in the rehabilitation stages of the ACL, in such a way that this test assesses the rate of a person's progress. This is a suitable test to predict the power and strength of the athletes' lower limbs (Hamilton et al., 2008). Also, Reid et al. consider this test as a test having high validity and reliability of 0.82-0.93 in the period of rehabilitation after the athletes' ACL surgery and, for this reason, know it as a suitable test for pre-season evaluations (Reid et al., 2007).

The jump is an inseparable component in many sports (e.g., basketball, handball, and volleyball), and due to the presence of gravitational acceleration, it is associated with landing. To prevent the motion, the athlete should change the motion of CoM to a motion perfectly or performance of the next work (for example, jumping, changing orientation). The landing sequence is associated with increased injury risk to the skeletal muscles, which support from the knee joint, particularly ACL. The ACL rupture occurs in non-contact conditions till 70-80% and sometimes is not directly applied by force

of the opponent player, including speed decrease, sudden change of orientation, and landing.

Figure 2: Single-leg jump test.

The Y balance test

This test is performed in three directions anterior, posterior-internal, and posterior-external; the single-leg subject is placed in the Y center and tried to reach it with another leg when keeping the balance on the support leg. The subject touches the farthest possible point with the help of toes in every determined direction without any error. The distance from the contact location to the center is the achievable distance measured in a centimeter. Since this test has a meaningful relationship with leg length, in order to perform this test and normalize the information, before starting the measurement process, the real length of the leg is measured from anterior superior iliac spine to medial malleolus using a tape measure in the supine position while lying on the ground (Moradi et al., 2015).

Figure 3: The Y balance test.

Results

The results of K-S testing showed that the variables were not normal, so the nonparametric test was used when predicting the variables. Therefore, univariate nonlinear regression analysis was used to predict the time loss and injury rate using the predictor variables. The results of descriptive statistics of the incidence rate and injury intensity have been reported in Table 1.

Table 1: The results of descriptive statistics of the incidence rate and injury intensity.

Variables	The indicator of descriptive statistics			
	The least	**The most**	**Mean**	**SD**
Time loss (the right side of the body) (day)	5 days	More than 90 days	20.1 (3-10 days)	72.1 (3-10 days)
Time loss (the left side of the body) (day)	0	45 days	7.2 (10-120 days)	51.0 (0-3 days)

The results of the univariate curve estimation regression test showed that among the predictor variables, only the single jump of the right leg (p=0.035) could predict injury intensity (Table 2).

Table 2. The results of the univariate curve estimation regression test for the prediction of injury intensity (time loss (day)).

Variable	Coefficient of determination	F	Df_1	Df_2	P	Constant	b1
FMS (loss time)	0.001	90.0	1	63	34.0	191.2	-05.0
Balance	0.10	95.0	1	63	33.0	350.3	-02.0
Single-leg jump	0.049	59.4	1	63	03.0	296.1	01.0

The results of the univariate curve estimation test showed that none of the variables could predict the injury rate of players (p=0.010) (Table 2).

Table 3. The results of the univariate curve estimation regression test for the prediction of the injury rate.

Variable	Coefficient of determination	F	Df_1	Df_2	P	Constant	b1
FMS	0.001	0.004	1	63	0.95	0.34	0.001
Y balance test (right leg)	0.004	0.38	1	63	0.53	0.72	-0.003
Single-leg jump	0.001	0.05	1	63	0.80	0.44	-0.001

Discussion

This research aimed to review the accuracy of functional testing to predict the rate and intensity of handball athletes' injuries. The results of the current study showed that only a single jump of the right leg could predict injury intensity.

This study is in line with some of the past research (Chalmers et al., 2017; Karlsson et al., 2019; Moran et al., 2017; Smith et al., 2015) and not in line with some of the research (Butler et al., 2013; Duk et al.; Keisel et al., 2007; Plisky et al., 2006). From the reasons that this research is not in line with the research by Butler and Keisel, it can be mentioned this point that Keisel's research was a retrospective that maybe not all injuries have been registered in this research as well as a few numbers of samples of this research have been other causes of the inconsistency. Also, they reported that their findings could not be used for establishing the relations between cause and effect (Keisel et a.,

2007). Another reason for contradiction among the studies is that the Y balance testing assesses flexibility, power, and coordination of the lower limb muscles, but Bakken et al. (2018), in their review article, have reported that the muscular power of muscles surrounding the knee joint is of the weak screening tools for the prediction of lower limb injuries in athletes (Bakken et al., 2018). But the quadriceps muscular strength relative to that of Hamstring as well as the hip adductor (HAD) muscular strength relative to the hip abductor (HAB) muscular strength ratio can predict the injury of Hamstring's muscle, quadriceps muscle, and HAD muscle (Dallinga et al., 2012). Butler et al. (2013) used the Y balance testing for predicting the American unprofessional football players' injury at the university level; and since the competition level of athletes is also one of the dangerous factors of the injury and amateur players relative to professional ones suffer from injuries with time loss (van Beijsterveldt et al., 2014), therefore, from the predictive reasons for the injury in this research can obtain the low point in this test and high injury rate in American football. Also, it should be noted that authors of both studies have contributed to the sales profit of Y Balance Test Kit TM Co. as inventors of Y balance testing. That this can affect the research results of these two researchers as well. Although the Y balance test, in contrast to the past findings, may still be suitable for the use of the rehabilitation program and identification of the failure in the dynamic postural control following the injury, our findings do not support this case that this test can be used as a screening tool to predict the risk of the injury in the athletes.

In the present study, the FMS could not predict the severity of the injury. Duk et al. (2017), in their research, used the FMS for the prediction of injuries leading to time loss in rugby athletes and achieved the opposing results compared to the current study (Duk et al., 2017). Also, Chelmerz concluded that asymmetry in doing FMS tests causes the players to be prone to injury during the season, but it was not found any relation between the FMS point lower than 14 and the injury (Chelmerz et al., 2017). Although the researchers have

recorded strong reliability for the screening test of functional movements but reported many contradictions in relation to the validity of this test (Bonazza et al., 2017; Dorrel et al., 2015). To predict the rate and intensity of the injury from one sport to another and according to the existing differences in its sample volume, statistical methods, and various definitions, the FMS use has given the opposing results. So, it must be done more research on the various sports fields to be confirmed the prediction of the FMS injury.

In the current study, the single-leg test of the right leg could predict injury intensity. As the mean injury intensity of the right side was between 3 and 10, this test has been able to predict only the injuries with low intensity, such as the first-degree complexity of the ankle. From inconsistent research, it can be mentioned to Brumitt's research which was reported that pre-season evaluations of vertical jump and single-leg jump in basketball men players of the university could not predict injury intensity (time loss) in the non-contact injuries of lower limbs (such as the ACL injury and ankle sprains), but these functional tests can help the sports medicine specialists return the injured players to the sport (Brumitt et al., 2016). Of course, Brumitt, in his research, assessed the single-leg jump compared to the people's height and another leg jump distance that in this research, this work was not performed. Also, Brumitt, in his research has only reported the non-contact injuries and time loss is more than 10 days due to the non-contact injuries, but in this research, both contact and non-contact ones have been recorded that it appears only contact injuries with low intensity have been predicted. From the limitations of Brumitt's research, it can be mentioned to lack of homogenization of sports fields of subjects that the athletes from 10 different sports fields were selected (tennis, football, wrestling, etc.) and therefore, the rate and intensity of the injury in these fields are different from and not compared with each other.

The human characteristic is two-sided symmetry which divides the body into the right and left along the longitudinal axis of the body with a moving airplane. The right upper limb is dominant in terms of

function. In most of the human, it is evaluated that the frequency of left-handed is 13%. This research has shown that left-handed athletes overinvolved in the exercise (in the professional level of contact sports) while such a dependent is not seen in the non-contact sport. This phenomenon can be described with the reality that this function which is preferred for the left upper limbs, provides an advantage in the one-on-one battle because it leads to behaviors whose prediction is so hard that it can improve the results directly. The adverse behaviors of the humans show themselves as the oriented asymmetry. In the morphological characteristics, the asymmetry rate is determined in the mechanical actions due to difference, which leads to the deviation from complete symmetry. In the human, the functional preference for the right upper limbs causes it to dominate, specifically the left upper limbs, in terms of morphological characteristics. Regular exercise can cause the bones and muscles of dominant limbs to grow asymmetrically as well. Some research has been done by the dual-energy X-ray absorptiometry (DXA) method and has shown that even 12-week exercise can affect the volume of muscles and bones. The examination of university athletes has also allowed the researchers to examine the impact of two-sided difference degree of the body mass without any fat in the lower limbs on strength asymmetry and the strength when jumping. As it has been shown in the research review presented here, various competitors of sports fields have some differences in the asymmetry rate of the body created on one side (Marcin Lijewski et al., 2021). One of the limitations of the current research is that it is unisex, which cannot be generalized to the general population of handballs. It is also possible to point out the lack of control of people's mental and emotional state and the lack of checking their familiarity with the performed functional tests.

Conclusions

In general, the results of this research show that the single-leg jump could predict the injury. However, in the current study, the screening tools of functional activities have very limited application to identify

the incidence rate and intensity of the handball athletes injury who are at risk of the injury. Due to the multiple nature of injuries and various risk factors such as the prior injury, the researchers must use the tests as far as possible, which have been paid attention to many risky factors of the injury and had the highest simulation based on the injury conditions in the exercise or competition.

Conflict of Interests

The authors declare that they have no conflict of interests to disclose.

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References

Akturk, A., Gouttebarge, V., Frings-Dresen, M. H., & Inklaar, H. (2014). Medical examinations in Dutch professional football (soccer): A qualitative study. International SportMed Journal, 15(4), 343-351. https://hdl.handle.net/10520/EJC164103

Azzam, M. G., Throckmorton, T. W., Smith, R. A., Graham, D., Scholler, J., & Azar, F. M. (2015). The Functional Movement Screen as a predictor of injury in professional basketball players. Current Orthopaedic Practice, 26(6), 619-623. https://doi.org/10.1097/BCO.0000000000000296

Bakken, A., Targett, S., Bere, T., Eirale, C., Farooq, A., Mosler, A. B., . . . Bahr, R. (2018). Muscle Strength Is a Poor Screening Test for Predicting Lower Extremity Injuries in Professional Male Soccer Players: A 2-Year Prospective Cohort Study. The American journal of sports medicine, 46(6), 1481-1491. https://doi.org/10.1177/0363546518756

Bonazza, N. A., Smuin, D., Onks, C. A., Silvis, M. L., & Dhawan, A. (2017). Reliability, validity, and injury predictive value of the functional movement screen: a systematic review and meta-analysis.

The American journal of sports medicine, 45(3), 725-732. https://doi.org/10.1177/0363546516641937

Brumitt, J., Engilis, A., Eubanks, A., Mattocks, A., Peet, J., & Bush, N. (2017). Risk factors associated with noncontact time-loss lower-quadrant injury in male collegiate soccer players. Science and Medicine in Football, 1(2), 96-101. https://doi.org/10.1080/24733938.2017.1282164

Brumitt, J., Engilis, A., Isaak, D., Briggs, A., & Mattocks, A. (2016). Preseason jump and hop measures in male collegiate basketball players: an epidemiologic report. International journal of sports physical therapy, 11(6), 954-961.

Brumitt, J., Heiderscheit, B. C., Manske, R. C., Niemuth, P. E., & Rauh, M. J. (2013). Lower extremity functional tests and risk of injury in division iii collegiate athletes. International journal of sports physical therapy, 8(3), 216-227.

Budnar Jr, R. G., Birdwell, R., Moody, C., Hill, D. W., Duplanty, A. A., Jackson, A. W., & Vingren, J. L. (2013). Functional Movement Screentm Scores in Collegiate Track and Field Athletes in Relation to Injury Risk and Performance. Paper presented at the International Journal of Exercise Science: Conference Proceedings. 2(5), 68.

Butler, R. J., Lehr, M. E., Fink, M. L., Kiesel, K. B., & Plisky, P. J. (2013). Dynamic balance performance and noncontact lower extremity injury in college football players: an initial study. Sports health, 5(5), 417-422. https://doi.org/10.1177/1941738113498703

Chalmers, S., Fuller, J. T., Debenedictis, T. A., Townsley, S., Lynagh, M., Gleeson, C., . . . Magarey, M. (2017). Asymmetry during preseason Functional Movement Screen testing is associated with injury during a junior Australian football season. Journal of Science and Medicine in Sport, 20(7), 653-657. https://doi.org/10.1016/j.jsams.2016.12.076

Dallinga, J. M., Benjaminse, A., & Lemmink, K. A. (2012). Which screening tools can predict injury to the lower extremities in team sports? Sports Medicine, 42(9), 791-815. https://doi.org/10.1007/BF03262295

Dorrel, B. S., Long, T., Shaffer, S., & Myer, G. D. (2015). Evaluation of the functional movement screen as an injury prediction tool among active adult populations: a systematic review and meta-analysis. Sports health, 7(6), 532-537. https://doi.org/10.1177/1941738115607445

Engebretsen, L., Soligard, T., Steffen, K., Alonso, J. M., Aubry, M., Budgett, R., & Mountjoy, M. (2013). Sports injuries and illnesses during the London Summer Olympic Games 2012. British journal of

sports medicine, 47(7), 407-414. http://dx.doi.org/10.1136/bjsports-2013-092380

Gabriel EH, Powden CJ, Hoch MC. Comparison of the Y-Balance Test and Star Excursion Balance Test: Utilization of a Discrete Event Simulation. Journal of Sport Rehabilitation. 2020; 1(aop):1-6.

GALI, J. C., et al. (2021). O RISCO DE NOVAS LESÕES APÓS RECONSTRUÇÃO DO LCA PODE SER MINORADO COM O TREINAMENTO FUNCIONAL. Acta Ortopedica Brasileira 29(1): 21-25. https://doi.org/10.1590/1413-785220212901240903

Gonell, A. C., Romero, J. A. P., & Soler, L. M. (2015). Relationship between the Y balance test scores and soft tissue injury incidence in a soccer team. International journal of sports physical therapy, 10(7), 955-966. http://hdl.handle.net/10045/71801

Hamilton, R. T., Shultz, S. J., Schmitz, R. J., & Perrin, D. H. (2008). Triple-hop distance as a valid predictor of lower limb strength and power. Journal of athletic training, 43(2), 144-151. https://doi.org/10.4085/1062-6050-43.2.144

Junge, A., Dvorak, J., Graf-Baumann, T., & Peterson, L. (2004). Football Injuries During FIFA Tournaments and the Olympic Games, 1998–2001 Development and Implementation of an Injury-Reporting System. The American Journal of Sports Medicine, 32(1), 80-89. https://doi.org/10.1177/0363546503261245

Junge, A., Engebretsen, L., Mountjoy, M. L., Alonso, J. M., Renström, P. A., Aubry, M. J., & Dvorak, J. (2009). Sports injuries during the summer Olympic games 2008. The American journal of sports medicine, 37(11), 2165-2172. https://doi.org/10.1177/0363546509339357

Junge, A., Langevoort, G., Pipe, A., Peytavin, A., Wong, F., Mountjoy, M., . . . Charles, R. (2006). Injuries in team sport tournaments during the 2004 Olympic Games. The American journal of sports medicine, 34(4), 565-576. https://doi.org/10.1177/0363546505281807

Karlsson, J., Heijne, A., & von Rosen, P. (2019). Handball and movement screening–can non-contact injuries be predicted in adolescent elite handball players? A 1-year prospective cohort study. Physiotherapy Theory and Practice, 37(10), 1132-1138. https://doi.org/10.1080/09593985.2019.1685034

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: NAJSPT, 2(3), 147-158.

Kiesel, K. B., Butler, R. J., & Plisky, P. J. (2014). Prediction of injury by limited and asymmetrical fundamental movement patterns in

american football players. Journal of Sport Rehabilitation, 23(2), 88-94. https://doi.org/10.1123/JSR.2012-0130

Konstantopoulos, I., et al. (2021). Fatigue-Induced Inter-Limb Asymmetries in Strength of the Hip Stabilizers, Postural Control and Gait Following a Unilateral Countermovement Vertical Jump Protocol. Sports 9(3): 33. https://doi.org/10.3390/sports9030033

Langevoort, G., Myklebust, G., Dvorak, J., & Junge, A. (2007). Handball injuries during major international tournaments. Scandinavian journal of medicine & science in sports, 17(4), 400-407. https://doi.org/10.1111/j.1600-0838.2006.00587.x

Laver, L., & Myklebust, G. (2015). Handball Injuries: Epidemiology and Injury Characterization. Sports Injuries: Prevention, Diagnosis, Treatment and Rehabilitation, 141-153. https://doi.org/10.1007/978-3-662-55892-8_11

Lijewski, M., et al. (2021). Asymmetry of Muscle Mass Distribution and Grip Strength in Professional Handball Players. International Journal of Environmental Research and Public Health 18(4): 1913. https://doi.org/10.3390/ijerph18041913

Manske, R., & Reiman, M. (2013). Functional performance testing for power and return to sports. Sports health, 5(3), 244-250. https://doi.org/10.1177/1941738113479925

Marques, V. B., Medeiros, T. M., de Souza Stigger, F., Nakamura, F. Y., & Baroni, B. M. (2017). THE FUNCTIONAL MOVEMENT SCREEN (FMS™) IN ELITE YOUNG SOCCER PLAYERS BETWEEN 14 AND 20 YEARS: COMPOSITE SCORE, INDIVIDUAL-TEST SCORES AND ASYMMETRIES. International journal of sports physical therapy, 12(6), 977-985.

Moradi, k., Mioonejad, h., & Rajabi, R. (2015). The immediate effect of core stability exercises on postural sway in athletes with functional ankle instability. Rehab Med, 4(3), 101-110. https://doi.org/10.22037/JRM.2015.1100154

Moran, R. W., Schneiders, A. G., Mason, J., & Sullivan, S. J. (2017). Do Functional Movement Screen (FMS) composite scores predict subsequent injury? A systematic review with meta-analysis. Br J Sports Med, bjsports. 51(23), 1661-1669. http://dx.doi.org/10.1136/bjsports-2016-096938

Morgan, B. E., & Oberlander, M. A. (2001). An examination of injuries in major league soccer: the inaugural season. The American journal of sports medicine, 29(4), 426-430. https://doi.org/10.1177/03635465010290040701

Myklebust, G., Maehlum, S., Engebretsen, L., Strand, T., & Solheim, E. (1997). Registration of cruciate ligament injuries in Norwegian top

level team handball. A prospective study covering two seasons. Scandinavian journal of medicine & science in sports, 7(5), 289-292.

Piry, H., Alizade, M., Nasiri, K., & Rahimi, M. (2011). Injury Rates in Iranian Handball Players. World Applied Sciences Journal, 14(11), 1670-1677.

Piry, H., Fallahi, A., Kordi, R., Rajabi, R., Rahimi, M., & Yosefi, M. (2011). Handball injuries in elite Asian players. World Applied Sciences Journal, 14(10), 1559-1564.

Plisky, P. J., Rauh, M. J., Kaminski, T. W., & Underwood, F. B. (2006). Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. journal of orthopaedic & sports physical therapy, 36(12), 911-919. https://www.jospt.org/doi/10.2519/jospt.2006.2244

Reid, A., Birmingham, T. B., Stratford, P. W., Alcock, G. K., & Giffin, J. R. (2007). Hop testing provides a reliable and valid outcome measure during rehabilitation after anterior cruciate ligament reconstruction. Physical therapy, 87(3), 337-349. https://doi.org/10.2522/ptj.20060143

Smith, C. A., Chimera, N. J., & Warren, M. (2015). Association of y balance test reach asymmetry and injury in division I athletes. Medicine and science in sports and exercise, 47(1), 136-141. DOI: 10.1249/mss.0000000000000380

Soligard, T., Steffen, K., Palmer, D., Alonso, J. M., Bahr, R., Lopes, A. D., . . . Mountjoy, M. (2017). Sports injury and illness incidence in the Rio de Janeiro 2016 Olympic Summer Games: A prospective study of 11274 athletes from 207 countries. Br J Sports Med, 51(17), 1265-1271. http://dx.doi.org/10.1136/bjsports-2017-097956

van Beijsterveldt, A.-M., Steffen, K., Stubbe, J. H., Frederiks, J. E., van de Port, I. G., & Backx, F. J. (2014). Soccer injuries and recovery in Dutch male amateur soccer players: results of a prospective cohort study. Clinical Journal of Sport Medicine, 24(4), 337-342. DOI: 10.1097/JSM.0000000000000028

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