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Development of A New Tool to Analyze Injury Risk: Turkish Get Up Injury Risk Tool

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ABSTRACT

Injury risk analysis is critical to preventing injuries' physical and psychological impact. The purpose of this study was to develop a new tool to evaluate the risk of injury particular to the Turkish get up (TGU) exercise. According to expert opinions, the Turkish Get Up Injury Risk Tool (TUGIR) is a biomechanical assessment tool developed based on the Turkish Get Up (TGU) movement. It evaluates the alignment and quality of movement during the exercise to assess the risk of injury. The upper and lower quarter Y balance tests (YBTs) and Functional Movement Screening (FMS) were performed to determine construct validity. A total of thirty- three wrestlers performed all the tests. Reliability was assessed by internal consistency determined with Cronbach's alpha coefficients and inter-rater reliability determined with Kendall's coefficient of concordance. The injury risk cut-off value was calculated according to the Angoff method. The internal consistency of the TUGIR was found to be 0.77 and 0.76, respectively, quite reliable for the right and left sides. Kendall's concordance coefficient of the total score was determined to be 0.998 for both sides. The injury risk cut-off value was found to be %72 for the overall TUGIR score. A low to moderate association was observed between TUGIR and YBTs—FMS. The TUGIR is a novel, reliable, and valid tool for assessing injury risk in sports. This tool offers several advantages, including being an easy-to-use, low- cost, and comprehensive method that can reflect sports-specific biomechanical characteristics. This research could lead to the use of this tool to assess the risk of injury in other sports branches.

INTRODUCTION

Athletes are faced with the risk of non-contact injuries due to several factors, such as overuse, lack of eccentric strength, excessive bending-stretching, and torsional forces. Complex injuries can make recovery challenging and costly (Bussey, 2002). In addition, changes in the athletes' neuromuscular functions and psychological states increase the risk of re-injury (Brewer & Redmond, 2016). As a result, it's critical to assess the risk of injury on a routine basis. For this purpose, various injury risk analysis methods have been developed.

Biomechanical testing, such as motion analysis, is required to determine the risk of injury and thus implement injury prevention programs. Due to the high cost of research equipment in currently utilized test methods, the length of evaluation procedure, and the lack of practical use by clinicians, screening instruments such as Functional Movement Screen (FMS), Y balance tests (YBTs), landing error score system have been developed and has gained popularity, especially FMS (Padua et al., 2009; Shaffer et al., 2013; Teyhen et al., 2012). However, according to the research, it is controversial that existing test batteries can predict the risk of sports injury. For instance, the results of the meta-analysis published by Bunn et al. reported that individuals classified as “high risk” by the FMS were found to be 51% more likely to be affected by injuries than those classified as “low risk” (dos Santos Bunn et al., 2019). Recent studies suggest that FMS, which is a suitable evaluation method in terms of observing asymmetry in particular movement patterns or poor movement formation, will not provide a deep analysis in terms of the prediction of injury. These weaknesses’ have highlighted the need for a more comprehensive analysis system (Bishop, et al., 2015; Hoover et al. 2020; Moore et al. 2023; Vehrs et al., 2021). While numerous tests are available to measure athletes' physical abilities and exercise status (McGuigan, 2016), considering the risk of injury, sport-specific biomechanical needs, biomechanical stress, and the ability to cope with such stresses differ significantly. Athletes in various sports disciplines are exposed to different biomechanical stresses and distinct injury mechanisms. Therefore, there is a need for sport-specific tools to assess the risk of injury (Loudon et al., 2014; Takahashi et al., 2019). The Turkish Get Up (TGU) exercise has been named due to its origins in old Turkish wrestlers. The TGU exercise, which increases the stabilization and focuses on the shoulder, knee, and spine, requires whole-body integration (Liebenson & Shaughness, 2011). TGU has many advantages to be used for assessment in sports since it requires a good level of flexibility and mobility, includes contralateral and asymmetrical loading, eccentric load, and the torque forces (Collum et al., 2020). It is also a low cost, coordinative movement in all planes which combines open-closed kinetic chain exercises and hasthe potential to create the injury scenario specific to sports (Leatherwood et al., 2014; Liebenson & Shaughness, 2011). Therefore, in this study, we aimed to create a new, comprehensive, and functional injury risk tool based on the TGU exercise.

METHODS

Participants

The athletes included in this cross sectional study were selected from the Turkish National Team camp and Wrestling Sports Club. Wrestling professionally for at least five years was set as inclusion criteria. Exclusion criteria were (a) any disease or surgery that could affect the normal function of the musculoskeletal system, (b) active injury.

All athletes gave written informed consent to participate in the study. Prior to scheduling their participation, each step of research was explained verbally. All athletes were informed about the experimental procedure to ensure that they qualified for the study. Athletes were allowed to withdraw from the study at any point. Written permission was obtained from the Ethics Committee of the Clinical Research Ethics Board of AYBU Education and Research Hospital (Approval No: 23.03.2018-94).

The ICC value as 0.85 was used to estimate the sample size when the number of raters was lower than 4 (Mukaka, 2012). Sample size calculation indicated that 31 participants were adequate to complete the study with an alpha error probability of 0.05 and power of 80%. The study was completed with a total of 33 professional wrestlers due to the possibility of dropouts.

Despite the common use of kettlebells among wrestlers, the Turkish Get Up (TGU) is not currently included in their training routines. The wrestling athletes were chosen for our research population considering its historical origins, being a contact sport, and requirement of the technical use of the whole body (Jang et al., 2009). The study included the expert committee members involved in the tool development and the wrestling athletes who performed the test. Wrestling athletes who performed the tests were also on the expert committee. The athletes were selected from the national team camp and an elite sports club. Wrestling professionally for at least five years was set as inclusion criteria. Exclusion criteria were (a) any disease or surgery that could affect the normal function of the musculoskeletal system, (b) active injury.

Procedures

The Delphi Method created the TUGIR tool (Niederberger & Spranger, 2020). An expert committee was formed, and we have collected expert-based judgments and used them to identify consensus. After completing the tool, 33 wrestling athletes were tested with the tool, FMS, and YBTs to demonstrate the validity and reliability.

Development of TUGIR Tool

Forming Expert Committee

The maximum diversity sampling method was used to form the expert committee. It comprised four physiotherapists specialized in athlete health, two statisticians, six athletic trainers, one biophysicist, three sports medicine physicians, and 33 wrestling athletes.

Construction of Tool Based on Turkish Get Up Exercise

The first draft of the tool was formed based on the 14-phase TGU exercise suggested by Onge et al. (St-Onge et al., 2019) and was sent to the expert committee. The feedbacks were received on several aspects, from the content of the draft to its scoring. The draft was revised several times due to the recommendations and divided into seven phases. Squat, which was not included in the first draft, was added in the final version, thus forming the tool in a total of eight phases. The phases were named as '*pelvis contact, pelvis raise, knee contact, standing up, squat, landing to knee contact, pelvis stabilization, landing to pelvis contact*' respectively. A certain number of parameters were created according to the content of each phase. The total number of parameters is 193, which varies between 19 and 35 for each phase. The final version of the TUGIR was included in the appendix (Appendix 1). The optimal weight of the kettlebell (KB) to be used during the exercise was determined as 15 % of the body weight by the athletes and expert committee.

A one-zero-point system for evaluating each parameter separately was chosen as the scoring system. The parameters are scored as 0 or 1 depending on whether the athlete performs the movement successfully or not. Each phase score was calculated by dividing the number of succeeded parameters by the total number of parameters in that phase. The same method was used for the overall TUGIR score. Comparing right and left side scores can determine functional asymmetry between sides.

Data Collection Tools

TUGIR

The athletes first completed the eight phases with the KB in the right hand, then repeated for the left side. Before the assessments, athletes were a) demonstrated the test (until you learn), b) informed about the possible errors during the tests, c) allowed five minutes warm-up period (Since it is a whole-body movement, warming movements for all extremities were used to warm up the whole body), d) allowed make three trials (A 1-minute rest was given after each test.). The tests were performed in the same order, at the same time of day (mid-afternoon). Cameras were placed to record the athletes from the front, back, and lateral sides holding the KB. Scoring was made according to data obtained from camera recordings.

Scoring was performed as described above. Additionally, an injury risk cut-off value was calculated by dividing the number of succeeded parameters by the total number of parameters and converted to percentage value for each phase separately and as a total. Thus, a person fully meeting all the parameters will score 100 points.

Y Balance Tests

The upper and lower quarters were tested using a Y balance test kit (Move2Perform, Evansville, IN, USA).

a) Lower Quarter Y-Balance Test (YBT-LQ)

The distal aspect of the stance foot was at the starting line as athletes stood on the middle footplate with both hands on their waist for the starting position. The athlete reached in the anterior, posteromedial, and posterolateral directions in reference to the stance foot with the free limb while maintaining single leg stance by pushing the indicator box as far as possible. The test was considered unsuccessful if the athlete received assistance from the equipment, touched the floor, or fell from the platform due to a loss of balance, and the test was repeated by returning to the starting position. For each reach direction, participants completed three trials in a row, and the best score was recorded (Shaffer et al., 2013).

The distance between the spina iliaca anterior superior and the medial malleolus was measured to calculate lower extremity length. A composite score was determined as reach distance divided by limb length, then multiplied by 100% to express reach distance as a percentage of limb length (Shaffer et al., 2013).

b) Upper Quarter Y Balance Test (YBT-UQ)

The athletes were in the push-up posture, with the stationary hand in the middle of the platform, the adducted thumb parallel to the red line, and the feet no more than shoulder width apart for the starting position of the test. The athlete's maximum reaching with the free hand in three directions (medial, superolateral, and inferolateral) with respect to the stationary hand was the focus of the test. If the athlete (a) fell off the stance platform or contacted the floor with the reaching hand, (b) failed to sustain reach hand contact with the reach indication on the target area while it was moving (e.g., shoved the reach indicator), (c) gets stance support by transferring weight onto the reach indicator, (d) failed to return the reaching a hand to the beginning position under control or move either foot off the floor the session was invalidated and repeated. This procedure was repeated until each hand had completed three trials in each direction, and the best score was recorded (Westrick et al., 2012).

The distance between the C7 spinous process and the most distal tip of the right middle finger was measured to calculate upper extremity length. To normalize for limb length, a composite score was calculated as reach distance divided by limb length, then multiplied by 100% to express reach distance as a percentage of limb length (Westrick et al., 2012).

Functional Movement Screening

FMS test tool was used. Athletes were instructed to do a series of movements which are "Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push-Up, and Rotary Stability" according to the FMS authors' instructions (Teyhen et al., 2012). All the tests were completed without a pre-test warm-up. The evaluation was made with dual camera recordings from frontal and sagittal planes. Each movement is rated on a scale of 0 to 3 with a total score ranging from 0 to 21 points: If the athlete feels pain during the movement = 0, is unable to execute the correct movement = 1, executes the movement with compensations = 2 and executes the correct movement without pain or compensations = 3. Each athlete was able to perform each component test three times, with the highest result getting recorded. Asymmetry is assessed in five of the seven component tests by measuring the test bilaterally. If there are discrepancies between the left and right sides, asymmetry is noted and the lower of the two values is selected in the FMS composite score (Cook et al., 2006a, 2006b; Teyhen et al., 2012). The testing was administered by two investigators with experience using the FMS in daily practice, and the principal investigator graded the results

Data Analysis

Data analysis and calculations were conducted using IBM SPSS Statistics 22.0 (IBM Corp. Version 22.0. Armonk, NY) and MicroSoft-Excel 2016. An overall p-value of less than 0.05 was considered to show a statistically significant result. As TUGIR, Y balance tests, and FMS scores did not follow the normal distribution, non-parametric statistical tests were used.

Reliability and validity

The Angoff method, which is one of the standard methods based on expert opinions, was used to determine the injury risk cut-off points. Lower scores than the cut-off point indicate that the athlete is prone to injury (Mills & Melican, 1988). The Cronbach's Alpha Coefficients were used to evaluate the internal consistency of the TUGIR for the right and left overall scores. Cronbach's Alpha values of 0.80-1.00 were accepted as high reliability, 0.60-0.79 as quite reliable, 0.40- 0.59 as low reliability, and 0.00-0.39 as non-reliable (Vaske et al., 2017). Kendall's Coefficient of Concordance was used to determine inter-rater reliability by three raters (sports physiotherapist, sports physician, and athletic trainer) who were also members of the expert committee. Raters examined the videos separately, and they were blind to each other's' scores. Face validity was assessed by gathering experts' opinions with backgrounds in sports science. *The construct validity* of the TUGIR was analyzed based on its correlation with FMS and Y balance tests (Ercan & Kan, 2004). The correlation values of 0.000 as no relationship, 0.001– 0.200 as very weak relationship, 0.201– 0.400 as weak relationship, 0.401– 0.600 as a moderate relationship, 0.601– 0.800 as strong relationship, 0.801– 0.999 as very strong relationship, and 1.000 as perfect relationship were accepted in the interpretation (Mukaka, 2012).

RESULTS

A total of 75 wrestlers were assessed for eligibility. Of these, 42 were excluded for various reasons; did not meet the inclusion criteria (n = 32), declined to participate (n = 7), discontinued tests (n = 3). Finally the study was completed with 33 male wrestlers, aged between 19-33. The study was completed with 33 male wrestlers aged 19-33. Table 1 shows the demographics of the athletes.

Table 1
Demographics of Athletes

Variables	Median [IQR25 – IQR75]
Age (year)	21.00 [19.00 – 23.00]
Sports year (year)	10.00 [7.00 – 14.50]
BMI (kg/m²)	25.61 [22.79 – 28.34]

BMI: Body Mass Index

Table 2 shows the descriptive istatistic of the TUGAR. The right and left side score were the lowest in phase 5 and the highest in phase 8. The relationship between TUGIR, FMS and YBT's scores are given in Tables 4 and 5, respectively. In order to determine the correlation level between TUGIR scores and FMS scores, the relationship between the subscores of these two scales was examined using the Spearman Rank Correlation coefficient. A positive relationship was observed between the right side of Phase 4 and Rotation Stability ($p<0.05$). A significant negative relationship was observed between the right side Phase 6 and the right

Hurdle Step ($p<0.05$). A positive, moderately significant relationship was observed between Right Phase 7 and Shoulder Mobility in right-side external rotation ($p<0.05$). A significant negative relationship was observed between the left F7 and the left foot supported Hurdle Step movement ($p<0.05$). A positive significant relationship was observed between Left Phase 2 and Shoulder Mobility movement in left side shoulder external rotation ($p<0.05$). A positive significant relationship was observed between Left Phase 4 and the left-supported Rotational Stability movement ($p<0.05$). A significant positive relationship was observed between Left Phase 6 and the left foot-supported Deep Squat movement ($p<0.05$). A positive, moderately significant relationship was observed between Shoulder Mobility movement in Left Phase 7 left side shoulder external rotation ($p<0.05$). No significant relationship between the TUGIR total score and the FMS total score for the right and left sides could be detected. In addition, apart from the parameters listed, it was determined that there was no relationship between the other phases of the TUGIR test and the FMS subparameters (Table 4).

Table 2
Descriptive Statistics of TUGIR

Side		Min-Max	X ± SD	Skewness 0.41	Kurtosis 0.80
Right	**P1**	0.500-0.950	0.824±0.100	-1.068	1.424
	P2	0.565-1.000	0.792±0120	0.145	-0.410
	P3	0.543-0.971	0.729±0.120	0.382	-0.683
	P4	0.474-1.000	0.716±0.150	-0.029	-1.242
	P5	0.357-0.857	0.644±0.110	-0.556	0.562
	P6	0.444-0.963	0.760±0.120	-0.677	0.281
	P7	0.476-0.952	0.750±0.110	-0.216	0.267
	P8	0.650-1.000	0.900±0.110	-1.310	0.838
	Total	0.533-0.899	0.764±0.080	-0.504	0.337
Left	**P1**	0.500-1.000	0.820±0.110	-1.136	1.825
	P2	0.565-1.000	0.769±0.120	0.232	-0.785
	P3	0.486-0.967	0.699±0.120	0.483	-0.160
	P4	0.526-0.895	0.740±0.090	-0.030	-0.878
	P5	0.357-0.857	0.633±0.110	-0.329	0.385
	P6	0.444-0.963	0.741±0.130	-0.250	-0.386
	P7	0.476-0.952	0.745±0.120	-0.059	-0.394
	P8	0.600-1.000	0.861±0.130	-0.516	-0.920
	Total	0.533-0.899	0.751±0.080	-0.490	0.120

P: Phase, P1: Phase 1, P2: Phase 2, P3: Phase 4, P5: Phase 5, P6: Phase 6, P7: Phase 7, P8: Phase 8

Spearman Rank Difference Correlation coefficients were examined for the relationship between TUGIR scores and Y balance test scores. A weak relationship was detected between the right phase 8 and the lower extremity right anterior reaching score (r = -0.368). A moderately weak correlation was detected between right phase 3 and upper extremity right lateral reaching (r = -0.419). Weakness between right phase 4 and upper extremity right supero-medial reach score relationship was detected (r = 0.377).

A weak correlation was detected between the left side Phase 4 and the lower extremity left postero-lateral reach and left postero-medial reach score (r = 0.400, r = 0.351). No significant relationship between the TUGIR total score and the Y balance total score for the right and left sides could be detected. In addition, apart from the parameters listed, no relationship could be detected between the other phases of the TUGIR test and the sub-parameters of the Y balance test (Table 5).

Table 3 lists cut-off points for each phase separately and as a total. Cronbach's Alpha values for TUGIR (from P1 to P8 and total) were found to be 0,772 and 0,769, respectively, quite reliable for the right and left sides. Kendall's concordance coefficient of the total score was determined as 0,998 for both sides.

Table 3
Cut off points

Phase	Cut off points (%) ± SD
Phase 1	78.00±6.37
Phase 2	75.90±5.61
Phase 3	72.00±5.29
Phase 4	69.75±6.40
Phase 5	69.31±6.46
Phase 6	73.36±6.52
Phase 7	70.63±6.70
Phase 8	75.00±4.89
Total	72.81±6.55

Table 4
Relationship Between Scores of TUGIR and FMS

		RIGHT							LEFT						
		HS	**DS**	**ILC**	**SM**	**RS**	**ASLR**	**Total Score**	**HS**	**DS**	**ILC**	**SM**	**RS**	**ASLR**	**Total Score**
RIGHT	**P1**	0.106	-0.013	0.090	0.139	0.254	0.116	0.241	0.223	-0.013	0.165	-0.024	0.164	0.116	0.214
	P2	-0.124	0.133	-0.092	0.256	0.107	0.087	0.167	-0.299	0.133	-0.103	0.122	0.175	0.087	0.049
	P3	-0.036	0.248	-0.197	0.280	0.308	-0.094	0.241	-0.127	0.248	-0.223	0.172	0.316	-0.094	0.142
	P4	-0.250	-0.083	-0.197	0.054	**0.381***	0.000	-0.008	-0.268	-0.083	0.010	0.118	**0.459***	0.000	0.095
	P5	0.021	-0.039	-0.220	-0.105	0.135	-0.074	-0.094	0.014	-0.039	-0.211	-0.059	0.221	-0.074	-0.038
	P6	**-0.378***	-0.120	0.230	0.007	-0.004	-0.067	-0.011	-0.176	-0.120	**0.407***	0.177	0.129	-0.067	0.189
	P7	-0.217	0.022	0.133	**0.358***	-0.104	-0.034	0.154	**-0.362***	0.022	0.156	0.263	-0.004	-0.034	0.061
	P8	-0.219	0.014	0.199	0.089	-0.244	0.083	0.047	-0.270	0.014	0.257	0.145	-0.124	0.083	0.066
LEFT	**P1**	0.180	0.013	0.229	0.197	0.158	0.136	0.321	0.175	0.013	0.297	0.075	0.038	0.136	0.253
	P2	0.013	0.304	-0.033	**0.356***	0.067	0.168	0.338	-0.228	0.304	-0.137	**0.360***	0.141	0.168	0.202
	P3	-0.087	0.083	-0.135	0.267	0.233	0.054	0.172	-0.335	0.083	-0.130	0.228	0.245	0.054	0.059
	P4	0.032	0.269	-0.192	0.167	0.325	0.095	0.266	-0.210	0.269	-0.178	0.233	**0.428***	0.095	0.230
	P5	0.092	-0.004	-0.089	-0.040	0.122	-0.075	0.027	0.003	-0.004	-0.114	0.020	0.218	-0.075	0.045
	P6	**-0.350**	-0.132	0.237	0.087	-0.072	-0.007	0.003	-0.299	-0.132	**0.395***	0.303	0.050	-0.007	0.156
	P7	-0.135	0.083	0.072	**0.433***	-0.170	0.054	0.182	**-0.349**	0.083	0.040	**0.397***	-0.104	0.054	0.055
	P8	-0.145	0.110	0.102	0.189	-0.153	0.122	0.132	-0.303	0.110	0.111	0.253	-0.042	0.122	0.097
TOTAL	**Right**	-0.278	0.033	-0.003	0.207	0.142	0.000	0.117	-0.302	0.033	0.103	0.175	0.239	0.000	0.130
	Left	-0.122	0.083	0.033	0.300	0.098	0.093	0.226	-0.326	0.083	0.046	0.327	0.173	0.093	0.158

HS: *Hurdle Step,* ***DS:*** *Deep Squat,* ***ILC:*** *In-line lunge,* ***SM:*** *Shoulder Mobility,* ***RS:*** *Rotary Stability,* ***ASLR:*** *Active Straight Leg Raise,* ***TSP:*** *Trunk stability push-up,* ***P:*** *Phase, P1: Phase 1, P2: Phase 2, P3: Phase 4, P5: Phase 5, P6: Phase 6, P7: Phase 7, P8: Phase 8, *: p <0,05*

Table 5
Relationship Between Scores of TUGIR and YBTs

		RIGHT						LEFT					
		Lower Extremity			Upper Extremity			Lower Extremity			Upper Extremity		
		L	PL	PM	L	SM	IM	L	PL	PM	L	SM	IM
RIGHT	P1	-0.305	-0.175	0.108	0.111	0.200	0.176	-0.222	0.010	-0.044	0.052	0.251	**0.109**
	P2	-0.279	0.018	0.051	-0.275	0.000	0.036	-0.157	0.095	-0.032	-0.147	0.076	**-0.048**
	P3	-0.158	0.161	0.168	**-0.419***	0.166	0.045	-0.121	0.069	0.171	-0.252	0.192	**0.040**
	P4	-0.088	0.038	0.063	0.135	**0.377***	0.038	-0.084	0.121	0.183	0.079	0.051	**0.265**
	P5	-0.137	-0.009	-0.005	0.308	0.246	-0.158	-0.035	0.037	0.019	0.260	0.041	**-0.021**
	P6	-0.250	-0.067	-0.252	-0.027	0.323	-0.036	0.126	-0.048	-0.116	-0.129	0.067	**-0.036**
	P7	-0.213	-0.004	0.104	-0.043	0.096	0.296	0.008	0.169	0.068	-0.045	0.134	**0.008**
	P8	**-0.368***	-0.191	-0.144	0.068	0.038	0.089	-0.097	0.043	-0.168	0.118	0.069	**-0.112**
LEFT	P1	-0.129	-0.102	0.080	0.077	0.224	**0.390***	-0.053	0.149	-0.054	-0.028	0.278	**0.221**
	P2	-0.085	0.163	0.200	-0.316	-0.045	0.271	-0.124	0.319	0.094	-0.155	0.067	**0.078**
	P3	-0.245	0.319	0.158	-0.291	-0.065	0.088	-0.134	0.195	0.065	-0.235	-0.044	**0.117**
	P4	0.130	0.207	0.215	0.073	**0.399***	0.193	0.046	**0.400***	**0.351***	0.083	0.176	**0.283**
	P5	-0.098	0.101	0.035	0.251	0.270	-0.062	0.089	0.160	0.061	0.214	0.052	**0.042**
	P6	-0.265	0.041	-0.158	-0.036	0.153	0.112	0.088	0.032	-0.183	-0.132	0.023	**0.041**
	P7	-0.136	0.107	0.171	-0.142	-0.029	**0.358***	0.012	0.242	0.052	-0.130	0.067	**0.063**
	P8	-0.298	-0.092	-0.033	-0.071	-0.092	0.146	-0.147	0.128	-0.099	0.012	0.034	**-0.087**
Right Total		-0.315*	-0.047	-0.004	-0.062	0.235	0.042	-0.085	0.097	0.015	-0.084	0.100	0.012
Left Total		-0.276	0.072	0.076	-0.173	0.128	0.220	-0.104	0.191	-0.040	-0.122	0.095	0.117

P: *Phase, P1: Phase 1, P2: Phase 2, P3: Phase 4, P5: Phase 5, P6: Phase 6, P7: Phase 7, P8: Phase 8,* ***PL****: Posterio-Lateral reach,* ***PM:*** *Posterio-Medial reach,* ***L:*** *Lateral reach,* ***SM:*** *Supero-medial reach,* ***IM****: Inferio-Medial reach *: p <0,05*

DISCUSSION

This study was conducted to create an effective tool for current need to determine the injury risk of athletes. The TUGIR, developed for this purpose, was shown as a novel, reliable, and valid test method capable of performing injury risk assessment.

There are different methods used for functional evaluation in athletes, such as FMS, jump tests, and core tests. These tests should also be able to determine the sports-specific biomechanical needs since athletes are exposed to various biomechanical stresses with variable injury mechanisms in different sports branches. While some functional movements in FMS may overlap with the sport-specific nature, some movements may not be effective for use to determine injury risk. For example, the study of Silva et al., which was conducted with surf players, stated that "Trunk Stability Push" may be a more effective tool in determining physical function rather than the FMS total score (Silva et al., 2017). Similarly, "Deep Squat" and "Hurdle Step" were shown to give better results in determining the risk of injury in basketball players (Silva et al., 2017). Therefore, there is a need for a comprehensive functional test tool to address biomechanical dynamics specific to various sports.

Our study demonstrated the reliability and validity of TUGIR. The internal consistency of our tool, which was found to be quite reliable, was similar to the value stated for FMS (Smith et al., 2013). The reliability of FMS scoring has been discussed in many studies which suggest that there may be a difference between inexperienced and experienced raters, and therefore the education of the evaluators is highly important (Moran et al., 2016). Conversely, TUGIR may provide a straightforward scoring system to the evaluator with the parameter scoring within each phase, thus reducing the margin of error that may occur during scoring. The near-perfect concordance between raters shows that the TUGIR is an appropriate test for scoring reliability. However, it should be noted that the inter-rater reliability may have been found to be quite high since the evaluation was performed by individuals who were specialized in the area and also participated in the expert committee that formed the tool.

The injury risk cut-off determined by the Angoff method in our study was approximately %72 for a total score. Athletes who scored below the cut-off value may be at risk for injury. In our study, all scores of the athletes were over the cut-off value, and athletes demonstrated good functional performance. According to the injury risk cut-off value determined for FMS (FMS total score<14), there was no risk of injury for athletes either (Bonazza et al., 2017). The fact that the athletes were above the cut-off value in both of these risk analysis systems indicates that the two test methods are compatible.

Different methods can be used to validate a functional movement instrument, such as face validity and factor analysis. Both face validity and factor analysis were used in the study of Butowicx et al., in which a comprehensive movement system screening tool for athletes was developed (Butowicz et al., 2019). The nine-test battery developed by Frohm et al. was also standardized in line with expert opinions (Frohm et al., 2012). Since removing any phase from the TUGIR would disrupt the integrity of the movement and cause problems in the transitions between phases, face validity, which was performed by applying expert opinion, was used as a validation method in this study. Therefore, biomechanical deficiencies at any phase can be easily determined. Since there is no test tool specific to sports branches, FMS, and YBTs, which are frequently preferred to determine the risk of injuries, have been chosen to test the convergent validity of our tool.

TUGIR has several advantages that overlap with the important features in sports such as head control, focus on shoulder and asymmetrical movements. Our tool has the capacity to provide information about head control and eye tracking of athletes since the athlete must hold eye contact with KB from the starting position to the end of the movement in all phases of the TGU. Shoulder injuries play a considerable part in sports injuries in athletes (Kraan et al., 2019). These injuries may recur, as in usually for shoulder dislocations, or may be severe, requiring surgery and causing the athlete to stay away from sports (Peterson & Renstrom, 2016). For these reasons, the shoulder should be especially focused on most athletes. The TGU exercise differs from the movements in the FMS by focusing on the shoulder. During the trunk movement in three different planes, the lower extremity and upper extremity joints must perform the movement under different stresses and joint angles. Since asymmetry and compensations are associated with a high risk of injury, their identification is important (Kiesel et al., 2014). Studies indicate that the presence of asymmetry rather than the total FMS score is more effective in showing the risk of injury (Chalmers et al., 2017). In TUGIR, all phases are calculated separately for the right and left sides. The asymmetrical nature of the TGU motion, on which the TUGIR is based, is sufficient to detect asymmetries and weaknesses (Leatherwood et al., 2014).

The study's limitation is that it only included male athletes who were not injured. Future studies may focus on the effectiveness of this tool in detecting injuries or determine how much right and left asymmetry in the TUGIR phases is in the pathological border. In addition, the effectiveness of this test battery in various sports branches should be investigated.

CONCLUSION

Due to the multifactorial nature of sports injuries, injury risk assessment tools must also be multifactorial. For this reason, evaluating the risk of sports injury is important of a tool that identifies specific injury risks and is developed with a multidisciplinary perspective may be helpful for the optimal management of risk analysis in the sport. For this purpose, TUGIR, which was developed by this study, is a novel, reliable, and valid test method that may determine the injury risk of athletes. It is a compelling tool that can analyze an athletes' whole biomechanical chain in a continuous cycle of motion with an external stress. This study can lead to the use of this tool in various sports branches.

Authors' contribution

The first author who contributed to this research carried out the conceptualization and design of the study. The first author also carried out the data collection and analysis, as well as the writing of the original draft. The second author contributed to consist of the validation of the methodology governing this study, the supervision and critical reviewing of the original draft, as well as the approval of the final draft. Other authors both played roles in conceptualizing the study and reviewing and editing the manuscript. These collective efforts were integral to the development and refinement of the study.

Declaration of conflict interest

The authors declare that there is no conflict of interests.

Ethics Statement

Written permission was obtained from the Ethics Committee of the Clinical Research Ethics Board of AYBU Education and Research Hospital (Approval No: 23.03.2018-94).

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