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Predictive Ability of Dynamic Balance and Throwing Accuracy Assessment for In-Season Shoulder Injuries in Competitive Volleyball Athletes

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ABSTRACT

Shoulder injuries are common in volleyball athletes. Although, research has shown the incidence of in-season shoulder injuries in this population, less is known about the ability of field-based tests to predict them. The purpose of this study was to examine whether assessment of dynamic balance and throwing accuracy performance of competitive volleyball athletes can predict in-season shoulder injuries. Thirty-nine volleyball athletes underwent dynamic balance assessment of the upper and lower extremities at the start of the season using the Y-Balance and Upper Quarter Y-Balance (UQYB) test, respectively. Furthermore, throwing accuracy was also examined using the Functional Throwing Performance Index (FTPI) test. Data collected at the end of the season were: injury, side and type of injury. Binomial logistic regression was conducted to ascertain whether the predictor variables could predict shoulder injury during in-season competition. Receiver operator characteristic (ROC) curve analysis was used to determine the cut-off scores for the statistically significant predictor variables. Twelve athletes sustained a shoulder injury during the season. From the five predictor variables, the Y-Balance Medial ($p<0.05$) and the UQYB Medial ($p<0.05$) were able to predict shoulder injuries with statistical significance. From calculating the Odds Ratios, this study found that those who scored less than the cut-off score on the Y-Balance Medial (117.6 cm) and the UQYB Medial (119.15 cm) were 2 and 1.6 times more likely to get injured in the shoulder complex, respectively. This study showed that the combination of upper and lower limb dynamic balance was able to predict in-season shoulder injuries.

Keywords: Y-Balance, Functional Throwing Performance Index, Shoulder, Volleyball

INTRODUCTION

Volleyball is a highly popular sport and one of the most practiced sports worldwide. Although it is considered as a safe sport, studies have reported increased risk of injuries with an incidence that may reach 10.7 injuries per 1000 playing hours [1]. These injuries include several body regions such as the ankle, knee and shoulder complex [2]. The high demands of the sport that include jumping, blocking and spiking the ball at a very high speed increases the demands placed on the athlete and as a consequence the risk of injuries in these regions [3]. Moreover, studies have shown that the incidence of in-season non-traumatic shoulder injuries in volleyball athletes may increase more and can reach up to 40% of the athletes [4]. Studies have examined the role of preventive measures for reducing the incidence of shoulder injuries in volleyball, however, high-quality studies on the prediction and prevention of these injuries are lacking [3].

With respect to shoulder injuries, research has shown that the repetitive movement of the arm overhead increases the risk of shoulder injury in volleyball athletes [5]. During the cocking, acceleration and deceleration phase of throwing increased forces are placed in the shoulder complex in extreme positions and while the Upper Extremities (UE) of the athletes may have to come in contact with a ball that can reach a speed of up to 128 kilometres per hour [5]. These factors make the shoulder complex prone to injury in competitive volleyball athletes. A significant proportion of overhead athletes with shoulder injuries (approximately 22%) are forced to refrain from training for more than 3 weeks [6]. This makes injury prediction and prevention an important aspect of modern sports physical therapy.

Studies have examined the predictive ability of shoulder muscle strength with the use of isokinetic dynamometry for shoulder injuries in volleyball athletes [6-9]. These studies indicated that shoulder internal rotation weakness increases the risk of shoulder injury [10]. However, an isokinetic dynamometer is not always available to use in the clinical or sport setting and thus, field-based shoulder testing may be preferable by sports therapists and coaches. Previous research studies suggest that a reduction in balance and throwing accuracy may increase the risk of shoulder injury in overhead athletes [11]. Field-based tests that are reliable and are often prescribed in this population are the Y-Balance test, the Upper Quarter Y-Balance (UQVB) test and the Functional Throwing Performance Index (FTPI) test [12]. Reference values have been provided for overhead athletes for the UQYB test [13]. However, the predictive ability of the aforementioned three tests is still unknown. Moreover, studies examining the ability of field-based tests to adequately predict shoulder injuries in volleyball athletes are not available in the literature. Thus, the purpose of this study was to examine whether the Y-Balance test, the UQYB test and the FTPI test can adequately predict in-season shoulder injury in volleyball athletes and report the relevant minimum cut-off values needed for the ones that can statistically significantly predict shoulder complex injuries. Our hypothesis was that field-based tests that assess balance and throwing accuracy will predict athletes who were at high risk of in-season shoulder injury.

MATERIALS & METHODS

For this study 39 pre-season competitive volleyball athletes were included on a volunteer basis. All athletes had to be adults (>18) and asymptomatic, without any injury or pain in the UE or cervical spine, based on subjective examination from the main investigator (Initials). Furthermore, pain within the last 6 months of >3/10 in the Visual Analogue Scale (VAS) was considered as an exclusion criterion. Also, athletes >30 years old were excluded to avoid an increased risk of injury due to age-related changes [14]. Athletes that had sustained an upper extremity injury in the last six months but were able to compete after clearing from their physician for unrestricted participation were not excluded. At the testing session, demographic data were collected after interviewing the athletes, including: age, height, weight, player position and previous injuries. The following assessment tests were conducted: Y-Balance, UQYB and FTPI test. The end-season data that were collected included the number of athletes that sustained any UE injury, side and type of injury. Athletes were considered as injured by the investigators of this study if they had a diagnosis of an in-season volleyball-related injury. Moreover, a medical examination should have established the diagnosis for each injured athlete. Non-volleyball-related injuries were not considered as cases for this study and athletes with these types of injuries were excluded. The investigators of this study considered an injury as any event that resulted in absence from training for no less than 24 hours following the injury [15]. Informed consent was taken from all the participants and the procedures followed were in accordance with Helsinki Declaration.

Assessment testing

Y-Balance

This test was used to examine lower extremity dynamic balance in multiple directions. The three reaching directions included: one in the Anterior direction (ANT) and two aligned at 135° from the ANT, in the posteromedial (PM) and posterolateral (PL) directions. The stance limb selected was on the same side of the dominant hand since this side of the lower limb is involved mostly in the generation of the ground reaction force during overhead throwing [16]. For the starting position the athletes were stood on the stance limb and faced forward in the anterior direction after they removed their shoes. All athletes performed 3 maximal reaching trials with the non-stance limb while they were instructed to place their hands on their waist. The maximal distance recorded was the point where the most distal part of the foot reached. Each athlete completed one practice trial before performing 3 reaches in each direction. Valid trials were the ones where the athlete maintained dynamic balance, the hands remained on the waist, the most distal part of the foot could touch each line in the three directions and the stance foot remained in contact with the ground.

The mean score of the 3 trials for each direction was used for the statistical analysis after normalizing the mean values with the lower extremity length. Lower extremity length measurement, was performed after placing each athlete in a supine position and the distance from the anterior superior iliac spine to the medial malleolus was measured. Furthermore, the composite score was computed by adding the mean value of the 3 trials, for each direction, and then dividing them by three times the LL length of each athlete and multiplied by 100 [(ANT+PL+PM/3xLL)x100] [17]. Research has shown that the Y-Balance is a reliable test for measuring dynamic balance in healthy asymptomatic adults (Intraclass correlation coefficients > 0.85) [18].

Upper Quarter Y-Balance (UQYB)

This test was used to examine core and UE dynamic balance in multiple directions. The three reaching directions included: one medially (M) and two aligned at 135° from the M, in the superolateral (SL) and inferolateral (IL) directions. The dynamic balance of all athletes was assessed in these 3 directions from a 3-point plank position while maintaining their feet at shoulder width apart, in a distance of less than 30.5 cm. The dominant hand was the third point of contact while the non-dominant hand performed all reaches in the three directions. Again, as in the Y-Balance, each athlete performed one practice trial before performing 3 reaches in each direction. The mean score of the final three trials in each direction was selected for the statistical analysis. The maximal distance recorded was the point where the most distal part of the hand reached. Valid trials were the ones where the athlete maintained the three points of contact during each trial. The dominant hand was the one that was used to hit the ball and it was tested since research has shown that deficiencies in the dominant side increase the risk of shoulder injury in this population [19].

The mean score of the 3 trials for each direction was used for the statistical analysis after normalizing the mean values with UE length. UE length measurement, was performed after placing each athlete in a standing position and their arms up to 90° in the frontal plane. The distance between the middle finger of the dominant hand and the spinous process of C7 were recorded. Furthermore, the composite score was computed by adding the mean value of the 3 trials, for each direction, and then dividing them by three times the UE length of each athlete and multiplied by 100 [(M+SL+IL/3xLL) x100]. Research has shown that the UQYB is a reliable test for measuring dynamic balance in healthy asymptomatic adults (Intraclass correlation coefficients > 0.80) [20].

Functional Throwing Performance Index (FTPI)

The FTPI assesses throwing accuracy in overhead athletes. For this test athletes stood 4.57 metres from a squared target with specific dimensions (30.48 × 30.48-cm), 1.22 metres from the floor. A rubber playground ball (50.8-cm circumference) was used for this test by asking from each athlete to throw it into the squared target as fast as possible for 30 seconds, using their dominant hand. The final score was calculated after dividing the total number of successful throws (throws inside the target) with the total number of throws [21]. This test has been shown to be reliable for the assessment of throwing accuracy (Intraclass correlation coefficient = 0.81) [12].

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS (IBM Inc., New York, NY, USA version 25.0) statistic software package. A binomial logistic regression was conducted to ascertain whether the predictor variables dynamic balance (Y-Balance and UQYB) and throwing accuracy (FTPI) can predict shoulder injury during in-season competition in professional volleyball athletes. Linearity of the continuous variables with respect to the logit of the dependent variable was assessed via the Box-Tidwell (1962) procedure. Outliers were assessed with standardized residuals and values >2.5 were considered as outliers. Nagelkerke R2 was calculated to examine the explained variation and correct classification of cases [22]. Receiver operator characteristic (ROC) curve analysis was used to determine the cut-off scores for the predictor variables that could predict with statistical significance in-season shoulder injury occurrence. Sensitivity, specificity, positive predictive value and negative predictive value were calculated by contingency tables.

RESULT

Demographic characteristics of the recruited athletes is presented in Table 1. We were able to re-assess for injury occurrence all 39 athletes that were initially recruited (17 males and the rest females). From this sample 12 athletes complained of an UE injury during the season. These injuries included 6 Rotator Cuff Related Shoulder Pain (RCRSP) syndrome, 2 Acromioclavicular Joint pain, 3 anterior instabilities with labral tears and 1 RCRSP in conjunction with acute injury from direct trauma. The time from baseline assessment until the re-assessment period lasted 6 months. All continuous independent variables were found to be linearly related to the logit of the dependent variable. No outliers were detected with values >2.5. The mean test scores are reported in Table 2.

Table 1. Sociodemographic Characteristics of the Study Sample

	Mean	SD
Age	21.9	3.6
Height	1.79	0.3
Weight	68.5	19.8
Body Mass Index	21.3	3.2

SD: Standard Deviation

Table 2. Mean test scores and Standard Deviations

Predictor Variable	Mean	SD
Y-Balance Anterior (cm)	89.4	13.1
Y-Balance Lateral (cm)	126.8	15.4
Y-Balance Medial (cm)	117.9	6.2
Y-Balance Composite (cm)	111.4	9.4
Upper Quarter Y-Balance Medial (cm)	118.1	7.4
Upper Quarter Y-Balance Superior Lateral (cm)	69.7	13.7
Upper Quarter Y-Balance Inferior Lateral (cm)	77.3	12.7
Upper Quarter Y-Balance Composite (cm)	88.4	8.9
Functional Throwing Performance Index	0.6	0.2
SD: Standard Deviation		

The logistic regression model was statistically significant x2(11) = 28.185, p<0.01. The model with all predictor variables explained 63.0% (Nagelkerke R2) of the variance in shoulder injury and correctly classified 72.0% of cases [23]. Sensitivity was 84.6%, specificity was 96.1%, positive predictive value was 90.4% and negative predictive value was 93.5%. The results from the binomial logistic regression analysis are presented in Table 3. The statistical analysis indicated that gender was not a predictor of shoulder injury. Furthermore, for all predictor variables the analysis showed that lower reaching distance increased the likelihood of injury occurrence.

Of the five predictor variables only two were statistically significant: Y-Balance Medial (logistic regression x2(1) = 6.679, p<0.05) and UQYB Medial (logistic regression x2(1) = 5.371, p<0.05). For the Y-Balance Medial the sensitivity was 66.6%, specificity was 75.7%, the positive predictive value was 54% and the negative predictive value was 84%. The area under the ROC curve was 0.77 (P = 0.006; 95% CI = 0.60-0.95) indicating acceptable discrimination [23] and the cut-off score that maximized both sensitivity and specificity was 117.6 cm. For the UQYB Medial the sensitivity was 71.4%, specificity was 78.1%, the positive predictive value was 58.3% and the negative predictive value was 86.4%. The area under the ROC curve was 0.70 (P = 0.04; 95% CI = 0.52-0.88) indicating acceptable discrimination [23] and the cut-off score that maximized both sensitivity and specificity was 119.15 cm.

Table 3. Logistic Regression Predicting Likelihood of Shoulder Injury based on demographics, balance and throwing accuracy.

Predictor Variables	B	SE	Wald	df	P	Odds Ratio	95% CI for Odds Ratio	
Age	-0.15	0.21	0.54	1	0.459	0.856	0.568	1.291
Height	-11.6	13.9	0.70	1	0.403	0.000	0	6073457.7
Weight	0.03	0.09	0.09	1	0.758	1.031	0.850	1.250
Gender	-5.34	3.32	2.58	1	0.108	0.005	0	3.222
BMI	-0.02	0.10	0.06	1	0.803	0.975	0.797	1.192
Y-Balance Anterior	-0.08	0.08	0.99	1	0.318	0.920	0.780	1.084
Y-Balance Lateral	-0.16	0.11	2.12	1	0.145	0.846	0.676	1.059
Y-balance Medial	0.70	0.34	4.08	1	0.043*	2.023	1.022	4.008
Upper Quarter Y-Balance Medial	0.49	0.21	5.16	1	0.023*	1.646	1.071	2.529
Upper Quarter Y-Balance Superior Lateral	-0.07	0.10	0.50	1	0.478	0.928	0.755	1.141
Upper Quarter Y-Balance Inferior Lateral	0.007	0.09	0.005	1	0.944	1.007	0.837	1.210
Functional Throwing Performance Index	-7.552	4.63	2.65	1	0.103	0.001	0	4.651

Note: Gender is for males compared to females. * Indicates statistical significance (<0.05)
BMI: Body Mass Index, B: B coefficients, S.E.: Standard Error, Wald: Wald test, df: degrees of freedom, P: statistical significance.

Table 4. Sensitivity, Specificity, Predictive values and Cut-off scores for the Y-Balance Medial and Upper Quarter Y-Balance Medial

	Sensitivity % (95% CI)	Specificity % (95% CI)	Positive Predictive Value % (95% CI)	Negative Predictive Value % (95% CI)	Cut-off Score (Threshold Value) cm
Y-Balance Medial	66.6 (22-95)	75.7 (58-88)	54.1 (34-72)	84.1 (62-94)	117.6
Upper Quarter Y-Balance Medial	71.4 (29-96)	78.1 (60-90)	58.3 (38-75)	86.4 (66-95)	119.15

CI: Confidence Interval

DISCUSSION

This study examined the ability of the Y-Balance, UQYB and FTPI test to predict in-season shoulder injuries in competitive volleyball athletes. The findings of this study partly support our initial hypothesis that balance assessment can predict those who were at increased risk of sustaining a shoulder injury during the competitive season. Specifically, we found the Y-Balance Medial and UQYB Medial were able to significantly predict in-season shoulder injuries. Also, calculation of the cut-off values, which may be seen as threshold values, along with the Odds Ratios, allowed us to suggest that athletes with scores below 117.6 cm in the Y-Balance Medial and 119.15 in the UQYB Medial are 2 and 1.6 times more likely to get injured in the shoulder complex, respectively. The importance of this study is mainly related to the fact that we were able to assess the predictive ability of multiple tests at once and identify the specific parameters of each test that could potentially identify those athletes who were at risk of injury as well as the cut-off scores (minimum scores) for each test.

Previous studies have examined the ability of balance field-based tests to differentiate overhead athletes with shoulder pain and asymptomatic overhead athletes. These studies have been conducted in various groups of throwing athletes, including handball and softball athletes [24], while the majority of these studies have recruited baseball players [25-27]. From these studies, Pogetti, Nakagawa, Conteçote and Camargo [24] found that posteromedial reach in the Y-Balance test was significantly reduced in patients that had shoulder pain which is in line with the findings of our study. However, the superiority of our study is related to the examination of the predictive ability of a relatively homogenous group of athletes (professional volleyball players), in contrast with other studies that examined only differences in performance in already predefined groups of athletes that were symptomatic or asymptomatic in the shoulder region.

For the UQYB test only the study of Bennett, Chalmers, Milanese and Fuller [28] has examined the predictive ability of this test on identifying athletes who are at risk of injury. However, this study was performed in football players and the UQYB test did not predict those at risk of any injury. Our study is the first that used the UQYB test for predicting shoulder injury in volleyball athletes. Research in military personnel has shown that UQYB deficiencies in superolateral reach may increase the risk of upper body injuries (including the torso) [29]. Nevertheless, this finding is not in line with our study since the medial reach in the UQYB test was able to predict shoulder injury in our population. This is probably due to the different nature of body mechanics in volleyball sport in contrast with combat sports in military personnel. Balance assessment of the upper and lower quarter seems to be able to predict shoulder injuries in athletes but differences in the reaching side may be evident in other sports as well. Furthermore, the findings of this study should be used to examine whether exercise programs that enhance the upper and lower balance towards the medial reach may in fact protect athletes from in-season shoulder injuries.

Examination of throwing biomechanics with advanced technology (3D motion analysis) has been incorporated in the past to assess the risk of injury in overhead athletes [30]. However, due to the high cost and expertise needed to use this equipment makes its application limited on the field or in clinical practice. Up to date there are no studies that have examined the ability of field-based tests to predict shoulder injuries in overhead athletes. Normative values for the FTPI have been provided in the past for overhead athletes and it has been recommended to use the FTPI as a return-to-sport test for athletes recovering from shoulder injury [31]. However, the ability of this test to trace those at risk of shoulder injury was not evident in our study. More research is needed to examine the ability of other field-based tests that assess throwing performance to predict in-season shoulder injuries.

The findings of this study have to be seen in light of some limitations. The sample size of this study may not be adequate to detect more statistically significant predictor variables. Although, lack of sample size calculation may have hindered our ability to detect more predictive variables through regression analysis, the identification of two predictors (Y-Balance medial and UQYB medial) for shoulder injury in volleyball athletes indicates that it is worth conducting more research with larger sample sizes. Furthermore, since all athletes volunteered to participate in the study, selectin bias is also possible, limiting the generalizability of our findings.

CONCLUSION

Based on the findings of this study, we advocate the inclusion of dynamic balance assessment for the prediction of shoulder injury in competitive volleyball athletes. Furthermore, this study suggests that upper and lower extremity stability exercise may be incorporated to prevent shoulder injuries in this population. However, more research is needed with larger sample sizes to establish whether more predictor variables of shoulder injury exist, including throwing accuracy.

Declaration by Authors

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