Predictive Value of Injury Risk Screening for Collegiate Volleyball Players

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BACKGROUND AND PURPOSE

- Associations between pre-participation status and subsequent injury can be used to identify athletes with elevated injury risk[1]
- Prediction models for core or lower extremity (LE) injury have been developed[1], but upper extremity (UE) models remain unrefined[2]
- Existing literature has primarily addressed injury prediction in male athletes, with limited evidence pertaining to female athletes
- Validated LE screening tests include Horizontal Trunk Hold (HTH)[3], Vertical Jump (VJ)[4], and Y-Balance Anterior Reach (YAR)[5]
- Proposed UE screening tools include Closed Kinetic Chain Upper Extremity Stability Test (CKC)[6], Shoulder Internal and External Rotation Strength Ratio (IR/ER)[7], Lateral Scapular Slide Test (LSST)[8], and Wall Angel Test (WAT)
- Sport Fitness Index (SFI) designed to quantify persisting effects of previous musculoskeletal injuries, without regard to location[9]
- The purpose of this study was to identify the most powerful prediction model for quantification of risk for any musculoskeletal injury (UE, core, or LE) among female collegiate volleyball athletes, thereby providing a guide for individualized injury risk reduction

METHODS

- 48 collegiate volleyball players from 4 different institutions representing NCAA Division I, NCAA Division III, and NAIA
  - Age 19.7±1.1 years; Height 172.6 ±8.7 cm; Weight 70.1 ±14.1 kg
- Pre-participation screening comprised of 10-item SFI survey and 7 tests administered prior to start of preseason practices
  - SFI: 6-level ordinal responses (5-0); frequency or severity of previous injury effects (0-100 total score; high = minimal effects)
    - Never, Not at all; Rare, Insignificant; Marginal, Infrequent; Occasional, Moderate; Frequent, Substantial; Persistent, Severe
  - HTH: kneeling position; 90º knee and 90º hip flexion; time (s) to failure (inability to sustain isometric horizontal trunk position)
  - YAR: dynamic measure of both unilateral postural balance and LE mobility; measured in cm of reach distance (Figure 1)
  - VJ: single-leg maximal effort; assessed with electronic jump mat (Just Jump or Just Run, Probotics Inc., Huntsville, AL; Figure 2)
  - CKC: dynamic test of alternating UE support; kneeling push-up position; number of crossover touches in 15 s (Figure 3)
  - WAT: dynamic test of both core strength and UE range of motion; binary pass/fail categorization for ability to perform test
  - LSST: mobility @ 0º abduction, hands on hips, and 90º abduction; spinous process to inferior angle distance in cm (Figure 4)
  - IR/ER: isometric maximal effort break test; handheld dynamometer (PowerTrack II, JTech Medical, Midvale, UT)
- Surveillance of number of sets played by each athlete and all time-loss musculoskeletal injury occurrences throughout season
  - Univariable exposure-outcome associations assessed by receiver operating characteristic (ROC) and 2 X 2 analyses
    - Cut-point, area under curve (AUC), sensitivity, specificity, odds ratio (OR), and 95% credible lower limit ($CLL_{95\%}$)
  - Logistic regression analysis used to identify strongest multivariable prediction model, with ROC analysis model simplification
    - Adjusted OR and 95% credible lower limit ($CLL_{95\%}$) for each retained factor; simplified model 2 X 2 OR and $CLL_{95\%}$
  - Stratification of data used to develop cascaded decision trees for categorization of an individual athlete's injury risk level

Figure 1

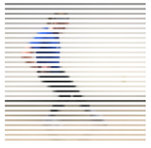

Figure 2

Figure 3

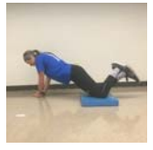

Figure 4

RESULTS

- Summary of ROC, 2 X 2 cross-tabulation, and logistic regression results for each meaningful predictive variable provided in Table 1
  - High performance for YAR, CKC, IR/ER, and VJ all associated with both injury occurrence and volume of game exposure
  - Logistic regression analysis yielded 3-factor model: 1) SFI, 2) game exposure, and 3) LSST Diff @ 90º abd
    - Model $\chi^2(3) = 19.57$; $P < .001$; Hosmer & Lemeshow goodness-of-fit $\chi^2(4) = 2.40$; $P = .662$; Nagelkerke $R^2 = .449$
      - ≥ 2 of 3 Factors: OR = 16.15, $CLL_{95\%}$ = 4.03, Sensitivity = 63%, Specificity = 91% (Figure 5)
- Stratification on basis of game exposure demonstrated effects of low SFI score and/or suboptimal symmetry of scapular positions
  - Athletes with ≥ 100 sets, high SFI score, and optimal symmetry of scapular positions had 0% injury incidence (Figure 6)
  - Athletes with ≥ 100 sets, low SFI score, and suboptimal symmetry of scapular positions had 100% injury incidence (Figure 7)
- Classification trees developed by recursive partitioning of dataset to facilitate clinical application of results (Figure 8 and Figure 9)
  - Game exposure used for first level of grouping, with SFI and LSST Diff @ 90º abd used for second level groupings
    - ROC analyses identified group-specific cut-points that maximized discriminatory classifications for injury incidence
- ROC analysis of individual SFI items demonstrated that all had predictive value for injury occurrence (Figure 10 and Table 2)
  - Strongest predictive value demonstrated by athlete responses to questions 3, 5, and 6

Table 1

Variable	Cut-Point	AUC	Sensitivity	Specificity	OR (CLL_{95})	Adj OR (CLL_{95})
Sport Fitness Index (0-100)	≤ 78	.760	74%	71%	7.14 (2.44)	8.88 (2.54)
CKC (hand touches in 15 s)	≥ 24	.563	37%	91%	5.59 (1.40)	--
Game Exposure (Sets)	≥ 100	.674	56%	81%	5.34 (1.74)	5.40 (1.50)
Y-Balance Anterior Reach (cm)	≥ 62	.671	70%	67%	4.75 (1.70)	---
LSST Diff @ 90º Abd (cm)	≥ 1.15	.631	37%	86%	3.53 (1.05)	4.73 (1.10)
Vertical Jump (cm)	≥ 57	.605	54%	71%	2.92 (0.98)	---

Figure 5

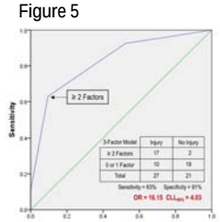

Figure 6

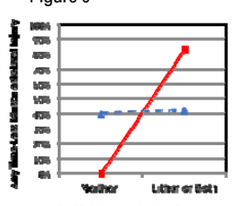

Figure 7

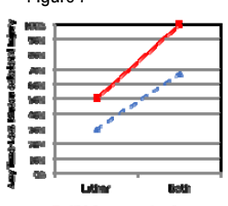

Figure 8

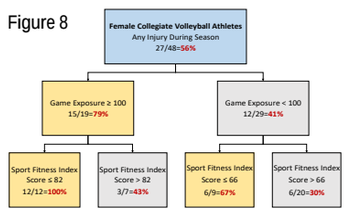

Figure 9

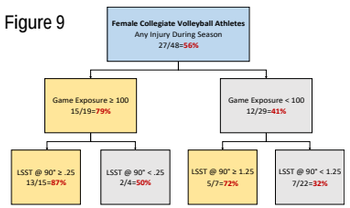

Figure 10

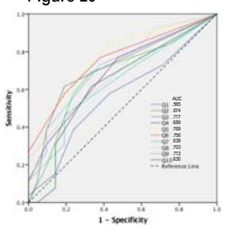

Table 2

Q1	Over the past several years, how often have moderate-to-severe muscle and/or joint injuries limited your ability to fully participate in sports-related activities?
Q2	Over the past several years, how often has PAIN in any body part limited your OVERALL sport performance capabilities?
Q3	To what extent do you feel that previous muscle and/or joint injuries currently limit your speed, power output, and/or endurance?
Q4	To what extent is your OVERALL ability to perform weightlifting exercises and/or activities that require explosive for output (such as maximum-effort jumping) currently limited by PAIN?
Q5	To what extent is your ability to perform any SPORT-SPECIFIC SKILL (such as throwing, swinging, or kicking accuracy) currently limited by PAIN
Q6	To what extent are you bothered by muscle spasms, stiffness, and/or aching discomfort during routine activities of daily living (such as sleeping, walking, climbing/descending stairs, etc.)?
Q7	How often do you experience sensations of joint instability, giving-way, and/or sudden pain that create apprehension during rapid and forceful movements (such as pivoting and cutting)?
Q8	As a result of participating in sport-related activities, how often do you experience joint aching, limited motion, stiffness, and/or swelling?
Q9	To what extent are you bothered by chronic joint symptoms like joint locking, catching, grinding, or persistent aching?
Q10	Over the past 12 months, to what extent have personal life events created emotional responses (such as sadness, depression, and/or anxiety) that have interfered with your enjoyment of life, ability to concentrate, and/or fulfillment of routine daily responsibilities?

CLINICAL RELEVANCE

- Game exposure is a factor that is often neglected in injury prediction studies, which do not adequately address confounding effects
  - High-level performance capabilities may associate with injury occurrence through the mediating effect of high game exposure
    - Athletes with high performance values for YAR, CKC, IR/ER, and VJ tests more likely to participate in high volume of sets
- Quantification of persisting previous injury effects was the strongest injury predictor, particularly among athletes with ≥ 100 sets
  - SFI score appears to be an exceptionally good indicator of the effect of previous injury on risk for subsequent injury
    - Optimal cut-point can differ for entire cohort (i.e. all team members) versus subgroups (e.g. high exposure athletes)
- Interventions for risk reduction should be focused on modifiable factors, which may be revealed by responses to SFI questions
  - Scapular positioning asymmetry appears to be a modifiable risk factor that may be addressed by therapeutic exercise
    - Injury prevention may be greatly facilitated by pre-participation risk screening that can identify potentially modifiable factors

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