Association of Pre-Participation Status with Injury Hazard over the Course of a Football Season

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BACKGROUND AND PURPOSE

- Overall injury rate in NCAA football is 8.1 injuries per 1000 athlete-exposures (1 exposure = 1 game or 1 practice)[1]
  - Strongest predictors of sport injury include injury history[2] and volume of participation in games[3]
  - Factors such as concussion history and post-injury impairment of neuromuscular control elevate injury risk[4]
  - Visumotor reaction time (VMRT) and lumbopelvic muscle endurance appear to be associated with injury risk[3,5]
- A prediction model for time to injury provides optimal representation of differences in injury hazard over a season
- The purpose of this study was to determine the extent to which starter status, concussion history, self-rating of function, VMRT, and postural balance predict sprain/strain hazard among college football players.

PARTICIPANT CHARACTERISTICS AND PROCEDURES

- Prior to the first practice, potential injury predictors were quantified as part of the pre-participation screening
  - 45 NCAA Division I-FCS football athletes: ± years; 105.5 ±20.16 kg; 186.0 ±6.0 cm
- VMRT quantified (time or number of hits) using D2™ system (Dynavision International, West Chester, OH; Figure 1)
  - Target buttons arranged in 5 concentric circles; centrally located LCD monitor
    - Proactive test mode; target buttons illuminated until hit
    - Reactive test mode; target buttons illuminated 750 ms; recitation of sentences scrolled across LCD monitor
    - Reactive test mode while standing on an unstable surface (BOSU® Balance Trainer, Ashland, OH)
- Unilateral postural stability quantified by smartphone accelerometer (Sway Balance, Sway Medical, Tulsa, OK)
  - 10-s test of ability to minimize postural sway with smartphone secured by strap to position between scapulae
    - Single-Leg Balance (SLB) with 45° knee flexion
    - Standing Horizontal Trunk Hold (SHT) with 45° knee flexion and 90° hip flexion (Figure 2)
    - SLB with heel raised (SLB-HR) with 45° knee flexion and 2.5 cm of heel elevation (Figure 3)
  - Root mean square (RMS) of rate of change in body mass acceleration (m/s^3) within each plane of motion
    - Anterior-Posterior (A-P), Medial-Lateral (M-L), and Superior-Inferior (S-I)
- Sports Fitness Index Survey (SFI) quantified effects of past injuries on functional capabilities
  - Previous injuries (including concussion) self-reported
- Injury defined as any upper extremity, core, or lower extremity sprain or strain (wrist, hand, and fingers excluded)
  - Evaluation and treatment provided by athletic trainer, with any degree of activity modification required
  - Injuries and exposures were tracked using an electronic injury documentation system
  - Starter vs. non-starter status determined from records maintained by university athletic program
- Data analysis procedures for assessment of association between potential predictors and injury occurrence
  - Receiver operating characteristic (ROC) analysis used to identify cut-points for binary classification of injury risk
  - Logistic regression analysis utilized to develop multivariable injury prediction model
  - Cox regression analysis utilized to assess time to injury difference for players in high-risk vs. low-risk categories

RESULTS

- A total of 17 injuries were sustained by 15 players (2 players sustained 2 injuries); 33% injury incidence (15/45)
  - No association of starter status (22/45) with injury occurrence (OR=0.77) or concussion history (OR=0.33)
- ROC analyses demonstrated strongest predictors to be the following:
  - Reactive test mode Rings 4-5 Hits, SLB, SHT, SLB-HR, and SFI score (Table 1)
    - Postural sway values were imputed (cohort mean value) for 2 cases, rather than their exclusion from analysis
- Logistic regression analysis identified the best multivariable prediction model, which yielded a 2-factor model
  - SLB-HR and Ring 4-5 Hits included in 2-factor prediction model, both factors + vs. 0 or 1 + (Tables 2 & 3, Figure 4)
    - Logistic regression model $\chi^2(2)=6.77$; p=.034; Hosmer-Lemeshow $\chi^2(2)=1.37$; p=.504; Nagelkerke $R^2=.194$
    - Both factors positive: $\chi^2(1)=7.79$; p=.012; Sensitivity=33%; Specificity=97%; OR=14.50 (90% CI: 2.17, 96.96)
      - ≥1 factor positive: $\chi^2(1)=2.38$; p=.112; Sensitivity=80%; Specificity=43%; OR=3.06 (90% CI: 0.90, 10.39)
- Cox regression analysis of binary categorization (high risk = both factors positive vs. low risk = 0 or 1 factor positive)
  - Model $\chi^2(2)=13.43$; p<.001; HR=6.02 (90% CI: 2.41, 15.03)
    - Log minus log graph analysis confirmed assumption of proportional hazards for groups
  - Exceptionally good concordance between actual cumulative injury incidence and Cox model for time to injury
    - Solid lines = actual data; Dashed lines = Cox model prediction (Figure 5)

Table 1

Predictor	Cut-Point	Sensitivity	Specificity	OR	*P*	Adj OR
Ring 4-5 Hits	≤ 11	67%	60%	3.00	.085	3.13
SLB	≥ .02	73%	50%	2.75	.120	2.30
SHT	≥ .03	40%	73%	1.83	.282	1.48
SLB-HR	≥ .06	47%	80%	3.83	.056	5.22
SFI	≤ 86	73%	40%	1.83	.294	2.34


Figure 1


Figure 2

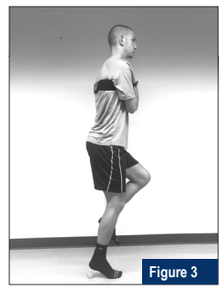


Figure 3

Table 2

2-Factor Model			
Factors	**Injury**	**No Injury**	**Incidence**
Both +	5	1	83%
0 or 1	10	29	26%
Total	15	30	RR = 3.25

Table 3

Risk Factors	Injury	No Injury	Incidence
0	3	13	19%
1	7	16	30%
2	5	1	83%
Total	15	30	33%

Figure 4

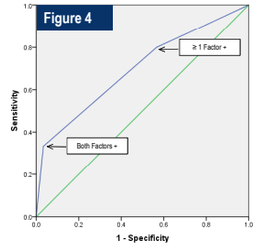
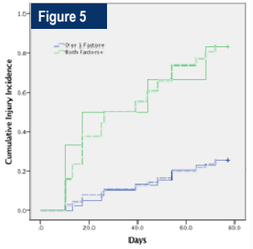


Figure 5



CLINICAL RELEVANCE

- Game exposure (starter) and previous injury were less predictive than slow VMRT and postural instability
  - Reactive mode test required central visual focus, which challenged peripheral visual perception-action response
  - SLB-HR test demonstrated greater discriminatory power than SLB test without heel elevated
- Our findings support recent evidence establishing the relevance of neuromechanical coupling to injury risk[6]
  - Over the course of the season, high-risk players clearly sustained injuries much earlier than low-risk players
  - Central-peripheral integration of visual input and highly coordinated neuromuscular control may be critical factors
- Injury risk screening should include tests that assess neuromechanical capabilities, which may identify players who would be most likely to benefit from a risk-reduction intervention designed to address performance deficiencies

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