Neuromechanical Factors Associated with College Football Injury Risk

Rachael C. Anthony, MS, ATC; Teig M. Palmateer, MS, ATC; Gladys G. Ruiz-Malca, MS, ATC; Gary B. Wilkerson, EdD, ATC; Shellie N. Acocello, PhD, ATC

THE UNIVERSITY of TENNESSEE CHATTANOOGA

BACKGROUND AND PURPOSE

- Sport-related concussion (SRC) affects 1.6 to 3.8 million athletes each year,[1] which can have long lasting adverse effects
  - Deficits in neurocognitive performance, coordination, and balance typically resolve within 7 to 10 days[2]
    - Subtle motor control impairments can persist beyond symptom relief that may elevate risk for subsequent injury[2,3]
- History of ≥ 1 SRC associated with increased risk for subsequent injury,[4,5] as well as increased risk for musculoskeletal injury[3,4,6]
  - Subtle perceptual and motor control deficits may be responsible for an increase in post-SRC musculoskeletal injury rate[3]
    - Altered coupling of visual, cognitive, and motor processes may adversely affect neuromechanical responsiveness[3,5]
- The purpose of this study was to assess the predictive value of SRC history, visuomotor reaction time (VMRT) and whole-body reactive agility (WBRA) for identification of college football players who possess elevated risk for core or lower extremity injury

PARTICIPANTS & PROCEDURES

- 89 NCAA Division I-FCS football players (20 ±1.3 yrs; 100.6 ±19.2 kg; 183.74 ±6.59 cm) tested during summer conditioning period
  - Concussion history (Con Hx) based on athlete self-report; current concussion symptoms (Con Sx) derived from survey question
    - 33 Con Hx: 20.1 ±1.3 yrs; 100.3 ±20.3 kg; 183.44 ±6.48 cm; 56 No Con Hx: 20.0 ±1.4 yrs; 100.7 ±18.8 kg; 183.71 ±6.62 cm
  - 10-item Sports Fitness Index (SFI) used to quantify persisting effects of previous injuries (0-100; high score = optimal function)
  - WBRA assessed by lateral shuffle test in right and left directions (TRAZER® Sports Stimulator, Traq Global Ltd, Westlake, OH)
    - Proper movement directions guided by appearance of 20 virtual reality targets on large monitor in front of athlete
    - Start position 3.12 m from monitor; movement of 0.91 m required to deactivate target (10 each direction; random order)
      - Reaction time (RT), speed (Spd), acceleration (Acc), deceleration (Dec), and total time (TT) quantified
        - Average value and right-left asymmetry (% difference) assessed for each performance variable
  - VMRT measured by computerized light board Dynavision D2 system (Dynavision International, West Chester, OH); 60-s tests
    - Proactive mode: target buttons illuminated until hit (Average VMRT represented in ms)
- Injury surveillance throughout pre-season practice period and 11-game season; each practice and game counted as 1 exposure
  - Injury defined as any core or lower extremity (LE) sprain or strain that required evaluation and treatment
  - Potential confounding effect of differential exposure to game conditions represented by number of games played (Exp-GP)
- Multivariable prediction model derived from a series of analyses for determination of relative predictive power of variables
  - Receiver operating characteristic (ROC) analyses identified cut-points for binary categorization (high risk versus low risk)
    - Association of each potential binary predictor variable with injury occurrence represented by univariable odds ratio (OR)
      - 95% credible lower limit ($CLL_{95\%}$) for OR determined (lower limit of 90% confidence interval for 1-sided low estimate)
  - Logistic regression analysis used to identify strongest set of binary variables; adjusted OR (OR-Adj) derived for each
    - Final model derived from ROC analysis of multivariable predictor set to simplify clinical application of results
      - Number of positive risk factors for optimal discrimination determined, with associated OR and $CLL_{95\%}$
  - Time to event analysis (Cox regression) performed to further evaluate final model (binary risk categorization)

RESULTS

- Univariable and multivariable analysis results for associations of predictive variables with injury occurrence presented in Table 1
  - Exp-GP identified as strongest injury predictor (Figure 3); ≥ 5 GP provided optimal cut-point for binary risk categorization
  - Logistic regression identified 4-factor model: Exp-GP ≥ 5 games, VMRT ≥ 745 ms, WBRA-TT ≥ 101 s, and Con Hx positive
    - Model χ^2 (4) = 20.08; *P* <.001; Hosmer & Lemeshow goodness-of-fit χ^2 (6) = 5.88; *P* = .437; Nagelkerke R^2 = .285
    - ROC analysis for model simplification identified best discrimination with ≥ 2 of 4 factors positive: OR = 5.60 ($CLL_{95\%}$ = 2.50)
      - Effect of number of positive risk factors on injury incidence presented in Table 2 and Table 3
      - Stratification of data performed to examine relationships among risk factors influencing injury incidence
        - Con Hx positive associated with elevated injury incidence for both high and low Exp-GP subgroups (Figure 4)
        - Slow VMRT associated with elevated injury incidence for both Con Hx positive and Con Hx negative subgroups (Figure 5)
        - 100% injury incidence observed for players positive for both Slow WBRA-TT and Slow VMRT (Figure 6)
  - Cox regression analysis of binary risk categorization (≥ 2 of 4 factors positive) demonstrated significant time to event difference
    - Model χ^2 (4) = 14.45; *P*<.001; HR = 4.16 ($CLL_{95\%}$ 2.19); time to injury difference clearly evident between risk groups (Figure 7)

Figure 1

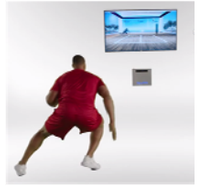

Figure 2

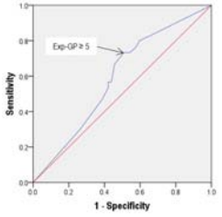

Figure 3

Table 1.

Predictor	Cut-Point	*P*-Value*	Sensitivity	Specificity	OR ($CLL_{95\%}$)	OR-Adj ($CLL_{95\%}$)
Exp-GP	≥ 5 Games	.035	73%	49%	2.66 (1.19)	5.55 (2.01)
VMRT	≥ 745 ms	.013	40%	84%	3.56 (1.51)	5.40 (2.03)
WBRA-TT	≥ 101 s	.124	20%	92%	2.60 (0.89)	4.16 (1.26)
Con Hx	Yes	.093	47%	70%	2.06 (0.96)	3.18 (1.27)
WBRA-RT	≥ 358 ms	.036	87%	34%	3.25 (1.20)	—
SFI	≤ 82	.021	47%	77%	2.96 (1.34)	—
Con Sx	Any	.042	43%	77%	2.59 (1.17)	—

* Fisher's Exact One-Sided Test

Table 2

Risk Factors	Injury	No Injury	Incidence	
≥ 2 of 4	20	15	57.1%	+LR=2.53
< 2 of 4	10	42	19.2%	–LR=0.45
Total	30	57	RR=2.97 (90% CI: 1.76, 5.03)	OR=5.60 (90% CI:2.50, 12.55)
Sensitivity=67%	Specificity=74%			

Table 3

Factors	Injury	No Injury	Incidence
0	0	13	0%
1	10	29	26%
2	16	14	53%
3	4	1	80%
Total	30	57	35%

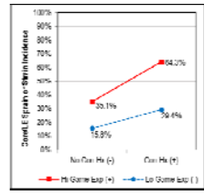

Figure 4

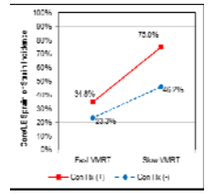

Figure 5

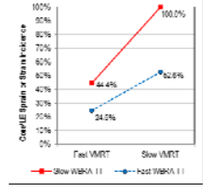

Figure 6

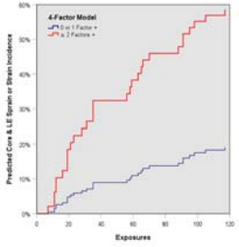

Figure 7

CLINICAL RELEVANCE

- Game exposure is often neglected as a potentially important effect-modification factor in football injury risk assessment studies
- Findings support emerging evidence that concussion history is associated with elevation of musculoskeletal injury risk
- Suboptimal neuromechanical performance capabilities may represent modifiable injury risk factors that should be assessed
  - Slow VMRT and slow WBRA-TT could be consequences of concussion, or independent musculoskeletal injury risk factors
- Injury susceptibility may relate to speed of motor responses to rapidly changing environmental conditions, as well as spatial position awareness, both of which were represented in measures derived from our pre-participation injury risk screening tests

REFERENCES

1. Langlois JA, Rutland-Brown W, Wald MM, The epidemiology and impact of traumatic brain injury: a brief overview. *J Head Trauma Rehabil.* 2006;5:375-378.
2. McCrory P, et al. Consensus statement on concussion in sport-the 5th International Conference on Concussion in Sport held in Berlin, October 2016. *J Sports Med.* 2017;51:838-847.
3. Wilkerson GB, Grooms DR, Acocello SN, Neuromechanical considerations for postconcussion musculoskeletal injury risk management. *Curr Sports Med Rep.* 2017;6:419-427.
4. Nordstrom A, Nordstrom P, Ekstrand J. Sports-related concussion increases the risk of subsequent injury by about 50% in elite male football players. *Br J Sports Med.* 2014;48:1447-1450.
5. Brown JA, et al. Cognitive-motor integration deficits in young adult athletes following concussion. *BMC Sports Sci Med Rehabil.* 2015;25:doi:10.1186/s13102-015-0019-4.
6. Lynall RC, Mauntel TC, Padua DA, Mihalik, JP. Acute lower extremity injury rate increase after concussion in college athletes. *Med Sci Sports Exerc.* 2015;12:2487-2492.