Association of Visual-Cognitive-Motor Integration with Core and Lower Extremity Injury in College Football

Veronica A. Bridges MS, ATC; Katherine E. Rogers MS, ATC; Quentin W. Johnson MS, ATC; Austin T. Albright MS, ATC;
Shellie N. Acocello PhD, ATC; Gary B. Wilkerson EdD, ATC

THE UNIVERSITY of TENNESSEE CHATTANOOGA

BACKGROUND AND PURPOSE

- Both mild traumatic brain injury (mTBI) and musculoskeletal injury clearly elevate risk for long-term disability among football players[1]
  - Recent research has linked mTBI to substantially increased risk for sport-related musculoskeletal injuries upon return to sport[2]
    - Subtle impairment of brain sensorimotor control processes may adversely affect responses to potentially injurious events
- The majority of college football injuries are lower extremity sprains and strains (55-60%),[3] which often result in recurrent injuries
  - Core (lumbopelvic and abdominal structures) and lower extremity (LE) injuries have been documented to have shared risk factors[4]
    - High volume of game participation, Core or LE injury history (CLEI Hx), and mTBI Hx are major factors influencing CLEI risk
- Previous research has established visuomotor (VM) and whole-body (WB) reactive metrics as potentially modifiable factors[5]
  - Optimal VM and WB reactive performance capabilities may offset other well-established CLEI risk factors that are not modifiable
    - 6.6 X greater injury rate during games compared to practice sessions makes volume of game exposure a primary risk factor[3]
- The purposes of this study were to assess pre-participation VM and WB reactive performance metrics, player attributes, and subsequent CLEI associations, and the extent to which reactive training may reduce CLEI risk among college football players

PARTICIPANTS & PROCEDURES

- 52 Division I-FCS football players who participated throughout an 11-game season completed pre-participation performance tests
  - 20.1 ±4.2 yrs, 186.3 ±5.3 cm, 104.2 ±16.3 kg; complete pre- and post-training assessment data available for 48 of the 52 players
- Single-task (ST) and dual-task (DT) VM reaction time (RT) quantified by Dynavision D2™ 60-s tests (Figure 1)
  - Buttons illuminated until hit; 60-s ST practice trial and 60-s ST test trial, followed by two different 60-s DT trials (A & B)
    - A: Flanker test – center arrow direction verbal responses (<<<<<, >>>>>, >><>>, <<><<); 20 LCD displays (DT-A)
    - B: Flanker test – center arrow direction motor responses (<<<<<, >>>>>, >><>>, <<><<); 48 LCD displays (DT-B)
- WB reactive agility (RA) quantified by TRAZER® 20-target lateral side-shuffle and 12-target diagonal movements (Figure 2)
  - Movements guided by randomized target appearances on monitor, which disappeared when contacted by avatar
  - Metrics included Reaction Time (RT), Acceleration (Acc), Deceleration (Dec), Speed (Spd), and Asymmetry (Asym)
- CLEI documented from initiation of pre-season practice sessions through end of 11-game season
  - CLEI defined as any sprain or strain that resulted in evaluation and treatment, regardless of whether or not time loss occurred
  - Cases of fracture, dislocation, contusion, laceration excluded from analysis, as well as any overuse condition
- Receiver operating characteristic (ROC) analysis used to define optimal cut-point for each potential predictor variable
  - Cross-tabulation and logistic regression analysis used to quantify associations with CLEI represented by odds ratio (OR)
- Training activity conducted over a 7-week period, which consisted of 60-s VMRT DT-A and WBRA trials 1-3 times per week
  - Between pre- and post-training assessments: median of 11 sessions completed by 48 players (range 3-13 sessions)

RESULTS

- 51 CLEI among 52 players between start of practices until end of season; ≥ 1 documented for 50% (26/52) of players (Table 1)
  - ROC and cross-tabulation analyses identified 7 variables associated with CLEI; logistic regression yielded 5-factor model (Table 2)
    - Adjusted OR values for backward elimination process: Step A. included all 7 variables; Step B. retained 5 strongest variables
      - 5-factor model $\chi^2(5) = 30.03$; $P \leq .001$; Hosmer & Lemeshow goodness-of-fit $\chi^2(8) = 5.08$; $P = .749$; Nagelkerke $R^2 = .586$
        - Beta weights: Starter 3.07, CLEI Hx 2.10, mTBI Hx 1.56, WB Diagonal-Back (D/B) Acc 2.72, WB Diagonal (Diag) Time 2.78
    - 5-factor Beta Sum ≥ 4.38: 91% Positive Predictive Value; 24% Negative Predictive Value; OR = 33.00 (90% CI: 8.05, 135.31)
- Interaction evident between non-modifiable risk factors (Starter, CLEI Hx, and mTBI Hx) and WB Diag Time (Figures 3-5)
  - Pre-participation training improvement in WB Diag Time and WB D/B Acc were associated with avoidance of CLEI (48 cases)
    - Failure to improve WB Diag Time ≥ 6 sec: 58% Sensitivity; 67% Specificity; OR = 2.80 (90% CI: 1.05, 7.50)
    - Failure to improve WB D/B Acc to any extent: 96% Sensitivity; 21% Specificity; OR = 6.05 (90% CI: 0.93, 39.37)
      - Failure to improve for Both WB Diag Time + WB D/B Acc: 53% Positive Predictive Value; 100% Negative Predictive Value
      - Effect of Both vs. 0 or only 1 improved on injury incidence: Starter vs. Non-Starter (Figure 6); CLEI Hx vs. No CLEI Hx (Figure 7)
- Cox regression analysis of binary risk categorization (5-factor Beta Sum ≥ 4.38) demonstrated significant Hi vs. Lo Risk difference
  - $\chi^2(1) = 30.13$; $P \leq .001$; HR = 8.54 (90% CI: 4.06, 17.97); instantaneous hazard for injury occurrence differed over time (Figure 8)

Figure 1

Figure 2

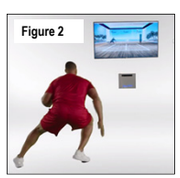


Table 1. CLEI Occurrences

Injury	Number
Ankle/Foot	20
Knee	11
Thigh	3
Hip/Groin	12
Core	5

Table 2. Results of Univariable and Multivariable Analyses

Variable	Cut-Point	AUC	Sensitivity	Specificity	OR	P-value*	Adj OR - A	Adj OR - B
Starter	≥ 2 games	.661	57	83	6.67	.003	20.79	21.46
CLEI Hx	Yes/No	-	65	72	3.60	.002	5.74	8.17
mTBI Hx	Yes/No	-	41	69	1.57	.248	5.19	4.74
WBRT Lat	≥ 483 ms	.555	36	88	3.89	.050	3.00	†
VMRT (ST)	≥ 765 ms	.516	43	71	1.82	.232	1.92	†
WB D/B Acc	≤ 2.26 m/s²	.600	21	96	6.27	.076	10.26	15.10
WB Diag Time	≥ 68 s	.631	57	75	4.00	.019	11.05	10.85
Beta Sum	4.38	.763	75	92	33.00	<.001	-	-

* Fischer's exact 1-sided test † Variable eliminated by backward stepwise logistic regression analysis

Figure 3

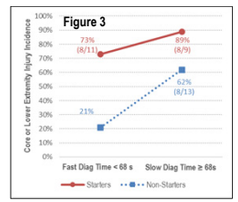


Figure 4

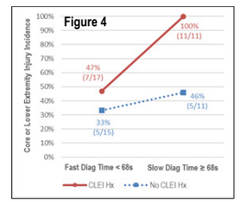


Figure 5

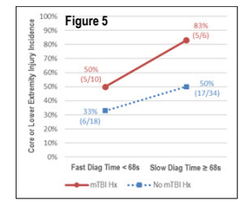


Figure 6

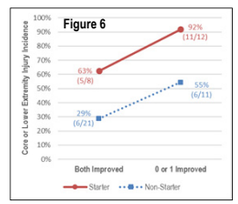


Figure 7

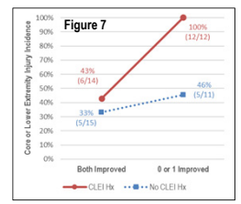
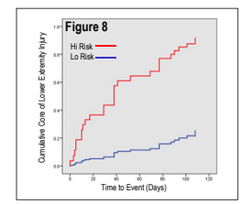


Figure 8



CLINICAL RELEVANCE

- Consistent with the findings of previous research, 3 non-modifiable factors had the strongest prospective associations with CLEI
  - Interactions among both modifiable and non-modifiable factors highlight the importance of individualized risk profile assessment
    - Greatest potential for CLEI risk reduction appears to be training for improvement of whole-body visual-cognitive-motor integration
- Slow WBRA Diag Total Time and slow D/B Acc may relate to slow neural processing and/or impaired visual-spatial awareness
  - WBRA diagonal movement pattern testing may replicate critical performance capabilities relevant to CLEI avoidance in football
    - Pre-participation WBRA training adaptations were associated with the probability for subsequent occurrence of CLEI
- Analysis of time to first CLEI occurrence provided exceptionally strong validation of 5-factor risk model over duration of football season, which clearly supports the potential value of properly designed risk screening tests and targeted training for risk reduction

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