# Dual-Task Screening for Identification of Persisting Concussion Effects on Cognitive Control in College Football Players

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## BACKGROUND AND PURPOSE

- An estimated 1.6 to 3.8 million sport-related traumatic brain injuries occur annually in the US[1]
  - Athletes with concussion history exhibit slower reaction time (RT), as well as memory and vision dysfunction[2,3]
  - These deficits have shown to persist for 7 years or more[4]
- Previous research has demonstrated increased incidence of musculoskeletal injuries after concussion[5]
  - RT and peripheral visual awareness appear to be particularly important modifiable factors for risk reduction
  - Emerging evidence suggests that visuomotor training may reduce risk for concussion,[6] as well as other injuries[7]
- Optimal responsiveness to a rapidly changing sport environment involves both neurocognitive and biomechanical factors
  - The term "cognitive control" refers to goal-directed processes underlying perception, memory, and action
  - The Eriksen Flanker Test has been widely used as a simple assessment of cognitive control[4]
- The purpose of this study was to assess the potential value of dual-task testing methods for identification of suboptimal cognitive control and the extent to which any performance deficiencies might be due to previous concussion

## PARTICIPANT CHARACTERISTICS AND PROCEDURES

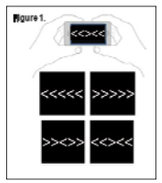
- 66 NCAA Division I-FCS football players available during summer conditioning assed prior to first pre-season practice
  - Pre-participation baseline ImPACT data used to determine athlete concussion history
    - History of Concussion (n=18): 20.1 ± 1.2 years; 108.64 ± 22.27 kg; 187.40 ± 6.01 cm
    - No History of Concussion (n = 48): 20.2 ± 1.3 years; 104.38 ± 20.30 kg; 187.75 ± 5.49 cm
- Eriksen Flanker performance quantified using Sport Injury Prevention Screen (SIPS®) phone application (Figure 1)
  - Flanker display presented for 100 ms; response registered by tipping phone in right versus left direction
  - 20-s trial used for familiarization; 1 recorded trial involving 16 flanker displays (average RT for correct responses)
- Single-leg balance assessed for 30 s, with and without verbal responses to 20 750-ms flanker displays on a laptop screen
  - Postural sway measured by HUMAC Balance System (CSMI Solutions, Inc., Stoughton, MA) for both legs (Figure 2)
- Visuomotor responses assessed for 60 s, with and without verbal responses to 20 1-s flanker displays on LCD screen
  - Responses quantified by Dynavision D2™ system (Dynavision International, West Chester, OH; Figure 3)
    - Proactive mode – target buttons illuminated until hit
    - Proactive mode + Flanker – simultaneous verbal responses to 5-arrow flanker displays on LCD screen
    - Reactive mode – target buttons must be hit within 1 s, while simultaneously reading scrolling text on LCD screen
- Receiver operating characteristic analysis used to establish cut-point for binary classification of cases
- Cross-tabulation analysis performed to assess association between binary classification and concussion history
- Logistic regression analysis used to derive multivariable model linking screening test results to concussion history
- Electronic documentation system used for injury surveillance throughout pre-season practices and 13-game season

## RESULTS

- Univariable analysis results for binary categorizations of test performance values presented in Table 1
  - Single-leg balance center of pressure (COP) average values slightly improved or unchanged with concurrent flanker test
    - No significant differences noted between average COP values for players with concussion history and those without
    - Concurrent flanker test dramatically increased discriminatory power of COP Medial-Lateral Movement Std Dev
      - Missing COP values imputed for 7 cases to permit inclusion in multivariable analysis
  - Discriminatory power of visuomotor performance variables greatest for those imposing concurrent visual task demand
    - Proactive mode with Flanker test verbal response and Reactive mode with verbal recitation of scrolling text
    - Proactive mode Outer/Inner RT calculated as Ring 4-5 Average RT / Ring1-3 Average RT
    - Proactive + Flanker Outer Efficiency Index calculated as Ring 4-5 Average RT / Response Accuracy
    - Reactive mode Outer/Inner Hits calculated as Ring 4-5 Hits / Ring 1-3 Hits during 60-s trial
  - SIPS App Average RT data available for only 49 players, therefore not included in multivariable analysis
- Logistic regression analysis identified strong interaction between single-leg balance and visuomotor performance
  - COP Medial-Lateral Movement Std Dev X Proactive Outer/Inner RT, both with and without concurrent flanker test
    - Dramatically increased discriminatory power with inclusion of concurrent flanker test (Tables 2 & 3, Figures 4 & 5)
- Core or lower extremity sprain or strain incidence greater for players with concussion history (OR = 3.18; $CLE_{95}$: 1.15)
  - 47% (7/15) of players with positive history versus 22% (11/51) with negative history (Risk Ratio = 2.16)

Table 1.

| Variable | Cut-Point | Odds Ratio | $CLE_{95}$ | Sensitivity | Specificity |
|---|---|---|---|---|---|
| Dynavision Proactive - Outer/Inner RT | ≥ 1.38 | 3.65 | 1.40 | 67 | 65 |
| Dynavision Proactive + Flanker - Outer/Inner RT | ≥ 1.44 | 4.90 | 1.72 | 58 | 78 |
| Dynavision Proactive + Flanker - Response Accuracy | ≤ 0.98 | 2.28 | 0.90 | 56 | 65 |
| Dynavision Proactive + Flanker - Outer Efficiency Index | ≥ 1.21 | 3.75 | 1.45 | 56 | 75 |
| Dynavision Reactive + Text - Outer/Inner Hits | ≤ 0.79 | 6.77 | 1.80 | 89 | 46 |
| Center of Pressure Med-Lat Movement Std Dev | ≥ .201 | 3.57 | 1.14 | 83 | 42 |
| Center of Pressure Med-Lat Movement Std Dev + Flanker | ≥ .271 | 10.75 | 3.57 | 56 | 90 |
| Center of Pressure Average Velocity | ≥ 1.62 | 2.92 | 1.01 | 33 | 85 |
| Center of Pressure Average Velocity + Flanker | ≥ 1.05 | 1.47 | 0.00 | 100 | 21 |
| Center of Pressure Max Deviation | ≥ 0.37 | 3.28 | 1.04 | 83 | 40 |
| Center of Pressure Max Deviation + Flanker | ≥ 0.35 | 2.02 | 0.75 | 72 | 44 |
| Center of Pressure Path Length | ≥ 31.32 | 1.49 | 0.00 | 100 | 23 |
| Center of Pressure Path Length + Flanker | ≥ 31.38 | 1.47 | 0.00 | 100 | 21 |
| SIPS App Flanker Test Average Reaction Time | ≥ 455 | 5.54 | 1.61 | 75 | 65 |
| ImPACT Visual Memory | ≤ 77.5 | 2.02 | 0.80 | 61 | 56 |





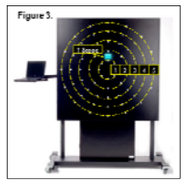
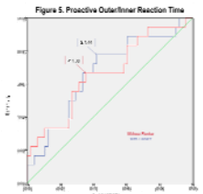



Table 2. Interaction Effect without Concurrent Flanker Test

| Factors | History + | History - | % History + | |
|---|---|---|---|---|
| Both + | 9 | 9 | 50% | OR = 4.33 ($CLE_{95}$ = 1.62) |
| 0 or 1 + | 9 | 39 | 19% | |
| | Sensitivity: 50% | Specificity: 81% | | |

Table 3. Interaction Effect with Concurrent Flanker Test

| Factors | History + | History - | % History + | |
|---|---|---|---|---|
| Both + | 9 | 1 | 90% | OR = 47.00 ($CLE_{95}$ = 7.51) |
| 0 or 1 + | 9 | 47 | 16% | |
| | Sensitivity: 50% | Specificity: 98% | | |


## CLINICAL RELEVANCE

- The addition of the Flanker task to visuomotor and balance testing greatly increased classification accuracy
  - COP Med-Lat Movement Std Dev OR = 3.57 → COP Med-Lat Movement Std Dev + Flanker OR = 10.75
  - Proactive Outer/Inner RT OR = 3.65 → Proactive Outer/Inner + Flanker RT OR = 4.90
    - Odds for concussion history 47 X greater with both dual-task factors positive versus 0 or 1 dual-task factors positive
- SIPS App Flanker Test Average RT demonstrated good discriminatory power, with OR = 5.54
  - A much larger cohort study is needed to confirm the predictive validity for identification of cognitive control deficiency
- Persisting concussion effects may be an important factor that increases musculoskeletal injury predisposition

## REFERENCES

1. Langlois JA, et al. The epidemiology and impact of traumatic brain injury. *J Head Trauma Rehabil*. 2006;21(5):375-378.
2. Covassin T, et al. Concussion history and postconcussion neurocognitive performance and symptoms in collegiate athletes. *J Athl Train*. 2008;43(2):119–124.
3. Clark JF, et al. Analysis of central and peripheral vision reaction times in patients with postconcussion visual dysfunction. *Clin J Sport Med*. 2017; DOI:10.1097/JSM.0000000000000381.
4. Moore RD, et al. Concussion history and postconcussion neurocognitive performance and symptoms in collegiate athletes. *J Athl Train*. 2014;49(1):24-35.
5. Herman DC, et al. Effect of neurocognition and concussion on musculoskeletal injury risk. *Curr Sports Med Rep*. 2015;14(3):194-199.
6. Clark JF, et al. An exploratory study of the potential effects of vision training on concussion incidence in football. *Optom Vis Perf*. 2015;3(2):116-125..
7. Wilkerson GB, et al. Assessment and training of visuomotor reaction time for football injury prevention. *J Sport Rehabil*. 2017;26(1):26-34.