Effects of mTBI on Neuromechanical Function of Olympic-Level Boxers

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BACKGROUND AND PURPOSE

- Accumulating evidence indicates that mild traumatic brain injury (mTBI) can have serious long-term adverse effects[1]
  - Up to 50-80% of highly competitive athletes may not report acute concussion symptoms to avoid restriction of activity[2]
- Research has documented that survey responses can identify athletes with persistent post-concussion syndrome (PPCS)[3,4]
  - Total number of PPCS symptoms has been related to evidence of degenerative changes in white matter integrity[3]
- Repetitive head impact (RHI) can produce similar adverse effects to those associated with diagnosed concussion[5]
  - Head blows sustained by boxers that do not produce short-term symptoms may actually cause cumulative damage
- Identification of athletes who possess subtle cognitive impairments could facilitate more effective clinical management
  - Visual-motor reaction time (VMRT) and whole-body reactive agility (WBRA) may be important in this regard
- Our purpose was to assess the potential value of self-reported symptoms and neuromechanical performance capabilities for identification of persisting effects of exposure to subconcussive head blows among elite competitive boxers

PARTICIPANTS & PROCEDURES

- 17 USA Olympic Boxing Team members completed surveys and performance tests during a single screening session
  - 10 males: (20.7 ±1.1 yrs, 177.8 ±9.5 cm, 69.7 ±15.5 kg) and 7 females: (27 ±6.1 yrs, 169.8 ±7.1 cm, 62.9 ±10 kg)
- Surveys: Sport Fitness Index (SFI),[7] Depression, Anxiety, and Stress Scale (DASS), and Overall Wellness Index (OWI)
  - OWI developed to document number of PPCS symptoms,[3,4] frequency experienced, and most recent occurrence
    - 82 symptoms represented in 10 categories; 0-5 scale for each category; sum created 0-100 score (low = adverse)
- Dynavision D2™ (West Chester, OH) used to test VMRT; TRAZER® Sports Stimulator (Westlake, OH) used to test WBRA
  - VMRT assessed by rapid upper extremity responses: 60-s single-task (ST) test and 60-s dual-task (DT) tests (Figure 1)
    - Flanker test DT (VMRT+FT): verbal responses to center arrow direction for 20 5-arrow displays on LCD screen
      - VMRT Avg, ratio of VMRT Avg for outer 2 rings to inner 3 rings (O/I), and Left minus Right difference (L-R Diff)
  - WBRA quantified by 20-repetition lateral (Lat) shuffle test and 12-repetition diagonal (Diag) movement test (Figure 2)
    - Proper movement guided by appearance of targets on large monitor in randomized directions; ST and DT (WBRA+FT)
      - Start 3.12 m from monitor; target deactivation 0.91 m for lateral shuffling and 1.29 m for diagonal movements
        - Reaction time (RT), acceleration (Acc), deceleration (Dec), speed (Spd), and bilateral differences (Asym)
- Receiver operating characteristic (ROC) analysis used to define optimal cut-point for each potentially predictive metric
  - Cross-tabulation analyses quantified univariable associations; odds ratio (OR) and one-sided 95% credible lower limit
    - Strongest 2-factor model analyzed to determine its positive predictive value and negative predictive value

RESULTS

- Boxers categorized as having PPCS on the basis of OWI ≤ median value, which was determined to be 90; range 40-100
  - 47% (8/17) ≤ 90; symptom number (range 0-10) strongly associated with median OWI cut-point ≤ 90 (Figure 3)
- 12 metrics strongly associated with PPCS (OR ≥ 4); WBRA-ST Lat Acc and Lat Total Time strongest predictors (Table 1)
  - 2-factor prediction model provided 100% positive predictive value and 100% negative predictive value (Figure 4)
    - Sex-specific cut-points: Lat Acc m/s^2 Male ≤ 3.78; Female ≤ 3.23; Total Time seconds Male ≥ 58; Female ≥ 66
- SFI ≤ median value defined as substantial persisting effects of prior injuries; determined to be ≤ 80; range 46-100
  - Association of SFI ≤ 80 with OWI ≤ 90: 70% positive predictive value and 83% negative predictive value (OR = 14)
- 9 metrics strongly associated with low SFI (OR ≥ 4); WBRA-ST Lat Acc and Lat Total Time strongest predictors (Table 2)
  - 2-factor prediction model provided 100% positive predictive value and 80% negative predictive value
    - Sex-specific cut-points: Lat Acc m/s^2 Male ≤ 4.12; Female ≤ 2.75; Total Time seconds Male ≥ 60; Female ≥ 66

Figure 1

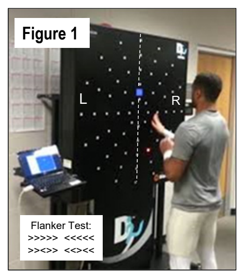


Figure 2

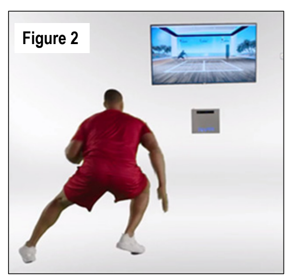
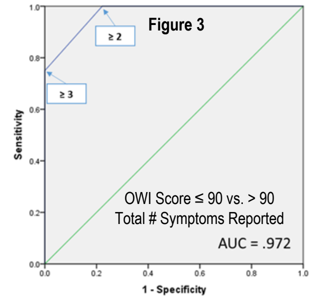


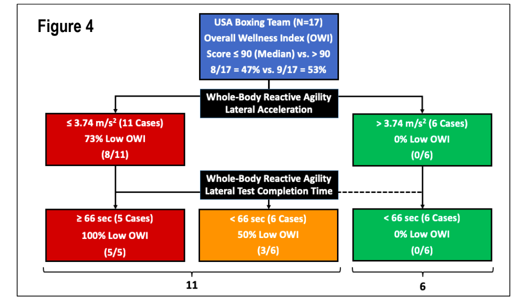
Table 1. Identification of Low OWI (≤ 90) Cases

Variable	AUC	Cut-Pt	Sens	Spec	OR	*P*
WBRA Lat Acc Avg (m/s^2) – ST	.778	≤ 3.74	1.00	.67	31.57*	.007
WBRA Lat Total Time (s) – ST	.833	≥ 66	.63	1.00	29.86*	.009
WBRA Lat Dec Avg (m/s^2) – ST	.681	≤ 3.22	1.00	.56	20.78*	.020
WBRA Lat Dec Avg (m/s^2) – DT	.653	≤ 3.43	.75	.78	10.50	.044
WBRA Diag RT Avg (ms) – ST	.681	≥ 536	.75	.78	10.50	.044
WBRA Diag/Back Acc Asym – ST	.681	≥ .16	.75	.78	10.50	.044
WBRA Lat RT Avg (ms) – ST	.639	≥ 508	.75	.78	10.50	.044
WBRA Lat Dec Asym – DT	.681	≥ .12	.50	.89	8.00	.111
WBRA Lat RT L-R Diff (ms) – ST	.681	≥ 64	.63	.78	5.83	.117
WBRA Lat Dec Asym – ST	.542	≥ .10	.38	.89	4.80	.241
VMRT Avg (ms) – DT	.563	≥ 900	.75	.67	6.00	.109
VMRT L-R Diff (ms) – DT	.563	≥ 20	.38	.89	4.80	.241

Table 2. Identification of Low SFI (≤ 80) Cases

Variable	AUC	Cut-Pt	Sens	Spec	OR	*P*
WBRA Lat Acc Avg (m/s^2) – ST	.714	≤ 3.86	.90	.57	12.00	.060
WBRA Lat Total Time (s) – ST	.786	≥ 66	.50	1.00	15.00*	.041
WBRA Lat Dec Avg (m/s^2) – ST	.671	≤ 3.22	.90	.57	12.00	.060
WBRA Lat Dec Avg (m/s^2) – DT	.629	≤ 3.21	.50	.86	6.00	.160
WBRA Diag RT Avg (ms) – ST	.557	≥ 530	.70	.71	5.83	.117
WBRA Diag/Back Acc Asym – ST	.543	–	–	–	–	–
WBRA Lat RT Avg (ms) – ST	.443	–	–	–	–	–
WBRA Lat Dec Asym – DT	.681	≥ .12	.40	.86	4.00	.278
WBRA Lat RT L-R Diff (ms) – ST	.643	≥ 65	.50	.86	6.00	.160
WBRA Lat Dec Asym – ST	.500	≥ .09	.40	.86	4.00	.278
VMRT Avg (ms) – DT	.479	–	–	–	–	–
VMRT L-R Diff (ms) – DT	.771	≥ 20	.40	1.00	10.39*	.088





CLINICAL RELEVANCE

- Subconcussive RHI may result in similar brain alterations as concussion, and may lead to neurological degeneration
  - PPCS quantified by OWI may result from subconcussive RHI, because only 2 boxers reported concussion history
    - SFI associations with OWI, VMRT, and WBRA metrics suggest RHI may elevate risk for musculoskeletal injury
- Cause-effect relationships not established, but associations consistent with findings of previous RHI research[1,5,6]
  - Neuromechanical responsiveness to environmental conditions critical for avoidance of head or musculoskeletal injury
    - Training programs focused solely on improvement of neuromuscular performance capabilities may be inadequate
- Our findings support emerging evidence that integration of visual, cognitive, and motor processing represents a critically important factor that can only be assessed by risk screening tests that impose complex neuromechanical demands

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