Whole-Body Reactive Agility Asymmetries Among Athletes with Concussion History

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BACKGROUND AND PURPOSE

- Susceptibility to neurocognitive degeneration has been linked to cumulative mild traumatic brain injury (mTBI) effects[1]
  - Adverse effects on brain function can result from either concussion occurrence and/or multiple subconcussive events
    - Absence of clinical symptoms associated with concussion does not necessarily exclude possible head impact effects
      - A possible clinical indicator of subtle mTBI or subconcussive effects is slowed visuomotor reaction time (VMRT)[2]
- Disruption of white matter tracts between brain hemispheres has been documented as a common consequence of mTBI[3]
  - Performance asymmetries may be a manifestation of suboptimal exchange of information between brain hemispheres[4]
    - Clinical tests are needed to identify individual athletes who may be experiencing persisting effects of previous mTBI
      - Whole-body reactive agility (WBRA) testing offers a means to quantify right versus left performance capabilities
- Our purposes were to assess the discriminatory power of VMRT and WBRA metrics to identify elite athletes who self-reported history of mTBI (mTBI Hx) and to assess the extent to which VMRT training might improve WBRA performance

PARTICIPANTS & PROCEDURES

- 20 healthy athletes at a residential training center volunteered to provide survey responses and to participate in training
  - 12 males: 176.7 ±9.5 cm, 74.4 ±11 kg; 8 females: 166.1 ±6.1 cm, 63.2 ±9.4 kg
- VMRT and WBRA baseline tests performed; Sport Fitness Index (SFI) survey quantified persisting effects of sport injuries
  - Single-task (ST) and dual-task (DT) VMRT quantified by 60-s tests (Dynavision D2™, West Chester, OH; 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)
  - WBRA quantified by 20-target lateral side-shuffle and 12-target diagonal movements (TRAZER® Westlake, OH; 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)
- Receiver operating characteristic (ROC) analysis used to define optimal cut-point for each potential predictor variable
  - Cross-tabulation and logistic regression analyses used to quantify exposure-outcome associations
  - Odds ratio (and one-sided 95% credible lower limit) calculated to quantify univariable and multivariable associations
- Training activity conducted over a 5-week period, which consisted of a single 60-s VMRT DT-A session on a given day
  - Participants completed a minimum of 6 and a maximum of 8 training sessions, followed by post-training assessment
    - VMRT ST, VMRT DT-B, WBRA Lateral, and WBRA Diagonal tests administered following training
      - Paired t-tests, standardized response mean (SRM), and percent change used to assess training effect

RESULTS

- mTBI Hx was self-reported by 50% of athletes (10/20) representing 6 different sport categories (Table 1)
  - Most recent mTBI: 5.6 ±5.2 years; Median: 4.5 years; Range: 0.3 – 16.5 years
- Analyses identified 10 performance metrics strongly associated with self-reported mTBI Hx; OR ≥ 4 (Table 2)
  - 7 WBRA Asym metrics demonstrated good discriminatory power; 2 WBRA metrics demonstrated 100% specificity
    - 4 Lateral (Lat) and 3 Diagonal/Backward (D/B) WBRA Asym metrics (no Diagonal/Forward discriminating metrics)
  - 2 VMRT (DT-B) metrics discriminated: Conflict effect (Incongruent-Congruent) and Left-Right Difference (L-R Diff)
    - Incongruent (>><>> or <<><<) minus Congruent (<<<<< or >>>>>); L-R Diff = Left side minus Right side VMRT
  - Average of 8 WBRA Asym values (Lat and D/B: RT, Spd, Acc, Dec) demonstrated exceptionally strong discrimination
    - WBRA Asym Avg ≥.18 (Figure 3): 70% sensitivity, 90% specificity, OR = 21.0 (90% CI Lower Limit: 2.64)
- VMRT (DT-A) Pre-Post improvement (Figure 4) 202 ±83 ms (mTBI Hx 192 ±104 ms; No mTBI 212 ±61 ms)
  - VMRT (DT-B) Pre-Post Conflict effect reduced by 43 ±85 ms (mTBI Hx 55 ±101 ms; No mTBI 31 ±68 ms)
    - Among athletes with mTBI Hx, 7 of 8 WBRA Asym values reduced after training (Table 3)
- SFI score ≤ 76 discriminated between mTBI Hx and No mTBI; greater persisting effects of prior sport injuries for mTBI Hx

Figure 1

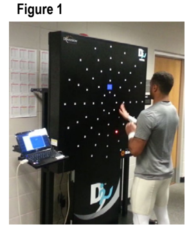


Figure 2

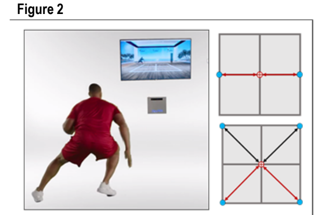


Table 1

Self-Reported Concussion History			
Sport	Male	Female	Total
Wrestling	0/1	2/3	2/4
Boxing	0/0	0/1	0/1
Sledding*	3/3	1/2	4/5
Figure Skating	1/4	1/1	2/5
Gymnastics	1/3	0/0	1/3
Pentathlon	0/1	1/1	1/2
Total	5/12	5/8	10/20

* Includes Bobsled and Skeleton

Table 2

Variable	AUC	Cut-Pt	Sens	Spec	OR	P
WB Lat RT Avg	.705	≥ 460 ms	.40	1.00	14.32*	*
WB D/B Dec Asym	.590	≥ 24%	.40	1.00	14.32*	*
WB Lat RT Asym	.780	≥ 16%	.90	.60	13.50	.029
WB D/B Acc Asym	.700	≥ 10%	.80	.60	6.00	.085
WB D/B Spd Asym	.570	≥ 17%	.40	.90	6.00	.152
WB Lat Spd Asym	.610	≥ 10%	.60	.80	6.00	.085
VMRT-DT Conflict	.690	≥ 80 ms	.80	.60	6.00	.085
WB Lat Acc Asym	.730	≥ 12%	.70	.70	5.44	.089
WB Lat Dec Asym	.570	≥ 14%	.50	.80	4.00	.175
VMRT-DT L–R Diff	.600	≥ 1 ms	.50	.80	4.00	.175
SFI Score	.600	≤ 76	.80	.50	4.00	.175

* 0.5 added to each 2X2 cell to estimate OR value

Table 3

Variable	Cut-Pt	Pre Mean	Post Mean	Mean Change	SRM*	% Change
WBRA Lat RT Asym	≥ .16	.583 ±.716	.234 ±.200	–.350 ±.667	.52	60%
WBRA Lat Spd Asym	≥ .10	.109 ±.099	.067 ±.053	–.041 ±.093	.45	38%
WBRA Lat Acc Asym	≥ .12	.129 ±.078	.093 ±.060	–.035 ±.079	.45	27%
WBRA Lat Dec Asym	≥ .14	.150 ±.137	.106 ±.120	–.044 ±.162	.27	29%
WBRA D/B RT Asym	≥ .09	.359 ±.408	.438 ±.291	+.079 ±.523	(.15)	(22%)
WBRA D/B Spd Asym	≥ .17	.126 ±.087	.093±.050	–.033 ±.104	.32	26%
WBRA D/B Acc Asym	≥ .10	.175 ±.110	.113 ±.113	–.063 ±.193	.32	36%
WBRA D/B Dec Asym	≥ .24	.215 ±.156	.167 ±.143	–.049 ±.218	.22	23%

* Standardized Response Mean

Figure 3

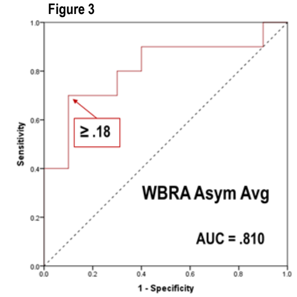
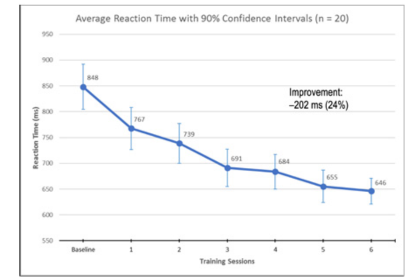


Figure 4



CLINICAL RELEVANCE

- Baseline VMRT and WBRA metrics revealed substantial differences between elite athletes with and without mTBI Hx
  - Subtle deficiencies in perception-action coupling capabilities may remain unrecognized for months or years after mTBI
- Asymmetries were strongly associated with mTBI Hx, which may relate to disrupted inter-hemispheric neural processing
  - Right hemisphere visuospatial processing dominance may explain DT results (Left slower than Right VMRT for mTBI Hx)
- Training only VMRT with the upper extremities resulted in improvements of lower extremity WBRA performance metrics
  - VMRT Conflict effect reduced more for mTBI Hx than No mTBI; WBRA Asym for mTBI Hx improved (7/8 Asym metrics)
- Impaired perception-action coupling may explain increased occurrence of musculoskeletal injuries following mTBI[5]
  - SFI discrimination between mTBI Hx and No mTBI cases suggests an association, but cause-effect cannot be inferred
- Our findings support emerging evidence that VMRT deficiencies and WBRA asymmetries may be due to mTBI effects,[6] and that a relatively small number of brief training sessions can produce substantial improvements in perception-action coupling

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