Association of Neuromechanical Responsiveness with Lower Extremity Injury

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BACKGROUND AND PURPOSE

- Lower extremity injury is extremely common among athletes, which frequently leads to chronic dysfunction and disability[1,2]
  - Little evidence exists to support specific methods for identification of elevated injury risk or reduction of risk[3]
    - Although some tests have been validated for specific populations, tests with broad applicability are needed
- Neuromechanical responsiveness may be a critical factor for injury avoidance that may be overlooked by clinicians
  - Previous injuries can have persisting adverse effects on functional capabilities that do not necessarily resolve over time[4]
    - Visual-motor reaction time (VMRT) and whole-body reactive agility (WBRA) may be important in this regard[5]
      - Integration of visual-cognitive-motor processes required to effectively respond to changing environmental conditions
      - Musculoskeletal injury may disrupt neuromechanical responsiveness, without overt evidence of an impairment
- Our purpose was to retrospectively assess associations between indicators of neuromechanical responsiveness and history of time-loss lower extremity sprains and strains over the previous 12-month period among elite athletes

PARTICIPANTS & PROCEDURES

- 48 healthy participants recruited at Olympic Training Center, with all testing completed at a single session
  - 34 males: 23.8 ±4.4 yrs, 178.3 ±8.9 cm, 80.2 ±17.5 kg; 14 females: 25.4 ±4.5 yrs, 160.2 ±27.8 cm, 64.2 ±12.8 kg
- Sport Fitness Index (SFI) administered to quantify persisting effects of previous musculoskeletal injuries (0-100 score)
  - Athlete self-report of time-loss lower extremity (LE) sprain or strain over previous 12 months used as binary classifier
- VMRT performance quantified by Dynavision D2™ system (Dynavision International, West Chester, OH) (Figure 1)
  - Target buttons illuminated until hit; single-task 60-s practice trial and 60-s test trial, followed by dual-task 60-s trials
    - Flanker test (VMRT+FT) – verbal responses to center arrow direction for 20 displays of 5-arrow sets on LCD screen
    - Scrolling text (VMRT+ST) – simultaneous verbal recitation of right-to-left scrolling text on LCD screen
      - Average VMRT for all 5 rings and ratio of average VMRT for outer 2 rings to that for inner 3 rings (O/I)
- WBRA quantified by TRAZER® Sports Stimulator (Traq Global Ltd, Westlake, OH); 20-repitition side-shuffle test (Figure 2)
  - Proper movements guided by appearance of targets on large monitor in randomized directions (10 right and 10 left)
  - Start position 3.12 m from monitor; lateral shuffle movement of 0.91 m required to deactivate target on monitor
    - Reaction time (RT), acceleration (Acc), deceleration (Dec), speed (Spd), and bilateral differences (% Diff)
- 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

RESULTS

- History of time-loss LE injury was reported by 46% of athletes (22/48) representing 6 different sport categories (Table 1)
  - Sledding includes Bobsled and Skeleton; Multi-event includes Pentathlon, Track & Field, Triathlon, and Weightlifting
- ROC and cross-tabulation analyses identified 8 variables strongly associated with history of time-loss LE injury (Table 2)
  - Dual-Task VMRT interaction effect evident between VMRT-FT and VMRT+ST O/I (both factors positive)
    - Logistic regression analysis yielded a 2-factor model: 1) Dual-Task VMRT Interaction and 2) WBRA Dec Avg
      - Model $\chi^2(2) = 18.80$; $P \leq 0.001$; Hosmer & Lemeshow goodness-of-fit $\chi^2(2) = 0.79$; $P = .674$; Nagelkerke $R^2 = .433$
- Cascaded classification tree for 2-factor model (Dual-Task VMRT Interaction and WBRA Dec Avg) presented in Figure 4
  - Both factors positive: 100% positive predictive value (7/7) for time-loss LE injury during previous 12 months
  - Both factors negative: 84% negative predictive value (16/19) for no time-loss LE injury during previous 12 months

Figure 1

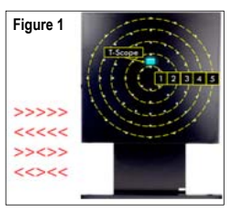


Figure 2

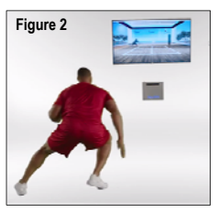


Table 1. Time-loss Lower Extremity Injury

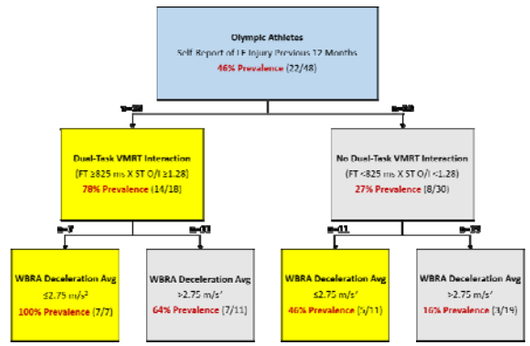
Sport	Male	Female	Total
Wrestling	8/12 (67%)	4/4 (100%)	12/16 (75%)
Boxing	1/6 (12.5%)	0/1 (0%)	1/7 (14%)
Sledding	1/3 (33%)	2/4 (50%)	3/7 (43%)
Figure Skating	3/4 (75%)	1/3 (33%)	4/7 (57%)
Gymnastics	1/4 (25%)	0/0 (0%)	1/4 (25%)
Multi-Event	1/5 (20%)	0/2 (0%)	1/7 (14%)
Total	**15/34 (44%)**	**7/14 (50%)**	**22/48 (46%)**

Table 2. Results of Univariable and Multivariable Analyses

Predictor	Cut-Point	AUC	P-Value*	Sensitivity	Specificity	OR ($CLL_{95\%}$)	Adj OR ($CLL_{95\%}$)
VMRT Interaction**	Both +	—	.001	64%	85%	9.63 (3.04)	13.84 (3.66)
**VMRT+FT	≥ 825 ms	.656	.017	82%	54%	5.25 (1.72)	**
**VMRT+ST O/I	≥ 1.28	.629	.011	82%	54%	5.25 (1.72)	**
WBRA Dec Avg	≤ 2.75 m/s²	.670	.022	55%	77%	4.00 (1.41)	6.47 (1.76)
WBRA Spd Avg	≤ 0.94 m/s	.664	.030	86%	42%	4.64 (1.38)	—
VMRT+FT O/I	≥ 1.36	.661	.021	68%	65%	4.04 (1.47)	—
WBRA Acc Avg	≤ 4.11 m/s²	.660	.028	77%	54%	3.96 (1.38)	—
SFI	≤ 64	.690	.040	82%	46%	3.85 (1.26)	—
WBRA RT % Diff	≥ 16.3	.631	.043	64%	65%	3.30 (1.22)	—
2-Factor Model	**≥ 1 +**	**.801**	**.001**	**86%**	**62%**	**10.13 (3.00)**	—

* Fisher's Exact One-Sided Test

Figure 3



CLINICAL RELEVANCE

- Combined results of Dual-Task VMRT tests and WBRA test demonstrated very strong association with injury history
  - Injury may have persisting effect on neuromechanical responsiveness, but pre-existing deficiency cannot be ruled out
    - Whether cause or effect of previous injury, suboptimal Dual-Task VMRT or WBRA test results may elevate injury risk
- Individualized training for improvement of neuromechanical responsiveness may address a highly modifiable risk factor
  - Risk screening test results should be used to guide development of training programs that target specific deficiencies
    - 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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