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Ashley Grillo
University of Tennessee at Chattanooga

Abigail Rogers
University of Tennessee at Chattanooga

Tyler Perry
University of Tennessee at Chattanooga

Association of Heart Rate Variability with Perceptual-Motor Measures among ROTC Cadets

Ashley Grillo, MS, ATC; Abigail Rogers, MS, ATC; Tyler Perry , MS, ATC; Gary B Wilkerson, EdD, ATC; Shellie N Acocello, PhD, ATC

THE UNIVERSITY of TENNESSEE CHATTANOOGA

BACKGROUND AND PURPOSE

- Rapid responses to the complex situational demands of combat is essential for operational success and survival of personnel[1]
  - Cognitive control refers to collective brain processes relating to decision-making and execution of goal-directed behaviors
- Heart rate variability (HRV) provides an important indicator of autonomic balance, which can influence performance capabilities[2,3]
  - Regulation of autonomic function involves neural circuits that overlap with those controlling goal-directed perception and action
- A combat scenario can impose an extreme degree of uncertainty and anxiety about responses that must be executed rapidly
  - HRV may reflect an individual's capacity to respond effectively while exposed to intense mental and physical demands
- Integration of perceptual-motor processes has been found to vary substantially among both general and elite populations[4]
  - Visual-motor reaction time (VMRT) and whole-body reactive agility (WBRA) metrics have demonstrated discriminatory power
- The purpose of this study was to assess associations between serial measurements of HRV and performance metrics relating to perceptual-motor integration required for rapid decision making and appropriate motor responses among male ROTC cadets

PARTICIPANTS & PROCEDURES

- 32 male ROTC cadets (178.8 ± 7.7 cm; 79.3 ±10.4 kg) provided HRV measurements 2X per week over a 10-week period
  - Resting-state HRV measures acquired prior to morning exercise; 0530 – 0600 (CorSense®, Elite HRV, Asheville, NC; Figure 1)
  - HRV represented as natural log of root mean-square of successive differences in R-R intervals during a 60-second recording
    - Intra-individual session-to-session HRV average (HRV-Avg) calculated from available data (minimum of 7 recording sessions)
    - Intra-individual HRV variability over time represented by coefficient of variation (HRV-CoV = Standard Deviation / HRV-Avg)
  - Cohort median values defined suboptimal (Lo HRV-Avg and Hi HRV-CoV) versus optimal status (Hi HRV-Avg and Lo HRV-CoV)[5]
- Prior to initiation of the HRV monitoring period, cadets provided survey responses and completed VMRT and WBRA tests
  - 10-item Overall Wellness Index (OWI) generates 0 – 100 score for frequency and recency of 82 physical or mental problems
    - List of 82 problems derived from recognized symptoms of post-concussion syndrome grouped into 10 categories
  - VMRT quantified by a 60-s test (Dynavision D2™, West Chester, OH; Figure 2) that incorporated 48 flanker test responses
    - Opposite-side button pairs illuminated; center arrow direction indicated correct response (<<<<<, >>>>>, >><>>, <<><<)
  - WBRA quantified by 20-target lateral (Lat) and 12-target diagonal (Diag) movements (TRAZER® Westlake,OH; Figures 3)
    - Randomized virtual targets on monitor disappeared with whole-body movements to corresponding spatial coordinates
    - Metrics included Reaction Time (RT), Acceleration (Acc), Deceleration (Dec), Speed (Spd), and Asymmetry (Asym)
- Receiver operating characteristic analysis used to define optimal cut-points for predictors with area under curve (AUC) ≥ .550
  - Cross-tabulation and logistic regression analyses used to quantify exposure-outcome associations for strongest predictors
    - Positive predictive value (PPV) and negative predictive value (NPV) calculated for univariable and multivariable associations
  - Logistic regression model estimates of log odds converted to probability (0.00 – 1.00) for Lo HRV-Avg and Hi HRV-CoV status
    - Odds ratio (OR) and 90% confidence interval (CI) calculated for univariable and multivariable associations

RESULTS

- Participants completed an average of 14.5 ± 2.9 measurement sessions (minimum of 7 sessions and maximum of 19 sessions)
  - Autonomic balance over time categorized as Lo HRV-Avg ≤ 4.49 (suboptimal) versus Hi HRV-Avg > 4.49 (optimal)
  - Variability in autonomic balance categorized as Hi HRV-CoV ≥ .0695 (suboptimal) versus Lo HRV-CoV < .0695 (optimal)
- 3-Factor logistic regression model demonstrated strong discrimination between suboptimal versus optimal HRV-Avg (Table 1)
  - 1) VMRT Left – Right Difference ≥ 23 ms, 2) Overall Wellness Index ≥ 82, and 3) WBRA Diagonal Avg Asym ≥ 18.4%
    - Probability for suboptimal HRV-Avg status (≥ .62): 87% PPV; 82% NPV; OR = 30.33: 90% CI: 5.95 – 154.77 (Figure 4)
- 2-Factor logistic regression model demonstrated strong discrimination between suboptimal versus optimal HRV-CoV (Table 2)
  - 1) Overall Wellness Index ≥ 82 and 2) VMRT Left – Right Difference ≥ 23 ms
    - Probability for suboptimal HRV-CoV status (≥ .51): 81% PPV; 81% NPV; OR = 18.78: 90% CI: 4.23 – 83.31 (Figure 5)

Figure 1

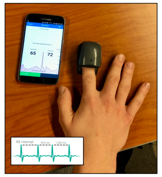


Figure 2

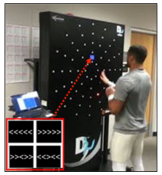


Figure 3

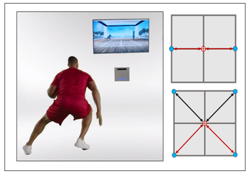


Table 1	AUC	Cut-Pt	PPV	NPV	OR	90% CI
VMRT Left – Right Difference*	.746	≥ 23 ms	72%	79%	9.53	2.41, 37.79
WBRA Lateral Test Duration	.664	≥ 62 s	67%	71%	5.00	1.40, 17.88
Overall Wellness Index*	.652	≤ 82	82%	67%	9.00	2.02, 40.11
WBRA Diagonal Avg Asymmetry*	.648	≥ 18.4%	73%	62%	4.33	1.14,16.49
WBRA Lateral RT Avg	.582	≥ 558 ms	62%	73%	4.33	1.14, 16.49

* Variables included in 3-Factor logistic regression model

Table 2	AUC	Cut-Pt	PPV	NPV	OR	90% CI
Overall Wellness Index*	.729	≤ 82	82%	67%	9.00	2.02, 40.11
VMRT Left – Right Difference*	.725	≥ 23 ms	67%	71%	5.00	1.40, 17.88
WBRA Lateral Speed Asymmetry	.652	≥ 6.5%	69%	63%	3.86	1.09, 13.61
WBRA Lateral RT Asymmetry	.607	≥ 32.8%	83%	58%	6.82	1.00, 46.34
WBRA Diagonal RT Asymmetry	.588	≥ 30.2%	65%	67%	3.67	1.07, 12.52

* Variables included in 2-Factor logistic regression model

Figure 4

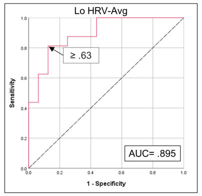


Figure 5

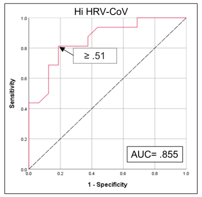
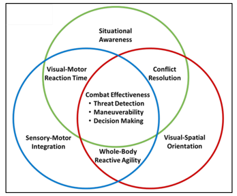


Figure 6



CLINICAL RELEVANCE

- Combat effectiveness critically depends on the ability to perceive and respond to rapidly changing environmental conditions
  - Threat detection, maneuverability, and rapid decision-making may be adversely affected by subtle neural impairments (Figure 6)
- Previous research has demonstrated that HRV values reflect self-regulation of behavioral, cognitive, and emotional processes[2,6]
  - Executive functions linked to HRV include inhibitory control and attention, which are highly lateralized to the right hemisphere
- Perceptual-motor performance capabilities may depend on neural processes that overlap with autonomic control reflected by HRV
  - Left – Right VMRT difference previously associated with concussion history; possibly due to persisting neural impairment[4]
  - OWI score inclusion in both suboptimal HRV prediction models suggests a neural deficiency similar to the effect of concussion
  - WRBA Diagonal Avg Asym may be an indicator of inefficient transfer of neural information between brain hemispheres
- Autonomic balance (HRV), perceptual-motor efficiency (VMRT and WBRA), and absence of symptoms related to neurological disorders (OWI) appear to be important interrelated indicators of abilities that are critical to warfighter combat effectiveness

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