Virtual Neuromuscular Training to Reduce Injury Risk After Concussion: A Pilot Study in Healthy Adults

Sports-related concussion is associated with an increased risk of musculoskeletal injury following return to play potentially due to an inability to effectively meet the complex cognitive and motor demands of sport. Interventions affecting neuromuscular control may reduce injury risk after concussion. Our purpose was to determine the efficacy of an 8-week virtual Neuromuscular Training (vNMT) program using a novel, smartphone-based platform in healthy adults.

Participants 22-30 years completed initial self-reported and clinically obtained measures used in concussion diagnosis and management (Table 1). Participants were randomized (stratified by sex) to control or vNMT conditions. vNMT group participants completed an 8-week intervention of three 30-minute guided workouts per week using a smartphone-based platform. Participants returned for follow-up testing after 8 weeks. We performed an intent-to-treat analysis comparing pre and post outcomes between groups.

At the time of analysis, n=18 participants had completed both pre and post intervention visits: 8 in the vNMT group (24.9±1.1 years; 75% female) and 10 in the control group (26.4±3.0 years; 70% female). Although not surprising given we were testing non-impaired individuals, we observed no significant between-group differences for any measurement obtained (Table 2). The vNMT group demonstrated fewer errors (Cohen's d = 0.84) in the multiple hop test at the post-intervention assessment compared to the control group, although this did not reach statistical significance.

This study is the necessary first step in assessing the efficacy of a smartphone-based rehab program in a healthy population. Our future work seeks to shift clinical practice by integrating this model into concussion management to reduce musculoskeletal injuries following return to sport after concussion.

Table 1. Description of self-reported and clinician-obtained performance measures.

Variable	Description
Self-Reported Measures	
Sleep Quality (PSQI)	The Pittsburgh Sleep Quality Inventory is a validated scale to calculate sleep duration and elements contributing to overall sleep quality.
Confidence in Movement Scale	The Adolescent Measure of Confidence and Musculoskeletal Performance is a validated measure used to assess confidence in movement abilities following injury.
Dizziness Handicap Index	Identifies problems related to dizziness in everyday life.
Tampa Scale of Kinesiophobia	A valid outcome measure used to identify post-concussion fear of pain with movement.
GAD-7	The Generalized Anxiety Disorder-7 is used as a brief screening tool and severity measure for GAD.
Clinician Obtained Measures	
Single-task and dual-task tandem gait	Participants walk heel-to-toe, as quickly as possible, along a 3-meter strip of tape, make a 180-degree turn at the end of the tape and return to the starting point with the same heel-to-toe gait. In the dual-task condition, participants complete a cognitive task while simultaneously walking heel-to-toe.
BESS	Balance Error Scoring System is a static balance assessment performed under 3 stance conditions: double-leg, single-leg, and tandem stance.
Reaction time (RT)	Reaction time was measured using both drop stick and smartphone techniques. Drop stick RT measures time required to catch a suspended vertical shaft by hand closure. Smartphone RT measures the speed at which patients respond to a simple on-screen stimulus.
Triple hop test	Participants perform a triple hop for distance test by performing 3 consecutive maximal single leg hops forward on each limb.
Multiple hop test	Participants perform a multiple hop test to assess dynamic postural control by hopping with their dominant limb along a multi-directional pattern of ten floor markers.

Table 2. Comparison of initial (pre-intervention) and follow-up (post-intervention) outcomes among the two groups, results presented as mean (SD).

Variable	Initial Visit (Pre-Intervention)				Follow-Up Visit (Post-Intervention)		
	vNMT Group	Control Group	P value		vNMT Group	Control Group	P value
Self-Reported Measures							
Sleep Quality (PSQI score)	6.0 (2.8)	6.2 (4.5)	0.92		5.4 (4.6)	5.4 (4.1)	0.98
Confidence in Movement Scale Score	95.5 (2.4)	93.2 (6.6)	0.43		94.5 (3.6)	92.9 (9.4)	0.66
Dizziness Handicap Index Score	1.0 (1.7)	0.3 (0.7)	0.28		2.0 (3.9)	0.6 (1.9)	0.33
Tampa Scale of Kinesiophobia Score	30.3 (4.3)	32.8 (3.9)	0.27		28.1 (9.5)	33.0 (4.7)	0.18
GAD-7 Score	3.9 (2.9)	3.3 (3.7)	0.75		3.5 (2.3)	2.5 (2.9)	0.44
Clinician Obtained Measures							
Single-task tandem gait time (s)	15.3 (3.1)	15.4 (2.3)	0.92		15.0 (2.7)	12.8 (2.9)	0.12
Dual-task tandem gait time (s)	18.5 (1.7)	17.9 (5.0)	0.80		17.7 (3.0)	15.0 (3.0)	0.10
BESS single-stance errors	1.4 (1.3)	3.0 (2.4)	0.11		1.8 (1.9)	1.5 (1.1)	0.73
BESS tandem-stance errors	0.5 (0.8)	0.9 (0.9)	0.36		0.3 (0.7)	0.2 (0.4)	0.85
Reaction time (drop-stick; ms)	246 (23)	248 (17)	0.83		243 (18)	231 (22)	0.21
Reaction time (smartphone; ms)	432 (37)	449 (30)	0.56		451 (36)	433 (36)	0.31
Triple hop distance: dominant limb (cm)	162 (29)	153 (39)	0.58		170 (33)	159 (34)	0.50
Triple hop distance: non-dominant limb (cm)	165 (39)	147 (51)	0.43		165 (42)	157 (38)	0.73
Multiple hop test: errors	2.2 (1.3)	2.2 (1.3)	0.97		1.1 (0.8)	2.1 (1.3)	0.10