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Original research

Outcomes, utility, and feasibility of single task and dual task intervention programs: Preliminary implications for post-concussion rehabilitation

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ABSTRACT

Objectives: To examine neurocognitive and balance performance in recreational athletes, prior to and following a dual-task training intervention compared to single-task controls in order to assess the utility and feasibility of these interventions in the clinical setting.
Design: Controlled laboratory study.
Methods: Thirty healthy, physically active recreational athletes (dual-task group = 15; single-task group = 15; age: 20.3 ± 1.9 years) completed neurocognitive and balance assessments before and after a four-week intervention. Sensory Organization Test composite score and ratio scores, Balance Error Scoring System total score, and nine CNS Vital Signs composite scores served as outcome measures. Mixed model analyses of variance were used to examine each measure.
Results: The single-task group showed greater improvement for complex attention ($F_{1,26} = 5.48$, $p = .027$) following the training period. Both groups improved their performance on the complex attention domain ($F_{1,26} = 6.73$, $p = .015$), the Balance Error Scoring System score ($F_{1,26} = 42.34$, $p < .001$), and the Sensory Organization Test vestibular ratio score ($F_{1,28} = 6.55$, $p = .016$) following the intervention.
Conclusions: Our findings suggest combining cognitive and balance tasks as performed does not provide additional benefit to performing these tasks independently among healthy individuals, but appear to be feasible in this setting. Future research should examine integration of single-task and dual-task exercises for concussed patients.

1. Introduction

Concussions are the most frequent form of traumatic brain injury occurring in sport.[1] Previously, the focus of concussion research has been on prevention, evaluation and acute management.[2] Although much more is to be understood in these areas, further research is necessary to determine how rehabilitation[3] and return-to-play progressions may play a role in recovery following a concussion. Although the majority of concussion symptoms resolve within a 7–10 days window,[4] some individuals may suffer from Post Concussion Syndrome (PCS) where physical, cognitive, and emotional symptoms do not resolve for several months to years following injury.[5]

The current standard of care for sports-related concussion centers on cognitive and physical rest followed by gradual return to activity once the athlete is asymptomatic.[2] If concussion symptoms include both cognitive and balance impairment, then it seems rational that clinicians should address these issues during the rehabilitation process to facilitate recovery. Rehabilitation has been used for patients with moderate and severe traumatic brain injury, but has not been considered as a standard of care for mild traumatic brain injury such as sport-related concussion with prolonged recovery.[3] Medical professionals need to address the functional capacity of systems affected by concussion to ensure safe return to play.[6] Following concussion the functional capacities of balance and cognitive resources are often impaired making

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Table 1
Demographic information.

	ST ($n = 15$) Mean (SD)	DT ($n = 15$) Mean (SD)	Total sample ($n = 30$) Mean (SD)
Age (years)	20.87 (2.23)	19.73 (1.33)	20.30 (1.90)
Height (m)	1.68 (0.11)	1.62 (0.18)	1.65 (0.15)
Mass (kg)	70.65 (14.71)	65.86 (12.81)	68.25 (13.77)
Days between pre- and post-test	33.27 (5.02)	34.80 (3.23)	34.03 (4.22)

dual-task executions more difficult.[7,8] It is unknown if each domain should be addressed separately in a "single-task" model, or if these tasks should be integrated in a "dual-task" model that more accurately represents the conditions a patient is going to encounter when returning to physical activity. This "dual-task" rehabilitation methodology would require a person to execute a secondary cognitive task while being physically exerted to address cognitive, balance, and or visual deficits following concussion.

To the best of our knowledge, no study has attempted to assess single vs. divided attention training intervention programs in an effort to provide background for future paradigms in concussion management. Therefore, the purpose of this study was to examine dual-task neurocognitive and balance performance in healthy collegiate recreational athletes, prior to and following a dual-task training intervention compared to matched single-task controls. The intent of this research was to determine the utility and feasibility of a dual-task training program to potentially be applied following concussion.

2. Methods

The study was conducted following the ethical guidelines set forth by the Department of Health and Human Services Office for Human Research Protection (U.S.A.) and approved by the University of North Carolina at Chapel Hill's (UNC-CH) institutional review board prior to study initiation (Reference Study # 11-0499). Participants represented a volunteer sample from sport clubs at the UNC-CH. All participants signed approved consent forms prior to participation. Thirty physically active males and females participated in the study. The study sample consisted of 15 males and 15 females that reported participating in at least 30 min of self-reported physical activity at least 3 times per week. Demographic information is located in Table 1. Participants were stratified by gender and then randomly assigned to either the *dual-task (DT)* intervention or *single-task (ST)* intervention group (15 DT and 15 ST). All participants were blinded to study hypothesis and group assignment and were not informed of training differences between groups. One additional participant was dropped due to lack of compliance.

The Sensory Organization Test (SOT) performed on the Smart Balance Master System (NeuroCom International, Clackamas, OR, USA) was utilized to assess balance. The SOT utilizes six conditions each lasting 20 s and performed three times in random order. The methods of the SOT have been described in detail in previously.[9,10] Each of the six conditions was used to compute a weighted average of all of the sensory conditions called the composite score. The data collected were used to calculate contributions of the visual, somatosensory, and vestibular system to each participants overall balance in the form of three sensory ratio scores. Higher scores represent improved ability to maintain postural control while other systems are being simultaneously altered.[9,10]

The BESS is composed of a total of six 20-s trials with three conditions including double leg, single leg on the non-dominant foot, and tandem (heel-to-toe) stances with the non-dominant foot behind the dominant foot as described in previous reports.[11] Each condition was completed on a firm surface and repeated on a foam surface (Airex Balance Pad, Alcan Airex, Switzerland) with time kept on a stopwatch (Fisher Scientific, Pittsburgh, PA). Each participants' performance was scored by adding one (maximum 10 points for each trial) point for each of the following errors committed during each condition: lifting ones hands off the iliac crest, opening of the eyes, a step, stumble, or fall, moving the hip into greater than 30° of abduction, lifting the forefoot or heel, and or remaining out of test position for greater than 5 s.

The CNS Vital Signs (CNS Vital Signs, Chapel Hill, NC) contained a battery of seven subtests: verbal memory test; visual memory test; finger tapping test; symbol-digit coding; the Stroop test; the shifting attention test; the continuous performance test; and the non-verbal reasoning test. We analyzed the following domain raw scores for the battery: verbal memory; visual memory; processing speed; executive function; psychomotor speed; reaction time; complex attention; cognitive flexibility; and reasoning.

All participants reported for pre- and post-intervention testing sessions, which each included two balance assessments and a computerized neurocognitive exam. These outcome measures were selected as they represent the battery of tests student athletes typically complete at baseline and following concussion in many settings. Participants were also administered a demographic and health history questionnaire. The BESS trials were captured using video analysis and independently scored by a single research assistant trained in the analysis of BESS errors. The PI was blinded to the baseline and post-intervention balance and neurocognitive performance until the study was complete. The SOT conditions were completed in a randomized order, following the first set, which was completed in ascending numerical order, no matter the task. The computer monitor was covered during administration of the SOT to assure test administrator blinding of balance scores. A member of the research team reviewed the CNS Vital Signs scores for validity.

All 30 participants were required to report to the clinical research center twice a week to complete their intervention program. Participants also completed an additional training session each week at home, which included exercises already completed during in-person intervention sessions. Participants were instructed and given a specific training log tailored to each week's home session with direct instruction and a list of exercises to complete. Participants logged their home training sessions including exercises completed previously and activities completed during the intervention period. In addition to completing the exercise log, participants were asked to report to the investigators whether they had completed the training sessions and exercises at each home training session. Participants completed the intervention over 4 weeks for a total of 12 training sessions (8 in person and 4 at home). Average days between pre- to post-test was 34.03 ± 4.22 days. Participants were required to complete at least one observed session per week and twelve sessions overall (8 in person and 4 home) to be included in study analysis. Participants were allowed a fifth week of intervention progression to account for missed observed sessions due to academic breaks and scheduling issues. All participants, regardless of group and task proficiency completed a mass intervention progression.

Participants in the single-task intervention group (ST) completed activities broken down into separate balance and cognitive exercises of varying degrees of difficulty. Each participant began at the entry level of both balance and cognitive exercises and progressed to the advanced level. Single task intervention difficulty levels are depicted in Fig. 1.

Participants in the dual-task intervention group (DT) completed activities from all four progressive dual-task levels broken down into the entry level, moderate level, advanced level, and the activity specific level. The balance and cognitive activities were always completed concurrently. The progression began with one week of