Effects of a Single-Task Versus a Dual-Task Paradigm on Cognition and Balance in Healthy Subjects


Context: Recent evidence has revealed deficiencies in the ability to divide attention after concussion. Objective: To examine the effects of a single vs a dual task on cognition and balance in healthy subjects and to examine reliability of 2 dual-task paradigms while examining the overall feasibility of the tasks. Design: Pretest–posttest experimental design. Setting: Sports medicine research laboratory. Patients: 30 healthy, recreationally active college students. Intervention: Subjects performed balance and cognitive tasks under the single- and dual-task conditions during 2 test sessions 14 d apart. Main Outcome Measures: The procedural reaction-time (PRT) test of the Automated Neuropsychological Assessment Metrics (eyes-closed tasks) and an adapted Procedural Auditory Task (PAT; eyes-open tasks) were used to assess cognition. The NeuroCom Sensory Organization Test (SOT) and the Balance Error Scoring System (BESS) were used to assess balance performance. Five 2-way, within-subject ANOVAs and a paired-samples t test were used to analyze the data. ICCs were used to assess reliability across 2 test sessions. Results: On the SOT, performance significantly improved between test sessions ($F_{1,29} = 35.695, P < .001$) and from the single to the dual task ($F_{1,29} = 9.604, P = .004$). On the PRT, performance significantly improved between test sessions ($F_{1,29} = 57.252, P < .001$) and from the single to the dual task ($F_{1,29} = 7.673, P = .010$). No differences were seen on the BESS and the PAT. Reliability across test sessions ranged from moderate to poor for outcome measure. Conclusions: The BESS appears to be a more reliable and functional tool in dual-task conditions as a result of its increased reliability and clinical applicability. In addition, the BESS is more readily available to clinicians than the SOT.

Keywords: postural stability, concussion, attention

Concussion evaluation involves assessing the function and interaction among the numerous systems affected by concussive injury. Current methodology for concussion assessment advocates a comprehensive approach evaluating reported
Single-Vs. Dual-Task Paradigm

This comprehensive assessment using information on symptoms, balance, and cognitive function enables clinicians to better understand the deficits after concussion. Current literature suggests that this comprehensive battery has up to 90% sensitivity.

Symptom assessment been shown to be a useful part of the evaluation of concussive injuries by giving the clinician an idea of the patient’s self-reported status. However, because these are self-reported, athletes may choose to mask symptoms and report feeling normal. Broglio et al found that even in the absence of symptoms over 30% of athletes still displayed deficits on at least 1 measure of neurological function, indicating that symptoms alone may not provide the most accurate picture of deficits after an injury. In addition, assessing cognitive functioning alone may not provide insight into all deficits after concussion. However, these cognitive tests, specifically, neuropsychological testing, have proven helpful when evaluating concussion with respect to verbal and visual memory, concentration, attention to a task, and reaction time. Cognitive assessments may also be conducted using auditory tasks by asking a patient to respond verbally to a stimulus as opposed to using a mouse. This type of task can be incorporated when the patient’s eyes are closed. Auditory assessment of cognition is not commonly used in the concussion-assessment paradigm; however, it is often used in other settings and in previous dual-task literature. Cognition may also be assessed using more traditional paper-and-pencil measures or with computerized testing. Balance deficits have also been identified after concussion as individuals are often unable to interpret and integrate sensory information needed for appropriate motor responses to maintain postural control. Clinically, balance is often assessed using the Balance Error Scoring System (BESS), a cost-effective and reliable test to assess balance after a concussive injury. More sophisticated laboratory measures such as the Sensory Organization Test (NeuroCom Inc, Clackamas OR) may also be used to assess balance and gain a better understanding of the specific sensory-integration issues after concussion. Recent literature has also focused on the reliability of these test measures over time as concussion assessments are completed in a serial manner. Much of this literature has focused on computerized testing, yielding low to moderate test–retest reliability depending on the source. The BESS has been shown to have high reliability over serial testing sessions in various populations. The reliability of the SOT is less studied, but in one of the few studies to examine this measure the reliability ranged from low to good. Establishing reliability of all measures used in the assessment of concussion is essential because of the serial testing paradigms.

Participation in sport requires athletes to divide their attention between cognitive and dynamic-balance tasks. Although the cognitive and balance demands are independently important, the 2 are linked in that they rely on an individual’s system of attention. Attention involves multiple systems in the brain and works with these related sensory systems simultaneously. Attention has been theorized to consist of alerting, orienting, and executive components. The alerting component is responsible for the arousal and ability to maintain effort while completing a task. The orienting component gives direction to the other sensory-processing systems that may be required for a task to enable greater efficiency in completing it. The executive component then ultimately focuses the necessary sensory and processing systems for a particular task and allows for adaptability by being able to switch between systems relative to the changing demands of a task, forcing the individual to make decisions about how to attend to the task at hand. In healthy individuals each of these components of attention enables them to identify the task at hand, identify symptoms, neuropsychological performance, and balance.
the needed mechanisms to respond to the task, and then ultimately complete the task with the greatest efficiency possible. When an individual is neurologically compromised, the function of these attention components and sensory systems is altered, thereby making it difficult for the individual to appropriately respond to a task, specifically if multiple tasks are being attended to at the same time.

Current sport-related concussion-assessment paradigms evaluate balance and cognitive tasks independently of each other and so fail to grasp the role of divided attention in the interaction between these systems. Preliminary evidence has suggested the ability to selectively allocate attention between cognitive and balance tasks, but a priority for balance has been demonstrated with increasing difficulty of these tasks. Attention deficits after concussion manifest in the difficult disengagement of attention from one stimulus to switch to another. These deficits may be observed as dynamic-balance impairments during gait for up to 28 days after concussion. Previous study of clinical balance alone suggests that recovery is usually seen within 3–5 days after injury. It has been established that cognitive and balance tasks influence each other when older adults are required to divide attention between the 2, although continued investigation is necessary to draw conclusions for use in athletics. Previous work has shown improvements in balance with the addition of a cognitive task in healthy subjects. Studies examining the effect of a dual task in concussed subjects have revealed more pronounced balance deficits and longer duration of impairment than when testing a single-task condition. To our knowledge, no studies have examined a dual-task paradigm in the context of commonly used clinical measures of concussion, such as the BESS.

Our goal was to investigate the feasibility and stability of the instruments used for 2 different dual-task paradigms and their appropriateness in combined cognitive and balance testing after concussion. Therefore, the primary purpose of this study was to examine the effects of a dual-task testing paradigm on procedural reaction time, procedural auditory task accuracy, and balance in healthy subjects. By analyzing the influence of divided attention on reaction time, accuracy of responses, and balance performance using previously established clinical tools, we hoped to observe patterns that occur in healthy young adults. A secondary purpose of the study was to examine the reliability of all these measures across 2 test sessions.

Methods

Design

A repeated-measures study design was used. All testing conditions were completed on 2 separate sessions 14 days apart in a research laboratory.

Patients and Participants

Thirty healthy, physically active (3+ d/week, 30+ min) college-age students (age 20.43 ± 1.33 y, height 173.44 ± 9.28 cm, mass 79.03 ± 19.29 kg) were used in the study. The sample consisted of 14 men and 16 women. Exclusion criteria were a history of diagnosed concussion, lower extremity injury in the last 3 months, diagnosis of attention deficit or attention deficit and hyperactivity disorder, and knowledge of the Automated Neuropsychological Assessment Metric testing procedures.
Instrumentation

**Procedural Reaction-Time Task.** Procedural reaction time (PRT) is one of the test modules used in the Automated Neuropsychological Assessment Metrics and is part of a computerized battery of tests used to assess overall cognitive function. During the PRT, a number (2, 3, 4, or 5) is presented on a computer screen. If a 2 or 3 is presented, the subject is asked to left-click the mouse button, and if a 4 or 5 is presented, the subject is asked to right-click the mouse button. The test combines the subject’s accuracy and speed of responses to calculate a throughput score representative of overall reaction-time performance. The PRT test module was altered to last 20 seconds (down from approximately 45 s in the original sports medicine test battery) to match the duration of each trial of the SOT. Prestudy pilot testing on 9 subjects revealed no significant difference in performance between the original and abbreviated versions of the PRT ($t_8 = 0.927, P = .381$). No significant practice effects within test session were observed on the abbreviated PRT on 5 serial administrations ($F_{4,32} = 0.722, P = .584$).

**Procedural Auditory Task.** The Procedural Auditory Task (PAT) module was adapted from the computer-based PRT test module in an effort to gain some understanding of cognitive performance during eyes-closed conditions of the SOT and the BESS. The PAT module consisted of a 20-second test during which an auditory stimulus (“2,” “3,” “4,” or “5”) was given to subjects, to which they verbally responded “left” to 2 or 3 and “right” to 4 or 5. The auditory stimulus was presented using audio files previously recorded in which the numbers 2–5 were spoken in random order at a rate of 1 stimulus every 1.5 seconds, for a total of 15 stimuli every 20-second trial. Random-number lists were generated using Microsoft Excel (Microsoft Corp; Redmond, WA), with a total of 12 audio files being created. The MPEG-1 Audio Layer 3 (ie, mp3) audio files were transferred to a digital music player, which was used to play the files during the test via external speakers. Data were recorded using a digital audio recorder, with each trial being scored for accuracy of responses after the test session was completed. Accuracy was determined by dividing the total number of correct responses by the total number of stimuli (15 for each trial).

**SOT.** The SOT was used to assess balance performance. The test selectively manipulates visual, somatosensory, and vestibular information to subjects while asking them to remain as still as possible over their base of support. The test consists of six 20-second conditions performed 3 times in random order. The sequence of these conditions is as follows (Figure 1): (1) fixed support surface with a fixed visual surround, (2) fixed support surface with the eyes closed, (3) fixed support surface with a sway-referenced visual surround, (4) sway-referenced support surface with a fixed visual surround, (5) sway-referenced support surface with the eyes closed, and (6) sway-referenced support surface with a sway-referenced visual surround.

**BESS.** The BESS is a clinical balance measure designed to assess balance performance after a concussion (Figure 2). It comprises six 20-second conditions consisting of 3 stances (double leg, single leg, and tandem) performed on a firm surface and repeated on medium-density foam (Airex balance pad, Alcan Airex, Switzerland); all conditions are performed with the eyes closed. Clinicians tally the number of errors committed during each condition. These errors include opening the eyes, moving into more than 30° of hip abduction, toes or heels losing contact
with the ground, hands being taken off the hips, touchdowns with the suspended leg, or being out of test position for more than 5 seconds. A maximum of 10 errors can be issued in any 20-second condition, with a total maximum error score not exceeding 60 errors; higher scores represent poorer balance performance.
Procedures

Figure 3 portrays the session test orders. Subjects were tested twice, with sessions occurring exactly 14 days apart. The administration of balance tasks (SOT or BESS) was counterbalanced between test session and subjects.

**Orientation to Single Tasks.** At the beginning of each testing session, subjects were asked to perform 5 trials of the PRT and PAT test batteries while seated in a controlled environment to obtain baseline performance measures for these 2 tasks.

![Flowchart](image)
The single-task PRT and PAT performance measures were the result of ensemble averaging the 5 trials for each task. One trial of the PAT was also performed before beginning each of the balance-test batteries to reorient subjects to the task because of the novelty of this auditory task. The BESS was also completed using its original procedures, in addition to the first trial of the 6 conditions of the SOT.

**SOT With PAT and PRT.** During the 2 remaining series of trials, 1 trial was performed under dual-task conditions and the other repeated the single-task condition. The sequence order was counterbalanced between test sessions and subjects. During the dual-task trials with eyes open on the SOT, the viewing pane in the field of the visual surround was opened, revealing a monitor displaying the PRT test module. The subjects were given a computer mouse to hold in their dominant hand at their side to complete the PRT concurrent with the eyes-open trials of the SOT. A throughput score was generated for each PRT trial; the mean of the 4 throughput scores for each of the eyes-open conditions was used to represent dual-task PRT performance on the SOT in the statistical analysis. During the 2 trials of the SOT performed with the eyes closed, the PAT test battery was performed. Audio files were played over external speakers controlled by the tester. The recording provided a stimulus every 1.5 seconds, with the first response given for each auditory stimulus being scored as correct or incorrect by the tester. The average of the 2 accuracy scores (1 score was obtained for each of the 2 eyes-closed SOT trials) was used as the dual-task performance variable for PAT on the SOT in the statistical analysis. For both the PRT and the PAT, subjects were not given direction as to where to focus attention.

Composite scores were used to represent balance performance in both the dual and single tasks. The overall composite scores were calculated from the equilibrium scores of each condition generated by the SOT. The composite SOT score for the single-task condition was calculated as the sum of the average of the equilibrium scores for conditions 1 and 2 under the single-task conditions and the 2 individual equilibrium scores for conditions 3–6. The dual-task composite SOT score was calculated as the average of the equilibrium scores from the 6 dual-task SOT conditions.

**BESS With PAT.** The BESS was performed under the single- and dual-task conditions during each test session. The total error score for the single- and dual-task BESS was the sum of the total errors for each of the trials of the respective testing conditions. The dual-task BESS always followed the single-task BESS to allow subjects to familiarize themselves with the test. During the dual-task BESS, external speakers controlled by the tester played the PAT test. The PAT tests each lasted 20 seconds, coinciding with the length of each trial in the BESS. The average of the accuracy scores from the 6 trials was used as the dual-task performance for PAT on the BESS in the statistical analysis. The BESS testing and dual tasks with the BESS were videotaped for all subjects. The principal investigator and another clinician (coinvestigator) independently scored the BESS from the videotape. The results were analyzed between testers to determine intersession reliability of the scores. Good intersession reliability and precision were observed for the single-task (ICC$_{2,k} = .79$, SEM = 1.65) and dual-task (ICC$_{2,k} = .81$, SEM = 1.87) BESS total error scores.
Statistical Analyses

Differences in balance performance on the SOT during a dual task compared with the single task were analyzed using a single 2-way Task (single or dual) × Test Session (1 or 2) within-subject ANOVA. In addition, differences in balance performance on the BESS between the 2 task conditions were also analyzed using a single, 2-way Task (single or dual) × Test Session (1 or 2) within-subject ANOVA. Furthermore, differences in PRT and PAT performance between the dual-task and single-task conditions were analyzed using 3 separate (PRT eyes open SOT, PAT eyes closed SOT, and PAT BESS) 2-way Task (single or dual) × Test Session (1 or 2) within-subject ANOVAs. No direct comparisons were made between the SOT and BESS or the PRT and PAT scores. Task (single or dual) and test session (1 or 2) were used as the 2 within-subject independent variables. Paired-samples t tests were employed on the average accuracy scores on each test battery to determine whether there were statistical differences between PAT performances only on the eyes-closed conditions on the SOT and the BESS.

Intersession reliability was assessed using 2 ICC2,1 (SOT composite score and BESS total error score) and 3 ICC2,k (PRT throughput score, PAT accuracy on the SOT, and PAT accuracy on the BESS) analyses. All data analyses were conducted using SPSS 15.0 (Chicago, IL).

Results

Effect of Task on Balance Performance

We examined the difference in balance performance on the SOT and on the BESS during a dual task compared with a single task (Table 1). Results from the SOT revealed no significant test-by-task interaction ($F_{1,29} = 0.340$, $P = .564$). There

Table 1  Means and Standard Deviations for Test Session and Type of Task

<table>
<thead>
<tr>
<th>Outcome variable</th>
<th>Session 1</th>
<th>Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single</td>
<td>Dual</td>
</tr>
<tr>
<td>SOT score$^{a,b}$</td>
<td>79.20 ± 4.43</td>
<td>81.43 ± 5.50</td>
</tr>
<tr>
<td>BESS total error score</td>
<td>1280 ± 4.97</td>
<td>12.66 ± 5.38</td>
</tr>
<tr>
<td>PRT score$^{a,b}$</td>
<td>117.24 ± 8.53</td>
<td>120.04 ± 9.61</td>
</tr>
<tr>
<td>PAT accuracy score$^a_{SOT}$</td>
<td>97.82 ± 2.41</td>
<td>97.77 ± 4.04</td>
</tr>
<tr>
<td>PAT accuracy score$^a_{BESS}$</td>
<td>97.82 ± 2.41</td>
<td>97.40 ± 2.95</td>
</tr>
</tbody>
</table>

*SOT*, Sensory Organization Test; *BESS*, Balance Error Scoring System; *PRT*, procedural reaction-time test; *PAT*, Procedural Auditory Task.

$^a$ Significant difference between test sessions (1 and 2).

$^b$ Significant difference between tasks (single to dual).
was a significant main effect for test session ($F_{1,29}= 35.695, P < .0005$) and task ($F_{1,29} = 9.604, P = .004$), with improvement during the second session compared with the first and in the dual task compared with the single task. Results from the BESS revealed no significant test-by-task interaction ($F_{1,29} = 2.460, P = .128$), as well as no significant main effect for test session ($F_{1,29} = 0.004, P = .953$) or task ($F_{1,29} = 1.961, P = .172$).

**Effect of Task on PRT and PAT Performance**

Means and standard deviations for task and test time concerning PRT and PAT are presented in Table 2. Results for the PRT test battery during the eyes-open conditions of the SOT revealed no significant test-by-task interaction ($F_{1,29} = 0.082, P = .777$), but there was a significant main effect for test session ($F_{1,29} = 57.252, P < .001$) and task ($F_{1,29} = 7.673, P = .010$), with significant improvement in the second test session compared with the first and the dual task compared with the single task. Results of the PAT test during the eyes-closed conditions of the SOT revealed no significant test-by-task interaction ($F_{1,29} = 0.002, P = .962$), main effect for test session ($F_{1,29} = 3.940, P = .057$), or main effect for task ($F_{1,29} = 0.023, P = .880$). PAT tests on the BESS also revealed no significant test-by-task interaction ($F_{1,29} = 0.342, P = .563$), main effect for test session ($F_{1,29} = 3.678, P = .065$), or main effect for task ($F_{1,29} = 2.225, P = .147$). Table 2 gives the effect sizes for all analyses. There was no significant difference found between these 2 measures of balance ($t_{29} = 1.359, P = .185$).

**Reliability Analysis**

Reliability data across test sessions for each task used are presented in Table 3, indicating the BESS as more reliable than the SOT concerning balance performance. Reliability across test sessions ranged from moderate to poor for each outcome measure.

**Table 2  Effect Sizes (ES) and Power for Interaction and Main-Effect Analyses**

<table>
<thead>
<tr>
<th>Outcome variable</th>
<th>Interaction Effect, Task × Session</th>
<th>Main Effect, Task</th>
<th>Main Effect, Session</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ES</td>
<td>Power</td>
<td>ES</td>
</tr>
<tr>
<td>SOT composite score</td>
<td>0.108</td>
<td>.11</td>
<td>0.575</td>
</tr>
<tr>
<td>BESS total error score</td>
<td>0.291</td>
<td>.49</td>
<td>0.260</td>
</tr>
<tr>
<td>PRT throughput score</td>
<td>0.053</td>
<td>.06</td>
<td>0.514</td>
</tr>
<tr>
<td>PAT accuracy scoreSOT</td>
<td>0.009</td>
<td>&lt;.06</td>
<td>&lt; 0.028</td>
</tr>
<tr>
<td>PAT accuracy scoreBESS</td>
<td>0.109</td>
<td>.11</td>
<td>0.277</td>
</tr>
</tbody>
</table>

SOT, Sensory Organization Test; BESS, Balance Error Scoring System; PRT, procedural reaction-time test; PAT, Procedural Auditory Task. ES is partial eta-squared.
Discussion

The introduction of a cognitive task aimed at attention and processing speed did not result in significant balance deficits in our healthy physically active subjects. Recent literature suggests that the ability to divide attention may be challenged after a concussive injury, in addition to acute deficits in balance and cognition. Our study was limited to healthy subjects, and additional research is needed to understand this phenomenon after concussion and to fully establish the utility and feasibility of paradigms assessing divided attention after concussive injury.

Dual-Task Balance

Effects of a dual task on balance performance were evaluated using the SOT and the BESS. Our finding of a practice effect between sessions for the SOT independent of task is consistent with previous reports identifying learning effects in healthy subjects under the single-task condition on serial administration of the SOT. We observed an overall improvement in balance performance on the SOT under the dual task, similar to other studies in the literature that added a simple cognitive task to a balance task; however, these results may be different with a more difficult cognitive task. These results were expected, because healthy individuals are able to divert attention from the conflicting sensory inputs created by the SOT, whereas previous studies have illustrated that concussed individuals are often unable to do so. The addition of the cognitive task also shifts attention toward an external focus (the cognitive task) instead of the individual’s body movements or actions. Our finding is consistent with the constrained-action hypothesis, which states that an internal focus of attention interrupts otherwise automatic processes of the motor system, implying that a shift toward an external focus may increase motor performance. An external focus has been shown to increase both motor learning and performance. During the tasks we also observed a high level of

<table>
<thead>
<tr>
<th>Outcome variable</th>
<th>Single Task</th>
<th></th>
<th>Dual Task</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC SEM</td>
<td>ICC SEM</td>
<td></td>
</tr>
<tr>
<td>SOT composite score</td>
<td>.245 4.24</td>
<td>.318 3.803</td>
<td></td>
</tr>
<tr>
<td>BESS total error score</td>
<td>.676 2.633</td>
<td>.662 3.198</td>
<td></td>
</tr>
<tr>
<td>PRT throughput score</td>
<td>-.038 8.310</td>
<td>.501 8.537</td>
<td></td>
</tr>
<tr>
<td>PAT accuracy score&lt;sub&gt;SOT&lt;/sub&gt;</td>
<td>.279 1.736</td>
<td>.142 2.742</td>
<td></td>
</tr>
<tr>
<td>PAT accuracy score&lt;sub&gt;BE&lt;/sub&gt;</td>
<td>N/Aa 1.706</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SOT, Sensory Organization Test; BESS, Balance Error Scoring System; PRT, procedural reaction-time test; PAT, Procedural Auditory Task.

a PAT ICC and SEM single-task calculations listed under PAT accuracy score<sub>SOT</sub>.
accuracy for the cognitive task during each of the SOT conditions. Previous studies with similar results proposed a potential refinement of the pathways responsible for each of these tasks because of this interaction. A potential explanation for this interaction may be that a dual task tests subjects in a more functional manner and represents the demands of everyday life. Although the cognitive task provided an external focus of attention, both this cognitive task and the SOT balance task were relatively simple in nature. Previous work has demonstrated improvement on the SOT when combined with a simple cognitive task and that the magnitude of this effect is proportional to the difficulty of each of the tasks.39

Our observed results for balance performance differed between the BESS and the SOT in that we found no significant difference in performance on the BESS across tasks. The BESS is a more difficult task that also requires corrections, most likely leading to our findings of no improvements in the dual task and no significant improvements in the cognitive task, suggesting a meaningful finding, with the normal increase in performance across time on the BESS not being observed. Based on the constrained-action hypothesis, the shift of attention to an external stimulus should have resulted in improved balance performance.37,38 Also, under the single-task condition in healthy subjects, serial administration of the BESS has been shown to result in a practice effect across test sessions.40,41 In our study, the dual-task BESS always followed the single task. Therefore, we expected an improvement in dual-task scores with consecutive administration of the test, as well as with the addition of the PAT; instead, we saw no change in performance between the tasks. Considering previous accounts in the literature citing the influence that balance and cognition have on one another22,42,43 and the magnitude of this influence being directly proportional to the difficulty of the respective tasks,39 the increased difficulty of the BESS may provide an explanation of why the improvements seen on the SOT were not seen on the BESS under the dual-task condition. The increased difficulty of the BESS is a result of the need for the subject to make corrections from errors in all planes and return to the testing position. To our knowledge, our study was the first to combine a cognitive task with the BESS; therefore, a direct comparison of our findings with previous work is difficult. Future studies should examine this relationship across serial administrations to draw further conclusions about this relationship.

**Dual-Task PRT**

The second portion of our study examined the influence of a dual task on PRT test performance and accuracy. Two test types were used: A computerized PRT was used during the eyes-open conditions on the SOT (ie, conditions 1, 3, 4, and 6), and a PAT was used during the eyes-closed conditions of the SOT (2 and 5) and during all conditions of the BESS. We observed an improvement in PRT during the dual task in addition to a learning effect observed in test session 2. This is in partial agreement with literature demonstrating a practice effect for some neuropsychological test batteries. Peterson et al.44 demonstrated the greatest learning effects on pencil-and-paper tests in the domain of information-processing speed, which most closely relates to our test battery. Our observed improvement in PRT in a dual task is supported by Broglio et al.28 who found that reaction-time speed
improved in a task-switching test performed during the eyes-open conditions of the SOT. The cognitive task used in both the PRT and the PAT is a relatively simple task, which may explain the significant improvements. In addition, the greatest practice effects seen during any neuropsychological tests are from the first test session to the second, which were the only 2 time points assessed in our study.

Limitations

Although our study has important observations regarding usefulness of a dual task in our current clinical testing paradigm for concussion assessment, there are some limitations. Most noticeable is the low reliability of the SOT, which raises questions about its usefulness as a component in a dual task. Our analyses also had low effect sizes, with differences between our observed means representing clinically insignificant changes compared with those between postinjury and baseline scores previously reported in the literature (SOT composite score approximately 7- to 14-point decline; BESS total error score increase of approximately 3 total errors, representing a decline in performance). Our study investigated the effects of a dual task in healthy subjects who are assumed to have the ability to adequately divide attention between 2 tasks; large differences between tasks were not expected in this population. Future studies investigating these effects in concussed athletes may provide more clinically meaningful information. We also always performed the single-task BESS before the dual task, which may have lead to practice effects; however, for the purposes of task orientation and examining the feasibility of the BESS in a dual task we felt this was appropriate. Furthermore, PRT and PAT tasks may not place sufficient cognitive demands on healthy individuals to observe any differences between cognitive and balance performance, rendering it difficult to determine the value of each of these testing models in the clinical setting. In the future, a paradigm including a more difficult visuospatial task, incorporating the link between cognition and motor performance, may be more appropriate.

Conclusions

The heightened demands of participation in sport challenge athletes not only in terms of cognition and balance separately but also ultimately in regard to how these systems interact. The ability to allocate attentional resources is imperative for safe participation in athletics. As clinicians, we currently attempt to examine the interaction of systems involved in cognition, neurological impairment, and postural control after concussion. Recent findings have suggested that to obtain the most sensitive results, we may need to develop reliable ways to look directly at this interaction. Our findings support the potential for a dual task, specifically using the BESS, to be a more reliable and useful concussion-assessment component than the tests performed alone. In addition, the BESS is more feasible because it is readily available to more clinicians and is more cost-effective than other balance measures. It also takes less time and may be more true to a sporting environment than the SOT. We also recommend a cognitive task that can be performed with the eyes closed because measures of balance with the eyes closed have been shown to be most sensitive to concussion. When making return-to-play decisions
regarding orthopedic injuries, a key component in the decision-making process is the functional capacity of the athlete to participate in a given sport. There is a need for further examination of this testing paradigm using larger samples of healthy subjects and including concussed subjects to make further conclusions as to the usefulness of a dual task in a sports medicine setting. It is important that future research continue to explore the role of attentional recovery after concussion, as well as exploring different methodologies that would be useful and feasible in the clinical setting to assess these deficits.

Our study was designed to examine the potential use of current assessment tools in a dual-task paradigm. Our findings suggest that combining a cognitive test aimed at processing speed and attention with the BESS, in particular, has the potential to be a more sensitive test of concussion than these measures performed during a single task. Although both the SOT and the BESS are sensitive to concussion, our findings may indicate that, given its increased reliability and demands, the BESS may be a better test to use in dual-task conditions than the SOT. Clinicians should be mindful of ways to challenge cognition and balance independently and combined to gain a better idea of functional performance before return to play after concussion. Future research should examine the effect of this dual-task paradigm to evaluate and track recovery after concusive injury.

References


