



# The Use of Tandem Gait & BESS Test for Concussion Management

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BY: JACLYN MORRISSETTE, PHD, ATC



# Disclosure Statement

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We have nothing to disclose.



# Course Objectives

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1. To identify the effects of how sustaining a concussion can have on motor and balance function of a patient.
2. Describe the evaluation process of motor and balance function using the tandem gait and BESS tests both pre- and post-concussion to properly manage and make return to play decisions.
3. Determine return-to-play guidelines following a concussion utilizing the BESS test and tandem gait test with modifications (single-task, dual-task) as functional rehabilitation techniques that address all deficits a patient may have post-concussion.



# Concussions

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# What is a Concussion?

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NATA Position Statement: Management of Sport Concussion- A concussion, which is a form of mild traumatic brain injury (mTBI), has been defined as a trauma-induced alteration of mental status that may or may not involve the loss of consciousness.<sup>1</sup>

McCrary et al., with updates from Patricios et al., defines a sport-related concussion as a **traumatic** brain injury caused by a direct blow to the head, neck or body **resulting in an** impulsive force **being** transmitted to the **brain that occurs in sports and exercise-related activities. This initiates a neurotransmitter and metabolic cascade, with possible axonal injury, blood flow change and inflammation affecting the brain. Symptoms and signs may present immediately, or evolve over minutes or hours, and commonly resolve within days, but may be prolonged.**<sup>2</sup>



# Concussion Frequency

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The World Health Organization's (WHO) Collaborating Centre Task Force estimate that the annual incidence of concussion is 200 to 300/100,000 emergency department visits<sup>3</sup>

- Many go unreported – closer to 700/100,000<sup>3</sup>

It is estimated that 1.6-3.8 million concussions occur annually as a result of sport participation<sup>4</sup>

- Many by high school, then college aged students<sup>5,6</sup>
- Account for approximately 5% of all collegiate sport-related injuries<sup>7</sup>



# Mechanisms of Concussion

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## Direct blow to the head or body

- Head snap forward, backward, or rotate to the side<sup>8</sup>

## Common in collision or contact sports<sup>9</sup>

- Football, soccer, lacrosse, boxing, ice hockey wrestling<sup>10</sup>

## Not limited to only contact sports

- Baseball, softball, gymnastics, field hockey, volleyball, cheerleading, track

## Non-sport related

- Motor vehicle accidents & direct contact with an inanimate object<sup>11</sup>



# Signs & Symptoms<sup>12</sup>

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Dizziness

Headaches

Blurred vision

Abnormal eye tracking

Diplopia

Photophobia

Tinnitus

Delayed verbal & motor responses

Slurred speech

Concentration problems

Memory deficit

Disrupted coordination

Behavioral changes

Loss of consciousness<sup>9,13</sup>





# Evaluation

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Determining level of consciousness

Assessing ABC's and cervical spine

## HOPS

- Neurological Exam
  - Cranial Nerves
  - Dermatome, myotome, and reflexes
  - Coordination (Cerebellar) Tests
  - Cognitive (Cerebral) Tests



# Cerebellar (Balance) Tests

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## Romberg Test

- Non-dominant single-leg stance
- Tandem stance
  - Eyes open and closed
  - Firm and foam surfaces<sup>14</sup>



# Romberg Test



Single Leg Non-Dominant Stance (eyes open/closed)

Tandem Stance Non-Dominant in Back (eyes open/closed)



Single Leg Non-Dominant Stance (eyes open/closed) on Foam

Tandem Stance Non-Dominant in Back (eyes open/closed) on Foam



# Cerebellar (Balance) Tests

## Balance Error Scoring System (BESS)<sup>9</sup>

### Types of Errors

1. Hands lifted off iliac crest
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into  $> 30^\circ$  ABD
5. Lifting forefoot or heel
6. Remaining out of testing position for  $> 5$  sec

The BESS is calculated by adding one error point for each error during the six 20-second tests.

| Score Card (# errors)                              | FIRM Surface | FOAM Surface |
|--|--------------|--------------|
| Double-Leg Stance<br>(narrow stance-feet together) |              |              |
| Single-Leg Stance<br>(nondominant foot)            |              |              |
| Tandem Stance<br>(nondominant foot in back)        |              |              |
| Total Scores                                       |              |              |



# BESS Test



# Coordination (Cerebellar) Tests

## Upper-limb Coordination

- Finger-to-nose test

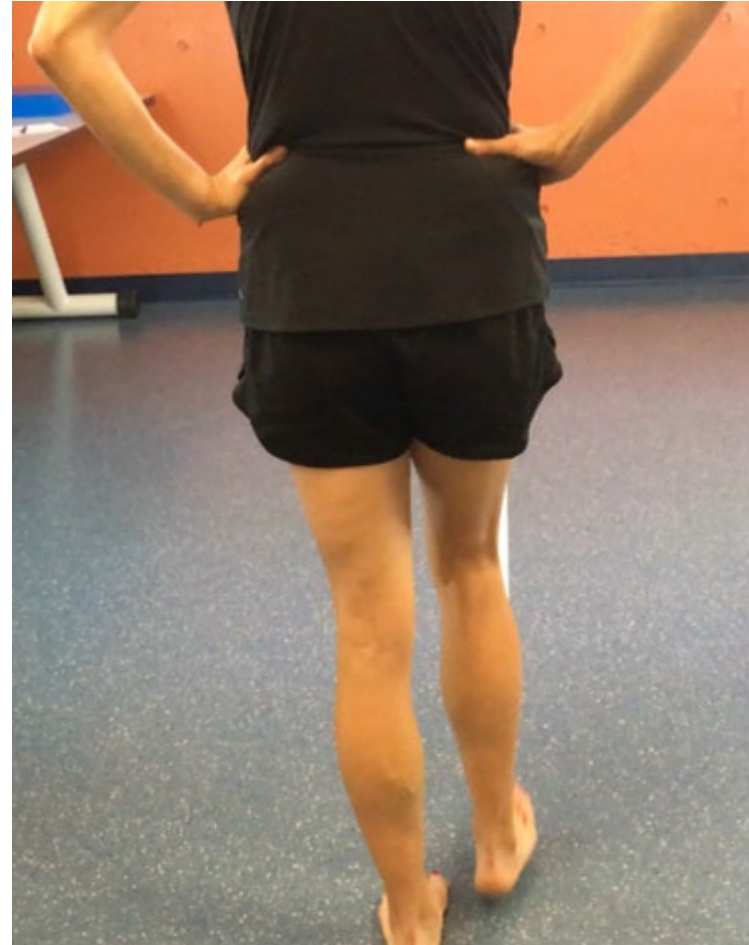


# Coordination (Cerebellar) Tests

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## Tandem Gait<sup>15-17</sup>

- Heel-to-toe walking



# Coordination (Cerebellar) Tests

## Tandem Gait scoring

- Heel-to-toe walking
  - Timed component
  - Dual Task (Optional)
    - Modified Serial 7

### Timed Tandem Gait

Place a 3-metre-long line on the floor/firm surface with athletic tape. The task should be timed.

Say *“Please walk heel-to-toe quickly to the end of the tape, turn around and come back as fast as you can without separating your feet or stepping off the line.”*

Single Task:

| Time to Complete Tandem Gait Walking (seconds) |         |         |                  |               |
|--|---------|---------|------------------|---------------|
| Trial 1  | Trial 2 | Trial 3 | Average 3 Trials | Fastest Trial |
|  |         |         |                  |               |

### Dual Task Gait (Optional)

Only perform if the child successfully completes complex tandem gait.

Place a 3-metre-long line on the floor/firm surface with athletic tape. The task should be timed.

Say *“Now, while you are walking heel-to-toe, I will ask you to count backwards out loud by 3s. For example, if we started at 100, you would say 100, 97, 94, 91. Let’s practise counting. Starting with 95, count backward by threes until I say “stop.”* Note that this practice only involves counting backwards.

Dual Task Practice: Circle correct responses; record number of subtraction counting errors.

| Task     |    |    |    |    |    |    |    | Errors | Time |
|----------|----|----|----|----|----|----|----|--------|------|
| Practice | 95 | 92 | 89 | 86 | 83 | 80 | 77 | 74     |      |

Say *“Good. Now I will ask you to walk heel-to-toe and count backwards out loud at the same time. Are you ready? The number to start with is 88. Go!”*





# Cognitive (Cerebral) Tests

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Baseline measurements vs. post-concussion<sup>10,18</sup>

- Memory recall
  - Retrograde amnesia - who won last week, where they live, food ate for breakfast
  - Anterograde amnesia - game score, last play, 12-15 word recall<sup>2</sup>
- Serial 7
- Digits backwards (groups of 3, 4, 5, or 6 numbers)
- Months in reverse order – timed<sup>2</sup>



# Sport Concussion Assessment Tool (SCAT)

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## Development & Implementation<sup>19,20</sup>

- Symptom scale
- Maddocks' questions/score
  - Memory
- On-field markers of concussion
  - Amnesia, loss of consciousness
- Return to play

## Revisions

- SCAT2: 2004 – Glasgow Coma Scale (GCS), alternate word lists, BESS (hard surface only)
- SCAT3: 2013 – additional physical/objective signs, option for foam stances or timed tandem gait
- SCAT5: 2017 – more alternative digits, neurological screen, modified tandem gait (no timing)

- SCAT6: 2023 – longer list words (12-15), adding more digits to the digits backward test, add a timed component to months backwards, add timed dual gait tasks, more robust set of observable signs (i.e. falling with no protective action, dazed look, etc.)
- SCOAT6 – give HCPs a standardized evaluation tool in office<sup>21</sup>

## Children's SCAT (< 13yo)<sup>22-24</sup>

- Versions 3, 5, & 6
- Child SCOAT6

# Do you know the differences between SCAT6 and Child SCAT6?

BESS TESTING

NONE

TANDEM GAIT

## Complex Tandem Gait

### Forward

Say "Please walk heel-to-toe quickly five steps forward, then continue forward with eyes closed for five steps"  
1 point for each step off the line, 1 point for truncal sway.

Forward Eyes Open Points:   
Forward Eyes Closed Points:   
Forward Total Points:

### Backward

Say "Please walk heel-to-toe again, backwards five steps eyes open, then continue backwards five steps with eyes closed." 1 point for each step off the line, 1 point for truncal sway.

Backward Eyes Open Points:   
Backward Eyes Closed Points:   
Backward Total Points:

Total Points (Forward + Backward):

## Dual Task Gait (Optional)

Say "Good. Now I will ask you to walk heel-to-toe and count backwards out loud at the same time. Are you ready? The number to start with is 88. Go!"

Dual Task Cognitive Performance: Circle correct responses; record number of subtraction counting errors.

| Task    |    |    |    |    |    |    |    |    | Errors | Time (circle fastest) |
|---------|----|----|----|----|----|----|----|----|--------|-----------------------|
| Trial 1 | 88 | 85 | 82 | 79 | 76 | 73 | 70 | 67 |        |                       |
| Trial 2 | 76 | 73 | 70 | 67 | 64 | 61 | 58 | 55 |        |                       |
| Trial 3 | 93 | 90 | 87 | 84 | 81 | 78 | 75 | 72 |        |                       |



# Balance & Stability

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# Balance & Stability

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## Control of joint posture & motion<sup>25</sup>

- Results from physiological constraints in the body
  - Muscular & non-muscular tissue
  - Nervous system's control of muscle activity
    - Brain & Spinal cord
  - Resulting muscle force
    - Voluntary & involuntary

## Develops in stages during childhood<sup>25</sup>

- Learns to integrate inputs from visual and other sensory sources





# Sensory Influence

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## Sensory signals

- Initiated by brain, peripheral nervous system (PNS), or both

## Visual (Eyes)

- Vision
- Spatial orientation & positions relative to environment

## Vestibular (Ear)

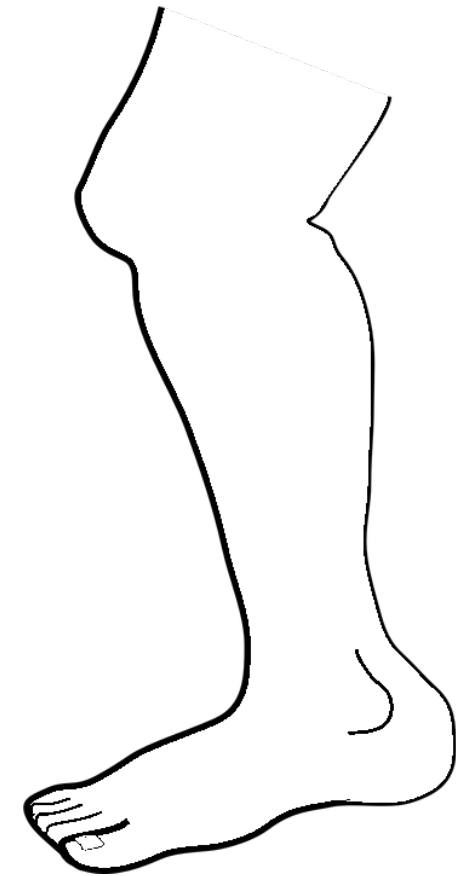
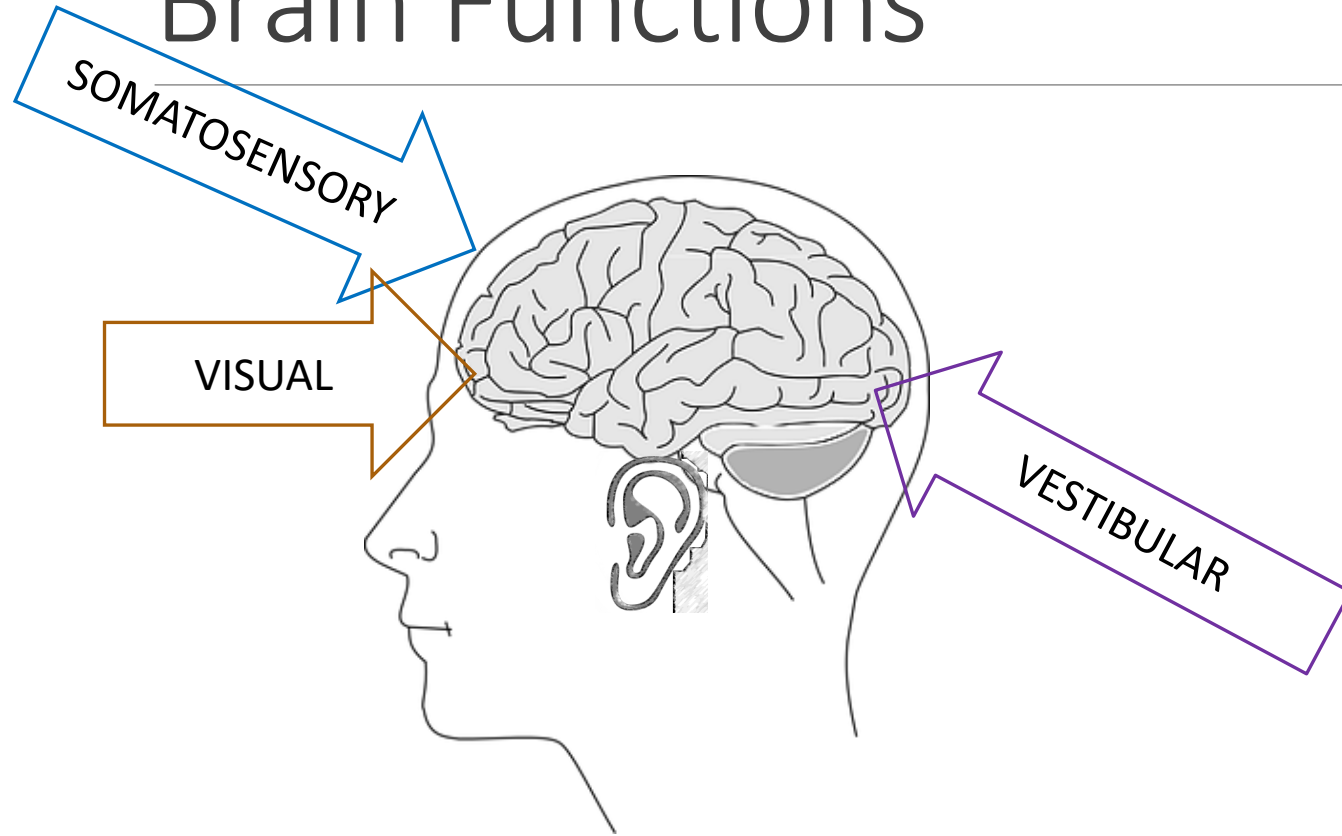
- Head movement & orientation relative to gravity

## Somatosensory (Receptors)

- Location of one body part to another
- Awareness in space (proprioception)
- Loads
- Joint position receptors
  - Ruffini endings, Golgi receptors, Pacinian corpuscles
- Muscle length & tension receptors
  - Muscle spindles & Golgi tendon organ



# Brain Functions



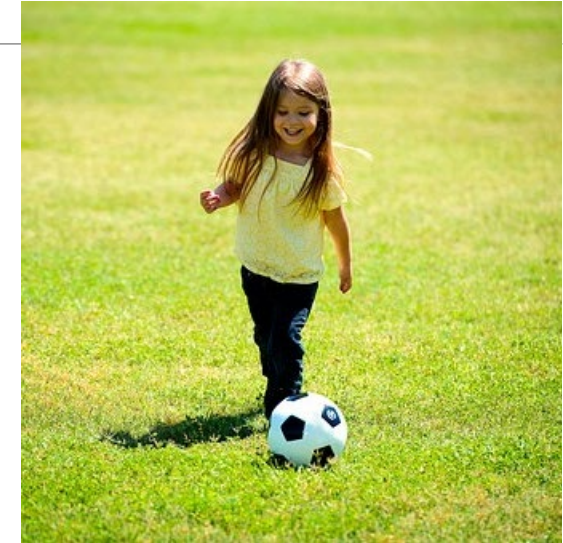
# Age Considerations<sup>26</sup>

## Ages 4 to 6

- Integration of all systems can overload brain
  - Balance & coordination may suffer

## Ages 7 to 10+

- More reliant on somatosensory & vestibular systems
- Fewer postural adjustments
- Concentrate on other tasks (ball movement, monitoring opponents)
- Process information related to developing strategies and tactics







# Evaluating Gait Post- Concussion

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# Balance & Motor Symptoms Associated with Concussion<sup>27-31</sup>

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## Short-term

- Balance & static postural control
- Gait unsteadiness & dynamic postural control

## Long-term

- Altered postural control
- Gait impairment
- Increased risk of lower extremity injury

Clinical symptoms vs. Balance & Gait alterations



# Evaluation of Gait Post-Concussion

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Number of objective tools to evaluate concussions<sup>32-36</sup>

- Concussion in Sport Group (CISG) recommends most recent version of SCAT

SCAT<sup>37</sup>

- $\geq 13$  y/o
- 8-12 y/o – use the Child SCAT
- Adapted as new knowledge develops

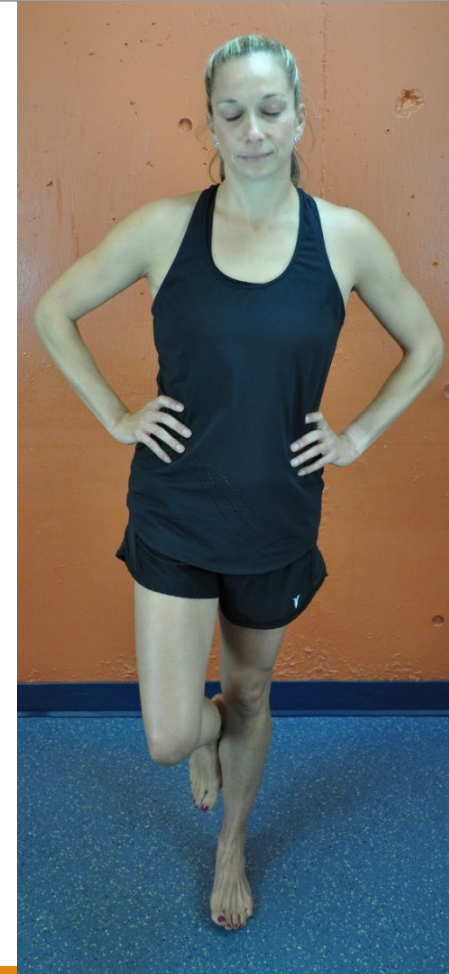
Tandem gait modifications<sup>38</sup>

- No timing in previous versions (SCAT2, SCAT5)
  - “One size does not fit all”
- Timing added back
  - Compare to baseline
  - Dual-task (modified Serial 7 or counting backwards by 3 for Child version)

# Balance Testing

## BESS

- Clinically feasible
- Low reliability<sup>39,40</sup>
  - Interrater – 0.57
  - Intrarater – 0.74
- Low sensitivity – 0.34
- Negatively influenced by:<sup>41-43</sup>
  - Affected by ankle instability
  - Acute fatigue after exertional activities
  - Testing environment

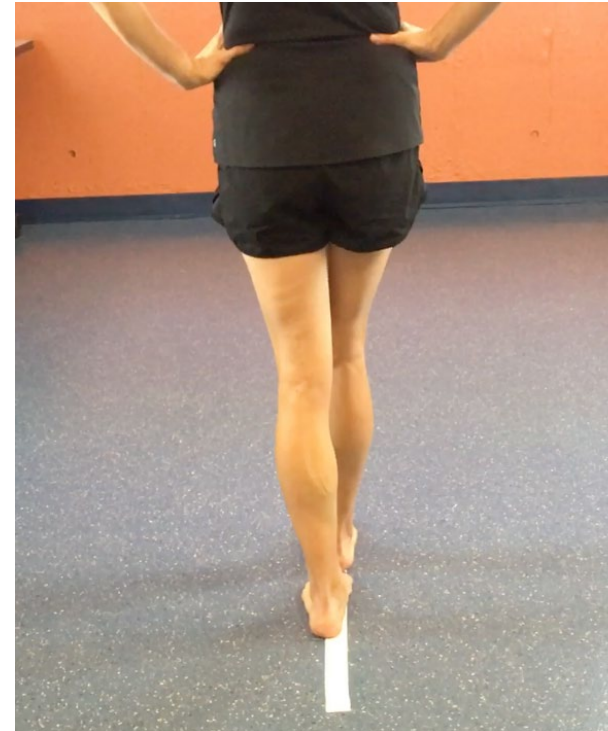


# Gait Testing

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## Tandem Gait<sup>15-17</sup>

- Clinically feasible
- Highly reliable – ICC 0.97
- Evaluates cerebellar activities<sup>44</sup>
  - Dynamic balance
  - Gait speed
  - Coordination



**Note:** If the mBESS yields negative or questionable findings then proceed to the **Tandem Gait/Complex/Dual-Task Tandem Gait**. If the mBESS reveals clinically significant difficulties, **Tandem Gait** is not necessary at this time. The **Tandem Gait, Complex Tandem Gait** and optional **Dual-Task** component may be administered later in the office setting as needed.



# Single-Task vs. Dual-Task Testing

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# Single-Task Balance & Gait Deficits

Increased sway during balance and gait

- Inability to balance
- Inability to stay on the line

Slower tandem gait velocities

All compared to baseline testing





# Dual-Task

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Require dividing attention to multiple stimulus<sup>30,45,46</sup>

- Motor task
- Cognitive task

Sport-specific

Return-to-play

- Decrease risk of further injury

Example

- Tandem gait with reciting the months backwards or Serial 7 (SCAT 6)





# Dual-Task Balance & Gait Deficits

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## Altered motor control

- Focus more on cognitive task
- Disrupted gait patterns (speed, transition from SS to DS, frontal plane sway)<sup>29,47</sup>
- Less suited for high-demand situations → ↑ rate of musculoskeletal injury<sup>48-52</sup>

## Altered cognitive response

- Slower response times

## Detect persistent post-concussion deficits beyond self-reported symptoms resolution<sup>53</sup>

- fMRI demonstrated diminished neural networking efficiency in adolescents<sup>54</sup>

## May yield more accurate index of readiness to RTP than ST<sup>55,56</sup>

- Baseline norms for ST assessment, deficits still present with DT<sup>57,58</sup>



# Population Considerations

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# Age Differences: Adolescents vs. Young Adults

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## Concussed vs. Controls<sup>28,59-61</sup>

- No differences in gait speed for adolescents; YA were slower (48-72 hours)<sup>32,55,62,63</sup>
- Both adolescents & YA had increased medial-lateral sway during a dual-task assessment<sup>31,52,64-69</sup>

## Baseline differences

- Normative values age-based<sup>70,71</sup>
- Longer RTP for adolescents based on symptoms & testing
  - ≤2.5 days to return to baseline for verbal memory, visual memory, & reaction time<sup>71</sup>



# Gender Differences

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## Females

- Females may report more concussion symptoms<sup>72</sup>
- Greater memory impairments<sup>73</sup>
- Require longer duration of time for symptoms resolution<sup>74</sup>
- Cadence & stride length differences during dual-task assessment<sup>75</sup>



## Males


- Report more symptoms with amnesia or confusion<sup>76,77</sup>





# Recommendations for Return to Play Post- Concussion

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# Timing of Return to Physical Activity

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## Testing

- DT vs. ST<sup>53</sup>

## Early return<sup>60</sup>

- Less gait stability, slower velocity

Symptoms may be resolved, but motor control disruptions still exist<sup>28,60,78,79</sup>

- Symptom resolution = RTP criteria<sup>32,80</sup>
- Decreased motor cortex function > recovery time<sup>79,81</sup>



# Clinical Decisions

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## Gait parameter assessment

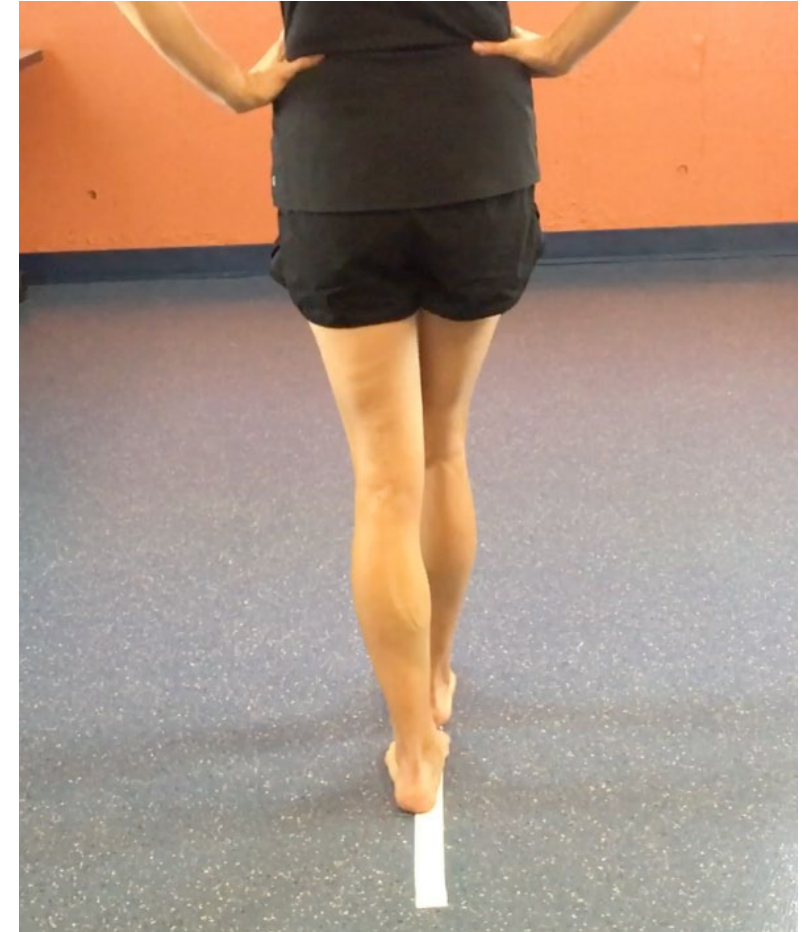
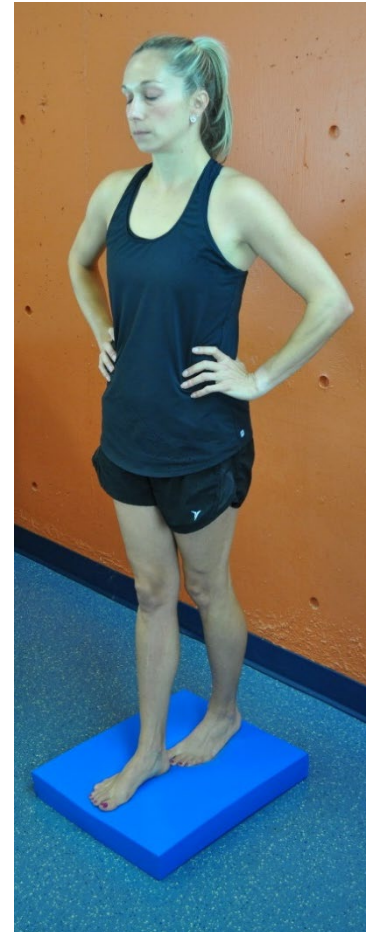
- Pre- & post-concussion
- Dual-task
  - Tandem gait
  - Cognitive task
- Always compare to baseline measurements

# Gait Rehabilitation

Assessment tests now become rehabilitation exercises

## Progression

- Static balance (eyes closed, foam surface) → ST Gait → DT Gait → RTP
- Asymptomatic
- No frontal plane sway
- Return to baseline speed with tandem gait





# Summary

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Clinical Symptoms

Cognitive & Motor Deficits

Subjective Criteria for:

- Assessment
- Population Considerations
- Return to Play Decisions





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# Thank You!

Jaclyn Morrissette, PhD, ATC

[morrissettej1@wpunj.edu](mailto:morrissettej1@wpunj.edu)



# Learning Lab

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- Station 1
  - BESS Testing
    - Hard Surface
    - Foam Pad
- Station 2
  - Tandem Gait Testing
    - Simple Task
    - Serial 7's
- Station 3
  - Dual Task
    - Complex
    - Ball
    - Free