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THE EFFECTS OF FATIGUE ON A DUAL-TASK POSTURAL CONTROL MEASURE

By

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Abstract

CONTEXT: Concussions are a major concern in sport and healthcare professionals are recognizing its profoundness in the impact it has on athletes. There may be limitations in the current approach to assessments among each individual evaluation involved; however, the combination of all three assessments adds to its strength and determining the overall understanding of the concussion and its effects. Any measure of assessment that connects underlying issues arising from concussion to help decrease long-term impairments by returning to play prematurely, risking further injury, is essential. The need for a dual-task assessment delivers an increased sensitivity to the assessment by combining two tasks forcing the individual to divide their attention. It is also important to determine if fatigue is a factor on the ability to complete a dual-task, the same way in which an individual would be asked to do during sport performance while fatigued. OBJECTIVE: The purpose is to evaluate the effect of fatigue on a dual-task postural control measure. DESIGN: Repeated measures. SETTING: Research laboratory. PATIENTS OR OTHER PARTICIPANTS: Sixty healthy, collegiate males and females (30 experimental 21.03±1.92 yrs., 30 control 20.70±1.93 yrs.) performed a dual-task balance test (Quick-Tap Concussion Assessment Protocol [QT-CAP]) at three specific times (baseline(T1), post-fatigue intervention(T2) and post-recovery(T3)). All participants took visual cues from a computer and were asked to respond by reaching with a specific leg to touch in a specific direction. INTERVENTION: Anthropometric measures were taken before all testing and other measures of performance, such as heart rate, rating of perceived exertion and vertical jump, were measured at each time. Testing was completed during one test session. Baseline (T1) testing on the QT-CAP protocol was completed followed by the experimental group participating in the fatigue protocol while the control group rested for ten minutes between T1 and T2. Post-fatigue intervention (T2) followed the fatigue protocol and the ten minute rest period for both groups. Both groups rested for an additional 15 minutes and then completed T3 testing. The fatigue protocol included completion of the PACER test until self-reported, complete exhaustion. MAIN OUTCOME MEASURES: Height, weight and age were used as descriptives to determine any differences between groups. Heart rate, RPE and vertical jump were used to determine level of fatigue within each individual. The QT-CAP protocol measures error scores in each group across three different time points. RESULTS: During T1 and T2, the control group had a significant increase in their QT-CAP scores (T1: 27.60 ±2.90; T2: 29.52 ± 4.29). The experimental group showed no significant increase in their QT-CAP scores (T1: 28.77 ± 2.90; T2: 28.93 ± 3.40), which could be due to the fatigue protocol. The experimental group had the opposite effect from T2-T3 and did show an increase in the QT-CAP scores (T2: 28.93 ±3.40; T3: 30.37 ± 2.06). The control group did not show any significant increase from T2-T3 on the QT-CAP (T2: 29.53 ± 4.29; T3: 29.87 ± 2.26). CONCLUSION: The control group showed an initial increase in their QT-CAP scores, showing a potential learning effect on the dual-task measure and then had less of an increase in their QT-CAP scores during T3. The experimental group showed a decreased learning effect after the fatigue protocol which helps to explain that fatigue does have an effect on the dual-task postural control measure. Following their 15 minute rest, an increase in QT-CAP scores shows the learning effect in the experimental group.

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INTRODUCTION

It is estimated that 1.7 million people sustain a concussion each year (Conn, Amnest, & Gilchrist, 2003; Gessel, Fields, Collins, Dick, & Comstock, 2007; Gilchrist, Thomas, Xu, McGuire, & Coronado, 2011). The rising incidence of concussions in sport and recreation has become a major concern among allied healthcare professionals. Due to the prevalence, severity, and growing cost of medical care for such injuries, this serious problem is of interest to those in the public health field, as well. The problem is larger than the stated epidemiologic data as not all concussions are treated in the emergency room and that as many as 50% of all concussions go unreported, estimates can soar as high as 3.8 million annually in the United States alone (Broglio, Ferrara, Macciocchi, Baumgartner, & Elliott, 2007; Makdissi et al., 2010).

When considering the estimate of concussions that occur annually, coupled with the increased risk of reoccurrence within 10 days post-injury, the risk of pronounced short-term deficits and potential long-term deficits compounds (Cavanaugh, Guskiewicz, & Stergiou, 2005; Guskiewicz, Weaver, Padua, & Garrett, 2000; Makdissi et al., 2010). As the number of concussions increase, especially prior to resolution of metabolic alterations, the potential severity of the injury also increases. Of those who have sustained multiple concussions, it has been suggested that they are at more of a risk for further injury than those who had no history of concussion. Furthermore, the risk for slower recovery was more prevalent in those who had sustained multiple concussions (Cavanaugh et al., 2005; Guskiewicz et al., 2000).

Additionally, these health concerns are not limited to just the more violent, contact sports; making the potential impact more wide spread. Though the number of concussions in sports like hockey and football exceed most other sports, incidence rates in soccer are relatively high and research confirms that female athletes are also at risk for these deficits to occur (Dvorak, McCrory, & Kirkendall, 2007). Due to the participation rate of female versus male soccer, the prevalence may not be as high but the incidence rate is substantially higher in comparable sports.

The other cause for concern that is often highlighted in the media is the unknown effect of concussions throughout the lifespan (Guskiewicz et al., 2005). This concern deals with recurring concussions as well as acute injury severity. Recurrent concussions lead to a heightened risk for mild cognitive impairment (MCI), Alzheimer's disease and memory impairment later in life. Therefore, the need for accurate assessment and management has never been more paramount when high incidence of injury, the likelihood for further injury and improper management of initial injury are all taken into account.

Current assessment methods involve a multifaceted approach including symptom reports, neurocognitive, and balance assessment (McCrory et al., 2009). Though the best practice on implementation of these measures can be debated, baseline testing is often recommended to allow for post-injury value comparison to pre-injury performance. This permits clinicians to assess for underlying conditions that are not easily noted when just assessing signs and symptoms from a concussion post-injury. However, it has been found that when assessing a player's pre-concussion ability at baseline with post-concussion performance in matched control players, the sensitivity of a test may be decreased (Makdissi et al., 2010). When an athlete undergoes baseline testing, his/her pre-concussion ability in baseline testing will be used as a norm when comparing post-injury. These norms should include any concussion related symptoms, postural control and neurocognitive functioning. Later, if injured, this information will provide the clinician with a better understanding of where the athlete should be in terms of symptom resolution, as well as determining return-to-play status.

Individually these assessments have limitations but all three contribute to the overall understanding of the impact of a concussion. According to Broglio et al. (2007), the sensitivity of the assessment battery to concussion must be high to minimize risk of a false-negative finding. Due to the brain's ability to adapt, an athlete may be functioning normally but still have underlying deficits when recovering from an injury. These changes often decrease the sensitivity of assessment methods leaving athletes at risk for returning to play prior to the resolution of the concussion when measures are used individually and farther from the time of injury. If these subtleties are not assessed, the athlete could be at risk for acute re-injury and potentially increased risk of long-term deficits, though these connections have not been fully elucidated in the literature to date.

Symptom reports have become a primary tool in evaluating concussions even though symptoms generally resolve a few days post-injury (Broglio, Sosnoff, & Ferrara, 2009). Some studies have found that in high school and collegiate American football players have demonstrated recovery of symptoms in a majority of concussed athletes within 5 to 10 days of injury (Makdissi et al., 2010). However, since symptoms are self-reported there are many disadvantages to full reliance on symptom reports. For instance, subjectivity of reports can lead to inconsistency and lack of standardization across individuals and the severity of the reports do not always correlate with the length of symptom resolution as injured athletes tend to underreport symptoms (Broglio et al., 2009). Furthermore, there is always the possibility of inaccurate reports due to an athletes' desire to return to play prior to symptom resolution.

The neurocognitive assessment has been deemed the most important element within the concussion-assessment battery providing the greatest amount of information to the clinician during testing (Broglio et al., 2007). Despite this, the sensitivity of the neurocognitive assessment is roughly at 60% when used individually, meaning that the presence of roughly 40% of concussions may be missed and an athlete could return to participation before symptom resolution. Concerns about the sensitivity of the neurocognitive assessment arise in its ability to test over longer periods of time as the symptoms persist. Though athletes are currently being able to focus all of their attention on this cognitive task and not having to put much effort into any other task concurrently, sensitivity decreases from immediate post-injury to the assessment being administered at Day 1 post-injury (Broglio, Macciocchi, & Ferrara, 2007).

Postural stability testing appears to provide a useful tool for objectively assessing the motor domain of neurologic functioning and should be considered a reliable and valid adjunct to the assessment of athletes suffering from concussion. Postural control is necessary to produce the ability to balance. Balance is defined as the process of maintaining the center of gravity within the body's base of support (Guskiewicz, 2011). Balance plays an integral part in maintaining dynamic movements that can also be reciprocated closely in sports. Balance can be seen as one of the most challenging of the three components to assess because it is difficult to quantify subtle deficits.

Sport participation requires a large variety of support in cognitive, sensory, and motor system functions. Balance is an integral part in sport performance and much of these systems combined can have an effect on balance (Makdissi, et.al., 2010). Balance deficits have been shown to be present in 30% of concussions following injury, along with other symptom reports of headache, dizziness etc. (Guskiewicz,

2011) Since balance testing could theoretically be manipulated similarly to symptom reports, consideration must be given to the reliability and sensitivity of a particular measure. In particular, the Balance Error Scoring System (BESS) test, when used at time of injury, has a 34% sensitivity. This test is widely used clinically and in research, due to its inexpensive and practical nature, yet it still has a high error rate (McCrea et al., 2003).

Though, postural control assessments obtained from patients after a concussion revealed deficits in the sensory integration process used for maintaining optimal balance, this decreased sensitivity necessitates a the multifaceted approach of concussion assessment which yields a higher sensitivity (Broglio et al., 2007). When self-reported symptoms, neurocognitive testing, and balance components are all brought together, the sensitivity is above 90%. The more sensitive the test; the better able to detect and the likelihood of the number of athletes returned to play will be lessened. Theoretically though, strengthening the sensitivity of any of these measures should improve the overall sensitivity of the battery. Weakness in current postural control measures gives rise to a need for a better, more comprehensive measure that can detect subtle differences in the coordination of sensory feedback and motor control. To accomplish this, a dual task measure that includes a postural control challenge while completing a cognitive task, forcing the athlete to divide attention on multiple tasks, may bridge the gap between practicality and sensitivity.

Dual-task is currently the closest model that replicates sport performance and the evaluation of multiple systems at the same time (Broglio, Tomporowski, & Ferrara, 2005). Many studies have found that underlying impairments may be missed due to general screening of symptoms and that computerized testing is much more sensitive to detecting impairments and defining return to play decisions. According to Makdissi and colleagues, (2010), there are currently no objective measures of brain function that can definitively indicate return to normal after concussive injury and to determine return-to-play guidelines and decisions. Therefore, signs and symptoms become the key in judging when a player can return to sport. Signs and symptoms alone are not enough to determine normalcy when it is known that metabolic deficits may continue after symptom resolution (Makdissi et al., 2010). Even brief cognitive tests, like the recall test, are simply not enough to determine return to normal brain function. Less sophisticated, inexpensive measures have been used to determine if athletes performed worse on cognitive and motor tasks following a concussion but have been successful in determining the presence of deficits. Typically a mathematical test while performing a static motor task describes what most researchers have used when assessing athletes using the dual-task method (Broglio et al., 2005). However, these components do not replicate how an athlete performs during sport. More functional movement and processing should be integrated into the dual-task assessment to gain proper replicable results. Simple modifications, including the inclusion of a cognitive task, to a quasi-dynamic measure of balance, like the Star Excursion Balance Test, may provide clinicians with such a task.

In addition to postural assessment modifications to a dual task paradigm, confounding factors affecting performance must be considered in situations where baseline comparisons are used. Fatigue is one of those confounding factors that can negatively impact performance and assessment of injury depending on the level of fatigue. Fatigue begins at the neural level, stemming either from central or peripheral mechanisms (Wilkins, McLeod, Perrin, & Gansneder, 2004). Central fatigue, or whole body fatigue, decreases postural stability and individual performance. Individual performance in sport and the effects that fatigue poses on it may have an effect on the vestibulocochlear and somatosensory systems that allow for optimal performance in an athlete. Once a decline is apparent in any one action from these systems, there is a cascade of events that happen within the body during performance. Improper mechanics will begin to surface and the athletes' focus can even be reduced. It is important; however, to remember that everyone is different and some athletes may show signs of fatigue at different stages, while fatigue may not be apparent in others and have no real effect. It is also imperative to understand that once fatigue begins to set in, injuries become more prevalent. By foreseeing these issues, it may become easier to assess injuries or possibly prevent minor injuries from happening. It is not enough to rely on the submission of athletes to report symptoms to warrant quicker return to play. This shows the need for a dual-task push to help identify any deficits and help prevent further serious injury.

In the evaluation process, it must be remembered that there are many factors that affect postural control, including mTBI and fatigue (Fox, Mihalik, Blackburn, Battaglini, & Guskiewicz, 2008). Most of the studies assessing the impact of fatigue on postural control have utilized the BESS though there is still a dearth of information on the topic. Both aerobic and anaerobic exercise protocols have assessed fatigue and scores on the BESS; however, neither type of exercise showed any clear impact on balance performance (Wilkins et al., 2004). Recovery time has also been assessed after fatigue for postural control measures to return to baseline. Research has shown decreased postural stability immediately post-exercise but no deficits as early as 20 minutes post-exercise (Susco, McLeod, Gansneder, & Shultz, 2004). Depending on the exercise protocol, whether it is anaerobic or aerobic, it will elicit different responses to recovery time.

It is indisputable that concussions are a major concern in the healthcare field and practitioners. As such, the proper assessment of concussions is paramount. Current methodology consists of a multifaceted approach that boasts weaknesses when the components are separated. Improving individual components may decrease assessment methods and consequently the risks of injury re-occurrence and long-term deficits. One possible improvement on postural control measures would be the inclusion of a dual-task but prior to testing such a measure with an injured population the practicality of testing after incidence must be explored. If fatigue influences the results of testing post-injury then the reliability of the measure will be compromised.

Statement of Purpose

The purpose of this study is to assess any performance alterations from an aerobic fatigue protocol on a dual-task postural control measure.

Hypotheses

It is hypothesized that postural control will decrease after fatigue protocol but will return to normal, or increase, after 15 minutes of rest.

It is also hypothesized that there will be more deficits shown in the experimental group than the control group in the test immediately administered post-exercise.

Chapter 2

LITERATURE REVIEW

Concussions

The rising incidence of concussions in sport and recreation has become a major concern among allied healthcare professionals. The science of concussion is evolving and therefore management and return to play decisions remain in the realm of clinical judgment on an individual basis. A concussion affects the brain through a complex pathophysiological process (McCrory et al., 2009). This process can be induced by traumatic biomechanical forces. There are several common features that incorporate clinical, pathological and biomechanical injury processes that may be useful in defining the nature of a concussion. The majority of concussions generally resolve in a short seven to ten day period, although the recovery time could be longer in children and adolescents (McCrory et. al., 2009).

A thorough concussion assessment and diagnosis involves a range of domains. The assessment includes clinical symptoms, physical signs, behavior, balance, sleep and cognition (McCrory et al., 2009). It is imperative that a detailed pre-season history is taken so it can be used post-injury, if necessary. Researchers have noted that it is important to recognize the psychological effects and mental health issues a concussion may pose on the body and how to manage them appropriately. It is also imperative that the pre-participation exam be assessed to note any changes that may take place in the body, psychological, physiological or any other form of changes, after concussive injury. The suspect diagnosis of concussion can include one or more of the symptoms described earlier in the concussion assessment. Each of the domains is at risk due to the neurologic dysfunction that arises after the brain responds to the biomechanical force. An energy crisis prevails, therefore making the athlete more vulnerable and less able to adequately respond to a second injury (Giza & Hovda, 2001). It is has been thought that this could lead to longer-lasting deficits. Most mTBI's, or concussions, have led to impairments that include: confusion, unsteadiness, disorientation, dizziness or a headache that usually resolve over time. However; without full symptom resolution, and early return-to-play, these deficits could become a health concern in terms of later-life impairments.

Concussions and traumatic brain injuries (TBI) are becoming a major health concern as the rise in head injuries is coupled with the risk of significant cognitive, emotional and functional disabilities and possible resultant fatalities. It is also likely that TBIs are an identifiable risk factor for the occurrence of neurodegenerative dementing disorders, including Alzheimer's disease (AD) and Parkinson's syndrome (Guskiewicz, Marshall, Bailes, McCrea, Cantu, Randolph, Jordan, 2005). Guskiewicz and colleagues (2005) wanted to study the association between TBI and dementia due to the lack of research in this area. Sport-related concussions and the long-term effects remain generally unclear, but with the vast amount of these injuries occurring and the accessibility of organized sport, it has made it easier for researchers to explore the consequences of concussion and any recurrent injuries associated with them. The study included a wide array of retired professional football players, those who had played professionally before World War II to much more recent retirees. The participants received self-reported questionnaires that included a variety of questions in regard to any musculoskeletal, cardiovascular or neurological conditions he or she may have experienced before or after retirement. The participants were also asked of their concussive history and if he or she had been diagnosed with any medical conditions, such as AD, depression or Parkinson's disease. Included with the questionnaire was also a functional assessment that addressed any activity of daily living issues. A second questionnaire was sent to question memory and any issues related to MCI. Information from both questionnaires was then cross-tabulated. Results were formulated from these questionnaires. Results suggested that having a history of concussion may be a risk factor for memory impairment that may occur later in life (Guskiewicz, Marshall, Bailes, McCrea, Cantu, Randolph, Jordan, 2005). This is relevant to the previous study due to concussions having an effect on cognitive function, as well as decrease the performance in this function; therefore, this may show a decrease in other systems when an athlete is concussed.

McCrory and colleagues (2009) expressed how important balance testing is in concussion evaluation. Postural stability, it appears, provides a useful tool for objectively assessing the motor domain of neurological functioning, and should be considered a reliable and valid addition to the assessment of athletes suffering from concussion, particularly where signs and symptoms indicate a balance component. This includes force plate technology, Sensory Organization Test (SOT), as well as less sophisticated balance tests, such as the Balance Error Scoring System (BESS). Neurologic assessment, genetic testing, and experimental concussion assessment modalities have all been considered insignificant in presenting findings for their assessment of concussion due to lack of research, but are all seen as aids in determining clinical severity of injury and can be added to the concussion evaluation regime, if accessible (McCrory et al., 2009; Guzskiewicz, 2003).

Current assessments like the BESS or the SOT, challenge sensory organization by altering the information that is sent to the various systems involved in maintaining postural control. If tested within the first few days following the initial injury, overall balance deficits and trying to maintain upright posture would be found in the subjects using various combinations of somatosensory, visual and vestibular systems (Guskiewicz, 2011). The integration of these symptoms plays a key role in the assessment of concussion, as well as a major role in balance testing.

Concussions have shown a steady increase between 1987 and 2003, based on the NCAA injury surveillance system. Baseline testing and administration of the assessment battery to help detect concussions has been discussed (Broglio et al, 2007). By recording baseline testing in the pre-season, each athlete can then be compared to post-injury performance. Components of the assessment battery vary among practitioners but many include evaluation of self-reported concussion-related symptoms, postural control and neurocognitive functioning. An athlete may seem recovered, or functioning normally, but could still be at risk for additional injury if returned to play too soon before injury resolution (Broglio et al, 2007).

Broglio and colleagues (2007) administered pre-season baseline concussion assessments to collegiate athletes who were at a high risk for concussion between 1998 and 2005. There was a total of 62 men and 13 women who had all been Division I athletes. The assessment battery included self-reported, concussion-related symptoms, an assessment of postural control and a neurocognitive assessment. Included in the self-reported symptoms was a nine-item concussion-related symptom inventory and each defined the severity and/or duration of headache, nausea, balance problems, fatigue, trouble falling asleep, drowsiness etc. and each item had its own rank. Included in the study were current assessments used in assessment batteries. The NeuroCom Sensory Organization Test (SOT) postural control assessment, as well as HeadMinder and ImPACT were used to display cognitive effects (Broglio et al, 2007). To evaluate sensitivity, all symptoms, balance and neurocognitive data were reviewed. The results showed that football accounted for 58 of the diagnosed injuries, followed by women's soccer, men's basketball etc. The tests with the highest sensitivity included the ImPACT and HeadMinder CRI tests when combined with cognitive test performance and symptom reports. Followed closely in sensitivity was the postural control evaluation test battery that showed a 61.9% sensitivity when determining concussions on the ImPACT and HeadMinder CRI tests (Broglio et al., 2007). Giza and Hovda (2001), also discussed that the athlete may be over-compensating from other areas in the brain, yet still not have full resolution at the actual site of the concussion. This is also why it is important to fully assess the injury using the proper assessments (Giza and Hovda, 2001). Sensitivity of assessments declines as the number of tests coupled together decreases. If a practitioner uses a postural control, or balance, assessment along with a neurocognitive assessment, the sensitivity will be higher than if they were to just use a balance or self-reported symptoms assessment.

Postural Control

Postural control is necessary to produce the ability to balance and balance plays an integral part in maintaining dynamic movements that are produced in sports (Guskiewicz, 2011). This ability is automatic, conscious activation is not required, but it is also task specific. Postural control can be accomplished through acquisition of afferent information from somatosensory, visual and vestibular sources (Lephart, Giraldo, Borsa, & Fu, 1996; Lephart, Pincivero, Giraldo, & Fu, 1997). Afferent pathways are formed by neurons leading to the central nervous system from sensory receptors. The central nervous system integrates and processes information for the selection and coordination of appropriate motor responses. The postural control mechanism is then completed through execution of motor commands by the musculoskeletal system. The afferent, sensory information received through the somatosensory, visual and vestibular sources is critical to the postural control mechanism. Visual information and vestibular information are analyzed by the central nervous system. Afferent information supplied to the postural control system collectively comes from visual, vestibular and somatosensory inputs. Somatosensory provides information concerning the orientation of body parts to one another and to the support surface (Flores, 1992) . Vision plays an important role in maintaining balance as it measures the orientation of eyes and head in relation to surrounding objects (Nashner, Jacobson, Newman, & Kartush, 1993). Vestibular inputs supply information that measures gravitational, linear and angular accelerations of the head in relation to inertial space. It does not, however, provide orientation information in relation to external objects and therefore only plays a minor role in the maintenance of balance when the visual and somatosensory systems are providing accurate information.

The central nervous system (CNS) plays two roles in its involvement in maintaining upright posture. Sensory organization is the first role of the CNS and involves those processes that determine the timing, direction and amplitude of corrective postural actions based upon afferent information (Nashner, 1982). Muscle coordination, the second role of the CNS, describes generation and execution of corrective motor responses. The central nervous system generally relies on only one sense at a time for orientation information, and impairment or alteration of one of the sensory inputs can usually be compensated for by the remaining two.

Most healthy people rely on somatosensory input for maintaining postural equilibrium under most conditions. Somatosensation, in relation to balance, refers to proprioception, kinesthesia and postural balance (Horak, F., 1987). This helps individuals identify where they are in space, recognizing contact through different sensations and maintaining upright posture. Proprioceptors are defined best as a specialized variation of the sensory modality of touch that encompasses the sensation of joint movement (kinesthesia) and joint position (joint position sense). Somatosensation is divided into tactile sense and proprioceptive sense. Tactile sense involves detection of sensations of touch, pressure, vibration and tickle. Proprioceptors detect senses of position, velocity and tension, which determine the relative positions and movement rates of the different body parts. Proprioceptors can be subdivided into slow adapting and fast adapting functional groups. Possessing both types of receptors is essential for the postural control system to operate during static, dynamic and functional activities (Horak, 1987). The overall purpose of the somatosensory system is to provide the postural control system with information concerning the orientation of body segments relative to one another, as well as to the support surface. Each somatosensory organ is triggered by a unique stimulus and thus has a particular role in postural equilibrium (Flores, 1992; Nashner et al., 1993).

Postural control traditionally has been characterized according to a biomechanical framework as postural stability, that is, the ability to maintain a desired postural orientation, either at rest or during movement, in response to perturbations (a disturbance in motion) generated from either internal or external sources (Cavanaugh, Guskiewicz, Guiliani, et al., 2005). Cavanaugh and colleagues (2005) have defined that postural stability specifically refers to the ability to resist perturbations such that the whole body center of mass is maintained within the limits of the base of support. It has been suggested that postural steadiness, or a person's ability to stand as motionless as possible in the absence of external perturbation, has returned to baseline levels within 3-5 days post-concussion (Cavanaugh, Guskiewicz, Guiliani, et al., 2005).

Multiple tests have been used to assess deficits in concussed individuals, yet the most appropriate assessments are not easily accessible to researchers or medical personnel when an injury first occurs. The Sensory Organization Test (SOT) is used as the gold standard in postural stability testing (Riemann & Guskiewicz, 2000). The SOT is the most sensitive test, meaning it picks up the highest amount of injuries, yet it is the most expensive test and not readily available to most researchers. The Balance Error Scoring System (BESS) was developed to be used on the sideline to measure an athlete's balance after a suspected mild TBI. Numerous extraneous factors may influence the results of the BESS that is taken during practice or competition and not at rest. The BESS has a poor sensitivity and misses most concussions or disruptions in postural stability, yet is the least expensive postural stability assessment and can be readily accessible to medical personnel.

Research has suggested looking into the valuableness of pre-season baseline testing and how valid these tests can be when making return to play decisions for athletes. Guskiewicz and colleagues (2001) examined the effects of neuropsychological and postural stability measures after sport-related concussion. Preseason baseline testing has posed many questions for medical personnel on its valuableness in helping to make return to play decisions; however, baseline testing is used as a norm to reference when injuries take place and is a good indicator of where an athletes' baseline levels were if an injury takes place. Postural stability testing has been a very important component that allows clinicians to obtain an objective measure of mild TBI. Postural stability testing has been shown to be the weakest, least sensitive, component when returning a player to competition so researchers feel this is where the need should be placed first (Guskiewicz, Ross, & Marshal, 2001).

Fox and colleagues chose to look at the effects of fatigue on the BESS after aerobic and anaerobic fatigue protocol (Fox et al., 2008). Postural control had been measured through the BESS, sway velocity (SV) and elliptical sway area (ESA). The findings showed that both anaerobic and aerobic exercise protocols adversely affected the postural control measure through each of the three measures. This single task measure of postural control still showed that postural control is adversely affected when introducing a fatigue protocol; therefore, introducing a dual-task measure could influence the effects at a greater rate.

Guskiewicz and colleagues (2001) wanted to determine the effect of concussion on postural stability and neurocognitive function in athletes, which in turn could provide a more comprehensive approach for obtaining objective information with which clinicians can assess sport-related concussion (Guskiewicz et al., 2001). Results have shown that neuropsychological and postural stability testing is becoming more of the standard when managing sport-related concussion. However, it is still being debated on the sequential order that best suits testing procedures. The researchers found most importantly that athletes recovering from cerebral concussion demonstrated postural stability deficits most likely linked to a sensory integration problem during the immediate post-injury period. The two days following injury seemed to be most problematic for concussed athletes as they began to recover and reach preseason postural stability baseline scores around day 3 (Guskiewicz et al., 2001). This deficit could be explained by a sensory interaction problem that prevents concussed athletes from accurately using and exchanging sensory information from the visual, vestibular and somatosensory systems. This leads to the need for a dual-task measure, such as integrating both the neuropsychological and postural stability testing, to divert attention away from the integration of the three systems that help maintain postural stability. By placing emphasis on two or more systems, the concussed athlete would have a more difficult time compensating and the deficits will be more clearly defined.

Dual-Task Testing

Dual-task testing is a newer phenomenon that introduces the idea of completing multiple tasks at the same time to assess for cognitive deficits. This idea is becoming more prevalent as researchers are beginning to see greater sensitivity in dual-task measures than their single-task counterparts. The study on the effects of concussions on gait stability by Catena and colleagues (2006), examined how those effects would alter gait stability when a cognitive or motor condition was introduced. Researchers have found that when an individual sustains their first concussion, a number of deficits in mental deterioration begin to rise. As the number of concussions sustained began to rise, so did the impact on the cognitive and motor functions and could lead to more permanent damage (Catena et al, 2006). This could lead to deficits in strength, balance, concentration or memory which are all used in activities of daily living. The subjects included twenty-eight young adults from the University of Oregon and were divided into two groups: 14 who suffered from concussion and 14 who were controls without injury. The subjects performed walking along an 8m runway that contained an eight-camera motion system. Then an obstacle-crossing test was performed where PVC pipe served as the obstacle. Finally, a dual-task situation was performed while the subjects were walking through the obstacle course and asked to answer cognitive questions from the researchers. Results showed that, conceptually and experimentally, question and answer and obstacle crossing (dual-task) are both more difficult than single-task walking. The Q&A resulted in slower velocities during walking showing that they developed a much slower, or conservative, gait to maintain stability. Attention tests show more deficits in the gait/balance that would have an effect on the concussed population (Catena et al, 2006). These results compare to the past research highlighted by Martini and colleagues (2011), stating that concussed persons adopt a conservative gait strategy to maintain stability and possibly decrease their risk for further injury from falling. In addition, gait studies have shown an advancement in postconcussion motor control when evaluated, posing altered gait patterns in those acutely concussed (Martini, Sabin, DePasa, Leal, NeGrete, Sosnoff and Broglio, 2011; Catena et al, 2006).

Martini and colleagues (2011) further discussed that during the acute stages of injury, any effects of concussion on both cognitive and motor function may persist in the years to come well beyond the injury, yet it had not been researched as to determining if gait would be affected in the years following a concussive injury (De Beaumont et al, 2009). In the study done by Martini and colleagues (2011), the participants were asked to perform a gait task simultaneously with a cognitive task, the gait differences became more apparent in those who were already concussed (Martini et al., 2011). It is important to note that the researchers also found that as the number of previous injuries increased, results showed decreased time in single-leg stance support and an increased time in double-leg stance support in all of the testing conditions. By introducing the dual-task measure to help further investigate the affects that two simultaneous tasks would have on a concussed individual, these findings supported the relationship between number of concussion and long-term cognitive dysfunction.

Continuing to look at the future of research by incorporating a dual-task measure to help closely mimic participation in sport, which combines the cognitive, sensory and motor systems tasks; this becomes the closest measure to assessing sport performance. Typically, dual-task evaluations involve less sophisticated testing measures to assess those who are concussed, yet still showed results in declining performance on cognitive and motor tasks immediately following a concussive injury (Broglio et al., 2005). Broglio and colleagues (2005) examined a deeper approach by replacing the less sophisticated field tests of walking on a balance beam while having the athlete count backwards with a more sophisticated measure in the Neurocom Smart Balance Master. Twenty male and female subjects were recruited to complete a series of four conditions to stress the somatosensory, vestibular and visual systems. Subjects also completed a cognitive measure that involved cognitive flexibility, attention and information-processing speed during a task-switching evaluation. Subjects did not go through a series of eye-closed conditions because that was in the visual requirements of the cognitive task, which later proved to be a major limitation on the study due to the involvement of eyesight during balance tests. The study found postural control improvements in the subjects who participated in the study when the balance and cognitive tasks were performed simultaneously, showing that the dual-task measure does, in fact, elicit changes in cognitive and balance function. These findings also suggest that under dual-task conditions, the balance component takes priority, and as balance continued to vary, the cognitive aspect become more impaired.

It is important to find measures that better predict, assess, care for and manage the increasing rate of concussions. The less sophisticated measures are used frequently, yet the sensitivity is so low that most concussions go unnoticed and the players return to play too soon without full symptom resolution (Resch, May, Tomporowski, & Ferrara, 2011). Resch and colleagues (2011) wanted to delve deeper into the previous study on dual-task assessment by Broglio and colleagues (2005). It was found in their study that under dual-task conditions, as balance conditions increase, cognitive function decreases. The use of this dual-task measure was thought by the researchers to prove to be a useful measure in assessing sport-related concussions. Twenty healthy, college-aged students were recruited to participate in study. The researchers chose visual and nonvisual conditions that replicated the study done by Broglio et al (2005), yet extended that work to elicit changes in the results. The balance assessment included 6 conditions at 60 seconds for each trial. This is extended from the previous study that included four conditions at 20 seconds long. The cognitive task was an auditory switch test that involved 40 computer-generated letter and number combinations. The subjects first performed single-task measures, balance and cognitive tasks performed separately, and then a dual-task measure with balance and cognitive tasks completed simultaneously. The results confirmed the results from the study done by Broglio et al (2005) and took those results one step further. The results indicated that balance would be maintained at the expense of cognitive function. Resch and colleagues (2011) explained that integration of sensory information that is provided by the visual, vestibular and somatosensory systems provides controlled balance under normal conditions. These findings show that during dual-task conditions, the cerebral processing modifies the central nervous system that helps to maintain postural stability. When trying to detect any cognitive changes in healthy individuals, the findings help to suggest that by measuring cognitive processes through a computer-based test with the addition of a balance test, these changes may be better detected (Resch, May, Tomporowski and Ferrara, 2011; Broglio, Tomporowski, and Ferrara, 2005). Here it shows that the ability to balance and cognitive decline are linked; therefore, helping us to define where the changes in cognition lie when another task, such as balance, is introduced and the individual has to divide their attention.

Fatigue

Fatigue is a reduction of maximal force or power that occurs with exercise (Taylor, Butler, & Gandevia, 2000). Changes can be seen at multiple levels with a loss of force that has been shown within the muscle, as well as within the central nervous system. Postural stability has been shown to decrease following isolated muscle fatigue, as well as whole-body fatigue. Whole-body fatigue is also known as central fatigue and affects the central nervous system output to the muscles. Wilkins and colleagues (2004) wanted to test the acute effects of a central fatigue protocol on performance of the BESS (Wilkins, Valovich McLeod, Perrin and Gansneder, 2004). There were twenty-seven male Division I college athletes recruited to go through two tests in one testing session. Participants were measured in nine conditions that consisted of double-leg stance, single-leg stance and tandem stances on firm, foam and tremor box surfaces. A control group and experimental group were designed to test the differences between the fatigue protocol and any differences noted during the BESS testing. The fatigue protocol was a circuit design that consisted of seven stations each made to test the participants cardiovascularly and to reach a certain score of fatigue noted on the ratings of perceived exertion scale. This fatigue test was chosen to replicate the fatigue that athletes would experience throughout the course of a practice or game. Subjects went through a pretest and posttest, with the fatigue protocol in between to elicit any changes within the two tests.

Wilkins et al (2004) found that the fatigue group had a higher score in errors on the posttest than the pretest, as well as a significant increase of errors in the fatigue group from the control group. In using both central and local means of fatigue, it has been found in previous studies that there is a decrease in postural stability following fatigue. The researchers feel that by using the RPE scale that the subjects reached a level of fatigue that would represent them working at 80% of maximal heart rate and that this amount of fatigue helped to elicit the changes in postural stability during the balance testing. The researchers also found that the tandem stance was too easy for the participants to elicit many errors during testing. However, the single-leg stance was notably hard for both groups with the possibility that fatigue would not play a factor regardless of the groups. Fatigue protocols that elicit central fatigue cause a decrease in the measures of postural stability and these findings have been identified through many investigations (Wilkins et al., 2004). Balance depends on the central nervous system and the integration of the three sensory systems (vestibular, visual and somatosensory), any alterations in the central nervous systems ability due to fatigue, whether it is central or local fatigue, will likely affect one's ability to maintain balance.

Athletes are usually not at rest when they sustain a concussion. Typically, an athlete is involved in some type of sporting event and engaged in physical activity. The athlete will also be under some type of physical stress, if he or she is not already fatigued, when a concussion is sustained (Susco, Valovich, McLeod, Gansneder and Schultz, 2004). It has not been clearly defined yet as to how much time is needed to recover from exertion and regain postural control measures that are consistent with baseline measures. However, the effect of exertion on a postural-stability measure is evident. When the BESS has been used for past research, scores have been indicative of increasing after exertion in a healthy population. Therefore, the BESS cannot be accurately used to assess balance after sustaining a concussion unless a timeline for recovery is set in place following exertion (Susco et al., 2004).

Susco and colleagues (2004) wanted to establish a balance recovery timeline after college-aged individuals went through a functional exertion protocol. One hundred college students who engaged in physical activity at least four times a week for 30 minutes participated in this study. The testing consisted of a balance test using the BESS with a 20 minute fatigue protocol intervention for the experimental group and a 20 minute rest period for the control group. The fatigue protocol consisted of seven stations designed to fatigue the participant to the point of adequate exertion with the athlete displaying their ratings on the ratings of perceived exertion (RPE) scale. The researchers found that exertion adversely affected balance. Balance recovery, or return to pretest score, occurred within 20 minutes after exercise had stopped. Susco and colleagues (2004) also found that during the double-leg stance condition, there was no effect from exertion, yet the greatest effect came from the more challenging stances. These results were also found in previous studies, confirming that the BESS is an appropriate clinical measure of balance. Results from this study also show that there is a decrease in scores immediately testing post-injury with the possibility of false-positive findings. It is inherently important to wait to administer the testing, as in any sporting event a player would be kept out of play at least 15 to 20 minutes to make a return-to-play decision, and then perform the evaluation towards the end of this time period to elicit a score that would be less likely to be influenced by exertion and more representative of the athlete's post-concussion postural-stability status (Susco, Valovich, McLeod, Gansneder, Schultz, 2004).

Most research has looked at exertion, whether aerobic or anaerobic, and its effects on scores on the BESS. The effects of fatigue related to aerobic versus anaerobic fatigue protocols was also studied by Fox and colleagues (2008). Both aerobic and anaerobic exercise protocols adversely affect postural control, which has been measured using the BESS system. However, any immediate effects of an anaerobic exercise protocol on postural control have yet to be established (Fox et al, 2008). Fox and colleagues (2008) not only wanted to evaluate the effects of fatigue on postural control after healthy, college-aged varsity athletes after aerobic and anaerobic protocols, but also wanted to establish recovery time from each exercise protocol and how long it takes for athletes to return to baseline status, as well as decreasing the effects of fatigue on postural control. The results showed that there was an adverse effect in both aerobic and anaerobic exercise protocols on postural control, measured through the BESS, SV and ESA. It is also important to note, especially for athletic trainers and clinicians, that regardless of the exercise protocol, effects of fatigue appear to persist up to eight minutes post-exercise. It was also found that postural control returned to baseline measures between 8 and 13 minutes after exercise. Postural control was affected by both aerobic and anaerobic fatigue protocols, scores were measured by the BESS, as well at force plate measures of SV and ESA. Postural control returned to baseline after the effect of fatigue diminished after 13 minutes. These findings help clinicians to gauge a better return-to-play decision after an athlete has sustained a concussion and will aid in understanding the effects that the aerobic and anaerobic measures, that help to mimic game-time situations, have on postural control post-injury (Fox, Mihalik, Blackburn, Battaglini and Guskiewicz, 2008).

Conclusion

It is clear that with the rising incidence in concussions, and the limited affect that single-task measures have on detecting postural control disruptions, that a need for a dual-task measure is increasingly important. Fatigue decreases a persons' ability to focus during sport performance and could lead to injury during sport participation. Assessment on the sideline is critical to determining return-to-play status for the athlete. By incorporating a dual-task measure to test a persons' ability to think and balance at the same time using a method that is easily accessible to personnel conducting the assessment, and also while the athlete is fatigued, may detect the subtle differences in a concussed individual not shown on other forms of concussion assessment.

Chapter 3

METHODS

Participants

A total of 60 participants, between the ages of 18-25, were recruited from a collegiate, general student population at a public university in Central Kentucky. Both males and females were recruited after completing the Health History/Criteria for Inclusion Questionnaire (Appendix C) that asked participants regarding any previous injuries to their lower extremities within the last 3 months, any major surgeries to their lower extremities within the last year or if there was any reason that they should not be able to participate in physical activity. Participants were also asked if they had any bone or joint abnormalities, were on any medication to control blood pressure or for a heart condition and had not been released by a doctor to participate in physical activity or were on any medication that would affect their balance. They were also asked if they were pregnant, or had any chance of being pregnant, as well as if they were a smoker. If the participant had answered yes to any of these questions, the researcher was to discern if the participant would be included in the testing. The participants were also asked to read and sign the Informed Consent document (Appendix D). Participants were randomly assigned to either the control or experimental groups based on inclusion criteria and their consent to participate.

Study Design

Participants were randomly assigned to four different groups. The experimental group contained 15 male and 15 female participants. The control also had 15 males and 15 females. All participants underwent similar baseline testing, involving anthropometric measures (height, weight, and age), report of activity level with the Modified Tegner Activity Scale (Appendix E) and Activity Level Scale (Appendix F). Resting heart rate was recorded, as well as the participants rating of perceived exertion (RPE) (Appendix G) and an initial vertical jump test. Following these procedures, the participants completed the baseline (T1) Quick Tap Concussion Assessment Protocol (QT-CAP). All information was recorded on the data sheets provided (Appendix H). Following this testing, the experimental group underwent a fatigue protocol, whereas the control group rested during the time in which the fatigue protocol is administered. Immediately following the fatigue protocol, the baseline measures will again be repeated in the same order and then completion of the post-fatigue intervention (T2) of the QT-CAP protocol. Both groups rested for 15 minutes following T2, followed by completion of the baseline measures and the post-recovery (T3) QT-CAP protocol. Based on previous research, it has been shown that the effects of fatigue may persist up to 13 minutes after testing and before postural control returned to baseline (Fox et al., 2008). For this study, participants repeated the measures after the fatigue protocol and then again 15 minutes after the completion of the fatigue protocol to monitor changes in performance following recovery. The control group followed the same timeline of events, but did not participate in the fatigue protocol.

Research Procedures

Completion of this project involved the use of several established measures of physical performance, a fatigue protocol and a unique modification to the Star Excursion Balance Test to measure balance performance.

Initially, the participants underwent anthropometric measures, as well as baseline testing that included the recording of heart rate, rating of perceived exertion and vertical jump measures. Second, if the participants were in the experimental group, they were fatigued with the PACER test and asked to participate in the test until they reached full fatigue. The QT-CAP protocol was used as the dual-task measure to assess postural control performance.

The vertical jump test was used to test the levels of the participants' fatigue. Researchers used the Vertec Vertical Jump Training Measurement System (Vertec Jump Stand, Gill Athletics, Champaign, IL) to record data. The researchers took the standing height of the subject with one arm fully extended upward. The subject was instructed to jump off of two feet from a standing position directly underneath the device and touch the highest possible vane on the device. The jump height is the difference between standing height and jumping height. Participants were asked to repeat this test three times during each testing measure. If the participant failed to jump off of two feet or used a one-step approach, the measure was not recorded. The data was recorded at baseline (T1) and then again post-fatigue intervention (T2) following the fatigue protocol and then at post-recovery (T3) after 15 minutes of rest. The reliability and validity of the Vertec Jump Stand is r = 0.88- 0.93, and was established through multiple test-retest trials (Caruso et al., 2010)

A heart rate monitor consists of two parts: a transmitter attached to a belt worn around the chest, and a receiver worn on the wrist like a watch. The device that was used is the Polar S810 heart rate monitor (2001 Polar Electro Oy, FIN-90440 KEMPELE, Finland). The participant was asked to wear the transmitter around their chest and the receiver on their wrist. The data was recorded in the same way as the vertical jump. No other instructions were needed for this protocol. The Polar S810 provided high correlations (.85-.99) (Nunan, Donovan, Jakovljevic, Hodges, Sandercock & Brodie, 2009). Heart rate provides a linear increase with exercise intensity.

The OMNI scale (Robertson, 2004) was used as an indicator of fatigue by assessing the participants' rating of perceived exertion. The scale ranges from one to ten and the participants were given instructions on how to assess their feelings of fatigue and were then asked to point to the number that best corresponds with their level of fatigue. This was measured at T1 and again at T2 and T3. Each level on the scale had an associated descriptor to aid the participant in making the correct choice on their level of fatigue. Vertical jump, heart rate and RPE were used to assess if the participants reached a full level of fatigue following the fatigue protocol. Reliability and validity of the OMNI scale is r = 0.95 and 0.91 for intraclass and single-trial tests, respectively (Pfeiffer, Pivarnik, Womack, Reeves, & Malina, 2002).

The PACER test was administered following standardized procedures. Participants run from one marker to another marker set 20 meters apart and were asked to keep pace with a prerecorded cadence. The cadence is set on a standardized application and increased after each level. Participants were asked to keep up with this cadence for as long as possible. When the participant had reached their full state of fatigue and failed to meet the marker in the time allotted between beeps, the test was terminated. The participants' level, or number of laps completed, and time were recorded. Previous research has deemed the average time to complete the PACER test to be 9 and 8 minutes for males and females, respectively (one minute equals one stage) (Ruiz, Silva, N. Oliveira, Ribeiro, J. Oliveira & Mota, 2009). For those in the control group, the participants were asked to rest for ten minutes during the time allotted for the PACER test. The reliability and validity of the PACER test is r = 0.75 when used in a cross-validation sample.

The Quick-Tap Concussion Assessment Protocol is designed to function as a dual-task (cognitive and motor), clinical test for concussion assessment. This measure combines elements of the Star Excursion Balance Test along with a cognitive task in an easily scored measure. The Star Excursion Balance Test is used primarily for lower extremity injuries. The Quick Tap Concussion Assessment Protocol (QTs-CAP) will contain the following items to administer the test: Computer w/ Microsoft PowerPoint, QTs-CAP Protocol PowerPoint Presentations, QTs-CAP floor design (Figure B-1)[1], measuring tape, tape and QTs-CAP data record sheet. The participant started by standing two feet together on the center tile with his/her hands on hips. The participant was instructed to respond to a number and background color on the computer screen that indicated which foot should be used to reach and what number should be touched. Each reach was to be followed by a brief touch on the appropriate tile that did not transfer any weight to the reach leg. The stance leg was to remain stationary in order to correctly complete the trial as well as hands on hips stance. After the indicated reach, the participant was to return to the starting position (two feet on the starting tile) in anticipation for the next direction. If a participant was unable to return to the starting position prior to the next reach it was not counted as a correct reach. Prior to test measurement, participants were given time to practice until they felt comfortable in completing the task. Participants were barefoot when completing this test. The QT-CAP protocol is a unique measure and does not have any reliability or validity measures established.

Statistical Analysis

Demographic data, independent variable, and dependent variables were initially recorded in Excel (Microsoft Corporation, Redmond, WA) and then analyzed using SPSS Statistics 19 (SPSS, Inc., Chicago, IL). Differences in the dependent variables (QT-CAP scores, vertical jump, RPE, and HR) that were elicited by the intervention were analyzed using a 2x2 (group x time) repeated measures ANOVA. This analysis included three separate 2x2 repeated measures ANOVAs to analyze differences from T1 to T2, T2 to T3 and T1 to T3. One-way ANOVA analyses were used as indicated to examine group differences at

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[1] See Appendix B for all Figures

each time point and paired sample t-tests were utilized to examine changes within groups across time. An alpha of $p<0.05$ was considered statistically significant for all comparisons.

Chapter 4

MANUSCRIPT

Introduction

The rising incidence of concussions in sport has become a major concern among allied healthcare professionals. The number of incidences occurring is roughly around 3.6 to 3.8 million annually; however, only half of those are reported cases (Broglio et al., 2007; Makdissi et al., 2010). It is important that the assessment and management of concussions are accurate to lessen the severity of possible long-term deficits that may occur due to repeat injury, insufficient recovery and improper management (Guskiewicz et al., 2005). Current concussion assessment methods involve a multi-faceted approach that includes symptom reports, neurocognitive evaluation and balance assessment (McCrory et al., 2009). Individually, each assessment may have limitations, but all three in combination contribute to the overall understanding of the impact of a concussion and increase the sensitivity of the assessment. In lieu of the potential consequences of undetected concussions and the challenges facing that assessment, a measure that increases the sensitivity of the battery; therefore, decreasing the risk of false-negative findings in which athletes with concussions are returned to participation pre-emptively, and is capable of capturing subtle differences is essential. To accomplish this, a dynamic dual-task measure that includes a postural control challenge while completing a cognitive task, forcing the athlete to divide attention on multiple tasks, may bridge the gap between practicality and sensitivity. In developing these instruments it is essential to determine the effect of fatigue on the measurement as fatigue is a confounding factor that can negatively impact performance on balance performance measures (Fox et al., 2008; Wilkins et al., 2004).

Methods

Participants

A total of 60 participants, between the ages of 18-25, were recruited from a collegiate, general student population at a public university in Central Kentucky. Both males and females were recruited after completing the Health History/Criteria for Inclusion Questionnaire. If the participant had answered yes to any of these questions, the researcher was to discern if the participant would be included in the testing. The participants were also asked to read and sign the Informed Consent document. Participants were randomly assigned to either the control or experimental groups based on inclusion criteria and their consent to participate.

Study Design

Both males and females were placed equally among experimental and control groups. Males and females were combined due to similarities in height, weight and age. All participants underwent similar baseline testing, involving anthropometric measures (height, weight, and age), report of activity level with the Modified Tegner Activity Scale and Activity Level Scale. Resting heart rate was recorded, as well as the participants' rating of perceived exertion (RPE) and an initial vertical jump test. Following these procedures, the participants completed the baseline (T1) Quick Tap Concussion Assessment Protocol (QT-CAP). Following this testing, the experimental group underwent a fatigue protocol, whereas the control group rested during the time in which the fatigue protocol is administered. Immediately following the fatigue protocol, the baseline measures will again be repeated in the same order and then completion of the post-fatigue intervention (T2) of the QT-CAP protocol. Both groups rested for 15 minutes following T2, followed by completion of the baseline measures and the post-recovery (T3) QT-CAP protocol. Participants repeated the measures after the fatigue protocol (T2). The effects of fatigue have shown to persist up to 13 minutes after testing; therefore, the participants will complete the measures again 15 minutes after the completion of the fatigue protocol (T3) to monitor changes in performance following recovery (Fox et al., 2008). The control group followed the same timeline of events, but did not participate in the fatigue protocol.

Research Procedures

Completion of this project involved the use of several established measures of physical performance, a fatigue protocol and a unique modification to the Star Excursion Balance Test to measure balance performance.

Initially, the participants underwent anthropometric measures and baseline testing. Second, if the participants were in the experimental group, they were fatigued with the PACER test and asked to participate in the test until they reached full fatigue. The QT-CAP protocol was used as the dual-task measure to assess postural control performance. Following fatigue, T2 and T3 were completed according to the study design.

The vertical jump test was used to test the levels of the participants' fatigue. Researchers used the Vertec Vertical Jump Training Measurement System (Vertec Jump Stand, Gill Athletics, Champaign, IL). The researchers took the standing height of the subject with one arm fully extended upward. The subject was instructed to jump off of two feet from a standing position directly underneath the device and touch the highest possible vane on the device. Participants were asked to repeat this test three times during each testing measure. If the participant failed to jump off of two feet, or used a one-step approach, the measure was not recorded. The data was recorded at baseline (T1), post-fatigue intervention (T2) following the fatigue protocol and post-recovery (T3) after 15 minutes of rest. The reliability and validity of the Vertec Jump Stand is r = 0.88- 0.93, and was established through multiple test-retest trials (Caruso et al., 2010).

A heart rate monitor consists of two parts: a transmitter attached to a belt worn around the chest, and a receiver worn on the wrist like a watch. The device that was used is the Polar S810 heart rate monitor (2001 Polar Electro Oy, FIN-90440 KEMPELE, Finland). The participant was asked to wear the transmitter around their chest and the receiver on their wrist. The data was recorded in the same way as the vertical jump. No other instructions were needed for this protocol. The Polar S810 provided high correlations (.85-.99) (Nunan, Donovan, Jakovljevic, Hodges, Sandercock & Brodie, 2009). Heart rate provides a linear increase with exercise intensity.

The OMNI scale (Robertson, 2004) was used as an indicator of fatigue by assessing the participants' rating of perceived exertion. The scale ranges from one to ten with each level having its own descriptor to aid the participant in assessing their feelings of fatigue, each participant was given instructions and then asked to point to the number that best corresponds with their level of fatigue. This was measured at T1 and again at T2 and T3. Reliability and validity of the OMNI scale is r = 0.95 and 0.91 for intraclass and single-trial tests, respectively (Pfeiffer et al., 2002). Vertical jump, heart rate and RPE were used to assess if the participants reached a full level of fatigue following the fatigue protocol.

The PACER test was administered following standardized procedures. Participants run from one marker to another marker set 20 meters apart and were asked to keep pace with a prerecorded cadence. The cadence is set on a standardized application and increased after each level. Participants were asked to keep up with this cadence for as long as possible. When the participant had reached their full state of fatigue and failed to meet the time allotted between beeps or missed two consecutive beeps, the test was terminated. The participants' level, or number of laps completed, and time were recorded. Previous research has deemed the average time to complete the PACER test to be 9 and 8 minutes for males and females, respectively (one minute equals one stage) (Ruiz, Silva, N. Oliveira, Ribeiro, J. Oliveira & Mota, 2009). For those in the control group, the participants were asked to rest for ten minutes during the time allotted for the PACER test. The reliability and validity of the PACER test is r = 0.75 when used in a cross-validation sample.

The Quick-Tap Concussion Assessment Protocol is designed to function as a dual-task (cognitive and motor), clinical test for concussion assessment. This measure combines elements of the Star Excursion Balance Test along with a cognitive task in an easily scored measure. The Star Excursion Balance Test is used primarily for lower extremity injuries. The Quick Tap Concussion Assessment Protocol (QTs-CAP) will contain the following items to administer the test: Computer w/ Microsoft PowerPoint, QTs-CAP Protocol PowerPoint Presentations, QTs-CAP floor design, measuring tape, tape and QTs-CAP data record sheet. The participant started by standing two feet together on the center tile with his/her hands on hips. The participant was instructed to respond to a number and background color on the computer screen that indicated which foot should be used to reach and what number should be touched. Each reach was to be followed by a brief touch on the appropriate tile that did not transfer any weight to the reach leg. The stance leg was to remain stationary in order to correctly complete the trial as well as hands on hips stance. After the indicated reach, the participant was to return to the starting position (two feet on the starting tile) in anticipation for the next direction. If a participant was unable to return to the starting position prior to the next reach it was not counted as a correct reach. Prior to test measurement, participants were given time to practice until they felt comfortable in completing the task. Participants were barefoot when completing this test. The QT-CAP protocol is a unique measure and does not have any reliability or validity measures established.

Statistical Analysis

Demographic data, independent variable, and dependent variables were initially recorded in Excel (Microsoft Corporation, Redmond, WA) and then analyzed using SPSS Statistics 19 (SPSS, Inc., Chicago, IL). Differences in the dependent variables (QT-CAP scores, vertical jump, RPE, and HR) that were elicited by the intervention were analyzed using a 2x2 (group x time) repeated measures ANOVA. This analysis included three separate 2x2 repeated measures ANOVAs to analyze differences from T1 to T2, T2 to T3 and T1 to T3. One-way ANOVA analyses were used as indicated to examine group differences at each time point and paired sample t-tests were utilized to examine changes within groups across time. An alpha of $p<0.05$ was considered statistically significant for all comparisons.

Results

Initial analyses of group differences analyzed the differences between males and females in each of the groups and same gender between groups. There were no significant group differences in age ($F_{3,56}$= 0.46, p= 0.71). Males and females were significantly different in height ($F_{3,56}$= 19.49, p= 0.00) (Table A-1)[2]. Significant difference was shown between males and females in weight ($F_{3,56}$= 8.47, p=0.00). Baseline differences on the QT-CAP protocol were the same between all four groups; there was no significant difference ($F_{3,56}$=1.51, p=.22). The height and weight were not significantly different between experimental males and control males or experimental females and control females; therefore, for further analyses we combined males and females into just an experimental and control group.

Quick Tap-Concussion Assessment Protocol

Separate 2x2 repeated measures analyses of variance (time x group) were used to determine differences between baseline testing (T1), post-fatigue intervention (T2) and post-recovery (T3). There was a significant time main effect between T1 and T2 ($F_{1,28}$= 10.43, p<0.01) and a significant time by group

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[2] See Appendix A for all Tables

interaction ($F_{1,28}$=7.38, p=0.01) (Table A-2). There was also a significant time main effect between T2 and T3 ($F_{1,28}$= 5.41, p =0.02), however, there was no significant time by group interaction ($F_{1,28}$= 2.1, p= 0.15). Post-hoc analyses revealed no significant differences between groups at any of the times points: T1 ($F_{1,58}$=1.82, p=0.18), T2 ($F_{1,58}$=0.36, p=0.55) and T3 ($F_{1,58}$=0.80, p=0.37). Post-hoc analyses of QT-CAP score changes with each group across time revealed significant difference in QT-CAP among the control group between baseline (T1) and post-fatigue intervention (T2) (t= -4.05, p=0.00). The experimental group did not show significance in score between T1 and T2 (t= -0.38, p=0.71). The second pair of variables indicated a significance in score in the experimental group betweenT2 and T3 (t= -2.87, p=0.01); however, the control group did not show any significance in score during this time point (t= -.58, p=0.57).

Exertion Protocols

The following variables were used to determine if the individuals were fatigued. Heart rate, RPE and vertical jump showed similar trends and had significant differences between groups from baseline testing (T1), post-fatigue intervention (T2) and post-recovery (T3). During T1- T2, heart rate and RPE showed a significant time main effect (p =0.00), as well as a significant group by time interaction (p= 0.00). During the paired t-test that was run for T1-T2, there was an increase in RPE for both control and experimental group (p= 0.00); however, for heart rate, the experimental group had an increase (p=0.00), while the control group did not (p=0.48) (Table A-3). During T2- T3, a significant time main effect was shown for both RPE (p=0.00) and heart rate (p=0.00). A significant time by group interaction was also present for both RPE (p=0.00) and heart rate (p=0.00) during T2-T3. Post hoc analyses reveal significant group differences from T2-T3 for both RPE (p=0.00) and heart rate (p= 0.00) in the experimental group, while the control group had no significant differences for RPE (p=0.26) and heart rate (p=0.98). Analysis of T1-T3 for RPE and heart rate showed a significant time main effect (p= 0.00), as well as a significant group by time interaction (p= 0.00). Post hoc analyses revealed a significant difference in the experimental and control groups for RPE (p= 0.00). The experimental group during T1-T3 showed a significant difference in heart rate (p= 0.00); however, the controls did not show a significant difference (p= 0.61).

A one-way analysis of variance was run for rating of perceived exertion and heart rate at each time point to determine differences between groups. For rating of perceived exertion ($F_{3,56}$=0.36, p= 0.78) and heart rate ($F_{3,56}$= 1.71, p=0.18) during T1 there were no significant differences between groups (Table A-4). During rating of perceived exertion and heart rate during T2, a significant difference was revealed between groups (RPE: $F_{3,56}$=198.15, p=0.00; Heart Rate: $F_{3,56}$=359.68, p=0.00). There was no significant difference for rating of perceived exertion during T3 ($F_{3,56}$= 2.43, p= 0.07). A significant difference was revealed for heart rate during T3 between groups ($F_{3,56}$= 11.49, p= 0.00).

A Tukey's post hoc analysis was run to determine where the differences lie between each group. When comparing experimental males and females, analysis revealed no significant difference for T1 for RPE (p=0.75) and heart rate (p=0.53), as well as control males (RPE:p= 0.96; HR:p=0.50) and control females (RPE:p= 0.88; HR:p=0.13). Tukey's post-hoc analysis revealed a significant difference between experimental males from control males on RPE and heart rate (p= 0.00, p=0.00, respectively) during T2 and control females (p= 0.00) but no significant difference between experimental females for RPE and heart rate (p= 0.74, p=0.10, respectively). Tukey's post hoc analysis also revealed a significant difference between groups for heart rate during T3. There was a significant difference between experimental males and control males (p =0.00) and control females ($p<0.01$). There was no significant difference between experimental males and experimental females for heart rate at T3 (p= 0.10). Post hoc analyses for RPE during T3 revealed no significant difference between experimental males and experimental females (p=0.86), as well as no significant difference between control males (p=0.07) or control females (p=0.31).

The vertical jump was also used to determine the level of fatigue within the individuals; however, it showed different trends than the heart rate and RPE. Initial analysis during T1-T2 showed no significant time main effect ($F_{1,28}$=3.81, p=0.06) and no significant group by time interaction ($F_{1,28}$= .70, p=0.41) (Table A-5). Therefore, a post hoc analysis was not run for T1-T2. A significant time main effect was revealed from T2-T3 ($F_{1,28}$= 6.21,p=0.02); however there was no significant group by time interaction ($F_{1,28}$=2.01,p=0.16) between T2 and T3 for vertical jump. During T1-T3, there was no significant time main effect ($F_{1,28}$=1.52, p=0.22), as well as no significant group by time interaction ($F_{1,28}$=0.73, p=0.40). Further analysis was not needed for this T1 –T3 time point. Post hoc analyses revealed a significant difference in the score in the experimental group from T2-T3 (t=-2.40, p=0.02); however, there was no significant difference in vertical jump in the control group from T2-T3 (t=-.93, p=0.36).

Discussion

The findings of this study support that fatigue has an effect on a dual-task postural control measure. The control group had an increase in QT-CAP scores from baseline to post-fatigue intervention. Due to this increase in the QT-CAP scores for the control group, it reveals a learning effect. This learning affect could be attributed to balance protocols, in general. A caution to this research is in the learning effect of the QT-CAP protocol. We know based on previous research that there is a learning effect with balance protocols, notably serial balance testing as with the Balance Error Scoring System (BESS) (Wilkins et al., 2004). A decrease in error scores found on the BESS after serial testing was attributed to a learning effect. It was also noted in this study, that one of the stances in the BESS protocol was susceptible to practice effects after repeat administration of the BESS and performance improved after previous exposure to the balance task. This proved to be true in both of our groups, although the experimental group had a diminished learning effect initially. This learning effect could be combatted with adequate practice time before administering the QT-CAP. By allowing for more practice time, the increase that we see in the control group from T1-T2, or in the experimental group from T2-T3, would be reduced or diminished, resulting in the direction the QT-CAP results should follow. Athletes could also be tested using this protocol in a study that involves a time frame with longer transition time that incorporates a large number of days in between each administration of the testing protocol, avoiding a shorter repeat administration timeframe, to aid in reducing the learning effect.

Fatigue protocol did have an effect on the dual-task measure based on the experimental group not showing a significant increase in QT-CAP scores. Overall, the experimental group increased but not until after 15 minutes of rest. According to Fox and colleagues, effects of fatigue were shown to exist for up to 13 minutes post-fatigue before postural control returned to baseline (Fox et al., 2008). In sport, athletes may be fatigued due to the exertion of their sport. The PACER test is short in duration, and may or may not produce changes in the QT-CAP. However, testing athletes following sport participation may prove to reduce the error scores in the individual if their sport provides an adequate amount of fatigue, opposite from our results from the PACER test in this study. The PACER test has averages of completion at 9 minutes and 8 minutes for males and females, respectively. However, these results may only produce aerobic fatigue and not enough to elicit changes in the QT-CAP scores overtime. Changes in postural stability after fatigue may result from a combination of central and localized means (Wilkins et al., 2004). We did not reach these changes in postural stability due to our fatigue protocol.

Conceptually and experimentally, dual-task test are more difficult than single-task walking (Catena, van Donkelaar, & Chou, 2007). Dual-task testing has become the closest measure to assess sport performance even with regard to the less sophisticated dual-task measures. Cognitive and motor tasks have immediately declined following concussive injury (Broglio et al., 2005). Also, when subjects first completed single-task measures, balance and cognitive tasks were performed separately, and then a dual-task measure, changes were better detected in the dual-task measure (Resch et al., 2011). Even though the QT-CAP protocol detected small changes in postural stability, it still could be better able to detect changes in postural stability than its single-task counterparts. The QT-CAP measure used in this study is more of a practical method of balance testing, and is inexpensive. One of its downfalls; however, is in being inexpensive, it is less able to detect subtle changes as computer testing could, like the sensory organization test (SOT). Future testing using the QT-CAP measure needs to still obtain its practicality, while implementing changes in increasing its sensitivity in detecting subtle changes in postural stability.

Conclusion

These results indicate that fatigue may have influenced performance on a dual-task postural control measure immediately after fatigue (T2) but not after rest (T3). Both groups improved across all three time points, however, the magnitude of change was dampened in the experimental group from T1-T2 and then accelerated from T2-T3 with opposite results in the control group. These improvements may be attributed to learning, even though both groups had ample practice time and instruction before baseline (T1) testing. These results are consistent with single-task postural control measures (Susco et al., 2004). Though this study does not examine the effectiveness of the QT-CAP in relation to concussion assessment, it does indicate that assessment of concussions on the sideline within a minimum of 15 minutes of maximum exertion exercise is not warranted using this measure. Future testing should examine the utility of the QT-CAP in concussion assessment with a protocol allowing ample rest (at least 15 minutes) prior to testing after injury. Future investigations should also look at guidelines to minimize the effect of learning on QT-CAP performance.

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APPENDIX A:

Tables

Table A-1. One-Way ANOVA Descriptives.

	Male	Female	Total
Experimental	15	15	30
Control Male	15	15	30
Total	30	30	60

Table A-2. General Linear Model: 2x2 ANOVA
Tests of Between-Subjects Effects
Baseline (T1) Post Fatigue Intervention (T2) Post-Recovery (T3)

	Df	F	Sig
T1-2 Exp_Control	1	4293.947	**.000**
T2-3 Exp_Control	1	6911.773	**.000**

Table A-3. T-Test: Paired Means.

Groups	T1- Baseline	T2- Post-Fatigue Intervention	T3- Post-Recovery
Experimental N=30	28.77 ± 2.897	28.93 ± 3.393	30.37 ± 2.059
Control N= 30	27.60 ± 3.756	29.53 ± 4.289	29.87 ± 2.255

Table A-4. T-Test: Paired Samples Test.
Baseline (T1) Post-Fatigue Intervention (T2) Post-Recovery (T3)

Group Name	T	Df	Sig (2-tailed)
1-Pair 1 (T1 and 2)	-.377	29	.709
Pair 2 (T1 and 2)	-2.87	29	**.008**
2-Pair 1 (T2 and 3)	-4.054	29	**.000**
Pair 2 (T2 and 3)	-.583	29	.565

Table A-5. T-Test: Paired Samples Test
Baseline (T1) Post-Fatigue Intervention (T2) Post-Recovery (T3)
Differences Within Groups at each time point.

Group Name	T	Df	Sig (2-tailed)
1- Pair 1 (T1-T2)	-30.73	29	**0.00**
Pair 2 (T2-T3)	19.90	29	**0.00**
Pair 3 (T1-T3)	-5.44	29	**0.00**
2- Pair 1 (T1-T2)	-6.19	29	**0.00**
Pair 2 (T2-T3)	1.15	29	0.26
Pair 3 (T1-T3)	-4.04	29	**0.00**

APPENDIX B:

Figures

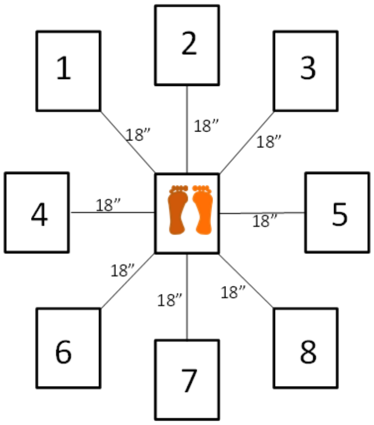

Figure B-1. QT-CAP Floor Design.

APPENDIX C

Health History/Criteria for Inclusion Questionnaire

Effects of Fatigue on a Dual-Task Postural Control Measure

ID #:_____ **DATE**: _______________

Inclusion/Exclusion Criteria

The following questions will help determine if you meet the criteria for inclusion into the study. Since the study is interested in examining your ability to balance it is important that you accurately answer each question.

Please answer the following questions with a yes or no response.	**YES**	**NO**
1. Do you have any serious symptomatic ankle, knee, hip, or lower back trauma requiring medical attention within the last 3 months?		
2. Do you have any bone or joint abnormalities (ie. arthritis)?		
3. Have you had surgery on your hip, knee, and/or ankle in the last year?		
4. Is your doctor currently prescribing drugs to control your blood pressure or a heart condition and has not released you to full/unrestricted physical activity?		
5. Do you know of any reason why you should not do physical activity?		
6. Are you currently taking medication for any of the following: vertigo, headaches, migraines, cold symptoms, or inner ear infection?		
7. Have you participated in any physical activity within the last 24 hours above and beyond activities of daily living?		
8. Are you, or is there any possibility of you being, pregnant?		
9. Do you smoke?		

Past Concussion History

- Have you sustained any previous concussion? Yes No

If you answered yes, please answer the following questions.

- How many reported/unreported concussions have you received?

  ____

- How long ago was the last concussion sustained?

  ____

Have you had any recurring symptoms since your last concussion? Yes No

- If so, what were those symptoms?

  ____

APPENDIX D:

Informed Consent

Consent to Participate in a Research Study

The Effects of Fatigue on a Dual-task Postural Control Measure

Why am I being asked to participate in this research?

You are being invited to take part in a research study that involves studying the effects of fatigue on a dual-task postural control measure. You are being invited to participate in this research study because you are part of a larger healthy population that will help us to determine if any greater effects will be elicited on a less healthy population. If you take part in this study, you will be one of about 100 people to do so. We are looking into this study to determine if fatigue will have any effects on a person's ability to balance while simultaneously completing a cognitive task. The dual-task measure allows us to test subjects closely relating to sport performance. If fatigue does have an effect on an individuals' ability to complete the dual-task, it will allow us to link this to sport performance and testing a concussed population.

Who is doing the study?

The person in charge of this study is Allisha Guzdial, a graduate student at Eastern Kentucky University. She is being guided in this research by her faculty advisor, Dr. Matthew Sabin.

What is the purpose of the study?

By doing this study, we hope to learn if any effects will be elicited from an aerobic fatigue protocol on a dual-task postural control measure.

Where is the study going to take place and how long will it last?

The research procedures will be conducted at Moberly Building, Eastern Kentucky University. You will be asked to come only one time during the study. This visit should take about one hour. The total amount of time you will be asked to volunteer for this study is one day for one hour. Beyond one session there is no further testing.

What will I be asked to do?

When you arrive, you will be asked to fill out a health history questionnaire and inclusion criteria form. This will allow the researchers to determine if you meet the criteria to be included in this study. You will then be assigned to a specific study identification number which is randomly assigned to either the experimental group or control group. You will be unable to complete the testing if you have participated in physical activity within 24 hours prior to the baseline test. Baseline measures will be taken that include: resting heart rate, height and weight. The start of the testing procedures include: vertical jump, rate of perceived exertion (RPE) and the Quick Tap Concussion Assessment Protocol (QT-CAP). Following these measures, the experimental group will be asked to complete the fatigue protocol, the PACER test. If you are a part of this group, you will be asked to complete the fatigue protocol until you have reached a full level of fatigue and are not able to run any longer. If you have been placed in the control group, you will be asked to rest for an allotted time equivalent to the time needed to complete the PACER test. Following the intervention, you will be asked to repeat the testing twice with a 15 minute rest in-between.

The specific protocols of each individual method are listed below.

Vertical Jump. This is a test of muscular power in which you will be asked to jump as high as possible off of two feet as you can. You will take a one-step approach, jump off of two feet and try to reach markers on a stand as high as possible. You will complete three trials of this at each testing period.

Rating of Perceived Exertion. This is a scale ranging from 1-10 that reflects your feeling of exertion. You will be asked at various points throughout the testing to indicate how hard you feel you are working.

Heart Rate. Heart rate will also be assessed sporadically throughout the testing using a wireless device that transmits from a chest strap to a watch. You will have the chest strap on and the watch will be held by the researcher for recording purposes.

Quick Tap Concussion Assessment Protocol. For this test, you will be asked to stand on a mat that has a center location marked with numbers 1-8 arranged around the center. You will be asked to go from a two footed stance position to a one-leg reach. The leg you reach with and the direction of the reach will be in response to what is seen on a computer screen that is directly in front of you. The screen will have either a blue or a green background with a white number in the center. The color corresponds to a particular leg you should reach with and the number to the direction of the reach. You will be given ample time to practice as needed prior to actual data collection.

PACER Test. The fatigue protocol will consist of moving between two cones that are separated by 20 meters. You will start the test at a slower pace and will have to move to the second marker before a pre-recorded cadence beeps. Upon reaching the next marker, you will turn around wait for the next beep and then move back to the previous marker before the cadence sounds again. You will continue back and forth in time to the cadence. After several laps, you will be notified that you have reached the next level where the cadence will increase. This test will continue until you are unable to keep up with the cadence and you fail to make the marker in time during two consecutive laps.

Are there reasons why I should not take part in this study?

You may be excluded from this if you do not meet the inclusion criteria. The researchers will discern if you do not qualify. You may find it difficult to partake in this study if you are a smoker, or may be pregnant, due to the extent of the fatigue protocol. All other predetermined factors will be taken into account that may exclude you from this study.

What are the possible risks and discomforts?

To the best of our knowledge, the things you will be doing have no more risk of harm than you would experience during vigorous physical activity.

You must be aware that by participating in the experimental group, you may experience muscle soreness that can persist for up to a few days following the testing.

This is a natural process for the body and should feel like any other muscle soreness you may experience when participating in physical activity.

You may, however, experience a previously unknown risk or side effect.

Will I benefit from taking part in this study?

You will not get any personal benefit from taking part in this study other than a contribution to science and a knowledge of your capabilities on all performance measures.

Do I have to take part in this study?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering.

If I don't take part in this study, are there other choices?

If you do not want to be in the study, there are no other choices except to not take part in the study.

What will it cost me to participate?

There are no costs associated with taking part in this study.

Will I receive any payment or rewards for taking part in the study?

You will not receive any payment or reward for taking part in this study.

Who will see the information I give?

Your information will be combined with information from other people taking part in the study. When we write up the study to share it with other researchers, we will write about this combined information. You will not be identified in these written materials.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from the information you give, and these two things will be stored in different places under lock and key.

Can my taking part in the study end early?

If you decide to take part in the study, you still have the right to decide at any time that you no longer want to participate. You will not be treated differently if you decide to stop taking part in the study.

The individuals conducting the study may need to end your participation in the study. They may do this if you are not able to follow the directions they give you or if they find that your being in the study is more risk than benefit to you.

What happens if I get hurt or sick during the study?

The demands of this test are not greater than you would experience during vigorous physical activity. However, if you believe you are hurt or if you get sick because of something that is done during the study, you should inform the researcher immediately. Proper care will be administered following the standard of care for first aid. It is possible that following testing, you will experience soreness from the increased exertion. You will be given instructions on how to handle this soreness after testing and you can call Allisha Guzdial at (989) 295-7246 as needed if you are no longer at the testing facility.

It is important for you to understand that Eastern Kentucky University will not pay for the cost of any care or treatment that might be necessary because you get hurt or sick while taking part in this study. That cost will be your responsibility. Also, Eastern Kentucky University will not pay for any wages you may lose if you are harmed by this study. Usually, medical costs that result from research-related harm cannot be included as regular medical costs. Therefore, the costs related to your child's care and treatment because of something that is done during the study will be your responsibility. You should ask your insurer if you have any questions about your insurer's willingness to pay under these circumstances.

What if I have questions?

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact the investigator, Allisha Guzdial at (989) 295-7246. If you have any questions about your rights as a research volunteer, contact the staff in the Division of Sponsored Programs at Eastern Kentucky University at 859-622-3636. We will give you a copy of this consent form to take with you.

What else do I need to know?

You will be told if any new information is learned which may affect your condition or influence your willingness to continue taking part in this study.

I have thoroughly read this document, understand its contents, have been given an opportunity to have my questions answered, and agree to participate in this research project.

Signature of person agreeing to take part in the study   Date

Printed name of person taking part in the study

Name of person providing information to subject

APPENDIX E:

Tegner Activity Level Scale

TEGNER ACTIVITY LEVEL SCALE

Please indicate in the spaces below the HIGHEST level of physical activity you are able to participate in <u>CURRENTLY</u>.

CURRENT: Level___________

Level 10	Competitive sports- soccer, football, rugby (national elite)
Level 9	Competitive sports- soccer, football, rugby (lower divisions), ice hockey, wrestling, gymnastics, basketball
Level 8	Competitive sports- racquetball or bandy, squash or badminton, track and field athletics (jumping, etc.), down-hill skiing
Level 7	Competitive sports- tennis, running, motorcars speedway, handball Recreational sports- soccer, football, rugby, bandy, ice hockey, basketball, squash, racquetball, running
Level 6	Recreational sports- tennis and badminton, handball, racquetball, down-hill skiing, jogging at least 5 times per week
Level 5	Work- heavy labor (construction, etc.) Competitive sports- cycling, cross-country skiing Recreational sports- jogging on uneven ground at least twice weekly
Level 4	Work- moderately heavy labor (e.g. truck driving, etc.)
Level 3	Work- light labor (nursing, etc.)
Level 2	Work- light labor Walking on uneven ground possible, but impossible to back pack or hike
Level 1	Work- sedentary (secretarial, etc.)
Level 0	Sick leave or disability pension because of knee problems

APPENDIX F:

Activity Level Scale

Effects of Fatigue on a Dual-Task Postural Control Measure

ID: __________ **Date**: ____________

ACTIVITY LEVEL SCALES

Please indicate (by circling) below in each of the categories, the type of physical activity you engage in, competitive, recreational or a mix of both and at what level of intensity you engage in. Also, indicate the number of days per week and at how many minutes per day you participate in physical activity.

Type	Intensity	Number of Days/Week	Minutes/Day
Competitive	High	7	3 hours+
		6	
	High-Med		2-3 hours
		5	
Recreational			
		4	1-2 hours
	Medium		
		3	30 min-1 hr
Mixed		2	
	Light		
		1	< 30 min.
None			
	None	0	0 minutes

Specific Number of Minutes per Day on Average = ______________________

APPENDIX G:

OMNI RPE Scale

Rating of Perceived Exertion Scale	
10	Maximum Effort
9	Extremely Hard
8	Very Hard
7	Hard
6	Somewhat Hard
5	
4	Moderate
3	
2	Light
1	Very Light
0	Very, Very Light

APPENDIX H:

Data Collection Form

Effects of Fatigue on a Dual-Task Postural Control Measure

ID #:_____ Height: ___________ Weight: _____________ Date: _________

Age: ___________ DOB: _____ Time: ______________

Test 1:

Vertical Jump _________ _________ _________

Heart Rate ______________

RPE ______________

Experimental Group:

PACER protocol time: ______________

Level: ________________

Control Group:

Rest Start: ___________

Rest Stop: ___________

QT-CAP

Protocol A (* mark correct touches with a √ [check] and incorrect touches with a – [dash])

L5	R2	R7	R3	R6	R4	L8	L7

R8	L3	R5	L4	R1	L6	L1	L2

R4	L3	R1	L7	L1	R6	L5	L8

R2	R7	L4	R3	L2	R5	L6	R8

Total Correct in 1st set: ____________ / 16

Total Correct in 2nd set: ____________ / 16

Test 2:

Fifteen Minute Rest Start Time: ______

Vertical Jump ______ ______ ______

Heart Rate ______________

RPE ______________

QT-CAP

Protocol A (* mark correct touches with a √ [check] and incorrect touches with a – [dash])

L5	**R2**	**R7**	**R3**	**R6**	**R4**	**L8**	**L7**

R8	**L3**	**R5**	**L4**	**R1**	**L6**	**L1**	**L2**

R4	**L3**	**R1**	**L7**	**L1**	**R6**	**L5**	**L8**

R2	**R7**	**L4**	**R3**	**L2**	**R5**	**L6**	**R8**

Total Correct in 1st set: ____________ / 16

Total Correct in 2nd set: ___________ / 16

Test 3:

Vertical Jump ______ ______ _______

Heart Rate _____________

RPE _____________

QT-CAP

Protocol A (* mark correct touches with a √ [check] and incorrect touches with a – [dash])

L5	**R2**	**R7**	**R3**	**R6**	**R4**	**L8**	**L7**

R8	**L3**	**R5**	**L4**	**R1**	**L6**	**L1**	**L2**

R4	**L3**	**R1**	**L7**	**L1**	**R6**	**L5**	**L8**

R2	**R7**	**L4**	**R3**	**L2**	**R5**	**L6**	**R8**

Total Correct in 1st set: ____________ / 16

Total Correct in 2nd set: ___________ / 16