Summer 2011

Effects Of Fatigue On The Balance Error Scoring System For Concussion Testing In Healthy And Previous Concussed Participants

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EFFECT OF FATIGUE ON THE BALANCE ERROR SCORING

SYSTEM FOR CONCUSSION TESTING IN HEALTHY

AND PREVIOUS CONCUSSED PARTICIPANTS

A Thesis Presented to the Graduate Faculty

of Fort Hays State University in

Partial Fulfillment of the Requirements for

the Degree of Master of Science

by

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Abstract

There has been a recent increase in the attention of concussions in the media and research world. One of the major factors that contribute to injuries including concussion is fatigue. This study has been designed to allow athletic trainers to decipher whether a potential balance insufficiency in an acutely concussed athlete is due to fatigue or the side affects of the concussion on postural stability. The study examined 30 college-aged athletes from a multitude of sports who had either sustained a concussion or never had a concussion. Participants were randomly grouped into one of three groups: non-concussed control group, non-concussed treatment group, or a concussed treatment group. The participants completed a pretest of the Balance Error Scoring System (BESS) followed three days later by a fatigue protocol for those in the treatment groups and finished by completing a posttest BESS. The fatigue protocol is a seven station circuit program that has been utilized in past research studies using the Rating of Perceived Exertion (RPE) scale to measure fatigue. The results showed no significant difference in BESS scores from the pretest to posttest in any of the sample groups. There was a significant difference (*p=.000)* in RPE scores between the two treatment groups and the control group. These results indicate there was significant fatigue induced for the BESS posttest in the treatment groups. However, fatigue did not appear to influence the BESS test for either non-concussed or concussed participants.

Acknowledgements

I would like to thank several individuals for their support in making it possible for this thesis to be completed. I would like to give a tremendous thank you to Dr. David Fitzhugh, thesis advisor, for putting a lot of time and effort into helping me succeed through this project and hopefully the future publishing of this research paper. I would also like to give thanks to my thesis committee Dr. Helen Miles, Dr. Jeff Burnett, Dr. Michael Madden and Dr. John Zody for their support and guidance.

My mother, Joyce, father, Phil, and sister Erika also are worthy of a large amount of gratitude for helping me through this project along with the rest of my amazing family friends. A big thank you to Dustin Bradstreet and the rest of the FHSU Athletic Training staff and students for aiding in the recruitment and testing of participants. The participants who volunteered their time are also immensely appreciated.

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Introduction

Due to several high profile athletes from the professional to high school ranks being held out of activity, concussions have gained a lot more attention recently (Domowitch, 2007). In high school football, injury rates show head, neck, or spine related injuries make up approximately 13% of all the injuries that occur (Valovich, Perrin, & Gansneder, 2003). Additionally, an average of 1.6 to 1.8 million mild traumatic brain injuries or concussions occur in people participating in interscholastic athletics (Langlois, Rutland-Brown, & Wald, 2006). Since concussions have such a large occurrence in sports, it is vital that athletic trainers be prepared with the best concussion assessment tools. Athletic trainers have used the Balance Error Scoring System (BESS) researched by Dr. Kevin Guskiewicz and fellow researchers at the University of North Carolina Sports Medicine Research Laboratory for conducting part of the initial objective concussion evaluation and for subsequent follow up evaluations to determine a return to play decision (Reimann, & Guskiewicz, 2000; Valovich, Barr, McCrea, & Guskiewicz, 2006).

Because of the nature of the intensity of athletic participation, all athletes will experience fatigue during their team's activities potentially increasing the probability of concussion occurrence. Wilkins, Valovich, McLeod, Perrin, & Gansneder (2004) found the BESS is affected by whole body fatigue, which would certainly affect the validity of the test during any athletic event or practice for athletes. Several researchers have examined this concept such as when Crowell, Guskiewicz, Prentice, and Onate (2001) had participants go through several different physical activities like squat jumps and treadmill sprints showing fatigue decreases postural stability. Even though fatigue has been shown to affect postural stability and balance, Susco, Valovich, Gansneder, and Shultz (2004) found postural stability does start to return to normal baseline as soon as 20 minutes after physical activity in healthy participants.

Problem Statement

The purpose for this study is to investigate the efficacy of the Balance Error Scoring System when fatigue is present in NCAA Division II athletes for the purposes of concussion testing.

Sub-problems

The following sub problems will be investigated as part of the main problem statement:

1. Effects of concussion on BESS pretest scores as compared to non concussed control groups
2. Fatigue effects on the scores of the BESS in Division II athletes without previous concussions.
3. Fatigue effects on the scores of the BESS in Division II athletes with previous concussions.

Definitions

Concussion. "Characterized by immediate, but transient posttraumatic impairment of brain function" (Starkey, Brown & Ryan, 2010, p. 886).

Dominant leg and foot preference. Determined by which leg the participant would choose to kick a ball for the purposes of the BESS test stances (Starkey et al, 2010).

Double leg stance. Characterized by placing both feet together flat on the ground (*Balance Error Scoring System (BESS) Owners Manual)*.

Fatigue. Measured on the Borg 20 point scale of the Rating of Perceived Exertion (RPE) as an increase in the numerical value at the end of the athletic activity from the pre activity value and must be at least a score of 15 (Borg, 1998).

Single leg stance. The participant stands on the non-dominant leg, with the dominant leg's hip flexed to 20-30° and knee flexed to 40-50° (Starkey et al., 2010).

Tandem stance. Characterized by placing the dominant foot in front of the non-dominant leg, with the heel of the dominant foot touching the toes of the non-dominant foot (Prentice, 2006).

Assumptions

It is assumed the participants will give an honest RPE score so fatigue can be objectively measured. It will be assumed participants will give maximum effort during the fatigue protocol. The test administrators are assumed to be competent in the administration and interpretation of the BESS test.

Limitations

The intensity of the fatigue protocol will be a limitation of this study, as the participants will be participating in the fatigue protocol in order to attain a level of fatigue of at least "high" or a rating of 15 on the Borg RPE scale. The athletes overall fitness level will be a limitation since athletes are assumed to have a higher level of fitness as compared to the average non athletic individual. The population will be limited to National Collegiate Athletic Association (NCAA) Division II athletes at a midwest university. Participants have their own sense of balance and proprioception, which is considered "normal" for each individual person.

Delimitations

The BESS testing will be carried out in a controlled setting where external stimuli such as noises, other people or numerous other distractions can be significantly reduced or eliminated to control the environmental surroundings of the testing. Participants will not be given any trial periods for the different stances. The different stances will be explained and demonstrated, but participants will not be allowed to practice them due to possibly establishing a testing effect, which would be confounding to the results of this study. The Borg RPE scale is also a delimitation due to its wide range of validity scores in exercise studies. Concussion severity will not be a selection factor for concussed participants.

Hypothesis

The first null hypothesis is there will be no significant difference in pretest BESS scores between the concussion, non-concussion and the control groups. The second null hypothesis is there will be no significant differences in the posttest BESS scores of the non-concussion group and control group. The third null hypothesis is the concussion group and the control group will not have any significant difference between their post treatment BESS scores. The hypothesis will be tested with a level of significance at $p < 0.05$.

Significance of Study

In concussion evaluations there are several influences such as fatigue, practice effects, environmental distractions, other injuries especially involving the lower extremity and head, and ankle stability, which can have an effect on how injured athletes perform on coordination tests like the BESS test. Fatigue was the most profound affect, due to the physical nature of athletics, therefore, having an impact on postural stability and concussion testing in athletes.

This study will benefit athletic trainers who are administrating the BESS test, as this study will give them an idea of how fatigue affects the postural stability in healthy athletes at the Division II level. Knowing the effects of fatigue will allow clinicians to apply the variance of fatigue to the results of the BESS test of injured athletes permitting them a better insight to the severity of a concussion in different individuals. Currently, only one study has been found looking at fatigue and the BESS test in Division I healthy athletes following a pre set fatigue protocol (Wilkins et al., 2004). This study uses the same fatigue protocol but incorporates participants that have and not had prior concussions. Recently there has been an increase in concussion research and this study will provide groundwork for further research related to the BESS test and concussions to be completed by further investigating other confounding factors such as practice effects or environmental surroundings.

Review of Literature

All athletic activities require the athletes participating to do physical activity, thus eventually leading to muscular fatigue throughout the body. An increase of fatigue in the body leads to an increased chance of injury including sport related concussions. When an athlete sustains a concussion, one of the major goals initially is finding the severity of the concussion. In order to attain an accurate severity level, medical personnel should complete a graded symptomology checklist, cognitive, coordination and cranial nerve assessments (Guskiewicz et al., 2004).

One of the most commonly used areas of assessment by athletic trainers listed above is assessing balance, also known as "postural stability." The Balance Error Scoring System (BESS) (see Appendix A) is a frequently used objective balance test conducted on the initial sideline and in follow-up concussion evaluations (*BESS Owner's Manual*). Reimann, Guskiewicz, and Shields (1999) found the reliability of five out of the six stances to range from 0.78 to 0.96, with the double leg firm surface not calculated since all the subjects had a score of zero. Although the test is a valid and reliable test for assessing concussions, several problems have become apparent such as fatigue influences, practice effects, environmental distractions, and previous injuries. Due to fatigue being the foremost confounding effect with the BESS, it needs to be assessed to determine the extent of the effect it has on postural stability in healthy and concussed individuals. Fatigue has been studied in its relationship with balance and proprioception. Therefore, this review will focus on how fatigue and balance are related along with an investigation of the relationship between balance and concussions.

Fatigue and Balance

Balance can be classified as the body trying to maintain its position around its center of gravity by the means of using different mechanoreceptors in the muscles and in the middle ear (Prentice, 2006). These mechanoreceptors sense the body's center of gravity moving out of the base of support, so the postural muscles have to constantly fire to maintain stability within the base of support. When fatigue occurs, neuromuscular control on the postural muscles diminishes thereby slowing the reaction of the postural muscles to changes in proprioception (Simoneau, Bégin, & Teasdale, 2006). Fatigue can affect balance by alternating different muscle groups in the back and the lower leg, thereby creating the sway exhibited by a person with decreased postural stability. The Borg scale is a digital analog scale ranging from a minimum rating of 6 to a maximum rating of 20, with the participants stating their perceived exertion at that particular point of time. Previous authors (Robertson et al., 2000; Susco et al., 2004) have used the Borg 20 point RPE scale using the rating of 15 as the minimum level for achieved fatigue, which has been determined to be equivalent to 75-90% of VO_2max. Wilkins, Valovich, Perrin, and Gansneder (2004) did not set a minimum level for their study, but found in their results RPE scores of 14-16 correlated to approximately 80% of the participants VO_2max.

Currently, only two studies (Wilkins et al., 2004; Crowell et al. 2001) have been completed looking at the relationship between the BESS test and fatigue. Wilkins et al. (2004), investigated the BESS test in NCAA Division I athletes by having them complete a fatigue protocol consisting of a circuit workout. This study used the 20-point Borg RPE scale to quantify the fatigue in subjects. They found the participants who were in the fatigue group scored higher on the BESS posttest after the fatigue protocol than the control group did in their BESS posttest. They also found the tandem stance was affected more than the other two stances. Crowell, et al. (2001) found similar results as Wilkins, et al. (2004), but they used a series of treadmill sprints and squat jumps for the fatigue protocol. These investigations are similar to this study, in that the focus is on fatigue and the BESS test. However, this study will be different due to the selection of NCAA Division II athletes and a more dynamic fatigue protocol with participants that have had and have not had prior concussion history.

Fox, Mihalik, Blackburn, Battaglini, and Guskiewicz (2008) studied aerobic and anaerobic exercises effect on balance, showing balance is not affected more significantly by either anaerobic or aerobic exercises. This proves significant in relation to the BESS test since athletes participate in either aerobic or anaerobic activities. Another research article (Simoneau et al., 2006) has been completed looking at aerobic treadmill protocols and how balance is affected with the results showing balance did decrease with the fatigue protocol. While the two studies (Crowell et al., 2001; Simoneau et al., 2006) use treadmill fatigue protocols, however, both Wilkins et al., (2004) and Susco et al. (2004) utilized a different protocol by using a seven station circuit workout with both studies finding an increase in BESS scores immediately following exertion, but then returning to baseline measurements within 20 minutes following the fatigue protocol. The seven stations are jogging, sprints the length of a basketball court, pushups, sit-ups, step-ups, sprints and fast pace jog.

Another factor taken into account should be how long balance remains abnormal following the onset of fatigue in healthy participants. This should be taken into consideration during concussion evaluations because fatigue may give false positive results of the BESS test indicating a more severe concussion. Susco, Valovich, Gansneder, and Shultz (2004) conducted a study with the BESS showing the balance recovers approximately twenty minutes after exercise is completed. However, Fox et al. (2008) found balance returned to normal even earlier, thirteen minutes after participants completed an anaerobic or aerobic fatigue protocol. Meanwhile, multiple studies (Broglio & Puetz, 2008; Cavanaugh, et al., 2005; Guskiewicz, 2001; Guskiewicz, Ross, & Marshall, 2001; Guskiewicz, Perrin, & Gansneder, 1996; Peterson, Ferrara, Mrazik, Piland, & Elliott, 2003; Sosnoff, Broglio, Shin, & Ferrara, 2011) have investigated balance in recently concussed participant's using the Sensory Organization Test (SOT), with results showing it generally takes between 3 and 5 days for balance to return to baseline values.

Balance and Concussions

Recently, McCrory et al. (2009) released the *Consensus Statement on Concussion in Sport 3rd International Conference on Concussion in Sport Held in Zurich*, with an updated definition of concussion as "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces" (p. 186). Due to the nature of mechanics of concussions, most of a concussion evaluation is subjective in nature, but doing objective measures such as the BESS test allows clinicians a means of assessing concussion severity. The BESS is commonly used for balance assessments by athletic trainers because it is an easy test to administer, requires few tools to conduct the test, only takes a few minutes to perform and can be completed in almost any setting (Valovich, 2009).

Balance is coordinated through the somatosensory, vestibular, and visual systems, which is relayed to the brain and postural muscles (Riemann & Guskiewicz, 2000). There have been several studies (Broglio, & Puetz, 2008; Cavanaugh, et al., 2005; Guskiewicz, 2001; Guskiewicz et al., 2001; Guskiewicz et al., 1996; Peterson et al., 2003; Sosnoff et al., 2011) done researching the relationship between concussions and balance outcomes of the injured athletes. Impairment to one of these systems can create a postural stability problem (Susco et al., 2004). Thus, the BESS test can give an objective measure of postural stability, by placing the body's center of gravity in different places within the base of support, due to the three different stances (Bandy & Sanders, 2001).

Summary

The link between fatigue and the outcomes of the BESS test have been investigated previously and have shown the results to be significant in the studies. From the findings of the previous research, athletic trainers in the field need to allow for variation in the interpretation of the BESS test when assessing concussions during physical activity. It is hoped that this research project along with past relevant studies looking at fatigue and balance, will enable clinicians to better estimate how much fatigue influences BESS scores in post concussed athletes.

Methodology

Participants

Thirty participants were chosen at random whom met qualifying criteria for this investigation. The participants were selected during the 2010-2011 school year from the intercollegiate athletics program at a Midwest Division II National Collegiate Athletics Association university. One participant was excluded during the study due to sustaining an ankle sprain prior to his posttest. This participant was replaced with another person at random who filled the criteria for the empty participant spot. Participants selected did not have any lower extremity injuries during the previous calendar year and were free of any vestibulocochlear problems. Concussion severity was not a selection factor for entrance into the study. Participants were placed in one of three groups. The control group (n=10) contained participants who have not had any prior concussions and did not perform the fatigue protocol. Experimental group one (n=10) underwent the fatigue protocol and had no concussion history. Experimental group two (n=10) had concussion history and completed the fatigue protocol. A third party individual, Dustin Bradstreet, MS, ATC was chosen by the investigator to serve as coordinator for selection and grouping of the participants. This individual was a certified athletic trainer at the participating school and is familiar with the medical history of the participants for the purposes of identifying which had previous concussions. He compiled a list of concussed and non-concussed volunteers using the injury documentation database the school utilized for the study and was then responsible for contacting and obtaining the completed participant demographic from eligible athletes for selection into the study.

After receiving all the participant demographic forms, and identifying the selected participants, the designee assigned each participant an identification number. The designee randomly put participants into the control, non-concussed experimental, concussed experimental group depending on their medical history. The investigator was not involved in the selection or grouping process. The individual looking at health records is bound by the athletic department confidentiality policy and the Family Educational Rights and Privacy Act (FERPA) to maintain privacy of the athlete's personal health information. Each participant in the study completed a participant demographic form (see Appendix B) and an informed consent form (see Appendix C). The Fort Hays State University Institutional Review Board approved this study (See Appendix D).

Setting

This investigation was conducted in the athletic training rooms on campus. The fatigue protocol for the study was carried out on the track and workout areas in the athletic facilities

Instrumentation

To subjectively quantify each participant's fatigue the Borg 20-point scale for Rating of Perceived Exertion (see appendix E) was used (Borg, 1998). The RPE was recorded immediately on the BESS Data Collection sheet (see appendix F) prior to and immediately after the fatigue protocol. Borg's RPE scale has been shown to have moderate validity ($r = 0.57$-0.72) for measuring exercise intensity (Chen, Fan, & Moe, 2002). However, in *Borg's Perceived Exertion and Pain Scales* (Borg, 1998) both validity and reliability have been shown to be greater than 0.90 for the 20 point RPE scale. The BESS has been shown to be a valid and reliable test for evaluating mild concussions with an intertester reliability (r = 0.78 to 0.96) (Reimann, & Guskiewicz, 2000). The BESS has also been shown to be reliable (r = 0.70) when testing young athletes ages nine to fourteen years old (Valovich et al., 2006).

Research Design

The quasi-experimental design was used with a non-equivalent control group setup. This design was chosen due to the design of the study comparing a non-concussed control group with the non-concussed and the concussed experimental groups. The dependent variable is balance being measured by the BESS in a pretest-posttest design to see if the independent variable, fatigue, affects it after the fatigue protocol is administered to the experimental groups. Seven interactions will be examined: pre-test and post-test scores of previously concussed treatment group, pre-test and post-test scores of non-concussed treatment group, pre-test and post-test scores of the control group, pre-test scores between concussed and non-concussed groups, post-test scores between concussed and non-concussed groups, post-test scores between the concussed and control groups and finally, the post-test scores of the non-concussed and control groups.

Testing Procedure

The participants were instructed on using the 20 point RPE scale to report honestly the perceived fatigue for that moment in time and then recorded on the data sheet (see Appendix B). The pretest RPE score and BESS test was conducted at least 3 days prior to the fatigue protocol to limit practice effects.

The BESS has three stances performed in sequence, which are the double leg, single leg and tandem stances in that order. The stances are performed first on a firm surface (e.g. ground) then on an unstable surface (e.g. foam pad) (see Appendix C). A 16.4” H by 20” W by 2½” T closed cell foam pad made by Airex was used for this study. The primary examiner was in charge of giving standardized instructions to each participant, along with counting and documenting the errors (see Appendix B) committed during the BESS test. The second examiner keeps time starting when participant initially closes their eyes, and stating when the time is complete. During the testing, the participant was instructed to remove their shoes (leave socks on), have their eyes closed, place hands on their hips and to maintain or return to the testing position as quickly as possible if the stance is lost. The three stances were first completed on a firm surface followed by the foam pad for 20 seconds each. A point is given for each error the participant commits during the testing. The errors are lifting a hand or both hands off the hip, opening the eyes, stumbling or putting a foot down, lifting a foot or heel off the ground, placing the hip into more than 30° of flexion or abduction, or staying out of the correct test position for more than five seconds. If two of these errors occur at the same time, only one point is assigned. This is done so the participant can open their eyes or regain their balance as quickly as possible. Therefore, before errors can start to be counted again, the participant had to resume and maintain the test position so there was not a continuation of errors from the previous mistake. Also, if the participant was unable to hold the test position for at least five seconds, the test was considered incomplete, and received a score of 10 points was given for that stance.

All participants completed the pre test RPE score and BESS test at least three days prior to the testing time. The fatigue protocol used the seven-station circuit workout designed by Wilkins et al., (2004). The first station is a moderately paced jog around the indoor track for 5 minutes. Station two was straight-line sprints the length of the basketball court for 3 minutes. Stations three, four, and five consisted of 2 minutes each of pushups, sit ups, and 12 inch step ups with the participant doing as many reps as possible within the time limit. Station six was 3 minutes of sprints again the length of the basketball court. The last station was a 2-minute fast paced jog around the indoor track. Immediately following the protocol a post test RPE score was obtained, which had to be a minimum rating of 15 to proceed with the posttest BESS test immediately following the protocol. Another third party designee was chosen to direct the fatigue protocol so the posttest BESS test could be done immediately following the fatigue protocol while another participant underwent the fatigue protocol simultaneously. The designee was trained by the principal investigator on the fatigue protocol, identification of control group participants and how to obtain the posttest RPE score. All participants were dressed comfortably in workout clothes and shoes for the fatigue protocol.

Data Analysis

A two-way two by three factorial repeated measures analysis of variance (ANOVA) was used to analyze the data for this study. The three groups to be analyzed were the control group and the two experimental groups. The dependent variable was the BESS scores before and after the participants were fatigued. Group differences were the focus of the ANOVA analysis looking for a difference between BESS scores of the experimental group who is fatigued, and the control group that did not undergo any fatigue. A separate repeated measure ANOVA was completed on the RPE scores to ensure there was a significant change in the amount of fatigue between the pretest and posttest.

Results

For each of the repeated measures ANOVA's the within subject factor is the pretest and posttest while the between subject factor is the three sample groups. The BESS pretest group (*n=30, M=11.27, SD=6.198*) and the BESS posttest group (*n=30, M=14.13, SD=8.866*) showed an increase in the descriptive statistics (see Table 1). There were no significant differences shown in the BESS pretest scores between any of the sample groups thus accepting the first null hypothesis (See Table 2). No significant differences *(p=.312)* were found in the BESS posttest scores between the control group and non-concussed treatment group indicating the second null hypothesis is accepted (See Table 2). The third null hypothesis is accepted as well since no significant differences *(p=.760)* were found between the control group and concussed treatment groups' BESS posttest scores (See Table 2). None of the seven interactions that were investigated showed significance as no significant findings *F(2,29), p=.06* were shown for within subject effects and between subject results *F(2,29), p=.579*, respectively. A LSD post hoc test (see Table 3) was done to look at the between subject comparisons and it was shown the control and non-concussed treatment group had closer correlation *p=.312* than the other group comparisons did.

Table 1

Balance Descriptive Statistics

Group	*n*	*M*	*SD*
Pretest	30	11.27	6.198
Control	10	12.00	5.249
Non Concussed	10	11.30	6.634
Concussed	10	10.50	7.138
Posttest	30	14.13	8.866
Control	10	10.80	8.270
Non Concussed	10	17.50	10.896
Concussed	10	14.10	6.420

Table 2

Balance ANOVA Repeated Measures

Source		df	Mean Square	F	Sig.
Time	Sphericity Assumed	1.000	123.267	3.849	.060
	Greenhouse- Geisser	1.000	123.267	3.849	.060
	Huynh-Feldt	1.000	123.267	3.849	.060
	Lower-bound	1.000	123.267	3.849	.060
Time * group	Sphericity Assumed	2.000	70.467	2.200	.130
	Greenhouse- Geisser	2.000	70.467	2.200	.130
	Huynh-Feldt	2.000	70.467	2.200	.130
	Lower-bound	2.000	70.467	2.200	.130
Error (time)	Sphericity Assumed	27.000	32.030		
	Greenhouse- Geisser	27.000	32.030		
	Huynh-Feldt	27.000	32.030		
	Lower-bound	27.000	32.030		

Table 3

Balance LSD Post Hoc Test

Group		Sig.
Control	Non Concussed	.312
	Concussed	.760
Non Concussed	Control	.312
	Concussed	.477
Concussed	Control	.760
	Non Concussed	.477

* P< .05.

The fatigue pretest group (*N=30, M=8.90, SD=2.857*) had a much lower overall mean than the fatigue posttest group (*N=30, M=13.80, SD=4.589*) as shown in the descriptive statistics (see Table 4). This change was shown to be significant for both the within subjects effects and the between subjects effects. The within subjects effects show a significant change *F(1,29), p=.000* in pretest and posttest RPE scores (See Table 5). The between subjects effects show a significant change *F(2,29), p=.000* showing there is significance between the groups. The LSD post hoc test (see Table 6) shows the between groups effect *p=.000* occurs between the control group and the two treatment groups, while there was no significance *p=.559* between the non-concussed and concussed treatment groups.

Table 4
Fatigue RPE Descriptive Statistics

Group	*n*	*M*	*SD*
Pretest	30	8.90	2.857
Control	10	8.20	2.974
Non Concussed	10	8.30	2.710
Concussed	10	10.20	2.700
Posttest	30	13.80	4.589
Control	10	8.70	2.584
Non Concussed	10	16.70	1.636
Concussed	10	16.00	3.859

Note. RPE = Rating of Perceived Exertion

Table 5

Fatigue ANOVA Repeated Measures

Source		df	Mean Square	F	Sig.
Time	Sphericity Assumed	1.000	360.150	63.869	.000
	Greenhouse- Geisser	1.000	360.150	63.869	.000
	Huynh-Feldt	1.000	360.150	63.869	.000
	Lower-bound	1.000	360.150	63.869	.000
Time * group	Sphericity Assumed	2.000	81.050	14.373	.000
	Greenhouse- Geisser	2.000	81.050	14.373	.000
	Huynh-Feldt	2.000	81.050	14.373	.000
	Lower-bound	2.000	81.050	14.373	.000
Error (time)	Sphericity Assumed	27.000	5.639		
	Greenhouse- Geisser	27.000	5.639		
	Huynh-Feldt	27.000	5.639		
	Lower-bound	27.000	5.639		

Table 6

Fatigue RPE LSD Post Hoc Test

Group		Sig.
Control	Non Concussed	.000
	Concussed	.000
Non Concussed	Control	.000
	Concussed	.559
Concussed	Control	.000
	Non Concussed	.559

Note. RPE = Rating of Perceived Exertion

* P < .05.

Discussion

The primary findings in this study showed no statistical significance of fatigue affecting the BESS scores between non-concussed and concussed participants. It appears history of concussion had no effect on how the participants were able to balance following fatigue. The outcomes of the study show no difference was found between the BESS pretest scores for each of the groups, therefore showing the history of concussion had no influence on the postural stability of those participants as compared to those who had concussion free histories when fatigue is not a factor. It was also shown in the results the posttest BESS scores did not show any significant differences between the control group and the non concussed and concussed treatment groups respectively. It was noticed the control group had a closer correlation with the non-concussed treatment group, which suggests fatigue in non-concussed participants does have a slight, but not significant effect on balance. When comparing BESS posttest scores between the control group and concussed participants, there was not a significant change in balance, suggesting concussion history does not have a significant influence on balance in fatigued participants.. Therefore, it can be inferred concussion history should not be a highly influencing factor when athletic trainers are interpreting post concussion BESS scores.

It was found the participants in the treatment groups were significantly fatigued during the posttest BESS test as there was a significant difference in RPE scores between the control group who did not receive any fatigue and the two treatment groups. There was not a significant difference in RPE scores between the concussed and non-concussed treatment groups demonstrating that concussion had no bearing on the participant's perceived exertion.

There are no studies supporting the results from this study. However, there are numerous studies (Wilkins et al., 2004; Crowell et al. 2001, Simoneau et al., 2006, Susco et al., 2004, Fox et al., 2008) showing fatigue does affect balance in healthy, non-concussed athletes using the BESS test. Another trend in the results is some of the control participants had better scores on the posttest, which indicates a practice effect may be occurring with these participants. This has been confirmed in previous research by Valovich et al. (2003) and Broglio, Zhu, Sopiarz, and Park (2009) showing participants tend to have improvements in their BESS scores if they have no previous experience with the BESS test and have multiple tests administered within a short period of time.

Future Research

This study had two limitations that could have imposed on the results found. The first issue was the time of day testing was conducted. Most of the testing was completed in afternoon and evening time period. This was done mostly for tester/participant convenience but really should be completed early in the morning to further limit induced fatigue from daily activity and athletic practices. During our baseline testing, there were several participants with RPE scores above 10 on the scale, which were several points above other participants. This would suggest these participants were already at a higher fatigue level, which could easily influence their postural stability.

The second issue that arose is the validity and reliability of the RPE scale to measure the amount of fatigue the participant is experiencing. An observation made by the investigator was participants would look extremely fatigued after the fatigue protocol, but then they would subjectively give a lower RPE score than expected even though they met the minimum rating of 15 after the fatigue protocol. This brings up the issue of where researchers draw the line for using the RPE scale for measuring exertion or for fatigue. It seems from this study exertion may have been measured more than fatigue truly was since athletes may have given all their effort to complete the task, but it was not enough to be completely systemically fatigued yet. A distinction needs to be made for the participant’s interpretation of them rating their exertion or their actual fatigue level or whether there is a difference between these two terms. For better reliability in this study, the investigator feel a different instrument is needed to better quantify fatigue such as a biological marker (i.e. pulse rate) or some instrument that is not as subjective in nature is needed.

Another factor needing further investigation is to build upon previous findings (Crowell et al., 2001; Valovich et al., 2003; Wilkins et al., 2004) the different BESS stances being affected by fatigue and concussion history has any further significance with particular stances. The two stances creating difficulty for participants are the single leg and tandem stances on firm surface somewhat, but more so on a foam surface. This is due mainly to a change in the base of support for the participant is narrowed drastically as compared to a double leg stance. Along with taking away other sensory mechanisms such as vision and limiting the center of gravity location by having the hands on each hip, the foam surface does not provide as much stability for this small base of support.

Concussion severity is another area of further research in relationship to its affect on balance. The relationship here might show a more severe concussion will lead to bigger balance deficits in the concussed athlete or there might not be any relationship at all. Concussion severity has been a big conversation topic lately to the point of eliminating the concussion grading scales previously used by athletic trainers. However, with that said it could be difficult to study such a topic with such a diverse range of opinion on the severity of concussions.

Even though the results did not come out as expected in this study, there is still significance to this study as it was seen the fatigue does affect balance moderately in non-concussed participants along with confirming trends of a practice effect and the importance time of day makes when testing athletes after the initial concussion evaluation. Hopefully in the future changes to this study design will show concussion does have implications in postural stability, but research will still be needed to investigate the effects of how recent concussions and fatigue interacts with concussion testing for athletic trainers.

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Appendix A

Balance Error Scoring System (BESS)

Double Leg Stance

Firm surface

Foam surface

Single Leg Stance

Firm Surface

Foam surface

Tandem Stance

Firm Surface

Foam Surface

Participant Positioning:

Participant can wear socks, but no shoes
Place hands on hips
Eyes are closed
Double Leg stance: feet are together
Single Leg stance: stand on non dominant leg. Non dominant hip is flexed to 20-30º and non dominant knee is flexed to 30-50º.
Tandem stance: non dominant leg is placed behind other leg in heel to toe position

Scoring:

Each error is worth one point.
- Lifting hands off hips
- Opening eyes
- Hip moves into more than 30º of flexion or abduction
- Stepping, stumbling, or lifting foot off the ground
- Remaining out of test position for more than 5 seconds
- One error is recorded if errors occur simultaneously

Test is obsolete if participant cannot hold position for 5 se

(Balance Error Scoring System (BESS) User's Manual)

Appendix B

Participant Demographic Information

Name ____

Sport: Baseball Volleyball Cross Country Volleyball

Softball Basketball Track & Field Wrestling

Dominant Leg (leg you would kick a ball with): Left Right

Have you had a concussion or your bell rung within the past year? Yes No

If yes, what is the date of your most recent concussion? ___________________

How many concussions have you had? ___________________

How long (minutes, hours, days, weeks, months, etc) did you have symptoms following your concussion? ___________________

What symptoms did you have? (please list them all):

Have you ever had in the past year any injuries to your ankle, foot, lower leg, knee, thigh or hip? Yes No

If yes state body part, the injury and date of injury:

Do you have any problems with maintaining your balance? Yes No

Is your respective sport currently: In Season Off Season

Participant ID#___________

Appendix C

INFORMED CONSENT

EFFECTS OF FATIGUE ON THE BALANCE ERROR SCORING
SYSTEM FOR CONCUSSION TESTING IN
HEALTHY PARTICIPANTS

You are asked to participate in a research study conducted by Jason Graham and Dr. David Fitzhugh from the Health and Human Performance Department at Fort Hays State University. This research project is currently being conducted as part of my thesis for my Master's Degree. Your participation in this study is entirely voluntary. Please read the information below and ask questions about anything you do not understand, before deciding whether or not to participate.

• PURPOSE OF THE STUDY

This study will help Athletic Trainer's assess concussions by determining a baseline for the effect fatigue has on balance, which is used in concussion testing. By finding the effect of fatigue it will allow athletic trainers to determine whether a balance deficiency after a concussion may be related to fatigue or to the concussion.

• PROCEDURES

If you volunteer to participate in this study, you will be asked to do the following things:

You will be asked to report to the Athletic Training Room in Gross Memorial Coliseum. You will be asked to give a baseline rating of perceived exertion prior to any activity involved in the study. Following this, a pretest Balance Error Scoring system will be done which involves six different stances each lasting 20 seconds in duration. You will return three days to complete the fatigue protocol, which will last approximately 20 minutes. Immediately following this fatigue protocol you will give a rating of perceived exertion followed by the posttest Balance Error Scoring System test.

• POTENTIAL RISKS AND DISCOMFORTS

Risks of participating in this research study include falling, muscle strains, ligament sprains, fractures, cardiopulmonary problems or even death. Risks will be minimized by setting up the fatigue protocol to have as few as risks as possible and someone will be beside you during balance testing to help you if you should happen to become unsteady.

In the event of physical and/or mental injury resulting from participation in this research project, Fort Hays State University does not provide any medical, hospitalization or other insurance for participants in this research study, nor will Fort Hays State University provide any medical treatment or compensation for any injury sustained as a result of participation in this research study, except as required by law.

• POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The participants will not benefit immediately from the results of this research study. As previously mentioned, the results of this study, will allow athletic trainer's to make better informed medical decisions in regards to concussions and how to treat them effectively, and when it is safe to allow a safe return to play for the injured athlete

- **CONFIDENTIALITY**

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of assigning each participant a unique identification number that will be chosen at random by the researcher.

The results of this study will not be released to anyone except those involved directly with the research study.

- **PARTICIPATION AND WITHDRAWAL**

You can choose whether or not to be in this study. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind or loss of benefits to which you are otherwise entitled. You may also refuse to answer any questions you do not want to answer. There is no penalty if you withdraw from the study and you will not lose any benefits to which you are otherwise entitled.

The investigator may withdraw you from this research if circumstances arise which warrant doing so including if you sustain any head or lower extremity injuries after the study has began.

- **IDENTIFICATION OF INVESTIGATORS**

If you have any questions or concerns about this research, please contact:

Jason Graham - Principal investigator – 785-313-3306, jmgraham@scatcat.fhsu.edu
David Fitzhugh, PhD – Faculty Advisor – 785-628-4354, dkfitzhugh@fhsu.edu

- **RIGHTS OF RESEARCH SUBJECTS**

The Fort Hays State University Institutional Review Board has reviewed my request to conduct this project. If you have any concerns about your rights in this study, please contact Dr. Greg Kandt of the Fort Hays State University HHP-IRB at email gkandt@fhsu.edu or Leslie Paige of the Fort Hays State University IRB at lpaige@fhsu.edu.

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____
Printed Name of Subject

______________________________ ____________________
Signature of Subject Date

______________________________ ____________________
Signature of Witness Date

Appendix D

FHSU IRB Approval Letter

FORT HAYS STATE UNIVERSITY

Forward thinking. World ready.

OFFICE OF SCHOLARSHIP AND SPONSORED PROJECTS

DATE:	March 14, 2011
TO:	Jason Graham, B.S.
FROM:	Fort Hays State University IRB
STUDY TITLE:	[223438-1] Effect of Fatigue on the Balance Error Scoring System for Concussion Testing in Healthy and Previous Concussion Participants
IRB REFERENCE #:	11-062
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	March 10, 2011
EXPIRATION DATE:	May 31, 2011
REVIEW TYPE:	Full Committee Review

Thank you for your submission of New Project materials for this research study. Fort Hays State University IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Full Committee Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

Appendix E

Rating of Perceived Exertion Scale

6	No exertion at all
7	
8	Extremely light
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very Hard
18	
19	Extremely Hard
20	Maximal Exertion

Appendix F

BESS Data Collection Sheet

Participant ID #_________

	Pre-activity	Post Activity
RPE Score	________	________
Single Leg (ground)	________	________
Double Leg (ground)	________	________
Tandem (ground)	________	________
Single Leg (foam)	________	________
Double Leg (foam)	________	________
Tandem (foam)	________	________