ABSTRACT

CHANGES IN SWAY SCORE USING THE CONCUSSION BALANCE TEST (COBALT) IN COLLEGE RODEO ATHLETES: A PILOT STUDY

Background: The number of concussions has continued to rise over the last decade due to an increase in awareness and activity participation. The Concussion Balance Test (COBALT) has a higher sensitive when compared to other traditional tests that was introduced to challenge the athletic population. **Purpose** The purpose of this pilot study is to look at the change in COBALT sway scores and errors in rodeo athletes who participated in 1 year of club competition. **Methods**: Thirty-nine Fresno State club rodeo athletes were recruited and performed 2 baseline tests within 10-12 months in between. All subject performed the COBALT protocol for conditions 3, 4, 7, and 8. Sway scores and number of errors were recorded. **Results**: Significance improvements were noted in sway scores for condition 4 ($p<.0125$) and condition 7 ($p<.0125$). Condition 7 ($p<.0125$) also showed significant improvements when comparing errors completed in baseline 1 compared to baseline 2. **Discussion**: Based on the results from this pilot study, 1 year of rodeo participation without the presents of a major injury does not cause vestibular deficits. This is the first study of its kind and there was no literature to compare with currently. Future research using larger sample sizes is needed to generalize to larger populations and better understand long term effects of rodeo participation.

Hannah Lynn Ramirez
May 2020

CHANGES IN SWAY SCORE USING THE CONCUSSION BALANCE TEST (COBALT) IN COLLEGE RODEO ATHLETES: A PILOT STUDY

by

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Prevalence

As of 2014, sport-related concussion (SRC) rates have risen and approximately 2.87 million children and young adults sustain a SRC concussion each year.[1] The definition of SRC is a mild traumatic brain injury that occurs during participation in a sporting or recreational event.[2] Besides those who compete in high impact sports, studies show an increased risk of concussion in those who participate in school physical education and recreational activities.[3] Though school-age adolescents are thought to be at the highest risk for concussions, research shows the risk of concussion increases based on age and activity level.[4]

Each concussion can present with symptoms that will vary in severity and duration.[5] As the brain moves through the fluid filled skull after a jarring movement, it comes in contact with 2 opposite walls of the skull. This is called a coup countercoup injury. For example, after the brain takes the impact from the frontal potion of the skull, the brain will bounce off and come in contact with the occipital region. The brain damage is caused by axonal shearing as the brain moves within the skull.[6] This mechanism of injury can occur without the person's head coming in contact with anything. A forceful movement in any direction, such as a horse that bucks or a fall from a bull, can cause this rapid acceleration/deceleration injury.[6] Even if the rider stays on the horse, the amount of force could cause the brain to move within the skull, providing an acceleration-deceleration injury.

As the incidence rate rises, researchers have started to track how many school and work days are lost due to symptoms of following a concussion. Special concern for student athletes and the effect that concussions have on school performance has come to the fore front of current research.[7] Many student athletes will suffer one, if not multiple concussions, that can leave them with deficits that may last for months to years.[7] These young adults then struggle to keep up in school. Decreased socialization and activity participation can be detrimental to these athletes' quality of life (QOL) due to decreased participation.[8,9] Most people who suffer a concussion feel they are able to return to work/school in approximately 7 to 10 days.[10] However, estimates show that up to 10% of those who experience a concussion may miss work or school for greater than 30 days due to continued symptoms.[10]

Pathology

The impact associated with a concussion transmits forces that change homeostasis at the cellular level in the brain.[6,11] The shearing force that accompanies concussion causes a rapid depolarization leading to neuronal depression.[11] Levels of excitatory neurotransmitters such as GABA and Glutamate are increased due to the depolarization of the cell.[11] In addition to the increase in neurotransmitters, intracellular levels of sodium and calcium rise, which leads to cell damage.[11] Due to the increased energy demands with these imbalances, the mitochondria are unable to keep up with the energy demand, which causes an energy crisis.[11] The poor ability of the cell to keep up with the demand leads to cell damage and inflammation.[11] Ultimately, cell death can occur days to weeks after the initial damage when the cells are unable to return to homeostasis.[11] It is well understood that concussions have multiple effects on all body systems, and symptoms can manifest in many different ways.[6,12]

Rodeo Participants

One population that is underrepresented in the literature is rodeo athletes. This is partly due to the lack of representation in the sports world and lack of popularity outside the western United States.[12] Poor organization, with no one governing group, but rather many different organizations overseeing competition, is thought to contribute to under reporting of concussions.[12] Incidence rates of concussion throughout the sport become hard to track when they are not reported to one single group.[12] However, concussion within rodeo athletes account for over 10% of all injuries sustained during competition.[13] Rodeo athletes have an 89% chance of suffering any type of injury in any one season, whereas its high impact counterpart football, only has a 46.6% chance over the course of 1 year.[14] Theadom et al. reported that, out of their sample of rodeo athletes, over two-thirds stated having at least one concussion during their career.[15] It is thought that anywhere from 10 to 29% of all injuries suffered over the course of a season are related to concussion.[12,13,16] In addition, these athletes tend to have no or a short offseason, which does not allow for adequate time to recover.[16]

One further complicating factor for this population is the culture of the sport. Most of these athletes grew up with the idea that, if it is not bleeding you should continue. When interviewed, the athletes have stated they do not have much understanding of the dangers that accompany the forceful movements that they encounter every day. This was more solidified in how they talk about falls and loss of consciousness. Many athletes interviewed used the phrase “having their bell rung” rather than concussion, even when a loss of consciousness occurred. These athletes reported the event almost as a rite of passage. To make matters worse, those who were interviewed and decided to put their health first and sit out after an injury, are considered to be the outcasts or outliers. One component that does not promote safety is that the athletic trainers and other medical staff have no authority to prohibit the athlete from continuing the competition. An athlete can fail the concussion testing and be told not to compete, however, since there is no governing body that has rules against competing with an injury, the choice is in the athlete’s hand.

This is starting to change after the sport lost one of their talented young stars to suicide. After Ty Pozzobon’s death in 2017, the family donate his brain to science.[17] He was the first Rodeo athlete to be diagnosed with chronic traumatic encephalopathy (CTE).[17,18] This condition is not well understood; however, it made an impact on how people in the rodeo community view injuries, specifically brain injuries. Head and brain injuries may not be visible, but they have lasting effects. Prior to Ty’s death, most athletes would not take more than a few days off after any type of injury, even after losing consciousness. Though this will be a slow process, the hope is that this can help change the mindset of the participants of one of the most dangerous sports.

While poor concussion knowledge complicates truly understanding its effect, the jarring repetitive movements associated with rodeo events can cause microtraumas to the brain tissue without presenting as a concussion. Though not all rodeo athletes are thrown from horses on a regular basis, they are put through repeated jarring motion, that can affect the brain tissue. This can lead to mild, long-standing concussion like symptoms. Not being able to fully recover due to repetitive movements poses problems as athletes work towards fully recovering once they have suffered a concussion.[19]

Concussions suffered during rodeo events typically occur from an oblique force with the turf or sand.[20] Unfortunately, the force and duration of the impacts of these head injuries are greater than what helmets can protect against.[20,21] Having the skull come in contact with an object is not required to have the brain move forcefully within the skull and cause injuries.[20-22] The amount of force from being jerked back and forth causes the brain to rock within the skull and cause the axonal shearing associated with the brain injury.[20,21,23]

Second Impact Syndrome

Many of these adolescents and young adults will suffer multiple concussions over the course of their careers.[3] The rates of obtaining multiple concussions are climbing for adolescents and adults, as is the research evaluating the changes in the brain with more multiple head injuries.[24,25] Several concussions within a short period of time lead to serious consequences. The major concern relates to an athlete's attempt to return to competition before symptom resolution.[3] A second concussion that is sustained prior to resolution of the first is known as second impact syndrome.[25] This condition carries many additional risks and can often be fatal.[25] Individuals who survive second impact syndrome will be severely disabled for a lifetime.[25] Disability of this nature also comes at a high financial burden because of the continuous medical care that is required.[25]

As studies continue to improve, newer research is showing that the second impact does not require as much force as the first to cause even more damage.[26] Since the brain is already working hard to repair itself, it is unable to defend against smaller blows that may occur.[26] With the extended time to recover taking more than previously understood, up to 6 months or years, the brain can be susceptible and is unable to defend from injuries for much more time than was previously understood.[26] This is a problem when medical professionals are sending the athletes back to compete after reported symptom resolution in one week. These athletes have an increased risk of re-injury, since most of their reaction times are slower, they have poor balance, and they can still be suffering from other post-concussion symptoms.[26]

Unfortunately, the exact mechanism of second impact syndrome is unknown. Current studies point to changes in metabolic processes.[24] Despite the high risk associated with concussions and a sequential concussion, athletes tend to underreport due to their desire to return to sports.[12] This raises the question of the best test to reduce the risk of athletes returning to activity to soon and risking re-injury. In addition, which symptoms should be monitored to provide appropriate rehabilitation.

Vestibular Effects

In addition to the commonly reported symptoms such as headaches, confusion, and nausea; concussions can impact the vestibular and visual systems, causing decreased balance, poor postural stability, and visual impairments.[5,27] Symptoms can range from dizziness, to blurred vision, diplopia, decreased attention span, difficulty learning new tasks, and neck pain.[5,27] Other secondary symptoms, such as depression and decreased QOL, can often accompany a concussion.[8,9] This is primarily thought to be due to a reduced ability to participate in activities. For many clinicians, the challenge is to know when it is safe to send the athlete back to competition without relying solely on the athlete's subjective response.[12]

Many times, the vestibular system shows impairment after a concussion, which impacts the brain and nervous system. The impairments can present in many different ways, such as the reduced ability to track objects and poor eye muscle activation, which can show in nystagmus.[28,29] Functionally, this causes impairments with eye movements. Due to the poor coordination with smooth eye pursuit and holding one's eyes steady, the person can suffer from increased difficulty with tasks such as reading.[29]

In addition to problems with reading, the patient may express an increase in symptoms with most head movements. Over recent years, clinicians have started to track these symptoms through the course of numerous concussions. Researchers have discovered that abnormal vestibular ocular reflex can be a predictor of the length of recovery.[30] Many studies looked at benefits for the use vestibular ocular reflex as a way to track the progression of symptoms and nystagmus.[31] Recent studies determined vestibular dysfunction as the result of a concussion, through increased symptom report during VOR tests.[32] Other, more traditional ways to measure VOR include the rapid head impulse test (RHIT) and video head impulse test (VHIT). Unfortunately, most of these tests take expensive equipment and training to perform and are not useful for on the field assessements.[31]

Vestibular Ocular Reflex

Vestibular ocular reflex (VOR) is a component of the vestibular system and is used to assess integrity of the associated structures.[28] The VOR functions to help stabilize images while the head is in motion.[28] This system works in opposition to the eyes. As the head moves to the right, the eyes will move to the left in order to maintain the image on the retina. The direct mechanism of the VOR relies on the input from the semi-circular canals, which receives information as the head moves.[28] As the head position shifts, the fluid within the semi-circular canals moves and causes the information to relay to cranial nerve VIII (Vestibulocochlear nerve).[28] The signal transmits to the brainstem, which signals the eye muscles to contract via cranial nerve VI, (Abducens).[28] This circuitry works similarly in the horizontal, vertical, and torsional planes.[28]

Many studies look at different metrics to analyze VOR. Current literature evaluates symptom provocation while performing the VOR to determine if it is intact.[32] Vestibular motor screening (VOMS) is starting to come up in the literature as the new, easy assessment tool since it requires no equipment and can help guide the therapist to the best type of treatment to address the systems that are involved.[32] Though research is starting to show that VOMS is proven to be effective with testing for the specific aspects of a concussion, it is still considered a subjective test.[32] This means that patients could falsify their symptoms to be able to return earlier to competition. Allowing athletes to have that much control in whether they are ready to return to sports can be a challenging balance. The athlete should provide their subjective report, but there should also be objective, numerical data to support the return to play. The COBALT is able to provide those numbers to compare to baseline to better know when an athlete is safe to return to play.

Concussion Balance Test

The Concussion Balance Test (COBALT) was created by the company Bertec for the assessment of concussions.[33,34] The set of tests are designed to challenge the visual, somatosensory, and vestibular systems to look for deficits.[33,34] Through a force plate, testing is able to measure the amount of sway present while the patient performs VOR cancellation on a compliant and noncompliant surface.[33,34] One of the advantages with this device is portability as compared to standardized postural tests. Additionally, it provides objective data and is a standardized test that can be easily retested. The COBALT's primary purpose is to provide a more strenuous test for the athletic population.[35] This is due to the increased challenge of this assessment tool. Unlike other tests, such as the BESS and SCAT 5, participants are less likely to use previous tests to practice to increase their chances of passing while performing the COBALT.[33-35] This holds those who are recovering to a higher standard when attempting to return to any athletic competition. In time, the COBALT may be applicable to more diverse groups due to the numerical data provided via sway scores and errors.[33,34] This method of testing is able to provide objective data to compare baseline scores of an individual to their post injury data after sustaining a concussion.[33,34]

Currently, there is limited data on set norms for any population due to the lack of literature that includes this specific test.[34] Each athlete will have a different score depending on their history, which can make it hard to assess subjects who have suffered a concussion to show when they are back to baseline. The advantages of the COBALT is that it can be used as an objective measure of an athlete's function before and after concussion. Rather than depending on symptom provocation and subjective report, the COBALT is able to provide objective data regarding brain function. The sway score report provided by the COBALT is a way to directly measure the athlete's postural stability in different, challenging conditions.

Postural Stability

Postural stability is defined as the ability to maintain the center of mass (COM) within a person's limits of stability.[36] The ability to hold one's body statically and dynamically in space, is a component that athletes must have to be able to perform at the highest level. The more efficiently a player can accomplish this task, the more energy they are able to direct to the game or activity. After a concussion, this system tends to work ineffectively.[36] This is thought to be due to the poor integration of the vestibular, visual and somatosensory systems after a concussion.[37,38] The brain is attempting to heal through cellular regeneration and is unable to correctly match up neurological signals, which produces symptoms such as diplopia and headaches. As previously mentioned, all these systems are critical to effective balance.[37,38]

Hypothesis and Purpose

The purpose of this pilot study is to assess the changes in Cobalt sway scores in college rodeo athletes between one-year baseline testing to determine any long-lasting effect as a result of participation in the sport. The alternative hypothesis of the current study is that after a year of competitive rodeo participation, participants will have increased sway scores and increased errors when performing VOR cancellation and postural stability tests on the Cobalt. The null hypothesis was that there would be no change or an improvement between the pre and post test scores.

METHODS

Subjects

Participants were recruited from California State University, Fresno Rodeo club sport team over the course of 3 years. In total 39 participants fit the inclusion criteria consisting of participating with the rodeo team for 2 consecutive years. Additionally, the inclusion criteria required the participants to have 2 separate baseline Cobalt tests performed within 10 to 12 months from each other and be 18 to 25 years old. The final sample included male and females with and without a history of past concussions.

All participants gave informed consent prior to participation in the research on COBALT baseline testing. This project was approved by the California State University, Fresno Committee on Protection of Human Subjects and compliant with all governmental regulation on the testing of human subjects that are identified by the Human Research Protection Office. Subjects completed all baseline testing on the COBALT.

Procedures

Participants were provided information about the testing and its use for further research when given the consent form. The consent form included consent to participate in the study, multimedia consent, and a page to collect additional demographic information about the subject. The demographic information collected included age, sport participation, years of participation, and brief medical history. After completing the form, a participant profile including name, age, gender, birth date, and height was completed in the BERTEC computer.[39]

The force plate was placed 18 inches from the wall. A tarp is hung on the wall 18 inches from the ground with a line at each end to ensure the subject had a wide enough head turn during testing.[39] The subject was provided a headlight to place on their forehead, and was instructed to stand with the medial malleolus on the horizontal line on the force plate. The heel was lined up with the vertical line that corresponded with the subject's height as directed by the Cobalt program. Per the baseline testing recommendations, conditions 3, 4, 7, 8 were performed. In condition 3, the subjects were instructed to stand with their hands on their hips and turn their head side to side at a rotation wide enough to allow the head light to touch the lines on the tarp (60 degrees) to the metronome of 120 beats per minute.[39] The subject was allowed a practice time with eyes open. After practicing for up to 30 seconds, the subject was asked to close their eyes and continue turning their head to the beat. The subject performed two, 20-second trials with a 1 to 2 minutes break in between trials, depending on any symptoms presented during the trials.[39] Condition 7 had the same instructions, however, the participant was required to stand on a 4-inch foam pad.

During condition 4, the subject was instructed to stand with the medial malleolus on the horizontal line and the inside of the feet touching in the center of the force plate.[39] The subject was then instructed to raise bilateral upper extremities to 90 degrees of shoulder flexion and complete elbow extension with hands clasped and thumbs pointing upward.[39] They were then instructed to look at their thumbs while turning their whole upper body to allow the head light to touch the lines on the tarp at rate of 40 beats per minute.[39] Two, 20-second trials were performed with up to 2 minute rest between trials based on symptom provocation. Condition 8 consisted of the same parameters while standing on a 4 inch foam pad.

During all testing, errors were tracked by the researcher with a remote. A participant was considered to have committed an error if they took any steps, opened their eyes during a closed eye trial, if their hands came off their hips, or if they were unable to hit the lines with the light in time with the beat at least twice in a row. In addition to tracking errors, the force plate recorded the amount to sway during each trial and also created a composite score of the 2 trials.[39] After each testing session was complete, a printout (see Figure 1) provided the participant's sway score for each trial and the average over the 2 trials. In addition, the following information was given: number of errors, average errors of the 2 trials and time from first error.

RESULTS

Data Collection

Testing began in August of 2017 and ran through November 2019. During this time period, a total of 430 subjects were tested from California State University, Fresno club sports teams. From the initial 430 subjects, 39 participants met the inclusion criteria and were enrolled in the study. Data analysis was performed on 39 participants who completed 2 baseline tests between the 2017 and 2019 rodeo seasons. Individual ages and gender are reported in Table 1.

Statistical Analysis

Statistical analysis was conducted using SPSS software version 26. After determining homogeneity of the data by the Levene statistic test (see Table 2) paired t-tests were run to compare pre and post results for the sway score and the total errors during the 4 conditions of the baseline tests. The pre-test score was considered the first of the participants 2 baseline tests, whereas the post-test score was considered the baseline test that was performed within 10 to 12 months after the first test. If more than 2 baseline tests were available for one participant, the 2 most recent tests were used that fit the criteria of being within 10 to 12 months of one another. To control for alpha level inflation within the 4 conditions, a Bonferroni post hoc test was used.

Analysis of Sway

Sways score significance and pre/post means and standard deviation for the 4 conditions are reported in Table 3. Significance was shown in conditions 4 and 7. After the Bonferroni was run to look for alpha level inflation, both conditions 4 and 7 continued to be statistically significant.

Analysis of Error

Significance, pre/post means and standard deviations are listed below in Table 4. Data analysis was only completed on conditions 3 and 7 because no errors were noted in condition 4 and 8. Condition 3 showed no significance, however, condition 7 showed statistical significance when comparing pre to post test.

DISCUSSION

Purpose

As the concern of concussions for all athletes in sports continues to rise, rodeo is one of the last sports to begin to look at the lasting impacts that each fall, impact or repetitive jarring can have on an athlete. As mentioned above, this new frame of mind is only recently being brought to the forefront after the suicide of one of rodeo's young stars.[18]

The purpose of this pilot study was to evaluate the changes in sway score and number of errors during pre and post baseline testing for rodeo athletes. The alternative hypothesis was that after 1 year of rodeo competition, the post-test baseline sway score and number of errors would increase indicating decreased postural stability. The null hypothesis was that there would be no change or an improvement between the pre and post test scores.

Postural Sway and Error Significance

After reviewing the results of the study, there was a significant change in sway scores for condition 4 and 7. Further evaluation of the means revealed that the sway score means decreased when comparing pre and post-test performance. This nullifies the alternative hypothesis. Though there is no clear reason for why the sway score means improved, one possible reason is that these athletes' brains and bodies are able to maintain postural stability and recover from daily microtraumas. A study by Olivier et al. showed that rodeo and equestrian athletes have better developed postural muscular tone that could account for the better performance during testing.[40] This could contribute to their performance during this type of testing.

There was no significance found in sway scores for condition 3 and 8 based on the paired t-test results. Despite there being no significant change, the means for condition 3 did decrease slightly when comparing pre and post-test scores. Condition 8, the test of visual motion sensitivity on a compliant surface, showed a minimal increase in sway scores when comparing pre and post-test scores. There is no current literature that suggests a reason for this increase in sway scores, however since this test is most representative of the visual motion sensitivity system, it can point to potential increase in dysfunction from year one compared to year two.[33,34]

Condition 7, head shake on compliant surface, showed a significant difference when looking at the number of errors completed comparing pre and post-tests. When looking at the means, there was decrease in errors, meaning that participants had an overall decrease in number of errors made during post testing. Like the results for the sway scores, this is contradictory to the original hypothesis. Since there is no current research discussing the change in the number of errors over any time period, this is the first study of its kind to show any significant change. This condition primarily focuses on targeting the vestibular system and, with this population, showed that they were not only able to maintain their baseline performance but able to improve it the following year. No significance was calculable for errors in conditions 4 and 8 due to there being no errors during either the pre or post- test. Over the group of participants, only one error was performed during each of those conditions.

Clinical Relevance

Though the data did not follow the pattern that was originally hypothesized, the results can be of some value. This study evaluated a small population but was able to assess that there are no significant negative changes that occur during a rodeo season that result in long term damage to the vestibular system. Due to the small sample that did not include anyone who reported a concussion, these results must be evaluated and require further studies to be able to generalize to a broader population. This study opens the door for additional research to continue to monitor athletes in these high impact sports.

The COBALT continues to show its importance since it is able to hold athletes to a higher standard and requires them to pass a more difficult task. This test is much different compared to most tests that can be easily passed after the initial acute phase of the injury, such as the BESS test.[35] The COBALT continues to show that it is more sensitive compared to its counterparts the BESS and the SCAT5, due to its ability to challenge the visual motion sensitivity and vestibular system.[35] Though there may be some ability to learn how to perform the test well and report no symptoms, the numerical sway score does not allow the athlete to fake how their brain is truly performing. As the mindset in rodeo continues to evolve, the hope would be that objective tests, such as the COBALT, would be used to provide the athlete with data that can better help them understand how their brain is performing and rehabilitating following an injury.

Limitations

Due to this study being the first of its kind, there are many limitations that were noted that could be improved on for further studies. As previously mentioned, this data looks at a very specific sub-group of the total rodeo population. Though it does represent many of the events that are performed during most competition, there was a limited number of bull riders which have the highest levels of injuries and concussions due to the nature of that event.

There is currently limited data and limited studies on the COBALT and its use with the adult population, which made it challenging to compare it to normative values. Thus, since no normative data for this age population was available, no comparison was performed. Having normative values for the general population and for other types of sports would have been useful and could prove to have some interesting findings. For example, though the sway scores for rodeo athletes did improve, there is currently no way to know if their baselines are significantly different than those who participate in other sports like baseball and basketball.

Follow up for these athletes was performed at the start of 2 separate seasons. Though there is no true off season for a majority of these athletes based on a survey that was completed, having testing at the beginning and immediately at the end of one season could have provided this study with more sub-analysis to understand actual effect of participation on the vestibular system and motion sensitivity.

One additional limitation is that, at this time, there is no way to know if the number of years that an athlete has competed will affect their body's ability to adapt to the brain changes. For example, someone who is starting to compete in rodeo may have a harder time maintaining their sensory, vestibular, and somatosensory system's integrity compared to someone who has been practicing and competing for an extended period of time. The opposite could be true as well. Participants who have competed for many years may have suffered more macro- and microtraumas and have a harder time returning to and improving their postural stability. Only further research can hope to answer those questions.

Recommendation for Future Research

Considerations for further research include having a larger sample size that can look at a more diverse population. It may be beneficial to divide rodeo athletes by the events that they participate in. Additionally, comparing rodeo to other sports may provide data on how rodeo competitors compare since there is limited research on this population.

To better understand how one season affects the athlete's vestibular, visual, and somatosensory systems, testing at the beginning of the season and after their last sanctioned event would provide a better understanding of any changes that occur during the season. One further step would be to look at athletes who are competing in their first season of rodeo. The idea behind this is that athletes who have competed for many years may not show significant deficits because their body is more effective at adapting, whereas someone who is just starting may have a harder time maintaining all 3 systems with the forces associated with participation in this sport.

Conclusion

This pilot study showed significant improvements in sway scores in 2 of the conditions of the COBALT testing system. Though this study is unable to determine the exact mechanism of these results, they are promising in providing support to the theory that the human brain is able to continue to remodel with each macro- or microtrauma. Further studies are needed to better understand these results, however as the sport begins to place more importance on brain health, this can open the door for additional studies of its kind.

REFERENCES

REFERENCES

1. Centers for Disease Control and Prevention USDoHaHS. Surveillance Report of Traumatic Brain Injury-related Emergency Department Visits, Hospitalizations, and Deaths—United States. 2014.

2. McCrory P, Feddermann-Demont N, Dvořák J, et al. What is the definition of sports-related concussion: a systematic review. Br J Sports Med. 2017;51(11):877-887. doi:10.1136/bjsports-2016-097393

3. Halstead ME, Walter KD, Moffatt K, Council On Sports M, Fitness. Sport-Related Concussion in Children and Adolescents. Pediatrics. 2018;142(6). doi:10.1542/peds.2018-3074

4. Gordon KE, Dooley JM, Wood EP. Descriptive Epidemiology of Concussion. Pediatr Neurol. 2006;34(5):376-378. doi:https://doi.org/10.1016/j.pediatrneurol.2005.09.007

5. Buckley TA, Oldham JR, Caccese JB. Postural control deficits identify lingering post-concussion neurological deficits. J Sport Health Sci. 2016;5(1):61-69. doi:10.1016/j.jshs.2016.01.007

6. Zufiría J, Fernández P, Fernández J, Degenhardt M, Núñez P. Concussion and Mild Head Injury: Epidemiology, Clinical Considerations and Prognostic Factors. J Trauma Treat. 2018;7(412):2167-1222.1000412.

7. Lowry R, Haarbauer-Krupa JK, Breiding MJ, Thigpen S, Rasberry CN, Lee SM. Concussion and Academic Impairment Among U.S. High School Students. Am J Prev Med. 2019;57(6):733-740. doi:10.1016/j.amepre.2019.08.016

8. Emanuelson I, Andersson Holmkvist E, Björklund R, Stålhammar D. Quality of life and post-concussion symptoms in adults after mild traumatic brain injury: a population-based study in western Sweden. Acta Neurol Scand. 2003;108(5):332-338. doi:10.1034/j.1600-0404.2003.00155.x

9. Renton T, Topolovec-Vranic J, Colantonio A, Reed N, Marshall C. Investigating Preseason Symptoms of Depression and Concussion in Adolescent Athletes. Arch Phys Med Rehabil. 2015;96(10):e38-e39. doi:10.1016/j.apmr.2015.08.124

10. Gioia GA. Medical-School Partnership in Guiding Return to School Following Mild Traumatic Brain Injury in Youth. J Child Neurol. 2016;31(1):93-108. doi:10.1177/0883073814555604

11. Romeu-Mejia R, Giza CC, Goldman JT. Concussion Pathophysiology and Injury Biomechanics. Curr Rev Musculoskelet Med. 2019;12(2):105-116. doi:10.1007/s12178-019-09536-8

12. Wicklund A, Foster SD, Roy AA. Getting Back on the Horse: Sport-Specific Return to Play in Rodeo Athletes After Concussion Injury. J Athl Train. 2018;53(7):657-661. doi:10.4085/1062-6050-310-17

13. Butterwick DJ, Meeuwisse WH. Bull riding injuries in professional rodeo: data for prevention and care. Phys Sportsmed. 2003;31(6):37-41. doi:10.3810/psm.2003.06.407

14. Meyers MC, Elledge JR, Sterling JC, Tolson H. Injuries in intercollegiate rodeo athletes. The American Journal of Sports Medicine. 1990;18(1):87-91. doi:10.1177/036354659001800114

15. Theadom A RD, Hume P, Hardacker N. Awareness of Concussion in Equestrian Sports. Report to Stakeholders. Auckland University of Technology. 2019;January 2019.

16. Zuckerman SL, Morgan CD, Burks S, et al. Functional and Structural Traumatic Brain Injury in Equestrian Sports: A Review of the Literature. World Neurosurg. 2015;83(6):1098-1113. doi:https://doi.org/10.1016/j.wneu.2014.12.030

17. Keene CD, Latimer CS, Steele LM, Mac Donald CL. First confirmed case of chronic traumatic encephalopathy in a professional bull rider. Acta Neuropathol. 2018;135(2):303-305. doi:10.1007/s00401-017-1801-z

18. Lamb K. Collegiate rodeo athletes and concussions. Tarleton State University. 2018([Order No. 10785952]).

19. Kawata K, Tierney R, Phillips J, Jeka JJ. Effect of Repetitive Sub-concussive Head Impacts on Ocular Near Point of Convergence. Int J Sports Med. 2016;37(05):405-410. doi:10.1055/s-0035-1569290

20. Clark JM, Adanty K, Post A, et al. Proposed injury thresholds for concussion in equestrian sports. J Sci Med Sport. 2019. doi:https://doi.org/10.1016/j.jsams.2019.10.006

21. Clark JM, Adanty K, Post A, Hoshizaki TB, Annaidh AN, Gilchrist MD. A parametric analysis of factors that determine head injury outcomes following equestrian fall accidents. International Journal of Crashworthiness. 2019:1-14. doi:10.1080/13588265.2019.1705694

22. Van Balen P-J, Barten DG, Janssen L, Fiddelers AAA, Brink PR, Janzing HMJ. Beware of the force of the horse: mechanisms and severity of equestrian-related injuries. Eur J Emerg Med. 2019;26(2):133-138. doi:10.1097/MEJ.0000000000000511

23. Gates JK, Lin CY. Head and Spinal Injuries in Equestrian Sports: Update on Epidemiology, Clinical Outcomes, and Injury Prevention. Curr Sports Med Rep. 2020;19(1):17-23. doi:10.1249/jsr.0000000000000674

24. Cantu RC. SECOND-IMPACT SYNDROME. Clin Sports Med. 1998;17(1):37-44. doi:https://doi.org/10.1016/S0278-5919(05)70059-4

25. McLendon LA, Kralik SF, Grayson PA, Golomb MR. The Controversial Second Impact Syndrome: A Review of the Literature. Pediatr Neurol. 2016;62:9-17. doi:https://doi.org/10.1016/j.pediatrneurol.2016.03.009

26. Marshall CM. Sports-related concussion: A narrative review of the literature. J Can Chiropr Assoc. 2012;56(4):299-310. Published 2012/12/04.

27. Armstrong RA. Visual problems associated with traumatic brain injury. Clin Exp Optom. 2018;101(6):716-726. doi:10.1111/cxo.12670

28. Bronstein AM, Patel M, Arshad Q. A brief review of the clinical anatomy of the vestibular-ocular connections—how much do we know? Eye. 2015;29(2):163-170. doi:10.1038/eye.2014.262

29. Feddermann-Demont N, Echemendia RJ, Schneider KJ, et al. What domains of clinical function should be assessed after sport-related concussion? A systematic review. Br J Sports Med. 2017;51(11):903-918. doi:10.1136/bjsports-2016-097403

30. Walsh EM, Bojrab DI. The Vestibulo-ocular Reflex and Head Impulse Testing. In: *Diagnosis and Treatment of Vestibular Disorders.* Springer; 2019:67-74.

31. Alkathiry AA, Kontos AP, Furman JM, Whitney SL, Anson ER, Sparto PJ. Vestibulo-ocular reflex function in adolescents with sport-related concussion: preliminary results. Sports health. 2019;11(6):479-485.

32. Mucha A, Collins MW, Elbin R, et al. A brief vestibular/ocular motor screening (VOMS) assessment to evaluate concussions: preliminary findings. The American journal of sports medicine. 2014;42(10):2479-2486.

33. Massingale S, Alexander A, Erickson S, et al. Comparison of Uninjured and Concussed Adolecent Athletes on the Concussion Balance Test (COBALT). J Neurol Phys Ther. 2018;42(3):149-154. doi:10.1097/NPT.0000000000000225

34. Massingale SL, Alexander AD, Erickson SM, et al. Assessing Balance in an Athletic Population: Normative Data for the Concussion Balance Test (COBALT©). International Journal of Athletic Therapy and Training. 2018;23(3):96-100. doi:10.1123/ijatt.2017-0042

35. McDevitt J, Appiah-Kubi K, Tierney R, Wright W. Vestibular and Oculomotor Assessments May Increase Accuracy of Subacute Concussion Assessment. 2016;37(9):738-747. doi:10.1055/s-0042-100470

36. Feigenbaum LA, Kim KJ, Gaunaurd IA, et al. Post-Concussive Changes in Balance and Postural Stability Measured with Canesense™ and the Balance Error Scoring System (BESS) in Division I Collergiate Football Players: A Case Series. Int J Sports Phys Ther. 2019;14(2):296-307. https://www.ncbi.nlm.nih.gov/pubmed/30997281

37. Murray NG, Szekely B, Moran R, et al. Concussion history associated with increased postural control deficits after subsequent injury. Physiol Meas. 2019;40(2):024001. doi:10.1088/1361-6579/aafcd8

38. Murray N, Salvatore A, Powell D, Reed-Jones R. Reliability and validity evidence of multiple balance assessments in athletes with a concussion. J Athl Train. 2014;49(4):540-549. doi:10.4085/1062-6050-49.3.32

39. BB A. Bertec Balance Advantage (R) COBALT (Concussion Balance Test) Manual. 2018.

40. Olivier A, Viseu J-P, Vignais N, Vuillerme N. Balance control during stance - A comparison between horseback riding athletes and non-athletes. PLoS One. 2019;14(2):e0211834. doi:10.1371/journal.pone.0211834

TABLES

Table 1. Population Demographics

	Female	Male	Previous concussion	Age Range	Participation Restriction
Baseline 1	23	16	7	18-22	3
Baseline 2	--	--	12	19-23	1

Table 2. Homogeneity Statistics for Sway Scores

Conditions	Levene Statistic	Significance
COB3	2.287	.135
COB4	1.279	.262
COB7	.701	.405
COB8	.977	.326

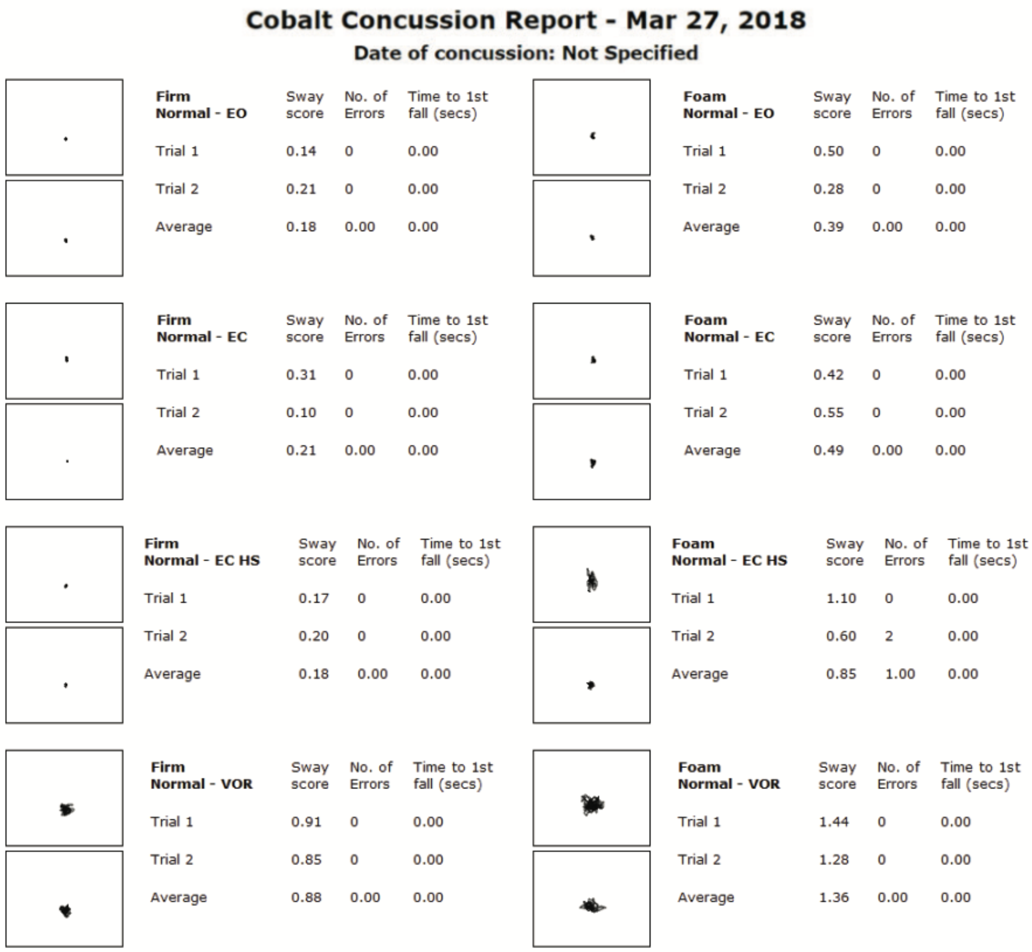
Table 3. Paired T-Test for Sway Score Significance, Baseline 1 and 2 Means with Standard Deviations

Conditions	Significance	Baseline 1 Mean	Standard Deviation	Baseline 2 Mean	Standard Deviation
COB3	.249	.4026	.18587	.3667	.09463
COB4	.001*	.8308	.27741	.7423	.19255
COB7	.011*	1.3590	.43153	1.2887	.40527
COB8	.113	.9321	.23366	.9682	.29407

Table 4. Paired T-Test for Errors During Trials Significance, Baselines 1 and 2 Means and Standard Deviations

Conditions	Significance	Baseline 1 Mean	Standard Deviation	Baseline 2 Mean	Standard Deviation
COB3	.887	.3205	.56763	.0897	.25318
COB4	-	.0128	.08006	.000	.0000
COB7	.001*	.8462	.85957	.7564	.73334
COB8	-	.0000	.00000	.0128	.08006

FIGURE



Cobalt Concussion Report - Mar 27, 2018

Date of concussion: Not Specified

Firm Normal - EO	Sway score	No. of Errors	Time to 1st fall (secs)
Trial 1	0.14	0	0.00
Trial 2	0.21	0	0.00
Average	0.18	0.00	0.00

Foam Normal - EO	Sway score	No. of Errors	Time to 1st fall (secs)
Trial 1	0.50	0	0.00
Trial 2	0.28	0	0.00
Average	0.39	0.00	0.00

Firm Normal - EC	Sway score	No. of Errors	Time to 1st fall (secs)
Trial 1	0.31	0	0.00
Trial 2	0.10	0	0.00
Average	0.21	0.00	0.00

Foam Normal - EC	Sway score	No. of Errors	Time to 1st fall (secs)
Trial 1	0.42	0	0.00
Trial 2	0.55	0	0.00
Average	0.49	0.00	0.00

Firm Normal - EC HS	Sway score	No. of Errors	Time to 1st fall (secs)
Trial 1	0.17	0	0.00
Trial 2	0.20	0	0.00
Average	0.18	0.00	0.00

Foam Normal - EC HS	Sway score	No. of Errors	Time to 1st fall (secs)
Trial 1	1.10	0	0.00
Trial 2	0.60	2	0.00
Average	0.85	1.00	0.00

Firm Normal - VOR	Sway score	No. of Errors	Time to 1st fall (secs)
Trial 1	0.91	0	0.00
Trial 2	0.85	0	0.00
Average	0.88	0.00	0.00

Foam Normal - VOR	Sway score	No. of Errors	Time to 1st fall (secs)
Trial 1	1.44	0	0.00
Trial 2	1.28	0	0.00
Average	1.36	0.00	0.00

Figure 1. COBALT printout

Fresno State

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