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Rehabilitation of an adolescent equestrian athlete with a history of multiple concussions: a case report describing an adapted return to sport protocol

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Abstract

Study Design: Case report

Background: Equestrian riding is a sport with a high risk of concussion. Currently, the literature guiding rehabilitation for concussions in equestrian athletes is limited, especially for directing return to sport.

Case Description: A 14-year-old female equestrian athlete presented to physical therapy following her third concussion in three years. Her primary complaints were headaches, dizziness, difficulty concentrating, light sensitivity, and neck pain. On examination, the patient demonstrated reproduction of symptoms during testing of vestibular-ocular reflex (VOR), showed a 3-line symptomatic loss on the Dynamic Visual Acuity Test (DVAT), and had impairments in the Joint Position Error (JPE) test (1/5 correct on the left; 4/5 correct on the right) and Balance Error Scoring System (BESS) (38/60 errors). A return to riding protocol was adapted from general return to sport guidelines and tailored to meet the unique demands of the patient's equestrian sport. The protocol included phased progression through no activity, light aerobic activity, moderate aerobic activity, sport-specific non-jumping skills, sport-specific jumping skills, full practice, and return to competition. During the protocol, the patient participated in eight physical therapy sessions over four weeks for vestibular training, aerobic conditioning, and cervical and core exercises, as well as equestrian exercises at her stables.

Outcomes: At the final evaluation, the patient reported no symptoms at rest, with exercise, or when testing VOR. Improvements were noted in the DVAT, JPE, and BESS, with changes in the BESS exceeding minimal detectable change. The patient completed the full return to riding protocol in eight weeks and was able to return to equestrian competition without complaints.

Discussion: This case report describes the physical therapy management and an adapted return to sport protocol for an equestrian athlete with a history of multiple sport-related concussions.

Level of Evidence: Therapy, level 5.

Keywords

concussion; pediatrics; post-concussion syndrome; horses; athletic injuries; return to sport

BACKGROUND

A concussion is a brain injury with a complex pathophysiological process that results from trauma to the head, neck or elsewhere on the body.^{3,9,32,33} In the United States, 1.6 – 3.8 million brain injuries, including concussions, occur during competitive sports and recreational activities.²³ Equestrian athletes are at substantial risk of a concussion due to falls or being bucked from a horse.^{27,43} Rates of concussion range from 10 to 45% of all equestrian-related injuries.^{22,27,38,43,50} These estimates are conservative as rates of concussion in equestrian sports are likely underreported.^{14,27} Typically, individuals experience symptom resolution within 10 – 14 days post-concussion;³² however 10 – 30% of individuals report persistent symptoms beyond this time frame.³⁹

Physical therapy can address post-concussion symptoms in order to facilitate symptomatic recovery and progress towards return to sport.^{11,36,39,40} Majerske et al.³⁰ reported that adolescent athletes who sustained a concussion during sport participation performed better on neurocognitive tests when allowed to engage in moderate intensity physical and cognitive activities. Progressive subthreshold aerobic exercise has been shown to be an appropriate strategy for addressing post-concussion symptoms in athletes with persistent symptoms.^{25,26} Schneider et al.⁴¹ demonstrated benefits of physical therapy on return to sport. A combination of vestibular and cervical spine interventions within physical therapy, in addition to range of motion and postural education, resulted in decreased time to return to sport clearance in adolescent and young adult athletes with persistent post-concussion symptoms.⁴¹

General protocols guiding return to sport after concussion have been developed and presented in the literature. In 2010, the American Academy of Pediatrics adopted the International Conference on Concussion in Sport's proposed 6-phase return to sport protocol that included periods of no activity, light aerobic activity, sport-specific exercise, non-contact training drills, full contact practice, and return to sport.^{31,33} A similar protocol was recommended in the recent Consensus Statement on Concussion.³² May et al.³¹ expanded on these 6-phase protocols by adding a moderate aerobic activity phase to bridge light activity and more demanding sport-specific tasks, as well as differentiating between limited and full contact drills. These general concussion guidelines can be used to tailor a sport-specific protocol for patients wanting to return to sport. Familiarity with the demands of each sport is vital because each sport has unique tasks that require different physical and cognitive skills.

To our knowledge there are no published cases describing the adaptation of general return to sport guidelines for equestrian athletes. Thus, the purpose of this case report was to describe the physical therapy management and adaptation of a return to sport protocol for an equestrian athlete with a history of multiple concussions.

CASE DESCRIPTION

History

The patient was a 14-year-old female competitive equestrian rider with a history of three concussions within a three-year span. The patient's first two concussions occurred as a result of being thrown from her horse. She reported she recovered from these episodes and had no residual symptoms or deficits. Three years after the initial concussion, the patient sustained a third concussion when she was struck in the left frontal region of her face with a hockey stick during a floor hockey game in physical education class. The patient was referred to neuropsychology and physical therapy. She experienced post-concussion symptoms for two weeks before her physical therapy evaluation was conducted.

Two days prior to her initial physical therapy visit, a neuropsychologist performed a neurocognitive evaluation, which included the computerized administration of Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT; ImPACT Applications, Inc., Pittsburgh, PA).^{1,48} ImPACT results revealed normal scores on verbal and visual memory, visual motor speed, and reaction time.⁴⁹ The patient scored a 27 on the 22-item Postconcussion Symptom Scale (PCSS) component of ImPACT, which is a "very high" normative score.²⁹ The PCSS is a reliable and valid measure of post-concussion symptoms.²⁹ An initial screen was conducted by a physical therapist at the neuropsychology visit to determine whether additional physical therapy was warranted. The quick screen involved assessment of the vestibular-ocular reflex (VOR) and visual motion sensitivity, which were both positive for reproduction of the patient's symptoms.

The patient self-reported symptoms of headache, dizziness, difficulty with balance, light sensitivity, neck pain, and concentration issues. Her past medical history was significant for myringotomy, tonsillectomy, and adenoidectomy. The patient was in the 9th grade and denied any history of learning disability, attention disorder, or failing grades. The patient's goal for physical therapy was to return to equestrian competition participation as quickly and safely as possible.

Initial Examination

The initial physical therapy examination included cervical spine screening, vestibular testing, balance assessment, and aerobic capacity (Table 1). An initial cervical screen included alar ligament, transverse ligament, and vertebrobasilar insufficiency testing due to the traumatic mechanism of injury.⁴⁵ The Sharp-Purser, Alar Ligament, and vertebrobasilar insufficiency tests are commonly used in physical therapy practice and were all negative.^{17,18} The patient demonstrated full cervical active range of motion with normal end-feels, but reported neck pain during cervical extension. Cervical segmental mobility and scapular mobility were not assessed during the initial evaluation. The patient was able to maintain the

deep neck flexor (DNF) endurance test for four seconds, indicating weakness in the DNF muscle group. For the DNF endurance test, the established normative time for adolescent females is 31 seconds²⁰ and the minimal detectable change (MDC) is 17.8 seconds.⁶ Joint position error (JPE) testing was used to assess proprioceptive awareness in the cervical spine. During JPE testing, a laser was attached to the patient's head and focused toward the center of a target. The patient was asked to close her eyes, turn her head to the side, turn her head back to the center, and open her eyes when she thought she was back at the target center. Correct performance is within 4.5 cm from the center of the target and a normal result is at least 4/5 correct performances per side.^{3,46} The patient scored 4/5 correct on the right and a 1/5 correct on the left indicating impaired cervical proprioception when turning her head to the left. The MDC for JPE has not been established.

Vestibular and oculomotor testing included a series of assessments for smooth pursuit, saccades, near point convergence (NPC), VOR, and visual motion sensitivity. These assessments were performed as described by Mucha et al.³⁵, however item scoring were adapted and only symptomatic response (i.e., reproduction of patient symptoms) was recorded. Additional testing included the head impulse test and the Dynamic Visual Acuity Test (DVAT).^{2,28,37,42} During smooth pursuit, the patient's eye movements were smooth and she was asymptomatic during horizontal and vertical movements. The saccades test, which examines a patient's ability to focus on a target and quickly move to another, was negative indicating her symptoms were not reflective of a central oculomotor disorder. During the NPC test, the patient was able to converge to five centimeters before seeing double and did not experience any symptoms. Thus, the patient's NPC was negative. During testing of VOR, the patient was unable to maintain a head speed of 180 beats per minute and experienced symptoms when the metronome was set to 120 beats per minute, indicating a symptomatic test. Moderate dizziness during the visual motion sensitivity test was provoked to 4/10 on a Numeric Rating Scale (NRS) with 0 meaning "no dizziness" and 10 meaning "worst possible dizziness." The head impulse test was used to rule out a unilateral vestibular hypofunction and was negative. Finally, the DVAT was positive as the patient lost three lines and reported symptoms of dizziness and headache. Impairments in VOR and DVAT with a negative head impulse test indicate that VOR is likely affected by visual sensitivity, rather than a true deficit in VOR.

Balance was assessed using the Balance Error Scoring System (BESS). The BESS consists of six testing conditions and is scored on the total number of errors during each position.^{10,47} The positions are Romberg, tandem, and single leg on firm ground and foam. Each position was held for 20 seconds with the patient's shoes off, hands placed on their hips and eyes closed. The maximum number of errors for each position is 10, with 60 total errors being the maximum score.⁴⁷ The MDC for the BESS is 9.3 points.⁸ The patient scored 38 errors during her initial evaluation, which was above the normative value of 16 errors for healthy adolescents between 11 and 14 years old, indicating impaired balance.¹³

During the patient's initial assessment with the neuropsychologist, it was recommended that the patient perform a graded exertion test during her initial physical therapy visit. The post-concussion syndrome submaximal symptom-limited threshold recovery protocol was administered. The submaximal symptom-limited threshold is determined by using the

modified Balke Treadmill Protocol in which the patient wore a heart rate (HR) monitor while walking on a treadmill at a constant speed of 3.6 mph.^{25,26,44} The incline of the treadmill was increased 1% every minute until the patient reported an increase in symptoms. The patient's maximum predicted HR was 206 bpm and she was able to perform 20 minutes of the modified Balke Treadmill Protocol with no increase in symptoms reaching a maximum HR of 180, which is above her 85% maximum HR, indicating no deficit in aerobic function.⁴⁴

Guided Physical Therapy Management within a Return to Riding Protocol

Since there was no equestrian-specific return to sport guidelines available, a return to riding protocol was adapted from guidelines proposed by May et al.³¹ Table 2 depicts the 7-phase return to riding protocol. Specific physical therapy exercises from each session are outlined in Table 3. Due to factors such as the patient's younger age, acuity of symptoms, and motivation, the patient was scheduled for physical therapy twice a week. The physical therapist and neuropsychologist collaborated with the patient's equestrian trainer to ensure the protocol included necessary sport-specific skills. As the patient advanced through the return to riding protocol, exercises transitioned from the physical therapy clinic to the stables where the patient's horses were maintained and her typical training occurred. The equestrian trainer supervised the stages of the return to riding protocol at the stables, while in communication with the physical therapist and neuropsychologist to ensure proper progression.

Phase I: No activity—The first phase of the return to riding protocol involved a period of no activity to provide physical and mental rest.^{33,39} This phase occurs during the acute injury period. In this case, Phase I occurred during the two weeks after the day of injury and prior to the patient starting physical therapy.

Phase II: Light aerobic activity—During the second phase, the patient began stationary biking at less than 70% maximum predicted HR for 10–15 minutes in the physical therapy clinic.³³ Stationary biking was chosen initially as this limited visual perturbation compared to other modes of aerobic training and allowed the patient to perform exercise without provoking dizziness. Other in-clinic exercises included seated VOR exercises progressing to standing, and supine chin tucks.³³ The initial VOR exercise performed was a replication of the VOR test. The goal of the exercise was to perform three sets of two minutes, while achieving moderate-level dizziness of 4–5/10 on the NRS. Reproducing dizziness during this exercise results in adaptation and habituation of the vestibular and visual system, respectively.⁴⁰ The metronome was set between 120 and 240 beats per minute and was determined by reaching the appropriate level of dizziness. Prior to initiating the subsequent set, dizziness symptoms were monitored for a return to baseline.³ The VOR exercise was prescribed as part of her home exercise program where she performed three sets of two minutes three times per day. Clinical recommendations for unilateral vestibular hypofunction state VOR exercises should be performed 3 to 5 times per day for a total of 20 minutes.¹² The patient was allowed to progress the intensity by increasing the beats per minute if 4–5/10 dizziness was not achieved. The goal of VOR exercises was to integrate the vestibular

and visual systems so that functional stimulation of these systems no longer provoked symptoms.^{3,47} Balance was addressed by changing the surface of the VOR exercises.

During an equestrian competition, the athlete must memorize the course design immediately prior to riding the course. Therefore, in order to add a cognitive task to this phase of the protocol, the patient memorized the course and walked through the course at the stables. The horse-rider connection is extremely important during equestrian activities; therefore, as quickly and safely possible, the connection should be restored. The patient rebuilt this connection by walking and leading her horse through the course. No horseback riding or resistance training was allowed during this phase. For the remainder of the phases, if the patient was asymptomatic for 24 hours following a phase, she progressed to the next phase.

³⁹ Phase II began on day 15 and lasted for one week. Phase II consisted of two physical therapy sessions and one session at the stables.

Phase III: Moderate aerobic activity—The third phase of the return to riding protocol was moderate aerobic activity, which included performing aerobic exercise on a bike, elliptical and treadmill for 20–30 minutes at less than 85% maximum predicted HR.³³ Elliptical and treadmill added a visual perturbation to challenge the vestibular system. VOR exercises were progressed to incorporate a busy background, unstable surface and walking. Light resistance training began during this phase including deep neck flexor and core stabilization exercises for addressing the patient's cervical impairments.

During stable sessions, the patient was permitted to ride her horse beginning with a walk and progressing to a slow trot on the horse. To add gaze stabilization into this phase, the patient focused on an object in the distance while riding. Strengthening exercises on the horse included riding in the two-point position - a position required for jumps - and riding without stirrups for one to two minutes. The goal of this phase was to increase HR, build up cardiovascular endurance, and improve core and lower extremity strength. Phase III began on day 22 and lasted two weeks. Phase III included four physical therapy sessions and four sessions at the stables.

Phase IV: Sport-specific, non-jumping drills—The fourth phase of the return to riding protocol was sport specific, non-jumping skills. During physical therapy, the patient continued light resistance training exercises as well as progressing VOR exercises. The riding position was mimicked in the physical therapy clinic using a Bosu Balance Trainer (Bosu, Inc., Ashland, OH), requiring the patient to maintain balance with perturbations.

Non-jumping skills included cantering, complete flat work, and cavalettis work. Cantering is a three-beat horse gait where both front and rear legs on one side land further forward than those on the other side and is typically around 10 – 17 miles per hour. Complete flat work includes skill where the horse is on flat ground such as circles, turns and transitions from pace to pace. Cavaletti is a small jump that is no more than 12 inches off the ground that is designed for the horse to step rather than leap over. Cavaletti work helps the patient with counting strides for bigger jumps. The goal of this phase was to improve control and coordination on the horse as monitored by the equestrian trainer. Phase IV began on day 36

and lasted one week. Phase IV consisted of two physical therapy sessions and two sessions at the stables.

Phase V: Sport-specific, jumping drills—The fifth phase of the return to riding protocol was sport-specific, jumping skills. At this phase and subsequent phases, all training was conducted at the stables. The patient progressed to multi-step training drills, such as small jumps over obstacles and normal resistance training exercises on land as well as on horse. The jumping drills require measuring distance and counting steps to insure proper take off distance. Progressing to larger jumps began after mastering the small jumps. Mastery, as assessed by the equestrian trainer, was based off consistent counting of steps before the jump and proper takeoff and landing. Cognitive load was increased during this phase by increasing the demand of the jumps and course memorization. The goal of this phase was to provide cognitive load while introducing sport-specific forces related to jumping. This was a crucial step in the protocol and was gradual due to sensitivity of forceful movements after concussion.³³ Phase V began on day 43 and was one week in duration. To ensure proper progression, the physical therapist was informed of patient performance and response to specific activities.

Phase VI: Full practice—The sixth phase of the return to riding protocol was full practice. The athlete participated in normal training activities (e.g., full course work), but no competitions. The goal of this phase was to restore confidence and allow the equestrian trainer to assess functional skills. Phase VI began on day 50 and lasted one week.

Phase VII: Return to Competition—The last phase of the return to riding protocol was return to competition. On post-concussion day 57, the neuropsychologist cleared the athlete for full competition based on symptom-free progression through the full protocol. The athlete competed in normal competition activities while monitoring symptoms.³³

OUTCOMES

The patient was re-assessed six weeks after the initial physical therapy evaluation (eight weeks after injury) and at the completion of the return to riding protocol. She demonstrated pain-free cervical extension and an increase in DNF endurance from four seconds at baseline to 15 seconds, which did not exceed the MDC of 17.8 seconds. However, since this patient did not present with neck pain at the final physical therapy session, DNF endurance was not seen as an impediment for return to sport clearance. There was an increase in the number of correct performances on the JPE from 4/5 correct on the right and 1/5 correct on the left to 5/5 correct on both sides, indicating an improvement in cervical proprioception. The VOR test at initial evaluation provoked dizziness symptoms at 120 beats per minute on the metronome. At the final evaluation, the patient was able to perform the VOR test at 240 beats per minute without any symptoms present. The visual motion sensitivity test provoked dizziness symptoms of 4/10 on an NRS during the initial evaluation, but did not provoke dizziness at discharge (e.g., 0/10 on NRS). The patient improved from a three-line loss with symptoms during the DVAT at evaluation to a one-line loss with no symptoms at discharge, which is considered a normal result. The BESS Test improved from 38 errors at evaluation to 12 errors at discharge, which is also considered a normal result and exceeded the MDC of

9.3 errors. The patient did not experience an increase in symptoms during progression of phases in the return to riding protocol. The patient scored a 0 on the PCSS, which reflects no symptoms at discharge and is considered a “low-normal” normative score.²⁹ She progressed through the full protocol in eight weeks and returned to competition without symptoms.

DISCUSSION

This case report describes the physical therapy management and successful return to sport of an equestrian athlete with a history of multiple concussions. The physical therapy program included an impairment-based approach that involved exercises for the cervical spine, vestibular system, and balance. Since there are no equestrian-specific return to sport guidelines, a protocol was adapted to direct the patient’s progression back to competition. The return to riding protocol was patterned after existing sport-specific guidelines and is an example of how guidelines can inform clinical application.

Concussion recovery timelines vary between individuals. McKeon et al.³⁴ reported 88.8% of high school athletes return to sport within three weeks post-concussion. However, prior work has shown that younger high school athletes recover from a concussion slower than college-aged individuals.^{7,19} Additionally, females take longer to recover and are more likely to have symptoms longer than a month in duration.¹⁹ In this case report, the adolescent female patient had an increased risk for slow recovery and future concussion episodes due to her age, sex, and history of multiple concussions.¹⁹ At the time of the initial evaluation, she was still experiencing symptoms two weeks post-concussion. Brooks et al.⁴ showed that adolescents with previous history of concussions present with more baseline symptoms than those without a history of concussion. Another outcome consideration for patients with prior concussions is the risk of other musculoskeletal injuries. For example, recent preliminary evidence suggests that individuals with a history of previous concussion may be at risk for subsequent lower extremity injury after returning to sport.^{5,16,21,24} Although no research has yet demonstrated this, it is plausible that physical therapy may serve as a preventive strategy to reduce risk of future non-concussion injury during sport participation.

The return to riding protocol described in this case report was adapted from other return to sport protocols.³³ The novel additions to the protocol include sport-specific tasks for equestrian athletes that were performed in the physical therapy setting and in the actual equestrian training environment. In the current case, a targeted rehabilitation approach directed interventions to the patient’s visual motion sensitivity, tracking deficits (e.g. impaired VOR) and cervical impairments with progression and adaptations to sport-specific tasks at the stables. In contrast to other sports, equestrian athletes not only have to control their own body but also must control the movements of the horse. A fundamental skill in equestrian athletes is the ability to be able to use their body to communicate with the horse during competition. The rider must be responsive to the horse’s character and movements in order to successfully complete the course.¹⁵ Therefore, we believe restoring the rider-horse connection early in the protocol in a controlled environment was critical to improving rider confidence and ensuring full return to competition. During equestrian competition, the rider must focus on the next jump in the distance. Adding in gaze stability on the horse to the

protocol helped keep the rider-horse connection as well as improve VOR in order to decrease symptoms.

There are limitations to consider. This is a single patient case study that is limited in generalizability to other patients with potentially complex presentation. Sport-related concussions can involve different clinical subtypes that may require personalized treatment approaches.³ While the patient was able to return to competition 6 weeks after initiating physical therapy, long-term follow-up data are not available. Additionally, there was a lack of data on the quality of sport performance once the patient returned to riding. While a validated measure of post-concussion symptoms was included, the pre-to-post administration of the PCSS differed in format. At baseline, the PCSS was administered as part of the ImPACT computerized program, while at follow-up, a written form was used. Additionally, it is common for “healthy” non-concussed adolescents to report low-level symptoms that range from scores of 1–9 on the PCSS.²⁹ The patient’s score of 0 is considered low-normal and it may not be representative of a typical outcome response. During the initial neuropsychologist visit, a quick screen was administered by a physical therapist to determine whether physical therapy was warranted. The choice of screening tests was based on the judgment and experience of the evaluating physical therapist; however, it is unknown whether the selected screening tests reflect the optimal set of tests for determining whether a patient will benefit from physical therapy. Cognition is commonly affected in concussions; however, cognition was not screened during the physical therapy evaluation, rather it was assessed by the neuropsychologist. It is important to note that not all concussed patients have access to a neuropsychologist in a primary care setting. In such cases, the physical therapist may be responsible for screening for cognitive deficits in this patient population.

In conclusion, this case report describes the physical therapy management of an adolescent equestrian athlete using an impairment-based approach. Moreover, this case depicts how existing return to sport guidelines can be adapted for use with patients with unique sport demands.

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Table 1.

Examination findings at the initial physical therapy visit.

Examination tests	Result
Cervical screening	
Sharp-Purser	Negative
Alar Ligament	Negative
Vertebrobasilar insufficiency	Negative
Cervical range of motion	
Flexion	WNL
Extension	WNL, but with pain
Rotation	WNL
Side-flexion	WNL
Deep neck flexor endurance	4 seconds
Cervical proprioception: Joint Position Error	4/5 correct to right side 1/5 correct to left side
Vestibular and oculomotor Screening	
Smooth Pursuit	WNL
Saccades	WNL
Near Point Convergence	WNL
VOR	Symptomatic
Visual Motion Sensitivity	Symptomatic
Head Impulse Test	WNL
Dynamic Visual Acuity Test	Symptomatic
Balance: Balance Error Scoring System	38 errors
Aerobic: Balke Treadmill Protocol	Negative

Abbreviations: VOR = vestibular-ocular reflex; WNL = within normal limits

Table 2.

Novel adaptation of a graded return to sport protocol applied to an equestrian athlete.

Protocol Phase	Phase Objective	Phase Duration and PT Sessions	Exercises	Progression Criteria
I: No activity	Symptom recovery	2 weeks (from injury to initiation of PT)	Complete physical and cognitive rest	Once medical clearance is provided, advance to phase II and begin rehabilitation
II: Light aerobic activity	Increase HR and restore connection between rider and horse	1 week in duration (began on day 15) PT sessions #1–2	PT Exercises * : Walking or stationary bike keeping intensity < 70% MPHR for 10–15 minutes Begin VOR exercises and cervical stabilization No resistance training Stable Exercises: Memorize and walk course (rider only) Walk (on horse) and focus on objects in the distance	If symptom-free for 24 hours following completion of phase II, progress to phase III
III: Moderate aerobic activity	Increase HR and build cardiovascular endurance Begin conditioning on horse Build core and lower extremity strength	2 weeks in duration (began on day 22) PT sessions #3–6	PT Exercises * : Stationary bike, elliptical, jogging keeping intensity < 85% MPHR for 20–30 minutes Begin light resistance training Stable Exercises: Trot Riding in 2 point position for 1–2 minutes without stirrups	If symptom-free for 24 hours following completion of phase III, progress to phase IV
IV: Sport-specific, non-jumping drills	Begin sport-specific drills on horse	1 week in duration (began on day 36) PT sessions #7–8	PT Exercises * : General sport-specific drills Light resistance training Stable Exercises: Sitting trot Cantering Ground pole and cavalettis work Complete flat work	If symptom-free for 24 hours following completion of phase IV, progress to phase V
V: Sport-specific, jumping drills	Advance sport-specific drills to prepare for return to full practice	1 week in duration (began on day 43)	Stable Exercises: Progression to multi-step training drills Progressive return to normal resistance training Small jumps with measuring lines Progress to larger jumps	If symptom-free for 24 hours following completion of phase V, progress to phase VI
VI: Full Practice	Restore confidence and assess functional skills by equestrian trainer	1 week in duration (began on day 50)	Stable Exercises: Participate in normal training activities but no competing Full course with related distance	If symptom-free for 24 hours following completion of phase VI, progress to phase VII
VII: Return to Competition		Patient cleared for full competition 8 weeks (day 57) after injury	Normal competition as tolerated Monitor symptoms	

* See Table 3 for specific exercises performed during each PT session

Abbreviations: HR = heart rate; MPHR = maximum predicted heart rate; PT = physical therapy; VOR = vestibular-ocular reflex

Table 3.

Detailed summary of physical therapy exercises at each session.

Session	Exercise
Protocol Phase II: Light aerobic activity	
1	Stationary bike for 20 minutes VOR performed in sitting facing a blank wall in a quiet room at 120 bpm for 3 sets $\times$ 2 minutes
2	Stationary bike for 15 minutes Supine chin tucks VOR performed in standing facing blank wall in a quiet room at 170 bpm for 2 sets $\times$ 2 minutes VOR weaving through cones for 2 minutes
Protocol Phase III: Moderate aerobic activity	
3	Stationary bike for 15 minutes Agility ladder drills Prone planks Supine chin tucks VOR performed in standing facing a busy gym at 150 bpm for 2 sets $\times$ 2 minutes VOR weaving through cones for 2 minutes
4	Stationary bike for 15 minutes JPE tracing an object on wall VOR performed standing on a Bosu Balance Trainer in busy gym at 230 bpm for 3 sets $\times$ 2 minutes VOR weaving through cones at 230 bpm for 2 sets $\times$ 2 minutes
5	Elliptical for 15 minutes Supine chin tucks Prone planks Quadruped exercises with a cuff weight on head and opposite extremity lifting Agility ladder drills VOR performed standing on a Bosu Balance Trainer in busy gym at 230 bpm for 3 sets $\times$ 2 minutes VOR weaving through cones at 230 bpm 2 sets $\times$ 2 minutes
6	Elliptical for 15 minutes Supine chin tucks Prone planks Quadruped exercises with a cuff weight on head and opposite extremity lifting VOR performed standing on a Bosu Balance Trainer in busy gym at 240 bpm for 3 sets $\times$ 2 minutes VOR weaving through cones at 240 bpm for 2 sets $\times$ 2 minutes
Protocol Phase IV: Sport-specific, non-jumping drills	
7	Supine chin tuck and lift Prone plank with cuff weight on head VOR performed standing on Bosu Balance Trainer in busy gym at 240 bpm for 3 sets $\times$ 2 minutes VOR weaving through cones at 240 bpm for 2 sets $\times$ 2 minutes Visual tracking of ball toss with 180 degrees turn for 3 sets $\times$ 1 minute Elliptical with head movements, ON for 1 minute/OFF for 1 minute, for 20 minutes total
8	VOR performed standing on a Bosu Balance Trainer at 240 bpm for 3 sets $\times$ 2 minutes VOR weaving through cones at 240 bpm for 2 sets $\times$ 2 minutes Visual tracking of ball toss with 180 degrees turn for 3 sets $\times$ 1 minute Agility ladder drills – memorize five exercises at once and then complete Squatting on a Bosu Balance Trainer with perturbations

Abbreviations: bpm = beats per minute; JPE = joint position error; VOR = vestibular-ocular reflex