Chapter

Concussion and Balance in Sports

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Abstract

Balance, spatial orientation and stable vision are imperative factors for sports or any other physical activity. It is achieved and maintained by a complex integration set of sensorimotor control systems that include sensory input from vision, proprioception or somatosensory and the vestibular system. A Sport-Related Concussion (SRC) is an individualized injury that presents a range of clinical signs and symptoms (cognitive, physical, emotional, somatic, and sleep-related). For this reason, SPR is a meaningful public health issue that involves a multidisciplinary team to properly manage it. In the sports medicine filed, Sports-Related Concussion assessment and management has become an argumentative issue. Presently, the consensus includes a combination of subjective examination, combined by multifactorial evaluation batteries that allowed to verify several components of brain function. Athletes frequently complain of dizziness and imbalance subsequent a concussion, and these symptoms can expect increased period to recover and return to play. Balance assessment is an important component of the concussion evaluation, as it can contribute with an awareness about the function of the sensorimotor systems.

Keywords: Assessment, Balance, Concussion, Sports, Vestibular

1. Introduction

Concussion is one of the most common sports-related injuries [1]. Lately, concussion has converted an import subject for injury prevention in sport due to the increasing concern surrounding its medium- and long-term consequences. The assessment should be conducted preferably in a systematic approach. The evaluation should contain clinical history and specific details about the injury, followed by assessing neurocognitive function and balance [1, 2].

Balance performances a fundamental role in the maintenance of fluid, dynamic movement common in sport. And complains related to it are commonly reported symptoms following a sport-related concussion [3]. This chapter provide an overview of the systems involved in balance, the importance of assessing motor function following a concussion, and concussion management and treatment of vestibular and balance impairments in athletes.

Replace the entirety of this text with the introduction to your chapter. The introduction section should provide a context for your manuscript and should be numbered as first heading. When preparing the introduction, please bear in mind that some readers will not be experts in your field of research.

2. Balance

Balance, spatial orientation and stable vision are important components of physical activity and athletic participation [2].

Balance is the capability to keep the body's center of mass over its base of support. It is managed and maintained by a sophisticate combination of sensorimotor systems that include (1) vision, (2) proprioception/somatosensory and (3) vestibular systems [2, 4].

The accurate function of balance is essential to daily activities as allows to see clearly while walking and/or moving, to determine direction and speed of movements, to recognize orientation according to gravity, and to accomplish automatic postural modifications to sustain posture and stability in several circumstances and events [4]. The integration of these three components are used to maintain one's postural balance (**Figure 1**).

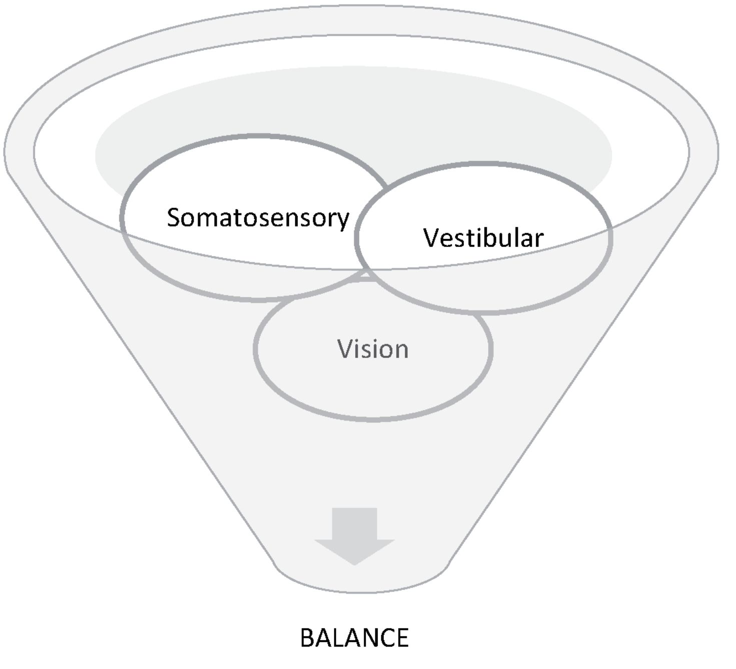

Figure 1.
The integration of three systems (vestibular, somatosensory and vision) are crucial to maintain one's postural balance.

3. Vestibular system

The vestibular system is a complex network that includes small sensory organs of the inner ear (utricle, saccule, and semicircular canals) and connections to the brainstem, cerebellum, cerebral cortex, ocular system, and postural muscles [4, 5].

The vestibular system is distinctive from other systems because it becomes immediately multisensory and multimodal [4]. For example, the vestibular system intercorrelates with the somatosensory system through the vestibulospinal reflex that is responsible for postural control and with the visual system controlling the vestibulo-ocular reflex (VOR), that maintains visual stability during head movements.

These linked group of systems allows the brain to differentiate active from passive head movements and provide information regarding head movements and positions to maintain visual and balance control. Furthermore, visual and somatosensory systems interact with the vestibular system throughout the central vestibular pathways and are essential for gaze and postural control. This interaction of multisensory and multimodal pathways is important for higher level of function such as self-motion perception and spatial orientation [2, 4–6].

Usually, individuals who present impairments related to the vestibulo-ocular reflex complain about dizziness and visual instability, this is due the organization and neurophysiology of the vestibular system [4].

Inversely, vestibulo-spinal dysfunction (correlated to the vestibulo-spinal reflex - VSR) normally present as consequences imbalance. Since these reflexes do not share the same neuronal circuitry, it is possible to have damages one without affecting the other [4, 6].

4. Sport-related concussion

Traumatic Brain Injury (TBI) occurs in subjects of all age groups and is a significant public health issue [7].

The Post-Concussive Syndrome (PCS) defines the set of symptoms and signs present frequently in a persistent mild TBI [8]. The Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) presents the clinical criteria for PCS [9]. The symptoms include headache, fatigue, vision changes, disturbances in balance, confusion, dizziness, insomnia, neuropsychiatric symptoms, and difficulty with concentration [7–9].

Disturbances in balance and dizziness are described in literature by 23–81% [8, 10–13] of concussed athletes [and is correlated with a 6.4-times higher risk to have another concussion if not treated, comparing to any other on-field symptom [11, 14]. Currently, several studies have presented that imbalance and dizziness are usual after a TBI have a correlation with the time to recovery (protracted recovery superior to 21 days), causing a delay comparing to the ones who did not present those symptoms [10–14].

Cohort studies and analysis had shown that women are at greater risk for persistent PCS. Besides, they are more likely to present headache, irritability, fatigue, and concentration problems post-concussion. Increases in age are also associated with a higher risk of PCS [15].

5. Assessment

The assessment of an injured player is facilitated by the presence of a certified athletic trainer, team physician, or other health care provider at the location where the injury occurred. It is important to mention that balance symptoms may not become apparent for several hours after injury bringing an additional obstacle to identification. Thus, the follow up for SRC is crucial to assess any balance dysfunction and treatment during the patient's recovery. Hence, vestibular and balance evaluations must be included in the concussion assessment battery and when available, objective tests may be used [16].

The assessments strategies present in this chapter were noted in scientific literature to be used as part of the concussion evaluation as well as a preseason baseline. The same tools for assessment are applied and can benefit other individuals with vestibular and ocular/oculomotor disorders as well [16–18].

Among the recommended assessments are physical examinations, clinical interviews, symptom reports, and neurocognitive and balance tests. For that reason, is recommended to use the Symptom Checklist. It is a self-report graded symptom checklist validated for concussion assessment. One example is the Sport Concussion Assessment Tool 5 (SCAT-5). The SCAT-5 contain 22 items and corresponding 0 to 6 points where higher numbers indicate greater symptom severity [19].

Below, it is described some assessments that can be applied in case of vestibular impairments after concussions:

Balance Error Scoring System (BESS)
Sensory Organization Test (SOT)
Head Shake-Sensory Organization Test (HS-SOT)
Concussion Balance Test (COBALT)
Vestibulo-Ocular Reflex and Vestibular/Ocular Motor Screen (VOMS)
Dynamic Visual Acuity Test (DVAT)
Head Impulse Test (HIT)
Post-Concussion Symptom Scale (PCSS)
Dizziness Handicap Inventory (DHI)
Dix-Hallpike Maneuver

5.1 Balance error scoring system (BESS)

The Balance Error Scoring System (BESS) is an objective measure of assessing static postural stability. It is an assessment that verifies three positions in different surfaces (firm and foam). The individual sustains the posture (feet together, tandem stance, or single leg stance) with the hands on their hips and without vision (eyes closed). During 20 seconds in each position, an examiner counts errors that include: to open the eyes, to remove hands from the hips, to lower the raised foot during single leg stance, to lift the heel or forefoot, or to remain out of the test position for more than five seconds. The advantages of the assessment are good reliability, low cost effective and easy to administer [20].

Figure 2.
Equipment for computerized Posturography. Courtesy: Interacoustics and Bertec.

5.2 Sensory organization test (SOT)

The Sensory organization test (SOT) is used to evaluate postural instability. It is a clinical tool used to that allows to manipulate the sensory systems that contribute to balance [21]. The SOT is completed via Computerized Dynamic Posturography (CDP), which provides objective measures of balance through implementation of software and protocols in combination with force plates (**Figure 2**). Through six unique conditions, the SOT examines sensory reweighting by challenging the somatosensory, visual, and vestibular systems. One of the benefits of the SOT identified in the literature is the assessment's potential to provide information about the specific sensory system affected by the injury that may assist in directing treatment for patients with a concussion (**Figure 3**). Studies suggested that the use of additional evaluation tools could increase the sensitivity of the SOT and improve the identification of balance issues after a concussion [22].

5.3 Head shake-sensory organization test (HS-SOT)

The Head Shake Sensory Organization Test (HS-SOT) is an expansion of the sensory organization test (SOT). HS-SOT has been proposed to increase the sensitivity of SOT incorporating head movements into the assessment for the two eyes closed conditions. The addition of the head shake provides an added challenge to the vestibular system, through stressing the Vestibulo-Ocular Reflex (VOR) [23].

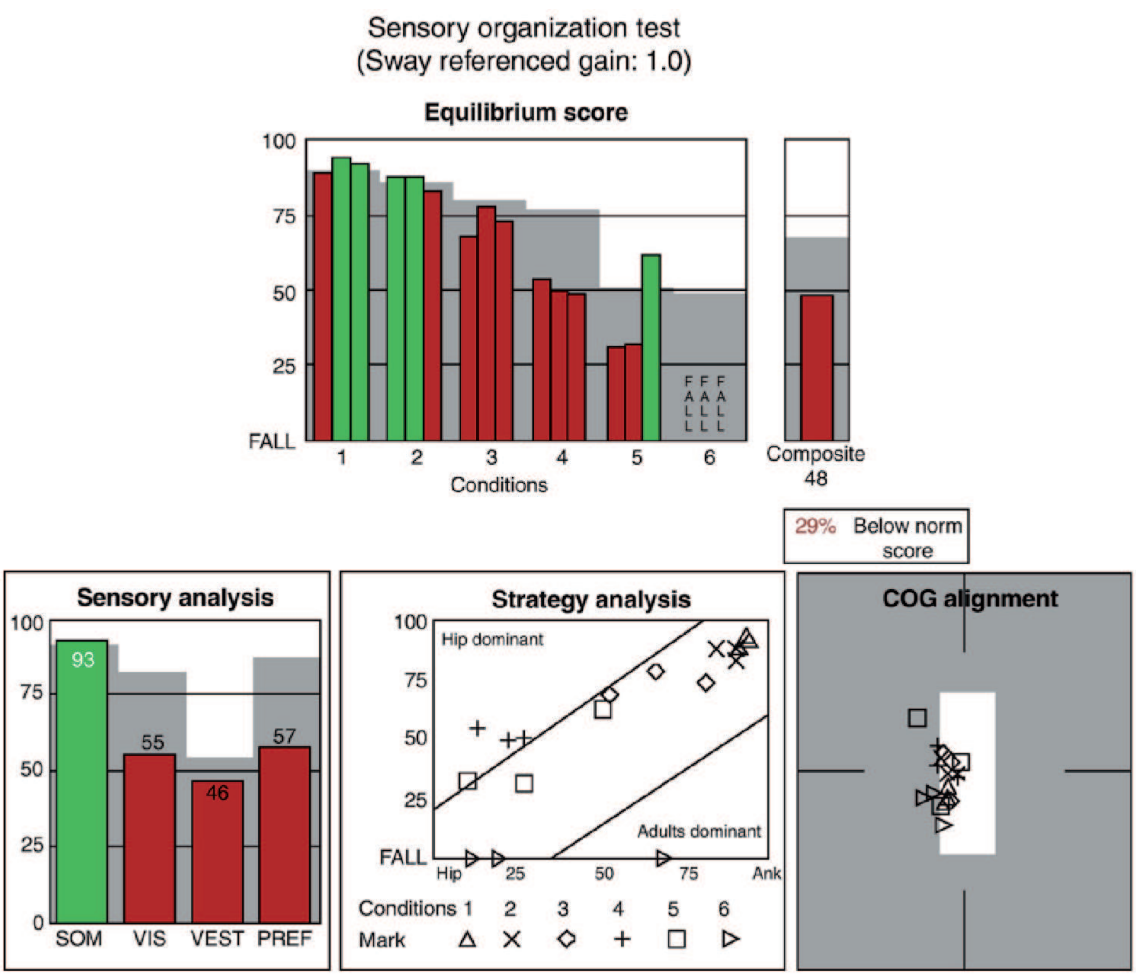

Figure 3.
Sensory organization test report. The green bars represent the patient's normal results, the red bars indicate that the patient had an abnormal result in the tested condition and the area with dark gray bars indicates the normative limit. Courtesy: Interacoustics and Bertec.

Researches indicated a deficit relative to evidence to the psychometric aspects of the HS-SOT, and appliance and value of this assessment in PCS and other clinical populations. Consequently, to evaluate the effectiveness of this tool, more studies must be done to evaluate the tool, prior to suggesting its use in clinical practice [22–24].

5.4 Concussion balance test (COBALT)

The Concussion Balance Test (COBALT), is an eight-condition test that assesses postural control with active vestibular stimulation using force plate technology (**Figure 4**). The test verifies the posture in a dynamic situation analogous to the one experienced during the sport. The goal is to try to reproduce the same or similar level of balance required to the activity. It is considered particular from other tools due the capability to identify subtle balance deficits. COBALT tasks the vestibular system by incorporating a head shake with an eyes-closed (visual suppression) [25].

5.5 Vestibulo-ocular reflex and vestibular/ocular motor screen (VOMS)

The evaluation of the Vestibulo-Ocular Reflex (VOR) and the oculomotor movements have been suggested as part of the clinical neurological examination for concussion. During the assessment, it evaluates aspects related to the interaction of both systems (vestibular and ocular) and other cranial nerves through functions that utilize both components. The VOMS (**Figure 5**) is a screening assessment that includes: (1) smooth pursuits, (2) horizontal and vertical saccades, (3) near-point of convergence (NPC) distance, (4) horizontal and vertical VOR, and (5) visual motion sensitivity (VMS). Initial studies including VOMS as a post-concussion assessment identified measurement properties that propose efficacy of this evaluation for SRC [26, 27].

5.6 Dynamic visual acuity test (DVAT)

The Dynamic Visual Acuity Test (DVAT) provides an instrumented, objective, behavioral assessment of vestibulo-ocular reflex (VOR) function in response to rotational or functional head movement stimuli by determining the smallest optotype an individual can identify during both dynamic and static conditions. One option to perform the DVAT is applying the Snellen Chart (**Figure 6**) combined with a metronome or other systems [28].

Figure 4.
COBALT courtesy: Bertec.

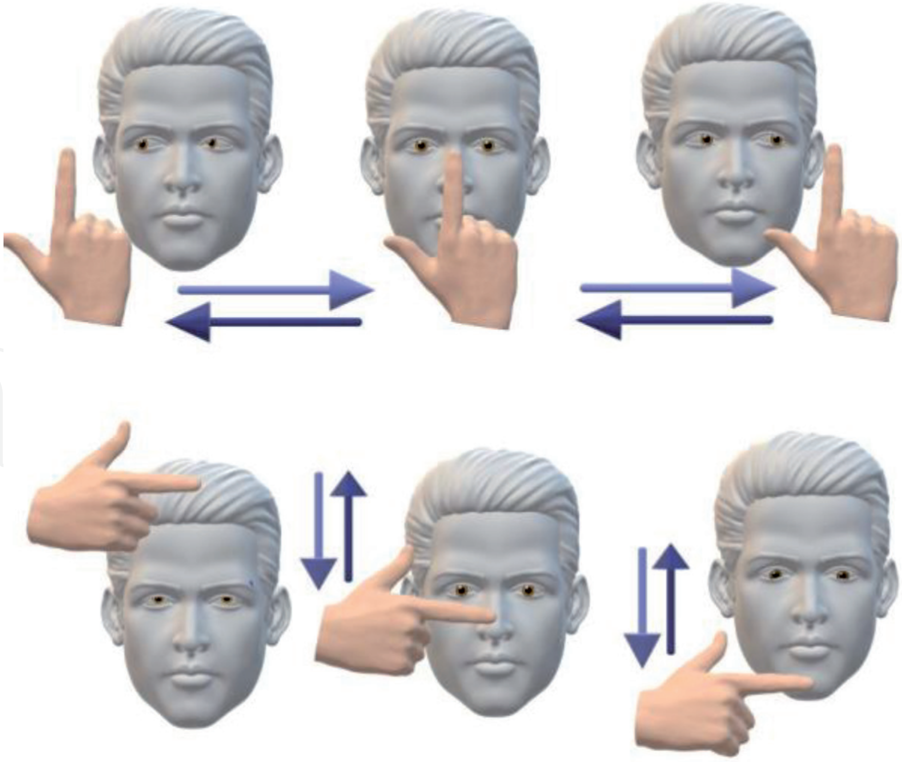

Figure 5.
Vestibular/ocular motor screen.

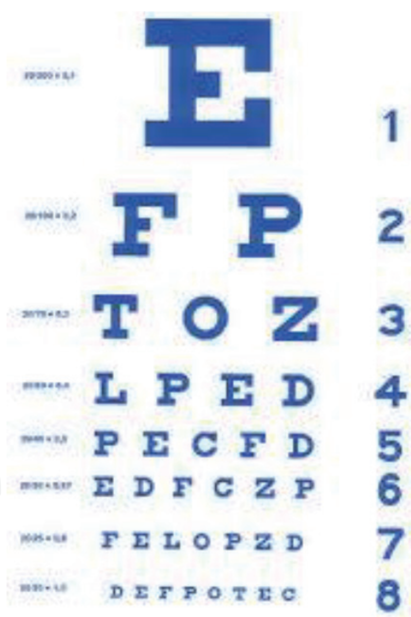

Figure 6.
Snellen chart.

It is also available in computerized systems. In this case, the patient is solicited to recognize the direction of the middle arm of the optotype while continuing either an active or passive head movement at a fixed velocity. According to the modification (increase or decrease) in the target size or optotype, established on the successes or failures on each trial until a final acuity is defined [29].

The test has been reported to have good reliability in healthy athletes however has not consistently demonstrated the ability to discern between those with and without a concussion. Further research is necessary to consider the clinical utility for SRC [28–30].

5.7 Head impulse test (HIT)

The HIT is a bedside technique used to diagnose reduction in vestibular function in one vestibular system versus the other. It allows the evaluation of VOR function in high head velocities (delivered by a clinician) in the direction of each pair of semicircular canals (**Figure 7**). During the head movement, the subject is asked to keep the eyes in a target or fixed object. The test can detect semicircular canal paresis or abnormal eye movements (as "catch up" saccade), which indicate peripheral vestibular disorder [31].

5.8 Post-concussion symptom scale (PCSS)

The inventory corresponds to 22-items (common concussion symptoms) and the athletes are asked to rate each symptom on a 7-point scale (**Figure 8**). The subjective measure is valuable in the clinical assessment for balance issues; however, studies

Figure 7.
Head impulse test (HIT).

SEVERITY RATING
Please use this scale to rate each symptom.
None 0 | Mild 1 2 | Moderate 3 4 | Severe 5 6

PATIENT'S NAME:

POST-CONCUSSION SYMPTOM SCALE

Symptoms	Date:	Date:	Date:	Date:	Date:	Date:	Date:
Headache							
Nausea							
Vomiting							
Balance Problems							
Dizziness (spinning or movement sensation)							
Lightheadedness							
Fatigue							
Trouble falling asleep							
Sleeping more than usual							
Sleeping less than usual							
Drowsiness							
Sensitivity to light							
Sensitivity to noise							
Irritability							
Sadness							
Nervous/Anxious							
Feeling more emotional							
Numbness or tingling							
Feeling slowed down							
Feeling like "in a fog"							
Difficulty concentrating							
Difficulty remembering							
Visual problems							
Other							
Total							

Figure 8.
Post-concussion symptom scale (PCSS).

frequently do not report comorbid circumstances or complains, such as cervical abnormalities that could affect in these symptoms associated with a lengthy recovery. More recently, the symptoms have been organized into clusters based on the etiology or concussion domain [32, 33].

5.9 Dizziness handicap inventory (DHI)

The inventory consists in 25-item questionnaire that assesses possible causes of balance issues and evaluate the impact of it in the quality of life (**Figure 9**). The possibly responses are "yes", "no" or "maybe". The DHI is distributed into three areas; emotional, functional, and physical to better identify the root cause of the dizziness The answers are graded and summed (varying in 100 to 0 total points), considering a higher score an indication of higher perceived handicap [34].

5.10 Dix-Hallpike maneuver

The Dix-Hallpike Maneuver evaluate the presence of Benign Paroxysmal Positional Vertigo (BPPV). It is important first to evaluate if no concern related

	Questions	Always	Sometimes	No
P1	Does looking up increase your problem?	☐	☐	☐
E2	Because of your problem, do you feel frustrated?	☐	☐	☐
F3	Because of your problem, do you restrict your travel for business or pleasure?	☐	☐	☐
P4	Does walking down the aisle of a supermarket increase your problem?	☐	☐	☐
F5	Because of your problem, do you have difficulty getting into or out of bed?	☐	☐	☐
F6	Does your problem significantly restrict your participation in social activities, such as going out to dinner, going to movies, dancing or to parties?	☐	☐	☐
F7	Because of your problem, do you have difficulty reading?	☐	☐	☐
F8	Does performing more ambitio dancing, and household chore putting dishes away; increase	☐	☐	☐
E9	Because of your problem, are home without having someone accompany you	☐	☐	☐
E10	Because of your problem, have you been embarrassed in front of others?	☐	☐	☐
P11	Do quick movements of your head increase your problem?	☐	☐	☐
F12	Because of your problem, do you avoid heights?	☐	☐	☐
P13	Does turning over in bed increase your problem?	☐	☐	☐
F14	Because of your problem, is it difficult for you to do strenuous housework or yard work?	☐	☐	☐
E15	Because of your problem, are you afraid people may think that you are intoxicated?	☐	☐	☐
F16	Because of your problem, is it difficult for you to go for a walk by yourself?	☐	☐	☐
P17	Does walking down a sidewalk increase your problem?	☐	☐	☐
E18	Because of your problem, is it difficult for you to concentrate?	☐	☐	☐
F19	Because of your problem, is it difficult for you to walk around your house in the dark?	☐	☐	☐
E20	Because of your problem, are you afraid to stay home alone?	☐	☐	☐
E21	Because of your problem, do you feel handicapped?	☐	☐	☐
E22	Has your problem placed stress on your relationship with members of your family or friends?	☐	☐	☐
E23	Because of your problem, are you depressed?	☐	☐	☐
F24	Does your problem interfere with your job or household responsibilities?	☐	☐	☐
P25	Does bending over increase your problem?	☐	☐	☐

Figure 9.
Dizziness handicap inventory (DHI).

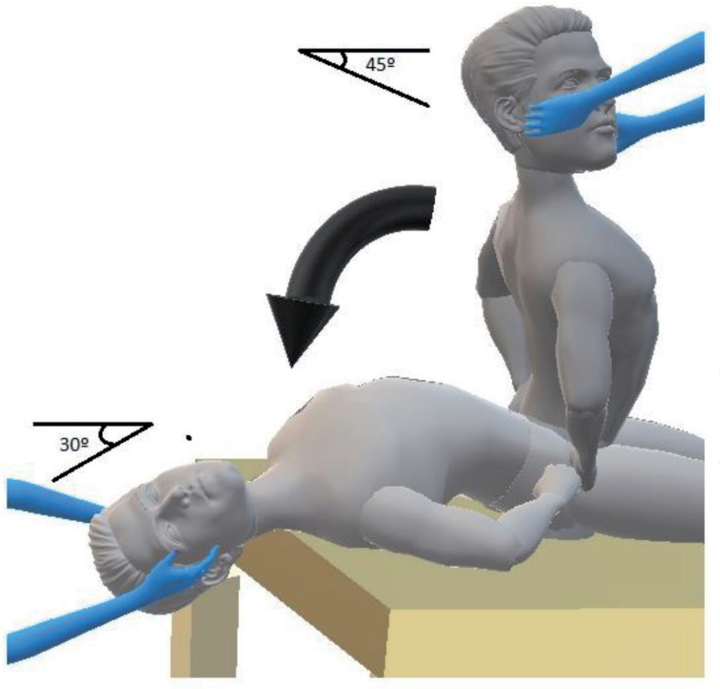

Figure 10.
Dix-Hallpike maneuver.

to cervical spine is present, before the administration. It is also termed the "head-hanging positioning maneuver" [35].

During the maneuver, the individual is positioned seated and the head is turned 45° toward the tested side. The individual is moved (lying down) into the supine position with the head extending (**Figure 10**). The patient's head is held in this position and the clinician verify the eyes to detect or not the presence of nystagmus. To complete the maneuver, the patient is returned to the seated position and they eyes are observed to detect presence of reversal nystagmus [35, 36].

6. Treatment

Vestibular Rehabilitation Therapy (VRT) is an exercise-based treatment program created to promote vestibular adaptation and substitution [37].

The objectives are: (1) to enhance gaze stability, (2) to enhance postural stability, (3) to improve vertigo, and (4) to improve activities of daily living. After SRC, different vestibular rehabilitation techniques may be used based on the symptoms and impairments present. Vestibular rehabilitation may help reduce dizziness and improve balance after SRC [38]. Studies combining individualized vestibular therapeutic rehabilitation techniques to an established physical therapy program has been seen to benefit individuals returning to play by decreasing recovery times and strengthening athlete's compensatory strategies to prevent reinjury [37–39]. Current evidence for optimal prescription and efficacy of VRT in patients with concussion is limited. Available evidence, although weak, shows promise in this population [37–40].

7. Conclusion

Poor balance has been associated with increased injury risk among athletes. The literature shows that over 6,000 athletes experienced a sport-related injury and over 25% of these injuries result in a loss of more than seven days of participation. Consequently, it is urgent to recognize instruments that prevent injuries and could improve balance.

A combination of tools for assessment, as: physical evaluation combined with other tests/exams/inventories provide a better comprehension for vestibular disorders in sport concussions. It is important to understand that the questionnaires and outcomes may have clinical utility in the evaluation of vestibular pathologies post-SRC but should not be used as a distinguishing point for vestibular diagnosis alone.

Knowledge of a patient's diagnosis is a critical foundation for planning comprehensive treatment programs with the goal to reduce impairment and symptoms and expedite the return to daily activities, sports, or work. Although vestibular rehabilitative therapy is beneficial among most populations post-concussion, further research should be conducted using individualized treatment protocol. Limitations of this review include the lack of available randomized controlled trials or cross-sectional studies; therefore, further research is determining the effectiveness of vestibular rehabilitative therapy is warranted. Additionally, normative data based on athletes should be included.

Conflict of interest

The author declares no conflict of interest.

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