MEDWIN PUBLISHERS
Committed to Create Value for Researchers

Annals of Physiotherapy & Occupational Therapy
ISSN: 2640-2734

The Role of Occupational Therapy in Concussion Rehabilitation and Symptom Management

Lew SV* and Waskiewicz M

New York University Langone Medicla Center, USA

***Corresponding author:** Stephen Van Lew, New York University Langone Medicla Center, 240 East 38th Street, 15th Floor, NYC, NY, 10016, USA, Tel: 646 5017707; Email: steve.vanlew@nyumc.org

Conceptual Paper

Volume 3 Issue 3

Received Date: August 26, 2020

Published Date: October 08, 2020

DOI: 10.23880/aphot-16000167

Abstract

Recently, there has been an increased focus in both the media and healthcare environment in the prevention, diagnosis, management and treatment of concussion and post-concussive syndrome. This increase in clinical concussion identification provides an opportunity for the profession of occupational therapy to promote itself as a viable option for individuals who may be experiencing difficulty in everyday occupations secondary to a concussion. Neurological dysfunction resulting from concussions, although often undetectable in conventional neuroimaging, can have considerable impact on an individual's overall participation in everyday life activities. This article outlines common categories of client factors and performance skill deficits and their impact on occupational performance seen in the post-concussion population. In addition, it proposes the potential roles of occupational therapy practitioners in the assessment and development of treatment interventions for this unique population, while highlighting the need for more occupational therapy treatment efficacy research studies addressing this population.

Keywords: Occupational Therapy; Physical Signs; Syndromes; Quality of Life

Abbreviations: PCS: Post-Concussion Syndrome; DTI: Diffusion Tensor Imaging; IADLs: Instrumental Activities of Daily Living; QOL: Quality of Life; PCSS: Post-Concussion Symptom Scale; NSUCO: Northeastern State University College of Optometry; DEM: Developmental Eye Movements Test; CISS: Convergence Insufficiency Symptom Survey; ASPS: Adult Sensory Processing Scale; COPM: Canadian Occupational Performance Measure; CNS: Central Nervous System; AT: Assistive Technology.

Introduction

Recently, there has been an increased focus in both the media and healthcare environment on the prevention, diagnosis, management, and treatment of concussion and post-concussion syndrome [1]. Multiple studies have indicated the rate of clinical identification of concussions is rising [2-4]. Currently, up to four million individuals sustain a concussion annually, with more than ten percent of those individuals losing consciousness [5]. Concussion is defined as a brain injury and "a complex pathophysiological process affecting the brain, induced by biomechanical forces," [6]. Further criteria for diagnosing concussion include

- Somatic, cognitive and/or emotional symptoms
- Physical signs (i.e. loss of consciousness or amnesia)
- Changes in balance
- Changes in behavior
- Cognitive impairment and
- Changes in sleep pattern [7].

This increase in clinical identification provides an opportunity for the profession of occupational therapy to promote itself as a viable option in the recovery process for individuals experiencing difficulty with everyday

occupations post-concussion given the complexity of the concussion diagnosis the trajectory for recovery is difficult to determine, however it is suggested that approximately 80%-90% of individuals spontaneously recover within 10 to 14days [8]. Particularly concerning to rehabilitation providers are individuals who have sustained a concussion and still present with symptoms after this 10 to 14day period of time. This condition is referred to as post-concussion syndrome (PCS). Individuals diagnosed with PCS experience symptoms that continue beyond the aforementioned 10-14day recovery period and can experience symptoms months and even years after the time of initial injury [7,9]. There is extensive literature outlining that individuals experiencing PCS often experience neurological dysfunction in the areas of somatic, cognitive, psychological and affective domains while simultaneously experiencing symptoms including headaches, dizziness, difficulty concentrating and depression [10]. More recently, literature has confirmed neurological dysfunction in both the visual and vestibular systems causing an overall increased demand on the sensory system [11-13].

Neurological dysfunction of this magnitude, although often undetectable in conventional neuroimaging, can have significant impact on an individual's overall participation in everyday occupations. Through the use of diffusion tensor imaging (DTI), recent research performed by Mustafi, et al. [4] confirmed that individuals who sustain a concussion often experience white matter damage in axonal structure and function. DTI neuroimaging measures water displacement and movement in the brain along the axonal white matter tracts [14]. Along with DTI demonstrating significant sensitivity to identifying axonal damage resulting from a concussion, significant positive clinical correlations have been identified with acute concussion symptoms and functional impairments in everyday occupations [4].

The previously described, often undetectable neurological brain dysfunction can negatively impact performance skills and client factors and, ultimately successful performance in occupations. Performance skills are goal-directed actions that are observable small units of engagement in daily life occupations, whereas client factors are specific capacities, characteristics or beliefs that reside in the person and then influence performance in occupations [15]. Occupational therapy is a rehabilitation discipline that uses therapeutic everyday activities (occupations) for the purpose of enhancing or enabling successful participation in roles, habits and routines in home, school, workplace, community or other settings [15]. This article will outline some of the more common performance skills, client factors and areas of occupational performance impacted by PCS and outline some assessments and treatment interventions that can be used to address functional limitations in the post-concussion population. The authors believe that promoting the positive impact that occupational therapy can have for this specific patient population is synergistic to the Occupational Therapy Practice Framework's III (OTPF-III) overarching statement describing the domain and process of occupational therapy as achieving health, well-being, and participation in life through engagement in occupation [15].

Visual Client Factors and Occupational Performance

PCS commonly manifests into deficits in the visual system, therefore negatively impacting the client factors of visual function. Such deficits can directly impact an individual's performance skills that are required to successfully engage in daily occupations. An example of this relationship can be seen through a significant reduction in the client factor of visual acuity and its negative impact on the performance skill of manipulating buttons, consequently affecting occupational performance in the occupation of dressing. The human visual system comprises greater than 50% of the brain circuits, and includes structures that are highly susceptible to injury after an individual sustains a concussion [16]. This large vision network involves both efferent and afferent neural inter-connections as well as processing from multiple areas of the brain, including frontal and posterior cerebral cortices, cranial nerves, and axonal interconnections [17]. Along with this cortical representation of vision, the cognitive control of vision, particularly eye movements, requires the coordination of reflexive and voluntary activity, including front parietal circuits and subcortical nuclei; both of these pathways are vulnerable to injury during a concussion [18]. It has been estimated that up to 82% of patients who sustain a concussion and have PCS will experience some type of deficits in visual function [11]. These could include functional visual deficits in monocular and binocular coulometer skills, accommodative and convergence/divergence dysfunction along with photosensitivity and visual-vestibular integration. Specific visual coulometer client factor deficits can be seen in fixation, pursuits and saccades. Saccades are integral in accurately providing the brain with the proper visual input of the letters and words on a page or screen during the task of reading.

Patients with post-concussion visual function deficits often report difficulty with the occupation of reading, including difficulty focusing on words, as well as increased eyestrain and headache when reading [1]. In addition, many instrumental activities of daily living (IADLs) are visually guided, such as reading, writing, computer use, cooking, cleaning, and driving [19]. Occupational performance impairments in these types of occupations can have a devastating impact on quality of life (QOL) and health status for individuals with PCS. An example of this can be seen in the findings of a study by Heitger, et al. [20] that found multiple

significant correlations between eye movement function and health status, with impaired eye movement function being negatively correlated with lower QOL and health status indicators.

Cognitive Client Factors and Occupational Performance

As previously outlined, individuals with PCS can also experience impairments in cognitive client factors of executive function, attention, and memory, which has been associated with impaired visual saccadic function [21]. The interplay between these cognitive skills and the visual system cannot be understated. A study by Pearce, et al. [22] found a statistically greater amount of cognitive deficits including attention and executive functioning performance in a group of post-concussion individuals as compared to a group of non-concussed individuals. As with some other PCS symptoms, cognitive client factor deficits are often subtle and yet have a significant impact on occupational performance. A particular area of impairment within this domain is dual-task occupational performance. Dual-task performance tends to involve a performance of a mobility activity while simultaneously performing a cognitive component to this activity. An example of a common dual-task occupation includes walking across a street while reading a street sign on their phone. The dual-task paradigm is highly relevant with this particular population because most occupations that they are performing involve simultaneous performance of cognitive and motor client factors and performance skills [23].

Sensory Processing Performance Skills and Occupational Performance

Sensory processing is defined as the ability to rapidly perceive, integrate, organize and respond to incoming sensory information [24]. The human body has eight sensory systems; visual, auditory, tactile, olfactory, gustatory, vestibular, proprioception, and interception. These eight sensory systems are considered sensory functions as part of the client factors domain found in the OTPF-III [15]. Sensory processing, by which individuals receive, process and then respond to sensory information can be considered as performance skills as indicated by the inclusion of processing skills as performance skills in the OTPF-III [15]. Accurate sensory processing is critical to adaptive functioning and successful performance in all aspects of occupations. Individuals experiencing sensory processing deficits post-concussion can have symptomatology in three different categories; sensory over-responsively, sensory under-responsively and sensory seeking [25]. The concussion literature is sparse in regards to this area of occupational performance challenges relating to post-concussion sensory processing deficits. Recently, Van Lew, et al. [26] completed a study demonstrating a greater prevalence of sensory processing dysfunction in a post-concussion population as compared to normative data. The results of this study also indicated some individuals' experienced challenges in occupational performance in certain IADLs. This study found moderate to high negative correlation between the presence of sensory processing dysfunction levels and independence in everyday functional activities.

In summary, a concussion, the mildest form of a mild traumatic brain injury, can result in neuropathology that can affect areas of client factors and performance skills, negatively impacting individuals' everyday successful engagement in occupations. Many of these impairments go undiagnosed due to the inability of conventional clinical neuroimaging to identify specific brain neuropathology [27]. Due to these factors, along with the evolving constellation of somatic, sensory, cognitive and neurobehavioral symptoms, concussion is considered to be among the most complex injuries to diagnose and manage from both a medical and rehabilitation perspective [6].

Implications for Occupational Therapy Clinical Practice

Achieving health, well-being, and participation in life through engagement in occupation is the overarching statement that describes the domain and process of occupational therapy in its fullest [15]. Considering the individualized challenges in occupational performance that individuals may experience with PCS, the role that occupational therapy can have is significant and needs to be further developed and researched in the clinical setting. The unique paradigm in which occupational therapy practitioners examine occupational performance and the individualized and subtle impairments that post-concussion individuals possess creates opportunities for our profession to assist these individuals given our professional domain. Only occupational therapy practitioners focus on the use of occupations to promote health, well-being and participation in life. This focus enables occupational therapy practitioners to assist individuals in achieving their desired outcomes in everyday occupations that might be negatively impacted by post-concussion symptomatology. Specifically, the occupational therapy process involves evaluating individuals through assessments, providing therapeutic interventions and targeting intervention outcomes.

Concussion Assessments

Occupational therapists rely on their unique set of activity analysis skills when evaluating individuals with PCS. Activity analysis is a process to help the client and occupational

therapy practitioner understand the demands of a specific activity [15]. When used in conjunction with an occupational profile and analysis of occupational performance, it is considered to be integral in assisting post-concussion individuals with identifying challenges in health, well-being, participation and successful engagement in occupations. Occupational therapy practitioners analyze the demands of an activity or occupation to understand specific client factors and performance skills necessary to successfully engage in an occupation. Assessing occupational performance includes an integrated approach examining all relevant aspects of successful engagement in daily occupations including performance skills, client factors and the context or environment in which the occupation is performed. Considering the subtle and sometimes very individualized symptomology that post-concussion individuals can present with, the use of both self-report and performance based assessments is recommended for this population. For example, through a detailed self-report occupational profile, which is a summary of a client's occupational history and experiences, pattern of living, interests, values, and needs, accurate identification of occupational challenges and client centered outcomes can be explored by the occupational therapist and client.

Along with engaging post-concussion individuals in an occupational profile and analysis of their occupational performance, the use of standardized concussion assessments can be useful during the occupational therapy evaluation process. Two very commonly used post-concussion evaluation tools include the Post-Concussion Symptom Scale (PCSS) and Sport Concussion Assessment Tool-5 (SCAT-5). These tools are fairly easy to administer and do not require any extensive formal training [28]. The SCAT-5 can be used to obtain baseline information on healthy athletes prior to the start of a sports season as well as post-injury. Both the PCSC and the SCAT-5 are standardized assessment tools used to assess individuals who have sustained either a sports or non-sports related concussion to evaluate a variety of physical, cognitive, emotional and sleep changes following the injury. Although these assessments are universal in nature and can be administered by other health care providers the information from these assessments can be very valuable in determining both client factor issues and performance skills issues during the occupational therapy evaluation process which can highlight difficulties in everyday occupations. Both the client factor of vision function, along the performance skills of sequencing or attending can be screened through these assessment tools. The two of these assessments have good levels of psychometric properties including inter-rater reliability, criterion validity and tool utility [29-31].

There are a variety of standardized assessments that can be used by occupational therapists to assess visual function including the Northeastern State University College of Optometry (NSUCO), Developmental Eye Movements test (DEM) and the Convergence Insufficiency Symptom Survey (CISS). These assessments are universal in nature but can provide excellent levels of assessment of the client factor of visual function. The NSUCO assesses the quality of both pursuit and saccadic eye movements while also taking posture, head movement and direction into account. Patients are scored looking at their ability, accuracy of the eyes and movement of both head and body. Difficulty in these visual client factors of pursuits and saccades can result in occupational performance difficulty visual guided occupations. The test requires only minimal language and cognitive skills and verbal instructions for the tests are simple [32].

The IADL of reading is a very important occupation that is often necessary for successful engagement in other occupations. In order to be successful in baking a cake, an individual would require the functional visual skills to read the recipe, find the ingredients on the shelf and carry out the activity in a safe, successful manner. Reading is a highly complex integrated occupation that involves both physiological and psychological processes. The way in which the eyes move can provide insight into the degrees to which these processes are functioning. The DEM determines saccadic eye movement efficiency based on the speed and accuracy that a series of single digit numbers can be located, recognized, and verbalized rapidly [33]. The test does not measure reading, but rather indirectly measures the required similar eye movements associated with the occupation of reading. Although it was originally developed for use with children, it has the potential for identifying the client factor of visual dysfunction with neurological impairments in adults [33].

The third standardized visual assessment mentioned, the CISS, is a validated 15-point questionnaire that was originally used to assess change in visual symptoms after treatment for convergence insufficiency. It is a self-report assessment and recently it's been used and studied as a screening tool to detect deficits in visual functions in patients who have suffered from a concussion [34]. As with the NSUCO and the DEM, this tool can provide valuable information on the client factors associated with overall of visual function along with helping the individual identify post-concussion visual function symptomology such as blurry vision when reading or eye strain when looking at computer monitor.

In addition to the previously mentioned vision assessments occupational therapy based sensory processing assessments that can be used for the post-concussion population. These assessments can provide important information on how individuals are perceiving and processing

sensory information. These self-report assessments, both created by a team of occupational therapists, include the Adult Sensory Profile (ASP) developed by Brown, et al. [35] and the Adult Sensory Processing Scale (ASPS) developed by Blanche, et al. [36]. They both examine adult sensory processing patterns and dysfunction as compared to normative data. Most importantly, these tools can help to identify an individual's sensitivity to certain sensory information and how they respond or adapt to such sensory input during everyday occupations.

Finally, a more comprehensive global assessment called the Canadian Occupational Performance Measure (COPM) was designed by occupational therapists to detect changes in the self-perception of an individual's occupational performance and satisfaction over time by identifying problems in performing everyday occupations specifically in the areas of self-care, productivity, and leisure [37]. The COPM is administered in a five step process through the use of semi-structured interview conducted by the therapist. Steps include defining the problem, problem weighting-once the specific problems have been identified, rating the importance of each of these activities on a scale of 1-10, scoring, re-assessment and follow-up [37]. The main purpose of the measure is to allow occupational therapists the ability to clearly establish goals based on individual client perceptions of need and measures change objectively in specifically defined problem areas. The COPM is a reliable and valid outcome measure that can be used in a variety of settings. Use of the COPM with the concussion population allows the occupational therapist to effectively structure and focuses the intervention process and provides the client the opportunity to specify occupational performance areas to concentrate on throughout the therapy process (Figure 1).

Assessment	Area Assessed
Occupational Profile	Detailed self-report summarizing clients occupational history; provides an accurate identification of occupational challenges and client centered outcomes can be explored by client and therapist.
Post-Concussion Symptom Scale (PCSS) Sport Concussion Assessment Tool-5 (SCAT-5)	Standardized assessments used to evaluate a variety of physical, cognitive, emotional and sleep changes following either a sports or non-sports related concussion. Valuable in determining both client factor and performance skills issues during the occupational therapy evaluation process.
Northeastern State University College of Optometry (NSUCO)	Standardized assessment used to assess the quality of both pursuit and saccadic eye movements while taking posture, head movement and direction into account.
Developmental Eye Movements Test (DEM)	Standardized assessment used to determine saccadic eye movement efficiency based on the speed and accuracy that a series of single digit numbers can be located, recognized and verbalized rapidly. This test does not measure reading.
Convergence Insufficiency Symptom Survey (CISS)	A validated 15-point self-report used to provide information on client factors associated with overall of vision function along with helping individuals identify post-concussion visual function symptomology.
Adult Sensory Processing (ASP) Adult Sensory Processing Scale (ASPS)	Both of these self-reports identify an individual's sensitivity to certain sensory information and how they respond or adapt to this input during everyday occupations.
Canadian Occupational Performance Measure (COPM)	Designed by occupational therapists to detect changes in the self-perception of an individual's occupational performance and satisfaction over time by identifying problems in performing everyday occupations in specific areas.

Figure 1: Concussion Assessments.

OT Interventions

Occupational therapists can use both compensatory and remedial approaches based on the findings from the evaluation process in order to successfully allow individuals to return to their occupations including and not limited to self-care, home management, sleep, education, work, play and leisure. Compensatory approaches include interventions directed at adapting the context or activity demands to facilitate successful performance whereas remedial approaches are designed to change client variables to establish as skill or ability that has not yet developed or to restore a skill or ability that has been impaired [38]. Interventions follow a recommended progressive general protocol which builds upon development of skills to achieve client centered goals. It is always based on the patient's deficits, symptoms, goals and occupational performance; however, since no two concussions or resulting symptoms

are alike, each treatment plan is tailored and individualized in order to address the specific needs of each patient. Based on each individual's needs, occupational therapy interventions can focus on visual-vestibular system rehabilitation, sensory processing re-integration, cognitive remediation and symptom management education. The use of remedial and compensatory interventions often requires significant patient education on home programs to augment and support therapy interventions.

Vision Function Interventions

An illustration of applying a remedial frame of reference is providing certain interventions for visual function deficits. For example, when working on functional pursuits, which are often required for tracking a moving object such as a moving vehicle, occupational therapists should focus on the quality of the eye movements and facilitating full eye movement range of motion in a dynamic environment, while remaining symptom free. When providing intervention for functional saccades, the patient should be instructed to focus on the rhythm and accuracy of the eye movements while working from larger to smaller targets, while simultaneously reducing head movement and increasing challenge to a dynamic environment all while managing symptoms**.** Both pursuits and saccades are client factors associated with visual function and addressing these in intervention is paramount to assisting individuals with their desired treatment outcomes. Meaningful everyday occupations such as inputting information into an excel spreadsheet, locating items in the kitchen or grocery store and engagement in meal planning activities are functional ways of therapeutically addressing the above mentioned eye movements. Other types of therapeutic activities that can be used to address visual function could be letter charts, tracking objects of various sizes, using reading material of an individual's interest for purposes of word cancellation and word finding or crossword puzzles. The ultimate goal is to remediate some of the vision function by using the eyes for activities in a repetitive manner while promoting visual deficit symptom reduction. Once individuals are able to tolerate these activities consistently, similar concepts can be applied to address their coulometer dysfunction and associated symptoms in a more functional context, such as going to the grocery store to search for items on a shelf, following a recipe to make a simple meal or looking up movie times.

Sensory Processing Intervention

A compensatory frame of reference with the PCS population can be used when individuals with PCS demonstrate sensory processing deficits. Common sensory processing symptoms can include over-responsively to movement, environment, visual and auditory stimulus. A common compensatory strategy can include using proprioceptive techniques such as a weighted blanket or weighted clothing which can provide sensory input to the central nervous system (CNS) thus possibly reducing CNS over-responsively. Anecdotally, this technique has been observed to produce a calming feeling among post-concussion individuals that describe sensory processing dysfunction thus at times reducing the sensory over-responsiveness. Other compensatory interventions to address both visual and auditory sensory over-responsively include the use of visual and auditory filters to reduce visual and auditory stimulus during performance in everyday occupations.

Assistive technology (AT) is a useful form of compensation when working with this population. The primary purpose of AT intervention is not remediation or rehabilitation of impairment, but rather a provision of hard and soft technologies that enable an individual with a disability to be functional and independent in activities of daily living. Occupational therapists introduce and provide many individuals who are suffering from post-concussion sensory processing symptomology with functional AT including tinted overlays for computer and smartphone screens, blue blocker lenses, and education on computer software, applications and modifications available. Through the provision of AT, a wide variety of performance in daily occupations can be improved including assisting with return to work and school based occupations.

Cognitive Function Interventions

Using both remediation and compensatory intervention strategies can helpful in addressing cognitive client factor deficits especially in the area of executive function. Executive function is described in the literature as seven specific cognitive skills including; self-awareness, inhibition, non-verbal working memory, verbal working memory, emotional self-regulation, and self-motivation and planning and problem solving. Using compensatory interventions to address working memory might include teaching individuals how to use external physical cues such as certain phone or computers apps, and the use of counters and timers for tracking time intervals. Other compensatory intervention strategies may include teaching individuals how to use a problem solving manual to analyze and break down larger activities into workable tasks. Using activity analysis by occupational therapy practitioners can be very helpful when addressing cognitive function deficits. Occupational therapy practitioners analyze the demands of an activity or occupation to understand specific client factors and performance skills necessary to successfully engage in an occupation. This can be very beneficial when providing clients with information and insight especially during cognitive problem solving activities.

Cognitive remediation intervention strategies may include having the client engage in certain board games that require sustained attention, planning, response inhibition and working memory. The ultimate goal of this would be for the client to a transfer some of this learning to other everyday occupations. Other examples include using certain cognitive remediation computer programs to challenge the client in executive function activities. In addition, teaching clients steps in self-reflection, self-awareness and positive self-affirmation can positively impact the areas of emotional self-regulation. For example, applying the concepts of positive self-affirmation during challenging occupational performance can allow the self-regulatory system to pause and reset using a more positive disposition which can result in improved occupational performance.

When providing occupational interventions to individuals with PCS, occupational therapy practitioners should view participation in occupations as a dynamic process, highlighting the transactional interaction of the mind, body and spirit [15]. Considering the diverse and sometimes complicated clinical presentations that individuals with PCS present, the need for occupational therapy practitioners to use a holistic and individualized perspective is paramount when providing interventions. Using either remediation and/or compensatory intervention strategies, individualized occupational therapy goals include reducing post-concussion symptomology that negatively impacts occupational performance while addressing both client factor and performance skills that influence such occupational performance. The successful engagement in meaningful occupations is crucial to successful occupational therapy outcomes for individuals with PCS [39,40].

Conclusion

Considering the recent significant increase in the clinical reporting of concussions along with the significant societal and individual impact that concussions can have on individuals, especially when diagnosed with PSC, promoting the benefits of occupational therapy seems synergistic as it is related to our professional domain. Individuals suffering from PSC can exhibit and experience debilitating symptoms that impact their performance in daily occupations. Occupational therapy practitioners have a unique base of knowledge and skills in activity analysis and occupational remediation and compensation which can have a positive impact on the rehabilitation of individuals suffering from PCS. One important factor is to ensure occupational therapists that provide intervention to individuals with post-concussion syndrome possess the knowledge and clinical skills necessary for this population.

This can be done by attending continuing education courses on concussion and post-concussion symptomology and rehabilitation management along with academic occupational therapy programs preparing students with foundational knowledge for this particular population. Occupational therapy practitioners need to engage with physicians and other rehabilitation colleagues to outline the unique skills that we can offer individuals suffering from post-concussion syndrome. In addition, occupational therapists should engage in concussion community resources to highlight how we may be able to assist in symptom management and QOL interventions for individuals with post-concussion syndrome. Finally, the field of occupational therapy should prioritize the development of more standardized intervention protocols, along with publishing efficacy studies to ascertain the success of occupational therapy interventions in this population.

References

1. Finn C, Waskiewicz MA (2015) The role of occupational therapy in managing post-concussion syndrome. Physical Disabilities Special Interest Section Quarterly 38 (1): 1-4.

2. Mitka M (2010) Reports of concussions from youth sports rise along with awareness of the problem. JAMA 304(16): 1775-1776.

3. Charmard E, Lefebvre G, Lassonde M, Theoret H (2016) Long-term abnormalities in the corpus callasum of the female concussed athletes. J Neurotrauma 33(13): 1220-1126.

4. Mustafi SM, Harezlak J, Koch KM, Nencka AS, Meier TB, et al. (2017) Acute white matter abnormalities in sports related concussion: A diffusion tensor imaging study from the NCAA-DoD CARE Consortium. J Neurotrauma 35(22): 2653-2664.

5. Harmon KS, Drezner JA, Gammons M, Guskiewicz KM, Halstead SA, et al. (2013) American medical society for sports medicine position statement on concussion in sport. Clin J Sport Med 29(2): 87-100.

6. McCrory P, Meeuwisse WH, Aubry M, Cantu B, Dvořák J, et al. (2013) Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. British Journal of Sports Medicine 47(5): 250-258.

7. Marar M, Mclvian NM, Fields SK (2012) Epidemiology of concussions among high school athletes in 20 sports. Am J Sports Med 40(4): 747-755.

8. McCrory P, Meeuwisse WH, Dvorak J, Aubry M, Bailes J, et al. (2018) Consensus statement on concussion in sport:

the 5th International Conference on Concussion in Sport held in Berlin, October 2016. British Journal of Sports Medicine 51(11): 838-847.

9. Jotwanni V, Harmon KG (2010) Postconcussion syndrome in athletes. Current Sports Medicine Report 9(1): 21-26.

10. Wojcik SM (2014) Predicting mild traumatic brain injury patients at risk of persistent symptoms in the emergency Department. Brain Inj 28(4): 422-430.

11. Gallaway M, Scheimann M, Mitchell GL (2016) Vision therapy for post-concussion vision disorders. Optom Vis Sci 96(1): 68-73.

12. Rosen MS, Feinberg DL, Doble JE, Rosner AJ (2016) Treatment of vertical heterophoria ameliorates persistent post-concussive symptoms: A retrospective analysis utilizing a mutil-faceted assessment battery. Brain Inj 30(3): 311-317.

13. Lin L, Liou TH, Hu CH, Ma HP, Ou JC, et al. (2015) Balance function and sensory integration after mild traumatic brain injury. Brain Inj 29(1): 41-46.

14. Shenton ME, Hamoda HM, Schneiderman JS, Bouix S, Pasternak O, et al. (2012) A review of magnetic resonance imaging and diffusion tensor imaging findings in mild traumatic brain injury. Brain Imaging Behav 6(2): 137-192.

15. (2014) Occupational therapy practice framework: Domain and process. 3rd (Edn.), American Journal of Occupational Therapy 68 (S1): 1-48.

16. Ventura RE, Balcer LJ, Galetta SL (2014) The neuro-ophthalmology of head trauma. Lancet Neurol 13(10): 1006-1016.

17. Kelts E (2010) Traumatic brain injury and visual dysfunction: a limited overview. Neuro-Rehabilitation 27(3): 223-229.

18. White O, Fielding J (2012) Cognition and eye movements: assessment of cerebral dysfunction. J Neuro-ophthalmology 32(3): 266-273.

19. Rizzo JR, Waskiewicz M, Kapoor N (2017) OT-OD synergy during management of the concussed: A case report illustrating seamless 'handoffs'. Vision Dev & Rehab 3(3): 131-46.

20. Heitger MH, Jones RD, Macleod AD, Snell DL, Frampton CM, et al. (2009) Impaired eye movements in post-concussion syndrome indicate suboptimal brain function beyond the influence of depression, malingering or intellectual ability. Brain 132(10): 2850-2870.

21. Kraus MF, Little DM, Donnell AJ, Reilly JL, Simonian N, et al. (2007) Coulometer function in chronic traumatic brain injury. Cogn Behav Neurol 20(3): 170-178.

22. Pearce AJ, Hoy K, Rogers MA, Corp DT, Davies CB, et al. (2015) Acute motor, neurocognitive and neurophysiological change following concussion injury in Australian amateur football. A prospective multimodal investigation. J Sci Med Sport 18(5): 500-506.

23. Kleiner M, Wong L, Dube A, Wnuk K, Hunter S, et al. (2018) Dual-task assessment protocols in concussion assessment: A systematic literature review. J Orthop Sports Phys Ther 48(2): 87-103.

24. Miller LJ, Nielsen DM, Schoen SA, Brett-Green B (2009) Perspectives on sensory processing disorder: a call for translational research. Front Integr Neurosci 3: 22.

25. James K, Miller LJ, Schaaf R, Nielsen DM, Schoen SA (2011) Phenotypes with sensory modulation dysfunction. Compr Psychiatry 52(6): 715-724.

26. Van Lew SF (2019) Identifying the prevalence of sensory processing dysfunction in a post-concussion population and its relationship to quality of life and functional indicators. ProQuest Dissertations Global database, pp: 1-19.

27. Barkhaudarian G, Hovda DA, Giza CC (2011) The molecular pathophysiology of concussive brain injury. Clin Sports Med 30(1): 33-48.

28. Matusak JM, McVige J, McPherson J, Willer B, Leddy J (2016) A practical concussion physical examination toolbox: evidenced-based physical examination for concussion. Sports Health 8(3): 260-269.

29. DaCosta A, Roccaforte A, Webbe F (2019) Development and clinical relevance of a summary score for the SCAT-5. Archives of Clinical Neuropsychology 34(5): 794-785.

30. Anderson MN, Covassin T, Bretzin AC, Petit KM, Savage JL (2018) Preliminary normative baseline data for the Sport Concussion Assessment Tool 5 (SCAT 5) in adolescent athletes: 1974 Board #235 May 313. Medicine and Science in Sports and Exercise 50(5): 478.

31. Merritt VC, Meyer JE, Arnett PA (2015) A novel approach to classifying post-concussion symptoms: The application of a new framework to the Post-Concussion Symptom Scale. J Clin Exp Neuropsychol 37(7): 764-775.

32. Maples WC (1994) NSUCO Oculomotor test. Optometric Extension Program.

33. Garzia RP, Richman JE, Nicholson SB, Gaines CS (1990)

A new visual-verbal saccade test: the development eye movement test (DEM). J Am Optom Assoc 61(2): 124-135.

34. Master C, Scheiman M, Gallaway M, Goodman A, Robinson R, et al. (2016) Vision diagnoses are common after concussion in adolescents. Clin Pediatr (Phila) 55(3): 260-267.

35. Brown C, Dunn W (2001) Adolescent/Adult Sensory Profile: User's manual. San Antonio, TX: Psychological Corporation.

36. Blanche EI, Parham D, Chang, M, Mallinson T (2014) Development of an Adult Sensory Processing Scale (ASPS). American Journal of Occupational Therapy 68(5): 531-538.

37. Law M, Baptiste S, McColl M, Opzoomer A, Polatajko H, et al. (1990) The Canadian occupational performance measure: an outcome measure for occupational therapy. Can J Occup Ther 57(2): 82-87.

38. Dunn W, McClain LH, Brown C, Youngstrom M (1998) The Ecology of Human Performance. In: Neistadt ME (Eds.), Willard and Spackman's occupational therapy. 9th (Edn.), pp: 525-535.

39. Laskowski RA, Creed JA, Raghupathi R, Kobeissy FH (2015) Pathophysiology of Mild TBI: Implications for Altered Signaling Pathways. In: Brain Neurotrauma: Molecular, Neuropsychological, and Rehabilitation Aspects. Boca Raton (FL): CRC Press/Taylor & Francis; Chapter 4.

40. Su CT, Parham DL (2014) Validity of sensory systems as distant constructs. Am J Occup Ther 68(5): 546-554.