Understanding concussion in para athletes with vision impairment

by

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A thesis

presented to the University of Waterloo

in fulfillment of the

thesis requirement for the degree of

Master of Science

in

Vision Science

Waterloo, Ontario, Canada, 2023

Author’s Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Introduction

Sports-related concussions occur in para sport as they do in able-bodied sport. There is evidence to suggest athletes with vision impairment (VI) may be more likely to sustain concussion injuries compared to athletes with other impairment types. However, there is limited understanding of best practices in concussion assessment and management for athletes with VI. Symptoms intrinsic to pre-existing conditions in para athletes are also commonly seen in athletes suffering from a concussion, which makes the assessment and management of concussion more challenging in the para athlete population. Perspectives and experiences of VI para sport athletes and coaches with concussion are also poorly understood.

The purpose of this project was to understand how concussions are currently assessed and managed in elite para athletes with vision impairment, to move toward establishing clinical practice guidelines and critical research priorities in concussion management for elite athletes with VI. The secondary objective of this thesis was to understand the perspectives, experiences, and knowledge of elite athletes with VI and coaches concerning concussion in VI para sport.

Study 1

A two-round Delphi study was conducted to solicit the opinions of healthcare professionals, researchers, and administrators in VI para sport concerning concussion assessment and management practices. Eight out of the nine interested participants completed the first-round survey; seven of those completed the second-round survey. Five out of eight participants were sports medicine physicians, and the remaining three participants had a background in physical therapy. Experts identified that VI

athletes may exhibit different observable signs of concussion (e.g., lack of blank look, balance issues at baseline, etc.) compared to able-bodied athletes. Experts unanimously agreed that pre-season baseline testing is necessary for para athletes with VI. While most experts (86%) agreed the SCAT5 currently represents the most effective assessment tool available for the evaluation of suspected concussion, one expert disagreed and explained that the SCAT5 is too complex for regular sideline use. Some experts suggested prescribing a longer period of initial rest or doubling the time between return-to-sport steps for athletes with VI. Experts came to a unanimous consensus that there is a lack of after-care in VI para sport in addition to the lack of on-site specially trained medical support.

Study 2

Elite para athletes with VI and coaches were invited to participate in a single-round survey study. The survey questions covered the following topics: Demographics; Concussion incidence, recognition, response, assessment, and management; Return-to-sport; and Education. Analysis consisted of categorizing written responses and analyzing response frequencies. A total of 8 participants (athletes (n = 4); coaches (n = 4)) from elite VI para sport took part. Athletes were found to have less awareness of medics at sidelines, assessment tools, how decisions are made to investigate for concussion, and the need for concussion assessments than coaches. Athletes were also more likely to not report incidents with reasons for not reporting including “don’t think it’s serious”, “time and money”, and “misdiagnosis because of underlying conditions”. Coaches are not considering athlete involvement in return-to-play decisions. Athletes and coaches agreed that it is important for medical professionals to have concussion education but differ on the need for education of athletes and guides. Athletes reported having little and poor quality concussion education.

Conclusion

Future investment in the provision of specially trained on-site medical support is needed to ensure the safety and well-being of VI para athletes. Education strategies should prioritize informing para athletes of the potential long-term consequences of concussion, so they understand the significance of failing to report concussion symptoms and of neglecting concussion injury protocol.

Acknowledgements

A heartfelt thank you to my supervisors, Dr. Kristine Dalton and Dr. Elizabeth Irving, for your ongoing support and encouragement throughout my Masters program. Thank you for this opportunity, for believing in me, and for inspiring me to achieve new heights. I am so incredibly privileged to have had the both of you in my corner over the last three years.

I would also like to thank my committee members, Dr. Daphne McCulloch and Dr. Ewa Niechwiej-Szwedo for your feedback and support throughout my Masters journey.

Thank you to my fellow lab mates, GIVS students, faculty, and staff at the School of Optometry and Vision Science for your friendship, encouragement, and for making the School feel like a second home.

I would like to thank our past and present graduate coordinators, Emily O'Connor, Holly Forsyth, and Angela Hare for all your hard work keeping graduate administrative affairs in order.

A special thank you to Brie McConnell who was instrumental in both the development of the Delphi survey and the literature review phase of my thesis. Your expertise in survey research methods made this project what it is today.

Thank you to Chris Mathers for his help and support with REDCap. You were always a quick email away and your in-depth knowledge of the platform saved me countless hours.

I would like to thank Jane Blaine for her kindness and passion for understanding concussion in athletes with vision impairments. Your devotion to your field is incredibly inspiring.

Thank you to the accessibility team at the Canadian Blind Sports Association for your work in ensuring the athlete/coach survey was accessible for completion by athletes with vision impairments. Thanks to you, participants were able to successfully complete our survey.

I would also like to thank the members of the IPC and IBSA Medical Committees for your invaluable help with participant recruitment and for lending your time to speak with me regarding this research project. I am honored to have had the opportunity to work with you as pioneers of understanding concussion in vision impaired para sport.

To my parents and brother, thank you for your unwavering support and love. To my friends, who always have my back and who are always there to cheer me on. And lastly, thank you Austin, I am forever grateful my Masters journey led me to you.

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List of Abbreviations

CATT: Concussion Awareness Training Tool

CBSA: Canadian Blind Sports Association

CIPS: Concussion in Para Sport

CISG: Concussion in Sport Group

CP: Cerebral Palsy

CRT5: Concussion Recognition Tool 5

GCS: Glasgow Coma Scale

IBSA: International Blind Sports Federation

ImPACT: Immediate Post-Concussion Assessment and Cognitive Testing

IPC: International Paralympic Committee

JAWS: Job Access With Speech

mBESS: modified Balance Error Scoring System

O&M: Orientation and mobility

RTP: Return-to-play

RTS: Return-to-sport

SCAT3/5: Sport Concussion Assessment Tool 3/5

SRIIPSS: Sports-Related Injuries and Illnesses in Paralympic Sport Study

TCS: Temporary Concussion Substitution

VI: Vision impairment

VOMS: Vestibular/Ocular Motor Screening

WEB-IISS: Web-based injury and illness surveillance system

Chapter 1
Literature Review and Objectives

1.1 General Introduction

Through participation in organized sport, persons with impairments can experience improvements in their physical health, mental health, and overall life satisfaction (1). However, participation in sport also increases athletes' risk of sustaining various injuries. One common sports-related injury is sports-related concussion, which is a traumatic brain injury induced by biomechanical forces that result in disturbances of brain function (2). The disturbances in brain function are typically transient in nature (2,3). Sports-related concussions are typically caused by an impulsive force to the head resulting from a direct or indirect impact to the head, face, or neck (2). The incidence of concussion from all causes is estimated to be approximately 42 million globally per year (4); sports-related concussions are thought to account for approximately 20% of these injuries, or 8.4 million injuries per year (5).

While concussion in able-bodied sport is relatively well studied, research on concussion in para sport is limited (6). A literature search conducted using EMBASE, Ovid Medline, PubMed, and Scopus databases revealed that as of November 2nd, 2022, there was a total of 153 results for studies related to concussion in para, adaptive, or disability sport, compared to 7,242 results on PubMed alone for concussion in sport more generally.

There has been considerable effort over the last two decades to address the lack of injury incidence data in para sport. The International Paralympic Committee (IPC) has conducted injury surveillance studies at every Paralympic Winter Games since 2002 and at every Paralympic Games since 2012 (6). London 2012 saw the introduction of the IPC's web-based injury and illness surveillance system (WEB-IISS) which allowed for the collection of more comprehensive injury data than previously had been possible (7). The WEB-IISS also enhanced injury reporting compliance by team medical staff and

facilitated the collection of exposure data, thereby allowing for more accurate calculation of rates of illness and injury (7).

While there has been progress in the epidemiology of injuries and illnesses in general in para sport, our knowledge of the true burden of concussion in para sport is largely unknown. Though the WEB-IISS was introduced at the 2012 Paralympic Games, questions specifically related to concussion were not added to the web-based injury surveillance system until the Rio 2016 Paralympic Games (6). Even with the inclusion of specific questions regarding concussion, the authors of the 2016 Paralympic Games prospective cohort study stated concussions may have been under-reported in the study population of para athletes (8). Authors explained that there were several incidents where athletes were observed to suffer a blow to the head followed by unsteady gait, yet no concussions were reported (8). At the Pyeongchang 2018 Paralympic Winter Games, a total of four concussions were reported among 29 injuries to the head, face, or neck, including two in Para Alpine Skiing and two in Para Ice Hockey (9). There was no further elaboration in terms of which impairment type (i.e., limb deficiency, vision impairment, etc.) the concussions in Para Alpine Skiing and Para Ice Hockey occurred in, making it difficult for clinicians to have a better understanding of the mechanism of injury involved in the sustainment of these concussions.

A recent study by Lexell and colleagues used data collected from the Sports-Related Injuries and Illnesses in Paralympic Sport Study (SRIIPSS) and assessed the incidence proportion and incidence rate of sports-related concussion among elite Swedish para athletes of a variety of impairment types (10). The SRIIPSS, a 52-week prospective longitudinal cohort study, was the first of its kind to prospectively assess the epidemiology of sports-related injuries and illnesses in para sport over a longer period of time (11). The authors found that athletes with vision impairment (VI) reported a significantly higher incidence proportion of sports-related concussion and a significantly higher incidence rate of

sports-related concussion than athletes of other impairment types (i.e., athletes with physical impairments and athletes with intellectual impairments) (10). In addition, researchers found almost two-thirds (62%) of all sports-related concussions reported over a period of 52 weeks occurred among athletes participating in VI para sports, even though athletes with vision impairment only accounted for approximately 21% of all athletes who participated in the study (10). Athletes with vision impairment were 6.2 times more likely to sustain a concussion compared to athletes with physical and intellectual impairments. Finally, Lexell and colleagues found that all concussions reported in this study in VI para sport occurred in Goalball, Para Judo and Para Swimming (10). These results suggest that athletes with vision impairment may be more likely to sustain a sports-related concussion compared to athletes with other impairment types. More prospective, sport-specific concussion injury incidence studies are clearly needed. It would also be useful to understand the injury mechanisms and risk factors that contribute to the seemingly higher concussion risk in VI para sports so that targeted preventive measures can be taken to minimize or prevent concussion in these sports.

In the absence of concussion injury incidence data specific to impairment type and sport, members of the IPC Medical Committee created a 'best estimate' risk assessment for para sports based on their experience (6). Impairment type, speed, collision potential, and whether protective head gear is worn in each sport were also considered in determining the risk assessment (6). A concussion risk rating was then assigned to each summer and winter sport, specific to impairment type, ranging from a score of '1' for low risk to a score of '5' for high risk (6). Blind Football, Goalball, Para Cycling, and Para Alpine Skiing were all rated a 3 or higher, putting all four of these sports at an estimated moderate to very high risk of concussion injury in comparison to other VI para sports (6).

1.2 Sport-Specific Concussion Incidence

1.2.1 Blind Football

Blind Football is a para sport played exclusively by athletes with vision impairment. All outfield players are classified as completely blind (B1; meaning they have visual acuity worse than 2.6 LogMAR or no light perception) and are required to wear eye shades to ensure fair competition (12,13). Goalkeepers are partially sighted, and can be classified as either B2 (i.e., visual acuity ranging from 1.5 to 2.6 LogMAR or visual field constricted to a diameter of less than 10 degrees) or B3 (i.e., visual acuity ranging from 1.0 to 1.4 LogMAR or visual field constricted to a diameter of less than 40 degrees) (12,13). Goalkeepers do not wear eye shades during play.

The IPC Medical Committee rated Blind Football a '4' out of a possible '5' in terms of a best estimate of concussion risk; putting the sport at a perceived moderate-to-high risk for concussion compared to other para sports (6). Although the impact speed in Blind Football is much slower than downhill Para Alpine for instance, the collision potential remains quite high considering all outfield players have no light perception on the field of play and are unable to see incoming objects or other athletes (6). Athletes with VI must rely substantially on their hearing ability to know where the ball, equipped with a bell inside it, is and where other players around them are on the field of play (14). As outfield players are completely blind, the athlete's ability to brace for or block impact to the head is reduced (14). Observations from Blind Football indicate that athletes with VI tend to play with a more anterior posture compared to their able-bodied counterparts which could expose athletes with VI to an even greater risk of head-to-head collision (14,15). These risk factors are coupled with the fact that no head protection is worn in Blind Football. Pending the results of a study by the International Blind Sports Federation (IBSA) testing the effectiveness of head protection at preventing head injuries in

Blind Football, it is suspected that a lack of protection to the head region could contribute to making concussions a more probable outcome in the sport (16).

The first group to independently investigate the nature and incidence of sports-related injuries in Blind Football over a period of five years was Magno e Silva and colleagues (15). They recruited a total of 13 Brazilian male Blind Football athletes and these athletes competed in 5 International competitions between 2004 and 2008 (15). A standardized injury report form was used to document all athlete injuries that occurred during all major international competitions (15). The report form documented the athlete's injured body part, mechanism of injury, and diagnosis of injury (15). The study found that 11 out of 13 athletes suffered some form of injury over the course of the 5 international competitions, which represented an injury prevalence of 84.6% (15). Injuries to the head represented the body region with the second highest injury prevalence (i.e., 8.6% of all injuries) (15). The authors of the study recognized that head injuries are of tremendous concern to the healthcare team as they can often lead to concussions, yet the study did not document the head injuries more specifically as concussions (15). In addition to documenting the anterior posture Blind Football athletes tend to adopt while running, Magno e Silva et al. also found some athletes had developed homemade eye shades made of an absorbent material with padding on the front and parietal zones of the head to decrease the possibility of severe injury to the head and face regions (15). Nevertheless, this form of protective equipment is optional and even at the most recent Tokyo 2020 Paralympic Games, no head protection was worn uniformly by Blind Football athletes.

In both the London 2012 and Rio 2016 Paralympic Games, Blind Football had the highest rate of injury out of all other summer sports (8,17,18). The injury incidence rate in Blind Football in Rio 2016 (22.5 injuries/1000 athlete days) was more than double the overall injury incidence rate at the Rio 2016 Paralympic Games (10.0 injuries/1000 athlete days overall) (8,18). Although the Rio 2016 study did

not document the prevalence of head injury as a percentage of overall injury in Blind Football, findings from the London 2012 study demonstrated that head and neck injuries were among the most prevalent, accounting for 25% of all acute injuries in Blind Football (14). Despite this high prevalence of injury to the head and neck, no concussions were reported in either the London 2012 or the Rio 2016 Paralympic Games (8,17). As mentioned previously, this was partially because the IPC did not include questions specifically related to concussion to the WEB-IISS until the Rio 2016 Paralympic Games (6). The under-reporting of concussions in the para athlete population could reflect that there is a need for increased clinician education regarding concussion recognition and assessment in this population (8). It could also be the case that there is less availability of specially trained medical staff in Blind Football, and there may be an added responsibility on the para athlete to recognize and report concussion symptoms (16). Ultimately, more education on concussion recognition is needed for all parties involved in Blind Football to improve concussion reporting, management, and clinical outcomes (16).

More recently, Weiler et al. conducted a three-year prospective injury surveillance study in elite English Blind and Cerebral Palsy (CP) Football squads and observed a high proportion (17%) of injuries were to the head and neck in both Blind and CP squads (19). The data also suggested that based on hourly exposure, Blind Football carried a higher incidence of injury in both training and matches compared to CP Football (19). Moreover, a total of 75% of injuries in Blind Football matches were sustained through contact, compared to 50% in CP Football matches (19). Although these results are expected – considering athletes with VI have limitations to their vision making it more difficult for them to avoid contact – these results also demonstrate that there is a need for stricter enforcement of the ‘voy’ rule in Blind Football (19). The ‘voy’ rule was implemented several years ago in Blind Football to limit the amount of contact between players defending and attacking the ball (19). The rule requires players to shout the word ‘voy’, which translates to “I go” in Spanish, when they are on the

defensive to allow the attacking player to determine the positions of the defenders on the field and to avoid a collision with them (19).

To promote the recognition and assessment of suspected concussions in Blind Football athletes, a new policy was recently adopted by the IBSA known as the 'Temporary Concussion Substitution' (TCS) rule (20). Adapted from the TCS rule first implemented in CP Football, the IBSA Blind Football TCS rule ensures that in the event of a head injury, a substitute player (i.e., TCS player) can enter the field of play to replace the player with the suspected head injury for a period of 10 minutes (21). Essentially, the rule gives clinicians more time to assess suspected head injuries without the pressure of returning to gameplay interfering with their expert medical decision (22). If after the 10-minute concussion assessment the athlete is deemed safe to return to play by the team medical professional, the TCS player must leave the field of play and be replaced by the player initially withdrawn (20). However, if the medical professional determines that it is unsafe for the athlete to return to play due to concussion concerns, the substituted player may remain on the pitch as the permanent replacement (20). By giving clinicians more time to assess suspected cases of concussion, this policy can provide a safer sport for athletes with VI while also allowing the football match to continue uninterrupted with an equal number of players on the field for both teams (23).

Acknowledging the high rates of injury to the head, face, and neck in Blind Football, additional rule changes and stricter enforcement of the 'voy' rule may be required in the future to limit the amount of contact injuries in the sport (19). Rule changes based on collaborative efforts, considering the perspectives from all stakeholders involved in the sport (i.e., athletes, coaching staff, medical staff, and event/sport organizers), and informed by the latest epidemiological research have the potential to create safer sports environments for athletes with VI.

1.2.2 Goalball

Goalball is a summer para sport played exclusively by athletes who are blind or vision impaired. Much like Blind Football, players are required to wear opaque eye shades to ensure fair competition (24). To participate in the sport, athletes must have a vision impairment, meaning they are classified as either B1, B2, or B3 (see above for classification criteria). The object of the game is to throw a 1.25kg ball across the court and into the opposing net to score points (24). Goalball athletes throw from a standing position and often defend oncoming shots from the opposing team by throwing themselves to the floor to stretch out and intercept the ball in the correct position (24). There is no designated goalkeeper in Goalball; all three players on each team play both defense and offense simultaneously.

The IPC Medical Committee rated Goalball a '3' out of a possible '5' as a best estimate for concussion risk; putting Goalball at a moderate risk for concussion compared to other para sports (6). Much like Blind Football athletes, Goalball athletes have no light perception on the field of play and are at risk of colliding into other athletes and objects (6). In addition, no head protection is worn in Goalball. Lexell et al. found that all sports-related concussions reported among Goalball athletes were related to a collision, and it was hypothesized that the lack of head protection could further increase athletes' risk of sustaining a concussion in the sport (10).

At the London 2012 Paralympic Games, Goalball had an injury incidence rate of 19.5 injuries / 1000 athlete days, which was the third highest injury incidence rate of all sports at the Games (17). A study by Zwierzchowska and colleagues reported that 44% of athletes who participated in the Goalball European Championship reported an injury of some sort, with 92% of all injuries occurring to athletes' upper limbs (25). Gajardo and colleagues, the first group to investigate prior-to-competition injuries and illnesses in Goalball athletes, found an injury prevalence of as high as 64.1% within four weeks prior-to-competition (26). This finding further emphasizes the value of conducting epidemiological

research during regular training and prior-to-competition periods to better understand the burden of injury in VI para sport.

Although all three of the above studies demonstrated a relatively high injury incidence and prevalence in Goalball in general, no concussions were reported. Nevertheless, Lexell et al. found that 31% of all concussions self-reported by para athletes in the SRIIPSS occurred in Goalball (10). In this study, Goalball was also the sport where athletes sustained the most concussions out of all other sports surveyed (10). Goalball athletes in this study reported that the mechanism of concussive injury was influenced primarily by their use of eye shades (10).

Given the information we have so far regarding the intrinsic (i.e., vision impairment) and extrinsic (i.e., use of eye shades) risk factors for concussion sustainment in Goalball, prevention strategies to reduce the risk of concussion in the sport should be implemented. Recently, the IBSA postulated that a combined eye shade with head protection may offer a protective benefit in the head-to-head collisions seen in Blind Football (6). Results from their internal study on the effectiveness of softshell helmets with integrated eye shades at preventing injuries to the head have yet to be published (16). Should this type of protective headgear confer a risk reduction benefit in Blind Football, it is worth investigating whether a similar type of headgear could provide a protective benefit in Goalball as well.

1.2.3 Para Judo

Para Judo was first adopted as a Paralympic sport in 1988 and is another sport exclusively for athletes with visual impairment in the Summer Paralympic program (27,28). The objective of Para Judo is to throw or takedown your opponent and to force them into submission or a pin (27). Para Judo athletes are subdivided into gender and weight categories in a similar fashion to their able-bodied counterparts in the Olympics (28). Paralympic judokas are classified into one of two vision classes depending on the degree of their visual impairment; either J1 (i.e., binocular visual acuity ≥2.6 LogMAR) or J2 (i.e.,

binocular visual acuity between 1.3 to 2.5 LogMAR or a binocular visual field of 60 degrees or less in diameter) (28,29)[1].

Injury incidence data from Olympic-level Judo indicates that judokas are prone to a range of injuries (30). From the available evidence in para sport, the former also seems to be the case in Para Judo. At the Rio 2016 Paralympic Games, Para Judo had the second highest injury incidence rate out of all other para sports with an incidence rate of 15.5 injuries / 1000 athlete days (8). In this study, Para Judo was also identified as being one of the highest risk sports at the Rio 2016 Summer Games (8). Another study by Fagher et al. investigated the sports-related injury prevalence among Paralympic judokas and found that 84% of athletes suffered from at least one injury during a one-year period (28). This study also found that most injuries (74%) occurred during Para Judo training, and 82% of all injuries occurred in the standing technique tachi-waza, a Judo term which refers to a collection of different throwing techniques (28,31).

The two studies discussed above demonstrated a high incidence and prevalence of injury in Para Judo, but neither of these studies reported any concussions which suggests concussion reporting may be an issue. Lexell et al. reported that 15% of all concussions in their study (two injuries total) occurred in Para Judo (10). The mechanism of injury for both concussions was related to a collision. Additionally, athletes reported concussion injuries were related to being thrown in an unexpected direction (10). Given the lack of additional data on concussion incidence in Para Judo and the high incidence of injury in general in this sport, more epidemiological concussion injury incidence studies are needed.

[1] The classification system for Para Judo described here came into effect in January 2022. Prior to January 2022, all athletes competed in a single class, regardless of their vision impairment.

In addition to the need for more epidemiological research on concussion incidence rates in Para Judo, technical research efforts focused on identifying possible risk factors and injury mechanisms in the sport are also needed (28). Fagher et al. identified that most injuries in Para Judo occurred in tachi-waza, which prompted the authors to suggest that a first step towards injury prevention in general could be to allow matches to continue into ne-waza (i.e., a Judo term which refers to a collection of ground techniques) (32) and minimize time spent in tachi-waza (28). Future studies should assess different techniques, throws, and falls in Para Judo to determine whether any other techniques may be putting judokas at an increased risk of sustaining a concussion (28). It was also suggested by the same authors that video footage analysis could be used in conjunction with injury surveillance data to better understand additional injury mechanisms at play in Para Judo (28). Authors from both the Rio 2016 injury incidence study and the Fagher et al. study agree that more research is needed to identify injury mechanisms and risk factors compounding the risk of concussion in Para Judo (8,28). In turn, this research will allow for the development of effective strategies for injury prevention in this sport (8,28).

1.2.4 Para Cycling

Para Cycling premiered at the Paralympics in 1984 and is now the third largest Paralympic sport in the Paralympic program (33). It is a multi-disability sport, featuring events for athletes with vision impairment and athletes with physical impairment (33,34). There are four main types of cycles used in Para Cycling, based on impairment, and they include handcycles, tricycles, standard upright bicycles, and tandem cycles (33). Para cyclists competing on standard bicycles and tandem cycles may compete in both road and track events, while para athletes competing on handcycles and tricycles may only compete in road events (33). Tandem cyclists are visually impaired, and they ride with a sighted guide in front known as a "pilot" (33,34). Para athletes with vision impairment are designated B1, B2, or B3 in accordance with the IBSA classification standards (see 'Blind Football' section) (33). All tandem

cyclists with a vision impairment compete together under a single classification (i.e., B) in the same events (33).

Injury surveillance data from the London 2012 Paralympic Games indicated that both para track cycling and para road cycling had some of the highest proportions of acute traumatic injuries out of all para sports at the 2012 Games (17). Track cycling saw 75% of total injuries classified as acute and similarly, road cycling saw 71% of total injuries classified as acute (17). While the study reported injuries by anatomical region, the data was not sport-specific, so it is unknown how many of the acute injuries seen in Para Cycling were to the head or face region (17). As for the Rio 2016 Paralympic Games, Para Cycling (both track and road) had a moderate injury incidence rate compared to other sports of 7.0 injuries / 1000 athlete days (8). Although injuries by anatomical area were reported in the study, these results were once again not sport-specific, making it difficult to know how many injuries occurred to the head region in Para Cycling (8). Unfortunately, Rio 2016 observed the first fatal injury of an athlete in a Games setting; a para cyclist suffered a head injury during competition and later succumbed to their injury (8). This catastrophic event highlights that life-threatening head injuries occur in Para Cycling, and we must continue to understand the risk factors and injury mechanisms involved to prevent these injuries from happening.

While head protection is worn during competition and para athletes with VI have a sighted pilot steering the tandem bike on the road/track, the high speeds that can be achieved in this sport predispose athletes to harmful falls (6,35). For this reason, the IPC Medical Committee rated para road cycling a '5' out of a possible '5' as a best estimate for concussion risk, making para road cycling one of only two para sports with the highest perceived concussion risk (6). Yet, according to Clarsen and colleagues, sports-related concussions remain a poorly quantified injury in both able-bodied and para sport cycling (36). Despite reports of head injuries in Para Cycling (8,35), at the time of writing, no

reported cases of concussion injury in Para Cycling were found in the epidemiological literature.

Clarsen and colleagues highlighted that para cyclists have received little research attention to date (36). Outside of studies conducted at the Paralympic Games, only one epidemiological study has focused on understanding the characteristics of sport injuries sustained by para cyclists, specifically (35,36). Going forward, researchers should strive to conduct high-quality epidemiological studies following the principles laid out in the most recent consensus statement on the methods for epidemiological studies in competitive cycling (36). Some of these recommendations in the consensus statement include reporting cycling-specific collision agents (i.e., whether the collision was with a person, inanimate object, vehicle, etc.), reporting collision mechanisms (i.e., equipment failure, avoiding objects, surface quality, etc.), and reporting related circumstances such as environmental factors (i.e., wind, rain, temperature, etc.) and track surface conditions (36). Improved documentation of injury mechanisms in Para Cycling will help guide key stakeholders (i.e., governing bodies, race organizers and equipment manufacturers) in the development of successful injury prevention initiatives (36).

1.2.5 Para Swimming

Para Swimming has been featured in every Summer Paralympic Games program and sees some of the highest numbers of para athlete participants out of all para sports (8,37). It is also a multi-disability sport where athletes in all eligible impairment types including physical, visual, and intellectual impairments can compete in a range of impairment classifications (37,38). Athletes with vision impairments are categorized into one of three sport classes: S/SB11, S/SB12, and S/SB13, which are equivalent to the B1, B2, and B3 classifications, respectively (38,39). Athletes in the S/SB11 sport class are required to wear blackened goggles to standardize the light perception amongst competitors in this category and to ensure fair competition (38,39). S/SB11 swimmers are also required to have an assistant

(i.e., known as a “tapper”) at both ends of the pool to “tap” the athlete to let them know they are approaching the pool end wall (39). Swimmers in the S/SB12 and S/SB13 sport classes may choose to use a tapper if they wish (39).

Injury incidence results from the Rio 2016 Paralympic Games found that Para Swimming had a moderate injury incidence rate compared with other summer sports (i.e., 7.1 injuries / 1000 athlete days) (8), despite being a sport with a relatively low collision potential and impact speed (6). Magno e Silva and colleagues found that overuse injuries made up 80% of all injuries reported in a group of 18 Brazilian Para Swimming athletes, with acute injuries making up the remaining 20% of all injuries reported (38). A notable observation from the Magno e Silva et al. study was that there were no reported injuries to the head or face region (38). This result suggested that the use of a tapper in Para Swimming may be an effective method of preventing acute traumatic injuries to the head or face, such as a concussion (38).

In contrast, Lexell et al. found that 15% of concussions reported amongst para athletes occurred in Para Swimming (10). Both concussions were sustained in Para Swimming athletes with VI (10). The mechanism of injury was reported to have been caused by swimming into the wall and the athletes reported that they believed their vision impairment influenced the injury (10). Athletes with VI reported that had there been more tappers available and better knowledge and awareness of the dangers of concussion amongst coaches, their sports-related concussions could possibly have been prevented (10). Even though Para Swimming may be associated with a lower incidence of injury in general compared to other para sports (8), concussions can still occur, and preventative measures should still be investigated and prioritized in this sport as well.

1.2.6 Para Alpine Skiing

Para Alpine Skiing is a downhill racing sport adapted for athletes with disabilities and is one of only two Winter Paralympic sports for athletes with vision impairment (40). Athletes with vision impairment are classified as either B1, B2, or B3, depending on their level of vision impairment (40). In addition, athletes with vision impairment ski with the assistance of a guide (40). The guide skis in front of the athlete and gives verbal direction to the athletes through a radio-frequency headset and microphone (40).

Para Alpine skiers with vision impairment compete in four skiing disciplines: slalom, giant slalom, Super G, and downhill. Across these disciplines, athletes can reach speeds of up to 116 km/h (40). As a result of the high speeds and potential for impact in this sport, injuries are commonplace (40). It is no surprise then that the IPC Medical Committee rated downhill Para Alpine for athletes with VI a '5' out of a possible '5' as a best estimate for concussion risk in this sport (6). Downhill Para Alpine in particular, is one of two sports with the highest perceived concussion risk out of all other para sports, the other being Para Cycling (Road) (6,40).

There is anecdotal evidence that concussions and other head and neck injuries are on the rise and are approaching the injury incidence of the more common injuries (e.g., shoulder joint and knee ligament injuries) in both standing and seated Para Alpine athletes (40,41). At the Sochi 2014 Paralympic Winter Games, 31 injuries to the head, face, and neck where reported, which accounted for an injury incidence rate of 4.7 injuries / 1000 athlete days (41). The incidence rate of all injuries in Para Alpine was found to be 41.1 injuries / 1000 athlete days, significantly higher compared to all other winter sports at the Sochi 2014 Games (41). Alarmingly, the incidence of injury recorded at the Sochi 2014 Paralympic Games was three times the incidence of injury recorded at the Sochi 2014 Olympic Winter Games, suggesting a higher risk of injury in athletes with impairment compared to their able-

bodied counterparts (6,41). Even so, no concussions were reported in the Sochi 2014 Paralympics study, again because the WEB-IISS was not specific enough to capture concussion injury data at that time (41). At the Pyeongchang 2018 Paralympic Winter Games, 4 of the 29 injuries reported to the head, face, or neck region were concussions, two of which occurred in Para Alpine (9). There was no further indication as to whether these concussions occurred in athletes with VI or in athletes with a physical impairment.

The high injury incidence rate in Para Alpine at the Sochi 2014 Paralympic Games prompted medical and sport-technical experts to create an action plan to reduce risk of injury for the following Pyeongchang 2018 Games (16). It was hypothesized that modifiable factors (i.e., course design, number of training runs, the command and control structure between the technical and medical staff, etc.) and environmental factors (i.e., temperature and altitude of the skiing venues in Sochi and their effects on snow conditions) were the likely contributors to the high injury rate observed in Sochi 2014 (42). In light of this information, the IPC Medical Committee engaged in discussions with the World Para Alpine Skiing management team to ensure injury risk and prevention was top priority for Pyeongchang (42). Measures for Pyeongchang included: more training runs; earlier start times; more optimal start location on the course; the widening of the course; official pre-Games technical and medical briefings; and the appointment of an independent race director who would facilitate the investigation into safety issues and have the final call to amend, postpone, or cancel an event if the conditions were deemed to be too hazardous (42). The outcomes of these measures were successful in lowering the total number of injuries (i.e., 98 injuries in Sochi compared to 39 in Pyeongchang), decreasing the number of acute injuries (i.e., 48 acute injuries in Sochi compared to 17 acute injuries in Pyeongchang), and decreasing the number of injuries in downhill skiing from 21 in Sochi, to only 5 in Pyeongchang (43).

The above is an example of how effective collaborations between sports medicine and sport management can realize changes in the policy, rules, and/or laws of sport to enhance the safety of

athletes (16,43). In terms of reducing the risk of concussion in Para Alpine, similar approaches can and should be taken going forward. Recently, World Para Alpine Skiing, World Para Snowboard, and World Para Nordic Skiing introduced concussion-specific rules to permit non-medically trained personnel to initiate a primary assessment of concussion, in accordance with Para Alpine skiing protocols (16). Going forward, conscious efforts should be made to include sports medicine professionals when informing sport-technical policy to ensure the safety of athletes remains a top priority amongst sports organizations (43).

1.3 Challenges and Limitations of Current Epidemiological Research

Injury and illness epidemiological research in para sport in general has improved over the last decade. This is largely due to the implementation of the web-based injury and illness surveillance system (WEB-IISS) at every Summer and Winter Paralympic Games since 2012, the prospective longitudinal cohort study in Swedish para athletes (SRIIPSS), and the recent sport-specific and impairment-specific injury epidemiological studies. An understanding of common injury mechanisms is starting to emerge in specific para sports. However, our understanding of the risk factors and mechanisms of concussive injury in para sport is preliminary at best due to the limited number of studies that have been undertaken.

A major limitation of current research is that most epidemiological studies are conducted during major competitions such as the Paralympic Games and other International World Championships. It should be noted that during the period of the Paralympic Games and other major international competitions, para athletes are typically training and competing less frequently than during the normal season (10). The prospective cohort study by Lexell et al. which looked at concussion injury over a period of 52 weeks, found that most sports-related concussions (69%) occurred during sport-specific training with a minority of concussions (31%) taking place during competition (10). Likewise, another

study by Derman et al. found that pre-competition injuries in general were significantly higher compared to injuries during the competition period itself at the Rio 2016 Paralympic Games (8). Consequently, only assessing concussion injury risk during major competitions is likely to vastly under-estimate the true incidence of concussion in para sports. More studies are needed that prospectively study concussion in para sport over longer periods of time (i.e., during both training and competition).

Injury surveillance systems should ask specific questions related to concussion in addition to looking at head injuries more broadly. As mentioned earlier, questions specifically related to concussion were not included in the WEB-IISS system until the Rio 2016 Games (6). As a result, both the London 2012 and the Sochi 2014 injury surveillance studies failed to report any confirmed cases of concussion. In the future, concussion injury surveillance study questions need to be sufficiently specific enough to capture concussion injury data.

While Lexell and colleagues' longitudinal prospective cohort study was exemplary in its design, there are a few limitations to it. For instance, the study included no athletes from the high-risk summer sport of Blind Football and included only two athletes from the high-risk winter sport of Para Alpine (10). The incidence of concussion injury in para sport may have been even greater had more athletes from high-risk sports been included (10). Additionally, only athletes from Sweden were invited to participate in this study (10). It is possible that concussion injuries could occur differently in other nations due to differences in training approaches, medical support, and/or concussion education programs. Future prospective cohort studies with athlete populations from different nations and across different continents are needed. Furthermore, 107 Swedish para athletes agreed to participate in the study out of a total of 150 athletes (10,44). This meant over 71% of all athletes in the Swedish Paralympic Program participated in the study (44). While the level of engagement of Swedish para athletes in the study is impressive, a larger sample size would have enabled the investigators to make more substantive claims regarding concussion injury risk, the mechanisms of injury, and the intrinsic

and extrinsic risk factors contributing to concussion sustainment in para sport (10). Considering a total of 4,403 para athletes competed in the Tokyo 2020 Paralympic Games (45), a larger sample size is attainable with the creation of a multi-national prospective cohort study to measure the incidence of sports-related concussion.

Issues related to limited research and the design of epidemiological studies are not the only reasons our knowledge of the burden of sports-related concussion in para sport is particularly limited. Lack of education among athletes, coaches, sports organizations, and even medical professionals regarding concussion recognition, assessment, and management is also an issue (6,10). A study that surveyed para athletes who participated in Wheelchair Basketball found that as many as 44% of athletes who experienced a sports-related concussion did not report it (46). Among athletes surveyed, the three most common reasons for failing to report a concussion consisted of: firstly, not wanting to be removed from the game; secondly, not thinking the injury was serious enough; and lastly, not knowing whether it was indeed a concussion (46). Another study found that athletes with vision impairment who had suffered a concussion believed that better knowledge and awareness among their coaching staff could have possibly prevented their concussion (10). Finally, during the Rio 2016 Paralympics as previously described, no concussions were reported among team medical staff despite several incidents where athletes were observed to suffer a blow to the head followed by unsteady gait (8). These findings demonstrate the need for improved concussion education and diagnostic capacity amongst all parties involved in para sport (8).

1.4 Concussion Management for Athletes with Vision Impairment

In November 2001, the first International Symposium on Concussion in Sport was held in Vienna, Austria (47). The aim of this symposium was to provide recommendations for sport governing bodies and health care providers on the epidemiology, assessment, management, and prevention of sport-

related concussion primarily in ice hockey and football (47). The outcome of this symposium was a consensus statement agreed upon by all concussion experts in attendance at the meeting (47). This group would then go on to be known as the Concussion in Sport Group (47). Since then, the Concussion in Sport Group (CISG) has hosted an international conference on concussion in sport approximately every four years and has published four subsequent consensus statements on concussion in sport. Each consensus statement was designed to build upon the principles outlined in the previous statements and to develop further understanding of sport-related concussion using an expert consensus-based approach (2,48–50). The most recent consensus statement on concussion in sport – the 2017 Berlin consensus statement – currently ranks first out of all articles on sport-related concussion in citation density, with an average of 161.5 citations per year (51). This finding indicates that the CISG consensus statements are of tremendous interest to clinicians, researchers, and sport governing bodies as their work helps to shape concussion policy from elite sport down to the grassroots level (52).

The CISG consensus statements have received worldwide recognition for their recommendations pertaining to the management of sport-related concussion. However, every consensus statement thus far has neglected to propose recommendations specific to concussion management in para athletes (16). Out of the 202 written abstracts featured at the fifth International Consensus Conference on Concussion in Sport, only two abstracts were specific to athletes with a disability (6). It is recognized that para athletes have intrinsic and extrinsic risk factors related to their impairments that may make them more susceptible to a sport-related concussion compared to able-bodied athletes (10). Considering the growing number of para athletes competing in both elite and recreational sport, tailored concussion recommendations for para athletes are needed more than ever (53).

To answer the call from medical professionals for the urgent need of a para sport concussion consensus statement (54), the Concussion in Para Sport (CIPS) multidisciplinary expert group was formed in 2020 (16). The goal of this expert group was to develop specific recommendations and

guidance related to para athletes and their attending medical professionals in the event a para athlete sustains a suspected concussion (16). For the creation of their first position statement on concussion in para sport, the CIPS group was divided into the following four working groups: concussion assessment; concussion management; return-to-sport (RTS) following concussion; and specific considerations related to the different impairments in para athletes (16).

The following sections of this review will explore the current recommendations for the management of concussion in para athletes, including recommendations from the CIPS group in addition to guidance from other sources. Where there is available evidence, this review will also explore specific recommendations for the management of concussion in para athletes who are blind or visually impaired.

1.4.1 Assessment

As highlighted in the CISG's Sport Concussion Assessment Tool 5, otherwise known as the SCAT5, the diagnosis of a concussion is a clinical judgement made by a medical professional (16,55). Concussions are an evolving injury with rapidly changing clinical signs and symptoms – making them among the most complex injuries in sports medicine to assess, diagnose, and manage (2). Currently, there is no perfect diagnostic test or biomarker that clinicians can rely on for an immediate diagnosis of concussion, and most concussions occur without a loss of consciousness or explicit neurological signs (2). As a part of the overall assessment of concussion, a clinician may choose to substantiate their clinical judgement by seeking the athlete's previous medical history, information pertaining to previous concussion diagnoses (if relevant), and additional information regarding the athlete from family members or carers of the athlete (16). In addition, clinicians are also encouraged to inform their clinical decision with the help of a variety of concussion assessment tools, including the SCAT5 as well as

other assessment tools that assess concussion symptom severity, balance and neuropsychological (or neurocognitive) outcomes (2,16).

The SCAT5 currently represents the most well-established and rigorously developed instrument for sideline assessment for concussion (2,6,55). It consists of an immediate (i.e., on-field) assessment section as well as an office (i.e., off-field) assessment section (55). The on-field assessment is comprised of the following: a list of "Red Flags" and observable signs for clinicians to look out for (i.e., these signs may indicate a serious and potentially fatal brain injury), a memory assessment (i.e., Maddocks questions), an examination of the best eye, verbal, and motor responses (i.e., Glasgow Coma Scale), and a cervical spine assessment (56). The off-field assessment includes the following: an evaluation of the athlete's previous medical history and background, a symptom evaluation, a cognitive screening portion to assess the athlete's orientation, immediate memory, and concentration, a neurological screening evaluation, a balance examination (i.e., using the modified Balance Error Scoring System, mBESS), and lastly a delayed recall assessment (56).

Although the SCAT5 encompasses a multitude of different domains in the evaluation of a suspected concussion, both the Concussion in Sport Group and Concussion in Para Sport group emphasize that the SCAT5 should not be used in and of itself to make or exclude the diagnosis of concussion (2,16). This is because an athlete may still have a concussion even if their SCAT5 is found to be 'normal' (16). It is also well documented that there could be a delayed-onset of symptoms following a suspected concussion injury, therefore, follow-up serial evaluation a few hours following injury should be considered regardless of a 'normal' sideline screening test (2,16). Ultimately, if the clinician has concerns regarding the concussion sideline assessment result, they should exercise discretion and remove the athlete from play (2). The clinician could also consider assessing additional domains that could add to the clinical utility of the SCAT5 such as measuring clinical reaction time,

assessing balance and gait, and observing video footage of the suspected concussion injury if available (2).

The CIPS group states that concussion in the para athlete population should, to the extent possible, be managed according to existing concussion consensus guidelines (16). However, in a survey conducted at the 2015 CP Football World Championships, only 29% of all medical professionals surveyed reported having used concussion assessment tools in a para athlete following suspected concussion (54). The apparent inconsistent use of concussion assessment tools in para athletes could be for a variety of reasons. To start with, even though a systematic review was performed to inform the development of the most recent SCAT5, the review did not consider examining the utility of the SCAT in athletes with disabilities (6,57). As para athletes were not considered in the creation of the SCAT5, medical providers are advised to interpret the results from SCAT5 assessments with caution – in recognition that the instrument is not validated for use in para athletes, nor was it created with para athletes in mind (16). Another reason for the inconsistent use of existing concussion assessment tools is that clinicians face difficulties when applying and adapting existing able-bodied concussion assessment and management guidelines to para athletes (16). This finding was highlighted in the survey study discussed earlier where 50% of clinicians stated that performing cognitive assessments in para athletes with CP was difficult (54). Additionally, existing concussion recognition and assessment tools assume certain 'normal' athlete functions to complete these assessments, such as the ability of the athlete to read, to see, to hear, and to understand with competence (16,55,58). It should be recognized that the ability to read, to see, to hear, and to understand may already be impaired for certain para athletes (16). Typical concussion symptoms that are being evaluated in the SCAT5 such as double vision, gait difficulties, and balance issues among others, may be characteristic of the para athlete's pre-existing impairment and not the result of a concussive injury (6,16).

Considering the Child SCAT was developed to address the controversial issues of concussion diagnosis and management in the pediatric population not addressed by the original SCAT, it would be reasonable to suggest that specific guidelines for athletes with impairments should also be developed (59,60). In the absence of concussion assessment tools specifically for use in para athletes, the Concussion in Para Sport group recently created sport-specific impairment type recommendations by evaluating the 'immediate or on-field assessment' and the 'office or off-field assessment' sections of the existing SCAT5 (16). The purpose of these recommendations was to provide clinicians with potential considerations and/or modifications to the existing SCAT5 when using this assessment tool in para athlete populations (16).

In terms of specific considerations for the use of the SCAT5 in athletes who are blind or visually impaired, the CIPS group divided their recommendations into three categories based on the level of vision impairment as follows: athletes with impaired vision, athletes with absent vision, and athletes with globe absent (16). For specific considerations into the suitability of the SCAT5 for athletes with physical and/or intellectual impairments, refer to the supplemental material at the end of the Concussion in Para Sport group's first position statement on concussion in para sport manuscript (16).

For the immediate assessment section of the SCAT5 for athletes with impaired vision, it is recommended that 'Red Flags' and observable signs of concussion such as 'double vision', 'balance/ gait difficulties/ motor coordination', and 'blank or vacant look' be interpreted with an additional degree of caution (16). Additional caution is also needed in the interpretation of 'facial injury after head trauma', as the athlete may have experienced a previous traumatic injury affecting the eye and/or face prior to the head injury (16). Many of these observable signs could be a manifestation of the para athlete's impaired vision, highlighting the importance of documenting the para athlete's pre-injury status and level of vision impairment (16). It is also noted that hearing may also be affected in a small proportion of ocular conditions, and the clinician should ensure the athlete's hearing is adequate before

they carry out the memory assessment (16). When it comes to the off-field assessment section, blurred vision, balance problems, and sensitivity to light are concussion symptoms that should also be interpreted with care in this population, as these symptoms may be pre-existing (16).

For athletes with absent vision, it is recommended medical professionals do not consider ‘double vision’ or ‘blank or vacant look’ an observable sign of concussion whatsoever (16). Both of these observable signs typically associated with concussion in able-bodied athletes are either pre-existing or are not possible to interpret in para athletes with absent vision (16). In terms of the off-field assessment section of the SCAT5, when performing neurological screening and balance examinations in athletes with absent vision, it is important for clinicians to recognize that baseline performance on any one of these domains may be lower in this athlete subgroup (16). As an example, athletes with absent vision may not be able to perform the ‘finger to nose coordination test’ with as much accuracy as an able-bodied person (16). For this reason, testing of this domain after a suspected concussion should be compared to the athlete’s own performance at baseline rather than comparing their performance to how an able-bodied athlete would perform on this test (16).

Experts have recommended removing assessments for ‘double vision’ and ‘blank or vacant look’ entirely from the SCAT5 when assessing athletes with globe absent (16). In addition, extra care should be taken when assessing all aspects of the ‘best eye response’ as a part of the Glasgow Coma Scale (GCS) in this subgroup of para athletes (16). For instance, if an athlete has both globes absent, there will likely be no response seen at baseline or post-concussion for ‘eye opening in response to pain’ or ‘eye opening to speech’ (16). In contrast, for athletes with one globe absent, the best eye response on the GCS could still be reliable if athletes are able to perform eye opening assessments in response to pain or speech (16). For other domains on the immediate and the off-field assessment sections of the SCAT5 that should be interpreted with an added degree of caution, see the appendix section of the CIPS group’s first position statement on concussion in para sport manuscript (16).

While the above recommendations provide a starting point for clinicians when they are assessing for concussion in athletes with VI, the validity and reliability of any adaptations and modifications to existing concussion assessment tools still need to be established (16). To accomplish this, more research is required to understand how concussion typically presents in athletes with VI, which signs or symptoms to look out for, and whether the pathophysiology of concussion in athletes with VI differs from that in able-bodied athletes. A better understanding of how concussions manifest in athletes with VI will help inform potential modifications to existing concussion assessment tools, and if necessary, the creation of new concussion assessment tools for use in para athletes with VI.

1.4.2 Baseline Testing

A baseline test is a pre-season examination conducted by a trained health care professional before an athlete begins training and competing for the season (61). Baseline testing typically includes an evaluation of baseline concussion symptoms, a balance assessment, and a neurocognitive or neuropsychological assessment (i.e., concentration, delayed recall, immediate memory, etc.) (61). During the baseline test, it is important for the health care professional to consider whether there has been a prior history of concussion for the athlete and whether there are any other medical conditions that could impact recovery after concussion (i.e., history of migraines, depression, mood disorders, anxiety, learning disabilities[2], Attention Deficit/Hyperactivity Disorder, etc.) (61). Currently, baseline testing is conducted using a battery of tests which often involve the use of the most recent SCAT5 as well as other tests to assess concussion symptom severity, balance, and neuropsychological (or

[2] There are differences in the meaning of the term "learning disability" in the United States of America (USA), Canada, and Australia compared to the United Kingdom (UK). In the USA and in the context of the Centers for Disease Control and Prevention (CDC), the term "learning disabilities" refers to people with specific learning difficulties such as dyslexia.

neurocognitive) outcomes such as the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) test, HeadMinder™, and CogSport™, among others (62).

According to the most recent CISG consensus statement, pre-season baseline testing of athletes with the SCAT5 can be a helpful tool to allow for the comparison and interpretation of post-injury test results (2,53,62). The CISG also recognizes that the symptom checklist on the SCAT5 demonstrates clinical utility in tracking recovery from a concussion (2). However, the current consensus among most medical experts is that while baseline testing may be useful, it is not necessary for interpreting post-injury scores in able-bodied athletes (2). The argument for this stance on baseline testing is rooted in the fact that the clinical value of SCAT testing when an athlete is well (i.e., not concussed) and subsequent follow-up (i.e., post-concussion) is currently not endorsed by scientific evidence and is neither validated in athletes in general nor in athlete subpopulations, such as athletes with impairments (53,63).

While the validity and clinical utility of baseline testing is under question among medical experts in able-bodied sport, experts on concussion in para sport recognize that there is value in baseline testing especially in para athlete populations (16). Para sport concussion experts argue that routine baseline testing is essential in establishing a baseline reference point for the assessment of concussion symptoms in the future (16). Experts go on to say that baseline reference scores are more important for para athletes than they are for able-bodied athletes, given the heightened need for para sport clinicians to distinguish concussion symptoms from symptoms that may be pre-existing due to a para athlete's underlying impairment (16). Having a baseline reference point for a para athlete's pre-injury cognitive, visual, and physical abilities enables the clinician to have comprehensive understanding of the athlete's baseline function prior to head injury (16). Through the collection of baseline scores in para athletes, clinicians are able to identify post-injury deviations from baseline, which in turn allows the clinician to diagnose and manage concussion in the para athlete more effectively (16). Furthermore, repeating baseline

testing, at least annually, would be beneficial in athletes with impairments due to progressive conditions as their baseline symptom levels will change over time.

To determine whether the SCAT could be used to collect baseline pre-injury data in para athletes, a study by Weiler et al. using the SCAT3 (i.e., the most current SCAT at the time) was conducted (53). The study also sought to identify whether differences existed between baseline SCAT3 scores for footballers with and without disability (53). The study population consisted of 249 English football players where 185 were able-bodied athletes (male: 119; female: 66) and 64 were football players with a disability (male learning disability[3] : 17; male cerebral palsy: 28; male blind: 10; female deaf: 9) (53). England team physicians and physiotherapists performed standardized baseline SCAT3 assessments on players when they were healthy (i.e., not concussed) (53). Results from this study found that compared to able-bodied male footballers, non-concussed male footballers with a disability scored significantly higher for symptom severity and male footballers with vision impairment scored significantly higher for total number of symptoms (53). Thus, even when healthy, footballers with vision impairment tend to experience significantly more symptoms typically indicative of a concussion and tend to experience these symptoms more severely compared to footballers without disability (53).

In addition to experiencing symptoms differently, male footballers with vision impairment scored significantly higher for total concentration and delayed recall compared to male footballers without disability, meaning that athletes with VI performed better than their able-bodied counterparts for total concentration and delayed recall (53). Furthermore, male footballers with vision impairment had significantly higher total SCAT3 scores compared to male footballers without disability (53). The

[3] In the UK and in the context of the Weiler et al. (2018) publication, "learning disability" is synonymous with the term "intellectual impairment".

results indicate that significant differences exist between non-concussed SCAT3 sub-scores for male footballers with vision impairment and male footballers living without disability (53).

The finding that male footballers with VI scored significantly higher for total concentration and delayed recall compared to male footballers without disability is consistent with literature that show improved brain plasticity and neurocognitive function relative to persons without vision impairment (64,65). Yet, male footballers with VI experienced significantly higher baseline concussion symptom severity scores compared to male footballers without disability, suggesting that SCAT3 symptoms are a more normal experience for footballers with VI (53). Although a relatively small population of athletes with VI (i.e., only 10 athletes) participated in the study, the results demonstrated that baseline testing results in para athletes with VI are important to collect. The study also underscored that baseline testing results should be interpreted with an extra degree of caution because athletes with VI appear to share many features with concussion at baseline when measured with the SCAT3 (53). While it is not yet well understood how SCAT3 scores in athletes with VI may change when measured post-concussion, the differences observed at baseline between athletes living with and without a disability do not support the use of the entire SCAT3 as a concussion assessment tool for athletes with VI (53). It is believed that the higher SCAT3 scores seen at baseline for athletes with VI may alter the sensitivity and specificity of the test (53).

Recognizing that there is currently no concussion assessment tool designed specifically for use in para athletes, clinicians are encouraged to use the most recent SCAT5 to the best of their ability when obtaining baseline and post-injury scores in para athletes (16). Despite its limitations, the SCAT5 still represents the most thoroughly developed instrument for sideline assessment of concussion (2,6,55). Fortunately, one way to help clinicians with their interpretations of baseline and post-injury concussion assessment scores in para athletes is through the collection of normative baseline scores. Most recently, the preliminary results from one study by Zdziarski and colleagues found that para athletes reported an

average of 5.0 ± 5.4 symptoms and an average symptom severity score of 11.0 ± 14.3 at baseline (66). Given that the maximum number of symptoms that can be recorded on the SCAT5 is 22 and the highest overall severity score that can be recorded is 132, the results from the previous study support findings from Weiler et al. that para athletes can exhibit symptoms at baseline akin to those typically observed post-concussion (66). One limitation to the Zdziarski et al. study was that it did not specify the impairment classifications of the athletes involved in the study. Therefore, we are unable to extract impairment specific trends from the normative baseline scores presented in the study. Nevertheless, the results do provide a starting point which may aid clinicians in their interpretation of baseline and post-injury scores amongst para athletes (66).

To summarize, there is conflicting opinion on the validity and clinical utility of comparing baseline results on concussion assessment tools when an athlete is healthy against results that are obtained post-concussion (53,63). While experts on concussion in para sport emphasize the importance of baseline testing in para athletes to establish a baseline reference point for concussion symptoms in this population, clinicians face additional challenges when trying to interpret baseline scores because the best concussion assessment tool currently available (i.e., the SCAT5) is not entirely suitable for capturing of baseline testing data in para athletes (16,53). Despite these problems, Weiler et al. and Zdziarski et al. were able to demonstrate that para athletes in general exhibit more symptoms typically indicative of concussion at baseline than their able-bodied counterparts (53,66). Future research should prioritize the collection of normative baseline reference values in athletes with different types and severities of vision impairment so normative scores can aid in the interpretation of baseline and post-injury scores in athletes with VI (66).

1.4.3 Management, Return-to-School/Work, and Return-to-Sport

A recent systematic review of the literature in concussion management in able-bodied athletes identified that sports medicine has not yet been able to develop a standardized protocol that clinicians can use to optimally care for athletes (67). The review found that the parameters adopted for clinical decision-making and management were variable and were based on a variety of clinical signs or scoring outcomes with little uniformity in protocol (67). In para sport, concussion management is highly variable, as demonstrated by a recent study examining the knowledge, attitudes, and beliefs regarding concussion amongst team physicians and physiotherapists at the Cerebral Palsy (CP) Football World Championships in 2015 (54). In this study, inherent difficulties were identified in the assessment and management of concussion in para athletes and most participants recognized an urgent need for expert clinical guidance in this population (54).

In their manuscript, the Concussion in Para Sport group outlines that once a concussion is suspected to have occurred, the para athlete should be promptly removed from the game or practice for further concussion assessment and to prevent additional harm (16). If a concussion diagnosis has been confirmed using a concussion assessment tool, or the clinician has concerns about the para athlete's well-being following a possible head injury, the clinician should err on the side of caution and instruct the para athlete to engage in both cognitive and physical rest for a period of 24-48 hours (16). From there, the athlete should progress through a period of active rest that includes a gradual and incremental increase in activity (16). During this period of active rest, the para athlete should be monitored to ensure they are staying below their cognitive and physical exacerbation thresholds (16). The active rest period should then be followed by a graduated return to other non-sport related activities first such as work and/or school (16). Finally, the para athlete can return-to-sport so long as there is no recurrence of concussion symptoms (2,16). In the case of persistent concussion symptoms (i.e., symptoms that persist

beyond 10-14 days in adults, or beyond 4 weeks in children), treatment should then be individualized to best address the specific medical, physical, and psychosocial factors of that athlete's injury (16).

Griffin and colleagues' study, which explored the concussion knowledge amongst the heads of medical services of the 15 participating countries at the CP Football World Championships in 2015, found that several clinicians reported a faster return-to-play than advocated by the 2013 CISG consensus statement (i.e., the most recent consensus statement at that time) (48,54,60). Among experts were misconceptions related to concussion prevention as well as an unawareness of the existence of the CISG's concussion management and return-to-sport recommendations (6,60). Although the results from this study were obtained in 2015, these results indicate that educational interventions may be needed for medical providers who are not yet fully informed of the recommendations regarding return-to-sport following concussion provided by the CISG and the CIPS group (60).

For para athletes with vision impairment, the Concussion in Para Sport expert group recommends no variation from the standard acute management protocol endorsed by the CISG for able-bodied athletes (16). However, when considering the 'Return-to-school/work strategy', experts argue that there is evidence for increased cognitive exertion in athletes with vision impairment over sighted individuals (16). Functional-imaging studies have shown that braille reading and other tactile discrimination tasks can increase cognitive exertion in individuals with vision impairment and blindness compared to sighted individuals (68,69). Due to this possible increased cognitive exertion in individuals with vision impairment, it is recommended that athletes with VI introduce cognitively demanding tasks (i.e., schoolwork, computer use, work-related activities, etc.) more slowly into their daily routines to protect from a recurrence or a worsening of concussion symptoms. In this way, athletes with VI can ease into their return-to-work or return-to-school strategy and are better prepared for a gradual return-to-sport without the increased cognitive exertion that could exacerbate concussion symptoms. It is also critically important for athletes with VI of any level, from amateur to elite Paralympic athletes, to make a return-

to-school or work before they return-to-sport (16). This is because returning to sport too early could induce the recurrence of symptoms related to concussion such as blurred vision, sensitivity to light, and visual fatigue more so than returning to school or work first (70).

In addition to the above recommendations provided by the experts in the CIPS group, the Canadian Blind Sports Association (CBSA) established a working group to create return-to-school, return-to-work, and return-to-sport resources specific to athletes who are visually impaired or blind (71). In terms of return-to-school, the CBSA recommended schools provide additional classroom supports for student athletes with VI who have recently experienced a concussion (70). Some of these classroom supports include the following: reducing the intensity and duration of tasks for the student by breaking tasks down into more manageable smaller chunks; taking acoustic considerations into account and providing noise cancelling headphones to the student; and recognizing the need to temporarily avoid classrooms that trigger sensory overload such as cooking classes, music classes and computer classes (70,72). When considering return-to-work for adult athletes with VI, the CBSA developed a list of possible accommodations for workplaces to consider including: taking lighting considerations into account and suggesting the employee wears a hat or sunglasses indoors and is located away from bright light and windows; making adaptations to printed documents such as increasing the print-size, contrast and magnification; and encouraging self-advocacy among employees with VI to explain the residual effects of their concussion and what other accommodations may help (73). It should also be recognized that everyone experiences concussion differently and the road to recovery is not always a linear path (74). Some individuals may reach a full recovery in a matter of days with limited accommodations to their school or work environment. Others who experience persistent concussion symptoms may require accommodations to their school, work, or daily lives for a longer period, and in some cases indefinitely (74).

For athletes with VI that compete with the assistance of a guide, the Concussion in Para Sport group recommended that graduated return to training with their guide is important to simulate the athlete's sport-specific training and competition environment during normal sport activity (16). In addition, the guide should monitor the athlete for signs suggesting recovery from concussion has not yet been achieved, for example, if the guide notices the athlete's balance is different from baseline (16). In terms of the management of persistent concussion symptoms, athletes with vision impairment may have reduced static balance and as a result, elements of vestibular rehabilitation and training may require adaptation (75). There is also evidence that individuals with reduced visual performance may have baseline chronic neck pain and consequently, elements of cervical-spine therapy may require adaptation following concussion in athletes with VI (76). The CBSA resource on return-to-sport for athletes with VI also indicates that an orientation and mobility (O&M) assessment performed by a trained O&M specialist may provide an additional benefit for athletes with VI prior to returning to sport (74). Orientation and mobility specialists coach individuals with vision impairment to travel through their environment safely and independently and can also help to identify any post-concussion changes in functioning (70,74).

The Concussion in Para Sport group emphasizes that clinicians must use the CISG return-to-sport strategy with discretion as it does not consider the nuances associated with the para athlete (16). Experts also suggest that if a clinician has concerns regarding the return-to-sport progression of a para athlete, the clinician should err on the side of caution when making return-to-sport decisions (16). Clinicians should consider whether a para athlete may need a longer initial period of physical/cognitive rest (i.e., over and above the 48 hours guideline) prior to starting their return-to-sport journey for impairment specific reasons such as a history of previous central nervous system injury, impaired function at baseline, or increased cognitive load during recovery (16).

1.4.4 Education

The survey study described earlier by Griffin and colleagues found most clinicians at the CP Football World Championships reported receiving at least some form of education regarding concussion and stated that they had experienced managing para athletes with suspected concussion in the past (54,60). While comprehensive concussion education is arguably most important among medical professionals, as they are the designated and licensed health care providers for para athletes, knowledge of concussion and its impact is also important for non-medically trained personnel such as team technical staff, coaches, and para athletes. Given that there is lesser availability of specially trained personnel and medical staff for para athletes during training and competition in comparison to able-bodied sport, there may also be an added responsibility on the para athlete and technical and coaching staff to recognize and report concussive symptoms themselves (16). Para athletes, coaches, and technical staff would benefit from increased awareness of the signs and symptoms of concussion so that they are better able to identify when a suspected concussion has occurred, remove the athlete from play as a precaution, and contact a medical professional if none are present.

A study by Fagher et al. explored the perceptions of para athletes regarding their experiences with sport-related injuries and risk factors by interviewing a group of 18 Swedish para athletes with a variety of different impairments (77,78). A concerning result from the study was even though para athletes recognized that injuries tend to get worse with more training, many cited that it is common for para athletes to continue to train and compete even though they are in pain (77). Although para athletes recognized that elite sport is inherently harmful and risky, there is often the perception in para sport that pain is something athletes must learn to live with and accept (77). The findings from this study suggest athletes may be less inclined to report injuries to their coaches and technical staff because of the general understanding that pain and injury is a part of para sport. Hence, there is a need to educate

para athletes, coaches, and technical staff on the dangers of sustaining a concussion and the advantages of seeking medical attention early following a concussion to improve recovery outcomes.

The key to educating non-medically trained individuals about concussion is effective knowledge translation (6). Without which, it is unlikely there will be good uptake of other concussion preventative strategies such as safer play, protective equipment usage, and adherence to the rules (6). Education strategies should be tailored towards the population you are trying to educate (16). For example, education for para athletes with vision impairment regarding return-to-sport following concussion should be in an accessible and athlete-friendly format (16). This can be achieved by providing resources in braille and by ensuring online educational resources can be equipped with text-to-speech functionality (16). For coaches and team technical staff, providing concussion education resources in a format that they are most likely to engage with, such as online courses and resources may be most effective (60). Coaches, technical staff, and para athletes should also be familiar with how to use the Concussion Recognition Tool 5 (CRT5) to screen for suspected concussion, as this tool was created by the CISG specifically for use by non-medically trained individuals (58). While the CRT5 is not yet validated for use in para athlete populations, nor have recommendations and modifications for its use in para athletes been identified, it is still a valuable tool to know how to use in the event there is no person with medical expertise present on or around the field-of-play where a suspected concussion has occurred.

Parachute Canada, a national concussion awareness campaign supported by the Public Health Agency of Canada, has also developed resources to build concussion awareness amongst athletes, coaches, trainers, parents, and caregivers (79). These resources are short in length (i.e., most are only two to three pages), with larger font, and they are devoid of medical terminology such that the average non-medically trained person can understand these resources to a full extent (79). There is also the Concussion Awareness Training Tool (CATT), developed by experts in concussion research and

prevention, which offers a series of online educational modules and resources for medical professionals, coaches, parents, athletes, schools, and workplaces (80). These educational modules are based upon the established principles of the CISG, are no more than 2 hours in length, and are offered free of charge (80). As for resources specific to athletes who are visually impaired or blind, the CBSA has developed short infographics and one-page resources for return-to-school, return-to-work, and return-to-sport, as previously discussed (71). These resources are an alternative to their more comprehensive several page documents to make learning about return-to-sport following concussion more accessible to para athletes, coaches, and team technical staff (71).

To promote the development of additional educational resources in VI para sport, future research efforts should prioritize surveying athletes, technical staff, and coaches to understand their perceptions of concussion and where the gaps exist in their knowledge of what to do following a suspected concussion. With the increased knowledge of the common signs and symptoms of concussion and an understanding of the dangers of concussion, it is the hope that all parties involved in para sport will take concussion seriously and will be able to better identify concussion injuries as they occur.

1.5 Summary of Objectives

The primary objective of this thesis was to understand how concussions are currently assessed and managed in elite para athletes with vision impairment, to start the process of establishing clinical practice guidelines and critical research priorities in concussion management for elite athletes with VI. The secondary objective of this thesis was to understand the perspectives, experiences, and knowledge of elite athletes with VI and coaches concerning concussion in VI para sport. These objectives were achieved through the completion of two studies, which are summarized in the following sections (1.5.1 to 1.5.2). The results of these studies will inform the development of evidence-based clinical practice guidelines and improve concussion education in para sport.

1.5.1 Study 1

The purpose of the first study was to understand how concussions are currently assessed and managed in elite para athletes with vision impairment. This study used the classical Delphi survey technique whereby an open-ended questionnaire was developed, and medical and scientific experts were asked to comment on concussion recognition, assessment, management, return-to-sport, and concussion education practices used currently in VI para sport. A second-round survey was then developed, based on the responses to the first-round questionnaire, to determine the level of agreement between medical and scientific experts in VI para sport on clinical practice guidelines and critical research priorities.

1.5.2 Study 2

The second study was conducted to understand the perspectives, experiences, and knowledge of elite athletes with VI and coaches concerning concussion in VI para sport. This study involved surveying elite para athletes with VI and coaches on their experience with and knowledge of concussion recognition, assessment, management, return-to-sport, and concussion education practices in VI para sport.

1.6 Thesis Overview

The following thesis is composed of two studies that have been formatted as individual manuscripts to be submitted for publication. These papers can be read independently or as part of the larger dissertation.

Chapter 1 included a General Introduction (1.1), a literature review on Sport-Specific Concussion Incidence in VI Para Sport (1.2), a review of the Challenges and Limitations of Current Epidemiological Research (1.3), a review on Concussion Management for Athletes with Vision Impairment (1.4), a Summary of Objectives (1.5), and a Thesis Overview (1.6). Chapters 2 – 3 detail the studies that were

conducted and are presented as individual manuscripts. Chapter 4 includes a discussion of the significance of both study results, a discussion of the limitations, as well as direction for future studies.

Chapter 2

The Assessment and Management of Concussion in Elite Para Athletes with Vision Impairment: a Delphi Study

2.1 Abstract

Purpose

The purpose of the Delphi study was to understand how concussions are currently assessed and managed in elite para athletes with vision impairment (VI), to move toward establishing expert consensus on clinical practice guidelines and critical research priorities in concussion management for elite athletes with VI.

Methods

A two-round Delphi study was conducted to solicit the opinions of healthcare professionals, researchers, and administrators in VI para sport concerning concussion assessment and management practices. Both surveys were developed in REDCap (81), a secure web application for building and managing online surveys. For the first-round survey, 25 open-ended questions regarding concussion recognition, assessment, management, return-to-sport, and concussion education practices were included. Content analysis was used to group similar participant responses together, and from there, themes were developed around similar responses. The second-round survey consisted of 43 statements across three domains relating to recommended clinical practice guidelines, research priorities, and perspectives/experiences when working in concussion management for athletes with VI. Participants were asked to rate each statement using a five-point Likert scale. Expert consensus was defined as 80% or more of participants either agreeing/strongly agreeing, disagreeing/strongly disagreeing, or remaining neutral with a statement.

Results

Eight out of the nine interested participants completed the first-round survey; seven of those completed the second-round survey. In Round 1, half of the participants (n = 4) were from countries in Europe. The other half (n = 4) were from countries in North America. Five out of eight participants were sports medicine physicians and the remaining three participants had a background in physical therapy.

Experts came to a consensus that observable signs, reported symptoms, mechanism of injury, and behavioural changes from normal are essential when determining if an athlete with VI has sustained a concussion. Experts also identified that VI athletes may exhibit different observable signs of concussion (e.g., lack of blank look, balance issues at baseline, etc.) compared to able-bodied athletes. Experts unanimously agreed that pre-season baseline testing is necessary for para athletes with VI. While most experts (86%) agreed the SCAT5 currently represents the most effective assessment tool available for the evaluation of suspected concussion, one expert disagreed and explained that the SCAT5 is too complex for regular sideline use. Some experts suggested prescribing a longer period of initial rest or doubling the time between return-to-sport steps for athletes with VI. Findings from our study suggest that there is minimal concussion education targeted to non-medically trained personnel in VI para sport. Experts came to a unanimous consensus that there is a lack of after-care in VI para sport in addition to the lack of on-site medical support. The validation of existing assessment tools was highlighted as an important research priority (≥86% consensus), whereas the need to develop entirely new assessment, management, and return-to-sport protocols was not considered necessary.

Conclusion

There was strong agreement among experts that understanding the VI athlete's pre-existing condition and conducting baseline testing prior to the start of every season is vital to assess for any change after a possible head injury. Critically needed in VI para sport is the investment in the provision of on-site

and on-going medical support and concussion education to improve the recognition of concussion injuries in athletes with VI .

2.2 Introduction

A sport-related concussion is a type of mild traumatic brain injury induced by biomechanical forces (2). A concussion may be caused by either a direct blow to the head, face, neck, or elsewhere on the body with an impulsive force transmitted to the head (2,82). Concussions typically lead to a range of signs and symptoms that tend to resolve spontaneously within a period of 1-4 weeks following injury (2,83).

Concussions are among the most challenging sports-related injuries to evaluate and manage due to the lack of laboratory biomarkers and the insufficient sensitivity of diagnostic imaging (84). For the evaluation and management of athletes with suspected concussions, clinicians typically rely on recent concussion consensus statements and guidelines developed by groups such as the Concussion in Sport Group (CISG) and the American Academy of Neurology, among others (2,85). Unfortunately, existing consensus statements and guidelines do not provide guidance for the assessment and management of concussions in para athlete populations (53).

Injury surveillance studies have demonstrated that head and neck injuries are as prevalent in para sport as they are in able-bodied sport (14,86). A recent prospective cohort study found that athletes with VI reported a significantly higher incidence proportion and a significantly higher incidence rate of concussion compared to athletes of other impairment types (i.e., athletes with physical impairments and athletes with intellectual impairments) (10). Researchers also found that almost two-thirds (62%) of all sports-related concussions over a period of 52 weeks occurred among athletes participating in VI para sports, even though athletes with vision impairment only accounted for approximately 21% of all athletes who participated in the study (10).

Concussion assessment and management practices in VI para sport are not documented in the scientific literature. Apart from the Concussion in Para Sport (CIPS) group's first position statement published in April 2021 (16), there are no specific clinical practice guidelines or recommendations for healthcare professionals that assess, manage, and treat concussions in athletes with vision impairment. Clinicians are left with no other choice but to adapt existing guidelines intended for use in able-bodied populations for use in para athlete populations (16). Symptoms intrinsic to pre-existing conditions in para athletes (e.g., vision impairment, double vision, poor balance, etc.) are also commonly seen in athletes suffering from a concussion (10), which makes the assessment and management of concussion more challenging in the para athlete population.

The purpose of the present Delphi study was to understand how concussions are currently assessed and managed in elite para athletes with vision impairment. This study will identify areas where experts agree and uncover areas where further investigation is needed to guide the development of future VI-specific clinical practice guidelines for concussion assessment and management in para sport.

2.3 Methods

2.3.1 Participants

All participants were required to have expertise in concussion management of elite para athletes with vision impairment, either as a healthcare professional, researcher, or administrator in para sport. Different from traditional survey designs that use a random sample representative of a target population, Delphi studies employ a limited number of 'experts' based on set inclusion criteria (87). While there is no consensus in the literature on the optimal number of participants to include in a Delphi study, Delbecq et al. have recommended the use of a minimally sufficient number of subjects to obtain a heterogenous sample of responses (88,89). Given the lesser availability of medical professionals for elite para athletes in comparison to able-bodied athletes (16), we aimed to recruit 10 participants.

To identify appropriate participants for inclusion in the study, representatives from the International Paralympic Committee (IPC) Medical Committee, the International Blind Sports Federation (IBSA) Medical Committee, the Canadian Blind Sports Association (CBSA), and the Concussion in Para Sport (CIPS) group were contacted. Once participants were identified, IPC and IBSA Medical Committees, the CBSA, and the CIPS group were requested to forward the study recruitment letter and study information letter to individuals that best met the inclusion criteria (described below). Participants responded by email to indicate their interest to participate in the study.

2.3.1.1 Inclusion Criteria

Participants were eligible for participation in the study if they met the following criteria:

- Current or former healthcare professional, researcher, or administrator in para sport (i.e., sports medicine physician, team physician, physiotherapist, occupational therapist, researcher in sports medicine, researcher in physical therapy, etc.),
- Have experience working with elite para athletes with vision impairment who have suffered a sport-related concussion,
- Be over 18 years of age,
- Have sufficient English language proficiency to understand and complete web-based questionnaires in English,
- Can commit to completing three web-based questionnaires over the course of a 9–12-month period.

Participants were considered ‘experts’ in the field of concussion management in athletes with vision impairment if they met the above criteria. When recruiting participants for a Delphi study, a heterogenous sample of experts is encouraged to ensure that the entire spectrum of opinion can be collected (90). To obtain a heterogenous sample of experts for this study, different types of healthcare

professionals and researchers were encouraged to participate including team physicians, tournament physicians, researchers, senior sport administrators, physiotherapists, and occupational therapists. To further increase heterogeneity of opinion, every effort was made to recruit experts from different continents and from different VI para sports.

2.3.2 Study Procedure

Participants were asked to independently complete up to three rounds of web-based questionnaires. Two rounds of questionnaires have been completed. REDCap, an electronic data capture tool hosted at the University of Waterloo, School of Optometry and Vision Science, was used to create questionnaires, and collect and manage survey data (81,91). The study received ethics clearance from the Office of Research Ethics at the University of Waterloo (ORE #42172).

2.3.2.1 Online Consent Form

Once a participant indicated their interest to participate in the study, they were assigned a participant number and sent their unique link to Round 1 of the survey by email. Before participants were able to complete Round 1 of the survey, they were taken to an online consent form. If participants consented to participate in the study, they were immediately able to complete the Round 1 questionnaire. If consent was not provided, an appreciation message appeared thanking them for their consideration of participating in the study and they were not able to view the first round of the survey. If at any point the participant wished to withdraw from the study, they could do so by closing the survey and exiting their web browser. If a participant chose to withdraw from the study, their responses up until the point where they chose to withdraw would be saved into REDCap. In this scenario, all survey response data collected from a participant who withdrew would be discarded and not included in the data analysis phase. Only survey responses where the participant selected the ‘Submit’ button at the bottom of the questionnaire form was included in the data analysis.

2.3.2.2 Round 1 Questionnaire

The Round 1 questionnaire opened March 18th, 2021, and closed on July 31st, 2021. The estimated time for participants to complete the questionnaire was 45-60 minutes. It was recommended for participants to complete the survey within 2-3 weeks of receiving the survey link. The Round 1 questionnaire was kept open for longer than the usual period due to the COVID-19-related delay of the Tokyo 2020 Paralympic Games, which made recruitment challenging.

The first round of a Delphi study traditionally begins with open-ended questions to collect specific information about a content area of interest from a group of experts (88,92). For the present study, the first round of the survey consisted of 25 open-ended questions, and participants were asked to provide written answers to each question. Questions for Round 1 were formulated based on a review of the literature on concussion management in VI para sport and through consultation with experts from the IPC Medical Committee. None of the experts who assisted in formulating the first round of the survey participated in the study. The questions were divided into five broad topics related to concussion management in athletes with vision impairment. The five topic areas and the number of questions in each topic included in the Round 1 questionnaire are described in Table 2.1. Participants could skip over any question(s) they did not wish to answer by leaving the appropriate text box blank.

Table 2.1: Round 1 questionnaire topic areas and the number of questions on each topic.

Topic number	***Topic name***	***Number of questions per topic***
1	Concussion Recognition and Response	5
2	Concussion Assessment	6
3	Concussion Management	5
4	Return-to-sport	5
5	Concussion Education	4

Once Round 1 of the survey closed, the research team analyzed the results from Round 1 to inform the development of the Round 2 questionnaire. An anonymized list of the responses to each question from the first round was created and the research team used a qualitative approach, namely content analysis, to analyze the survey response data. The Round 2 questionnaire was designed based on participant responses in Round 1.

2.3.2.3 Round 2 Questionnaire

The Round 2 questionnaire opened November 4th, 2021, and closed December 15th, 2021. Participants were notified by email that the Round 2 questionnaire was available and were provided with the link to the questionnaire. The estimated time for participants to complete this questionnaire was 10-15 minutes. The second round of a Delphi study involves participants independently rating statements using a set scale to establish the level of importance and/or agreement on all statements (88). For this study, a five-point Likert scale was used. The Likert scale used in this round of the survey is shown in Table 2.2. Participants were asked to rate each statement from either 'Very important' to 'Not important' or from 'Strongly agree' to 'Strongly disagree', depending on how the statements were phrased. There was one exception, where participants were instead asked to identify whether 'New tools are urgently needed' or whether the 'Current tools work fine'. If a participant was uncertain about the answer to a statement or they believed they were unqualified to answer, they could leave the answer blank or select the radio button 'Uncertain / Unqualified to answer'. This option was added in the event a participant felt they needed further clarification on a particular statement, or, if the participant was not directly involved in the assessment and management of concussion in para athletes with VI and therefore unable to provide an opinion.

Table 2.2: Likert scale value for each response selected on the Round 2 questionnaire.

Likert scale value	***Level of importance***	***Level of agreement***	***New tools needed?***
0	Uncertain / Unqualified to answer	Uncertain / Unqualified to answer	Uncertain / Unqualified to answer
1	Not important	Strongly disagree	Current tools work fine
2	Less important	Disagree	Current tools are mostly okay
3	Neutral	Neutral	Current tools with necessary modifications are okay
4	Important	Agree	New tools would be helpful
5	Very important	Strongly agree	New tools are urgently needed

The Round 2 questionnaire consisted of 43 statements in total. Statements were created from responses obtained in the Round 1 questionnaire. The statements were divided into three broad domains. The three domains and the number of statements in each domain are described in Table 2.3. A free-text response option was available to participants within each domain, providing participants the opportunity to comment on the wording of the statements, or elaborate on their responses. Further, an additional free-text response option was included in the Critical Research Priorities and Future Directions domain to give participants the opportunity to identify other critical research priorities that need to be addressed.

Table 2.3: Round 2 questionnaire domains and the number of statements in each domain.

Domain number	***Domain name***	***Number of statements***
1	Recommended Clinical Practice Guidelines	25
2	Critical Research Priorities and Future Directions	8
3	Perspectives and Experiences when Working in Concussion Management for Athletes with VI	10

2.3.3 Analysis

Anonymized data were compiled in REDCap and exported as a CSV file to Microsoft Excel. The research team used content analysis to analyze the anonymized list of responses to each question in Round 1. Content analysis consisted of grouping similar responses together and developing themes around similar responses in the same area of interest (87). The grouping of responses was initially completed by one member of the research group (Juliette Teodoro) and was subsequently reviewed by the other two (Dalton and Irving). Similar responses were collapsed into one statement, and wording was kept as true to the original responses as possible (87). Unique responses provided by experts were kept as originally worded and are included in the results section as anonymized expert quotations.

The frequency and percentage of each of the responses to each of the statements from Round 2 were calculated to determine whether a given statement reached consensus or not. The Delphi method defines consensus based on a chosen percentage of the expert panel that agrees on a given statement (93). For this study, expert consensus was defined as 80% or more of participants either agreeing/strongly agreeing (or equivalent), disagreeing/strongly disagreeing (or equivalent), or remaining neutral with a statement. A conservative 80% consensus threshold was chosen because we anticipated 10 or fewer participants taking part in the study. All ‘Uncertain / Unqualified to answer’ responses in Round 2 were excluded from the group response. This was done to ensure that the reported percentage agreement or disagreement (or equivalent) for each statement represented the consensus among only participants who felt confident with their answer.

Demographic data of participants (i.e., role in VI para sport and continent of origin) were collected in both rounds to give an overall profile of the expert panel (87). Demographic data for each participant was presented as a frequency and percentage of the total population of participants to ensure participant anonymity and confidentiality were maintained in the publication of results.

2.4 Results

2.4.1 Population Demographics

Initially, nine experts expressed interest in taking part in the present study. Eight out of the nine interested participants completed Round 1. Seven out of eight participants completed Round 2. In Round 1, half of the participants (n = 4) were from countries in Europe while the other half (n = 4) were from countries in North America. Five out of eight participants were sports medicine physicians while the remaining three participants had a background in physical therapy. Participants had expertise in a range of different VI para sports including Blind Football, Goalball, Para Judo, Para Alpine Skiing, Para Nordic Skiing, and Para Cycling.

2.4.2 Round 1 Results

2.4.2.1 Concussion Recognition and Response

Participants gave a variety of answers in terms of their perceived frequency of concussion injury in VI para sport. Some participants found concussions to be rather common. One expert stated the following:

> "My observation is multiple alleged cases during every competition (e.g., World Champs/Games) and series of events (e.g., match)."

Others found concussions to be more uncommon in VI para sport. For example:

> "1 athlete in 3 years."

Another expert recognized that concussions also occur outside of elite VI para sport settings.

> "My athlete has experienced minor concussive injuries in other leisure sport/activities (i.e., mountain biking, ski-doo) on two occasions."

Refer to Figure 2.1 for a summary of the key observations to consider when investigating concussions in VI athletes. All eight experts agreed that reported symptoms by the VI athlete must be

considered when investigating a suspected concussion injury. Most participants (7/8) also stated that the mechanism of injury is another key aspect to consider. Observable signs were also considered important by several experts (6/8) and four experts added that behavioural deviations from normal are another key aspect to consider. One expert added:

> "In recent years, I have been more and more aware of the importance of behavioural deviations from the norm, and have seen short-lived personality changes from players with VI who have sustained a concussion."

A different expert recognized that VI athletes may have different observable signs of concussion compared to able-bodied athletes. For example:

> "VI athletes seem to pick themselves up as quick as they can to continue playing sport (in my experience) sometimes making it impossible to even assess them. They often don't have a blank look and balance issues after getting up are not uncommon."

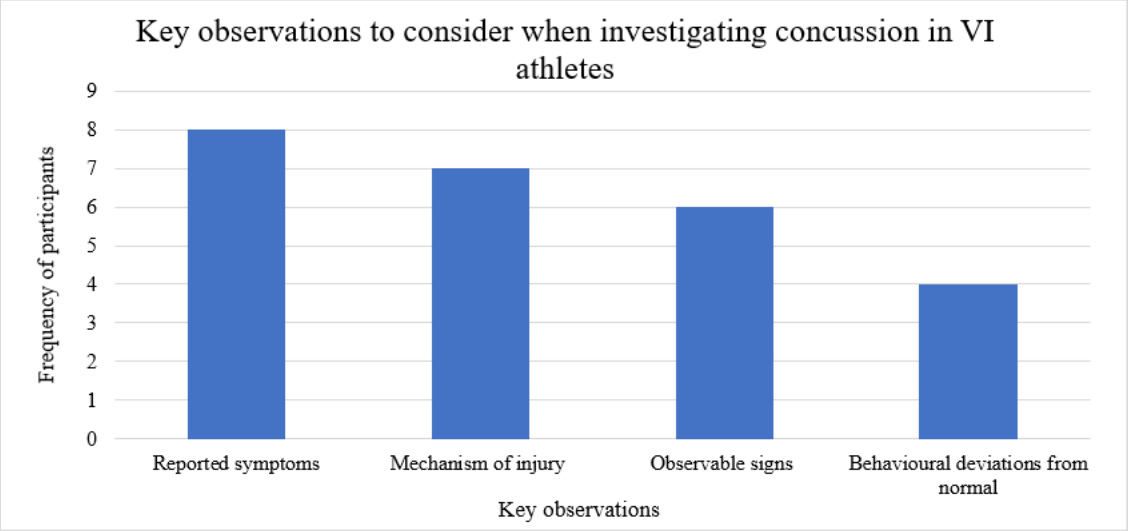

Figure 2.1: Key observations to consider when investigating suspected concussions in athletes with VI.

Participants were asked to consider a scenario describing an athlete with VI experiencing a hard fall on the field of play without any medical professionals around and subsequently asked participants to describe what they think would happen next. All eight participants expressed that the VI athlete would be removed from play even if there were no medical professionals on the sidelines. Most experts (5/8) described that the athlete would be immediately sent for a medical concussion assessment.

> "The athlete is removed from play immediately and a concussion assessment is started immediately if there is a medical professional present, or the athlete is sent for a concussion assessment by a medical professional otherwise."

The remaining three experts believed that the athlete would not be immediately sent for a medical concussion assessment. One expert stated:

> "From there I would imagine that they may not automatically seek a referral to a medical professional and may only look to do so if there were issues that were more concerning from their perspective (e.g., repeated nausea, constant headaches, etc.)."

2.4.2.2 Baseline Testing

Most participants (7/8) said their VI athletes participated in baseline testing at the beginning of each season. Experts stressed the importance of obtaining baseline testing measurements to understand their athlete's pre-existing condition and to be able to compare the baseline scores against post-injury scores in the event of a concussive injury. One expert indicated:

> "We aim to take baseline measures at the start of each season with all of the disability football squads to provide us with data to compare any injured players with."

To collect baseline testing data, six participants said they used the SCAT3/SCAT5 with their VI athletes. Experts also said they used other tests such as the Vestibular/Ocular Motor Screening (VOMS)

assessment, balance tests, symptom screening tests, and visual tests to understand their athletes' baseline performance.

> "Yes we perform baseline testing at the beginning of each season including full SCAT5, VOMS (and King Devick - but not with VI athletes)."

> "Pupillary dilation reflexes are noted at baseline to be able to properly assess a change after a possible head injury."

One participant highlighted that baseline testing may not be conducted as often as expected in VI para sport.

> "[Baseline testing] happens rarely, [baseline testing] is not systematically implemented."

2.4.2.3 Assessment

Most participants (7/8) indicated that the team physician typically conducts the concussion assessment for athletes with VI. Six experts identified that the team physiotherapist or an emergency medical professional would typically aid the team physician with administering the concussion assessment.

> "If the team physician is traveling with the team, it will usually be the team physician assessing. Otherwise, it will be the physiotherapist who performs the concussion assessment and communicates with the team physician through email/video chat, etc."

Two participants acknowledged that not all para sport teams have access to a team physician.

> "Not all teams have MD on site, thus assessment often falls on shoulder of physio or coach."

Refer to Figure 2.2 for an illustration of the number of participants that use each type of concussion assessment tool. Most participants (7/8) said they used the SCAT5 with athletes under their care. Three

experts identified that they used other concussion assessment tools in addition to the SCAT5 including the Glasgow Coma Scale (GCS), balance testing, and the VOMS assessment.

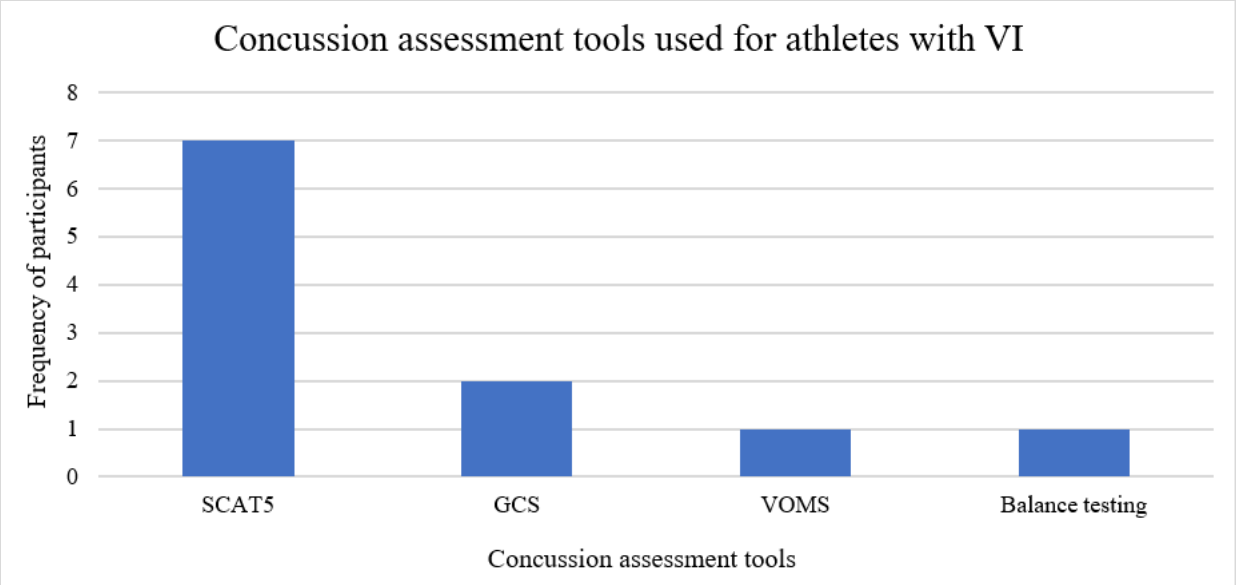

Figure 2.2: Concussion assessment tools used for athletes with VI.

Some experts (4/8) stated that there are sections of the SCAT5 and components of the VOMS that are not appropriate for use in athletes with VI. Examples of how the SCAT5 and the VOMS were modified for use with VI athletes follow:

> "The athlete is verbally asked to rank the items of the SCAT symptom scale instead of reading them him/her-self."

> "The VOMS is modified to include what the athlete is capable of doing depending on their visual impairment."

One expert offered their opinion on the drawbacks and the advantages of using existing concussion assessment tools for athletes with VI.

> "I have never known if the tests we use are valid and reliable, so I have always had doubts about my own assessment and advice. I think maybe this is healthy as it tends to make you consider each case more deeply and come to a cautious and safe decision. My own national support teams have always been supportive to me personally, but I don't know about other medical staff."

2.4.2.4 Management

Five out of eight participants expressed that for the acute management of concussion in athletes with VI, there are no specific management strategies outside those recommended by the Concussion in Sport Group.

> "I have not had to use any specific concussion management strategies to assist my VI players recover from their concussion. The Graded Return to Play process has been sufficient (allied to physical and cognitive rest)."

Three experts added that modifications to physical therapy and vestibular rehabilitation should be considered case-by-case, depending on the athlete and their circumstance.

> "Vestibular rehab is modified to the athlete's visual abilities if necessary. Otherwise therapies/exercises are largely un-modified."

Two participants expressed that a VI athlete may be referred to his/her individual physician should the athlete require medical assistance beyond the time they are training and/or competing with the national team. However, another two experts acknowledged that professional after-care is likely missing in VI para sport. For example:

> "[…] a certain level of self-care/self-management by athletes with an impairment, and thus professional after-care might be missing."

2.4.2.5 Return-to-Sport

Most participants (7/8) stated that a VI athlete is safe to return to sport once they have successfully progressed through a multi-staged return-to-play concussion protocol. Two experts indicated that a VI athlete is considered safe to return to sport once their post-concussion injury score returns to baseline. Six participants added that in addition to following a multi-staged return-to-play protocol, the athlete should be asymptomatic. One participant stated:

> "We follow our concussion return to sport protocol (ensuring the athlete no longer has reproduction of [concussion] signs or symptoms with gradually increasing activities)."

Participants (3/8) highlighted the importance of following a graded return-to-sport process that is as sport-specific as possible.

> "We follow the SCAT5 in order to determine RTP. As part of this there is a graded process, and we ensure that this is as sport-specific as possible (e.g., the running drills are to be done on the football pitch, etc.)."

Experts also indicated that they use other strategies in addition to a graded return-to-sport protocol to determine when an athlete can safely return to sport. For example:

> "We use SCAT5, VOMS, and physical exertion tests (cardio and strength output), and then gradual return to the sport in question starting with dry-land training ---> sport-specific training ---> competition."

Some participants (3/8) reported that return-to-sport strategies are slightly modified for athletes with VI, but that there are no major modifications to the return-to-sport process. Two participants suggested increasing the amount of time between return-to-sport stages:

> "We have modified these slightly by taking longer [at each stage of the return-to-sport protocol] than the maximum speed recommended [by the] SCAT5."

2.4.2.6 Concussion Education

All eight participants expressed that concussion education is extremely important for non-medically trained individuals (e.g., athletes and coaches). Two experts stated the following:

> "[Concussion education is of] utmost importance and to be prioritized (also in absence of medical support in some teams / at some competitions)."

> "I think athlete and coach education are essential to improve attitudes/behaviours and take this serious injury more seriously."

Some experts added that VI athletes and coaches do not need to know everything about concussions, but should understand the following:

> "I don't think they need to know everything [about concussions] but [athletes and coaches] do need to understand why it is so important and the unwanted repercussions and dangers that can develop if not managed properly or if symptoms are concealed."

Experts also identified that currently, there are knowledge gaps related to concussion among the wider para sport population, and that there is minimal education targeted to athletes and coaches in particular.

> "[Concussion] is too often downplayed by athletes/ support personnel – to some extent also by (International) Federation / Event Organizer (due to related expenses, e.g., having qualified physician on-site)."

One expert stated that there is still much more work that needs to be conducted in the field of concussion assessment and management in para athletes with VI. They explained:

> "I think VI concussion knowledge has much more work to do in order to have quality information to share. At the moment we are adapting guidance for sighted athletes and this seems to be the

best we can do currently. It makes you wonder how safe our practice is, but we are tied by the lack of guidance/knowledge."

2.4.3 Round 2 Results

2.4.3.1 Recommended Clinical Practice Guidelines

Table 2.4 and 2.5 describe whether consensus was achieved for each statement included in the Recommended Clinical Practice Guidelines domain, and the percentage of participants who agreed with each statement. Consensus was achieved for 88.0% (n = 22) of the 25 statements in this domain. On three of the statements, experts did not agree.

Table 2.4: Responses to statements included in the Recommended Clinical Practice Guidelines domain.

Statements ***Domain 1: Recommended Clinical Practice Guidelines***	***Consensus achieved (YES/NO), % Agreement***
Key observations to consider when investigating a suspected concussion in an athlete with VI:	
Reported symptoms	**YES, 100%**
Mechanism of injury	**YES, 100%**
Observable signs	**YES, 100%**
Behaviour deviations from normal	**YES, 86%**
Input from staff/individuals involved with the squad/team	**YES, 100%**
Team technical staff (coaches, trainers, guides, etc.) should be educated on recognizing suspected concussion using concussion recognition tools (eg, CRT5).	**YES, 86%**
If concussion is suspected in an athlete on an opposing team and there are no medically trained professionals to provide an assessment on the opposition's team, who should intervene and assess the athlete?	
Medical staff provided by the IPC	**YES, 86%**
Medical staff provided by local event organization committee	**YES, 86%**
Referee (with concussion screening training)	NO, 57%
Medical staff from the other team	NO, 43%
The SCAT5 with necessary modifications/considerations for athletes with VI (see recent Concussion in Para Sport group position statement) currently represents the most effective tool available for assessment of suspected concussion in athletes with VI.	**YES, 86%**
Routine baseline pre-participation examinations are essential in athletes with VI for the following reasons:	
To establish a point of reference of the athlete's baseline function	**YES, 100%**
To be able to compare pre-injury results with post-concussion results	**YES, 100%**
To be able to manage the athlete with VI more effectively if concussion is diagnosed	**YES, 86%**
In making return-to-sport decisions, to determine when the athlete has returned to baseline / pre-injury levels	**YES, 86%**
†Pre-participation examinations are not necessary	**YES, 0%**

Table 2.5 (continued from Table 2.4): Responses to statements included in the Recommended Clinical Practice Guidelines domain.

Statements ***Domain 1: Recommended Clinical Practice Guidelines***	***Consensus achieved (YES/NO), % Agreement***
Concussion management strategies for athletes with VI remain largely un-modified from those recommended for use in able-bodied athletes (eg, Graded Return to Play process, targeted physical therapy, vestibular rehabilitation, etc.), apart from having to adapt management protocols to suit the athlete's visual abilities if necessary.	**YES, 86%**
An athlete with VI is safe to return to sport if both are true: **a. The athlete has followed a graded return-to-sport protocol and has 'passed' each stage with no recurrence of concussion symptoms, and;** **b. The athlete is symptom-free, or baseline is back to where it was pre-injury.**	**YES, 100%**
How important are each of the following concussion education topics for non-medically trained individuals (eg, athletes, coaches, guides, etc.)?	
Knowledge of the unwanted repercussions and dangers of concussion if not managed properly or if symptoms are concealed	**YES, 100%**
Knowledge of what to look for and how to recognize concussion signs/symptoms	**YES, 100%**
Knowledge of the importance and implementation of a properly followed protocol in the event of a head injury	**YES, 100%**
Knowledge of concussion assessment tools	NO, 71%
Knowledge of concussion management strategies	**YES, 100%**
Knowledge of return-to-sport protocols	**YES, 100%**
*Knowledge of concussion prevention strategies	**YES, 100%**
†Consensus achieved, 100% of participants disagreed with the statement. *Statement only received six responses in total as opposed to seven.	

2.4.3.1.1 Best Assessment Practices for Teams Without Medical Support

Experts came to a consensus (~86% agreement) that medical staff provided by the IPC and medical staff provided by local event organization committee would be appropriate individuals to provide an assessment in the event the athlete does not have a medical team of their own. See Figure 2.3 for an illustration of the relative agreement between participants on this collection of statements.

One participant provided additional feedback to the 'Medical staff provided by the IPC' statement and suggested the following:

> "'Medical staff provided by the IPC' should read 'medical staff provided by the International Federation (IF)' (the IPC not necessarily is the IF, and will not be present at IF events)."

The panel did not reach the criterion for consensus on whether it would be appropriate for a referee (with concussion screening training), and/or medical staff from the opposing team to intervene and assess an athlete with VI.

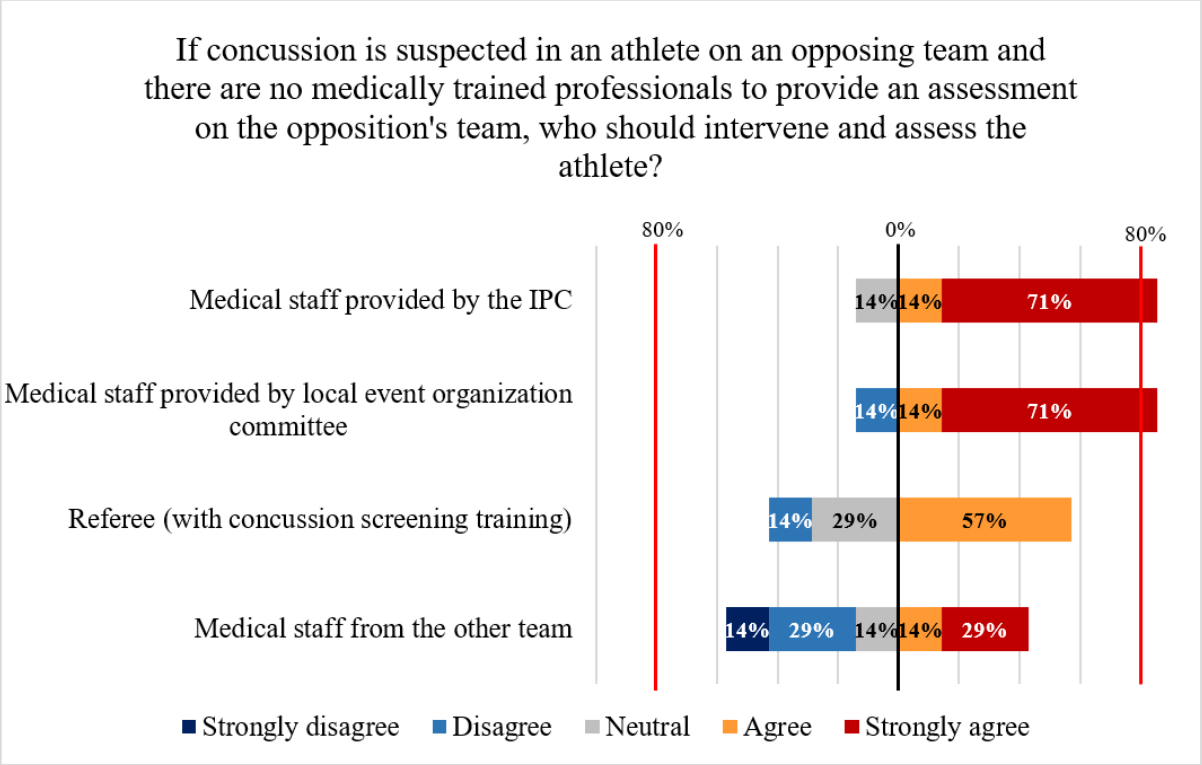

Figure 2.3: Relative agreement between participants on who should intervene and assess an athlete if there are no medically trained professionals on their team to provide a concussion assessment.

Note: The red vertical lines at the 80% mark represents the 80% threshold needed for consensus to be achieved.

2.4.3.1.2 Expert Opinions on the Use of the SCAT5 with VI Athletes

The expert panel reached consensus (~86%) in agreement that the SCAT5 with necessary modifications currently represents the most effective concussion assessment tool for athletes with vision impairment.

One participant disagreed with the statement and provided the following feedback:

> "[The SCAT5] is too large and unwieldy for regular sideline use. […] Each iteration from SCAT1 to SCAT5 has added components and complexity without measured additional benefit for

athletes, without evidence of improved discriminatory value over previous SCAT version nor with improved clinical care of a concussed athlete. […] In many areas of medicine, such as venous thrombosis, the evidence consistently shows "clinical gestalt" is equal or better than the multiple validated clinical tools. For concussion in VI athletes, knowing your athlete is better than application of the SCAT5."

2.4.3.1.3 Education of Non-Medically Trained Individuals in Para Sport

Results for this collection of statements are presented in Figure 2.4. Six out of the seven concussion education topics asked reached consensus (≥ 80% agreement) on their level of importance.

The only concussion education topic that failed to reach consensus was the knowledge of concussion assessment tools. ~71% of experts agreed that this was an important or very important concussion education topic for non-medically trained individuals. One participant provided the following feedback:

"Non medics need less knowledge of assessment tools but need to know they exist."

Another participant offered an additional comment and wrote:

"My answers above are probably shaped by my deep seated beliefs that concussion education is imperative and essential for all involved in sport."

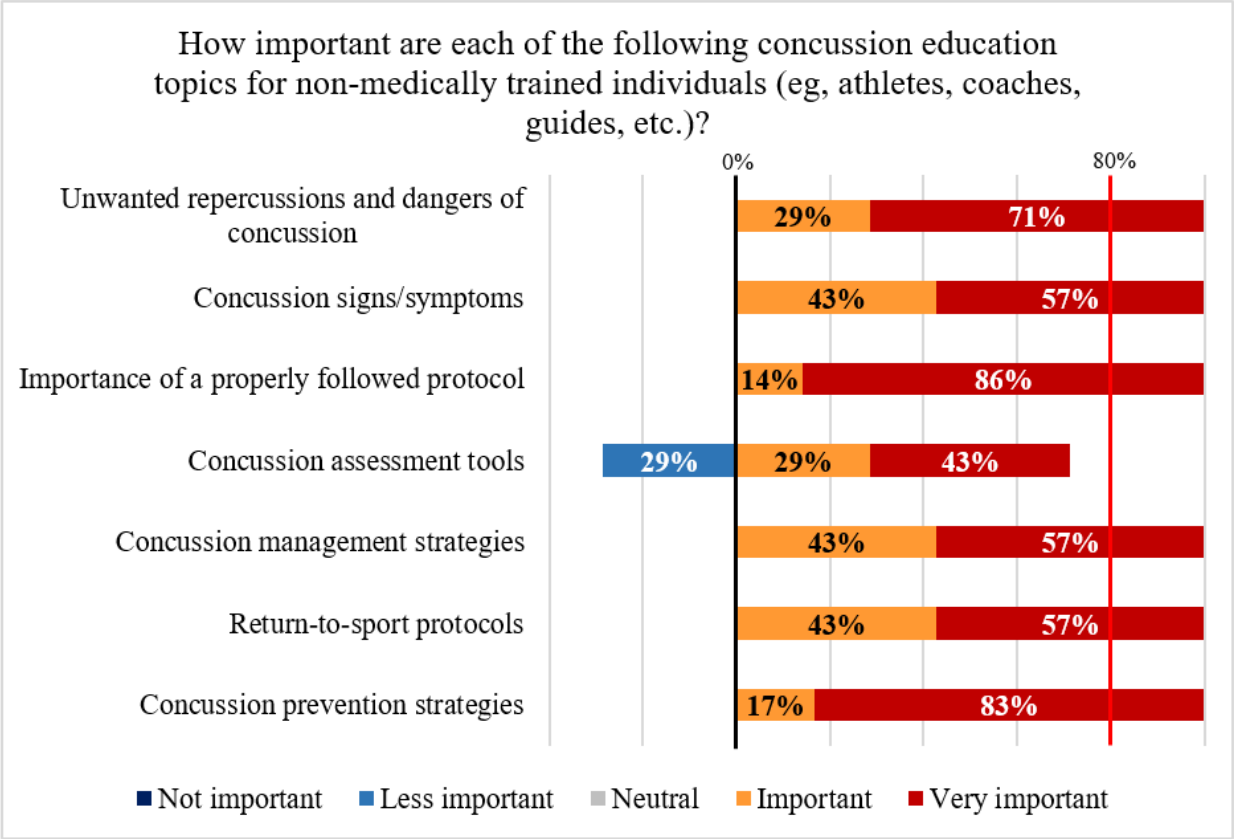

Figure 2.4: Relative importance of concussion education topics for non-medically trained individuals (e.g., athletes, coaches, guides, etc.).

2.4.3.2 Critical Research Priorities and Future Directions

Table 2.6 describes whether consensus was achieved for each statement included in the Critical Research Priorities and Future Directions domain and the percentage of participants who agreed with each statement. For this domain, consensus was achieved on 5 out of 8 statements. Three statements did not achieve consensus.

Table 2.6: Responses to statements included in the Critical Research Priorities and Future Directions domain.

Statements ***Domain 2: Critical Research Priorities and Future Directions***	***Consensus achieved (YES/NO), % Agreement***
Research to validate the following tools/strategies/protocols for use in athletes with VI:	
Concussion assessment tools (e.g., SCAT5, VOMS, GCS, etc.)	**YES, 86%**
Management strategies (e.g., vestibular rehabilitation, targeted physical therapy, etc.)	**YES, 100%**
Return-to-sport protocols (e.g., graded return-to-play protocol, etc.)	**YES, 86%**
Creating new tools/strategies/protocols for use in athletes with VI:	
Concussion assessment tools	NO, 71%
Management strategies	NO, 57%
Return-to-sport protocols	NO, 43%
***Research to identify why certain teams do not have health care professionals (medical doctors, physiotherapists, etc.) on-site during training and competition and how to overcome this issue.**	**YES, 83%**
***Making baseline pre-participation examinations compulsory and systematically implemented across all national teams (with medical staff) and across all Paralympic sports.**	**YES, 100%**
*Statement only received six responses in total as opposed to seven.	

2.4.3.2.1 Expert Opinions on the Need to Create New Tools for Athletes with VI

Three statements sought to determine whether entirely new assessment tools, management strategies, and return-to-sport protocols are needed for athletes with VI. Consensus was not obtained on the need for the creation of entirely new tools/strategies/protocols for athletes with VI, and the results are illustrated in Figure 2.5.

One expert elaborated on their answer with the following:

> "A validated, short, clinically applicable at the field of play concussion tool for VI athletes is a welcome idea."

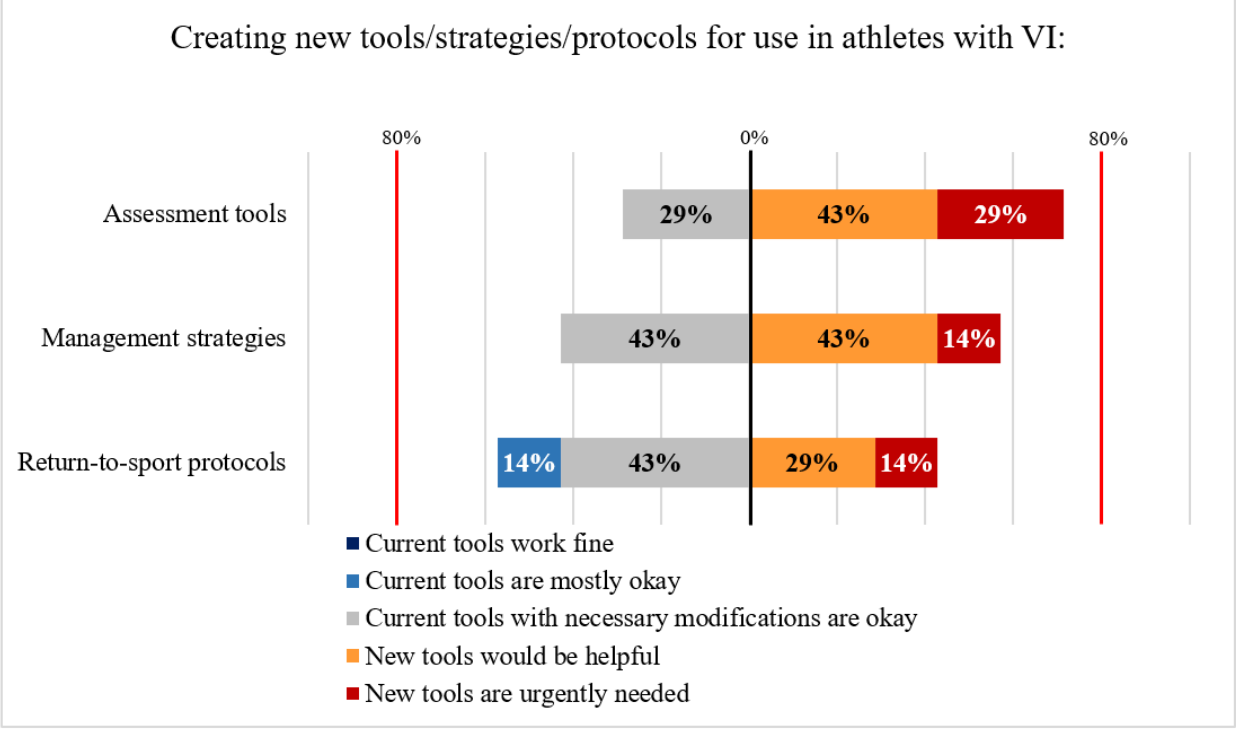

Figure 2.5: Relative need to create new assessment, management, and return-to-sport protocols for use in athletes with VI.

2.4.3.2.2 Understanding Why There is a Lack of Medical Support in Para Sport

When participants were asked to consider whether research is needed to understand why certain teams lack access to on-site medical support, there was a consensus (~83% in agreement) that this would be an important research priority. It should be noted that only six experts provided an answer to this statement, as opposed to seven.

While consensus on this statement was achieved, three participants shared that the reason for the lack of medical support in para sport is already known. One participant expressed:

> "The answer will be funding. Most teams rely on volunteer health professionals and do not have the budget to pay for long term ongoing professional support."

A different expert added that they believe research is needed in this area:

> "I still think that research would be warranted into this area however."

2.4.3.2.3 Expert Opinions on Making Baseline Testing Compulsory in Para Sport

When experts were asked whether baseline testing should be made compulsory and systematically implemented across all national teams (with medical staff) and across all para sports, 100% of experts considered this future direction to be either 'Important' or 'Very important'. Noted is that six participants provided an answer to this statement as opposed to seven.

While the above statement obtained consensus, one expert expressed their concern with making baseline testing compulsory:

"[Mandatory baseline testing] will simply burden existing volunteers and stress organizations to jump through another hoop without funds to do so – resulting in poor quality and haphazard pre-participation exams."

2.4.3.2.4 Additional Research Priorities and Future Directions

Three experts reinforced the importance of developing education strategies that are tailored to different stakeholders in VI para sport. One expert stated the following:

"Athlete education work (what methods is most effective education) is vital."

Another expert recognized the importance of conducting research that is athlete-centered:

"I am aware that research is currently being undertaken looking at the opinions of VI athletes towards concussion, and I hope that the findings from this will help to shape future research projects (as this will enable any research to be athlete-centered."

The same expert also added the following future directions:

"It is also imperative that clinicians working in the field are confident and competent with the management of concussion, and that coaches and other support staff can be educated too and be in a position to help."

2.4.3.3 Perspectives and Experiences when Working in Concussion Management for Athletes with VI

Table 2.7 describes whether consensus was achieved for each statement included in the Perspectives and Experiences when Working in Concussion Management for Athletes with VI domain and the percentage of participants who agreed with each statement. In this domain, consensus was achieved on

3 of the 10 statements (i.e., for two of these statements, the consensus was that the statements were incorrect). Experts were unable to come to a consensus on the remaining seven statements. See Figure 2.6 for the distribution of responses for all ten statements included in this domain.

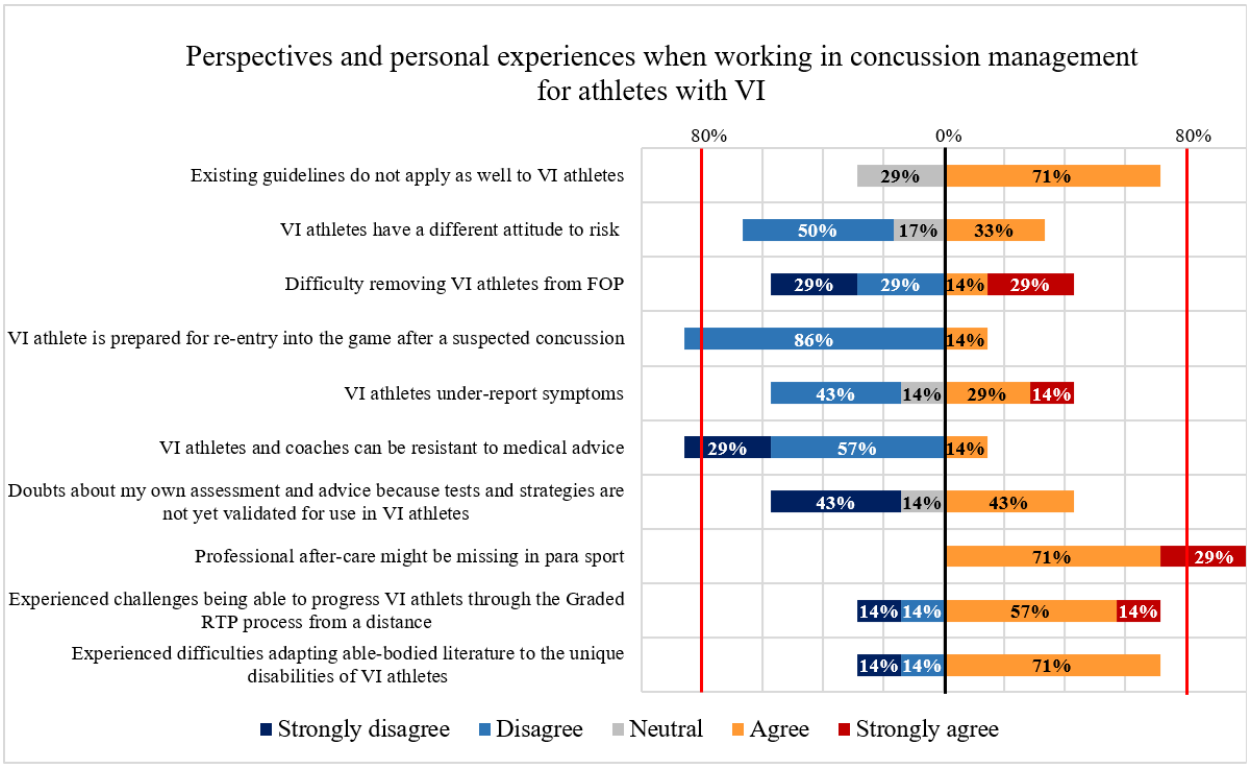

Figure 2.6: Relative agreement amongst participants on different perspectives and experiences when working in concussion management for athletes with VI.

Note: FOP is the abbreviation of 'field of play'.

Table 2.7: Responses to statements included in the Perspectives and Experiences when Working in Concussion Management for Athletes with VI.

Statements *Domain 3: Perspectives and Experiences when Working in Concussion Management for Athletes with VI*	*Consensus achieved (YES/NO), % Agreement*
Existing concussion assessment/management guidelines for able-bodied athletes do not fit or apply as well to VI athletes.	NO, 71%
^VI athletes seem to have a different attitude to risk (eg, they take more risks than able-bodied athletes) and appreciation of concussion (eg, they tend to downplay the severity of concussion).	NO, 33%
I have had difficulty removing VI athletes with suspected concussion from the field of play.	NO, 43%
†I have noticed too often that the VI athlete is removed from the field of play, quickly assessed by the team support (or not at all if there is no doctor present), the athlete is given a break, and then the athlete is prepared for re-entry into the game.	**YES, 14%**
I have worries that VI athletes may be under-reporting symptoms they are experiencing.	NO, 43%
†I have found that VI athletes and coaches can be resistant to medical advice.	**YES, 14%**
I have doubts about my own assessment and advice because assessment tests and management strategies are not yet validated for use in athletes with VI.	NO, 43%
There is a certain level of self-care/self-management by athletes with an impairment, and thus professional after-care might be missing in Paralympic sport, especially in teams without medical staff.	**YES, 100%**
I have experienced challenges being able to progress athletes with VI through the Graded Return-to-play process from a distance when they are away from national training camps. I find I am dependent upon others (eg, family, friends, local coaching staff) to progress the athletes through the RTP process to a greater extent than I am with non-VI athletes.	NO, 71%
I have experienced difficulties adapting able-bodied literature to the unique disability and adaptations of individual athletes.	NO, 71%
^One participant selected 'Uncertain/Unqualified for answer' and this response was excluded from the group response. Statement out of six responses. †Consensus achieved, 86% of participants disagreed with the statement.	

2.4.3.3.1 Consensus on a Lack of After-Care in VI Para Sport

In Round 1, two experts suggested that after-care might be missing in para sport. To determine whether lack of after-care is a widespread issue in VI para sport, this statement was asked in Round 2. Consensus (100% in agreement) was obtained for this statement with all seven experts either agreeing or strongly agreeing that there is a lack of after-care in VI para sport.

2.4.3.3.2 Consensus in Disagreement Among Experts Whether VI Athletes and Coaches are Resistant to Medical Advice

Two statements achieved consensus in disagreement, which means that over 80% of experts agreed that the following two statements were not representative of athletes and coaches in VI para sport. Participants came to a consensus (~86%) in disagreement with the statement suggesting that after a suspected concussion has occurred, the athlete is prepared for re-entry into the game without undergoing a concussion assessment. Consensus in disagreement (~86%) was also obtained for the statement which suggested that VI athletes and coaches can be resistant to medical advice.

2.4.3.3.3 Additional Expert Opinions and Perspectives

With regards to the statement asking whether existing concussion assessment/management guidelines for able-bodied athletes do not fit or apply as well to VI athletes, one participant provided the following comment:

> "I feel that existing concussion assessment/management guidelines for able-bodied athletes can apply as well to VI athletes, however, the assessment/management tools or methods may need to be modified or different."

For the statement which suggests that VI athletes seem to have a different attitude to risk and appreciation of the severity of concussion injuries, two participants offered their personal opinions. One participant stated:

> "I agree that VI athletes might have different attitudes to risk, but I do not necessarily agree with the examples provided. I do not think it necessarily is a matter of taking risks or downplaying symptoms, but a matter of ignorance."

The other participant offered a different perspective on the matter:

> "Some VI athletes (younger, less experienced, and sometimes more committed) are more concerned about the impact on their team performance or personal performance than they are about their own safety. […] They have been known to conceal concussion symptoms or be prepared to take more risks throughout the process."

2.5 Discussion

The aim of the current study was to understand how concussions are currently assessed and managed in elite para athletes with vision impairment. This survey study identified areas where there was consensus in expert opinion and uncovered topics for which there was no obvious agreement. The sections that follow will highlight areas where consensus was reached as well as areas where further investigation is needed to guide the development of VI-specific clinical practice guidelines for concussion assessment and management in para sport.

2.5.1 Concussion Recognition and Response

Results from the present study indicate that VI athletes may exhibit different observable signs of concussion compared to able-bodied athletes due to the underlying conditions of para athletes. The SCAT5 cites “blank or vacant look” as a common observable sign of concussion in able-bodied athletes (56). In contrast, results from the current study suggest that VI athletes tend not to have a blank look after sustaining a concussion. In agreement, the CIPS group recommend that a blank or vacant look should not be considered an observable sign at all in athletes with VI (16). This recommendation was made because a blank or vacant look may be either pre-existing or not possible to interpret in athletes with VI (16). While balance, gait difficulties, and motor incoordination are common observable signs of concussion in both able-bodied athletes and in athletes with VI (56), results from a study by Zetterlund et al. (2019) suggest that individuals with vision impairment are predisposed to balance issues at baseline relative to those without visual deficits (94). As such, medical professionals should be mindful in recognizing changes in balance from normal in athletes with VI after a suspected concussion, as athletes with VI likely have pre-existing balance issues (16,94). Lastly, experts reached a consensus that they have paid closer attention to behavioural deviations from normal when assessing concussion in athletes with VI, with one expert acknowledging that they have seen short-term personality changes from athletes with VI who have sustained a concussion. Recognizing behavioural deviations and short-term personality changes from normal is only possible if the medical professional understands the athlete’s behaviour and personality prior to a concussion injury. The former is yet another argument for further investment in the provision of on-site medical support in elite VI para sport.

2.5.2 Baseline Testing

Experts reached a unanimous consensus that baseline testing is critical in establishing a point of reference of the athlete's baseline function and in the comparison of pre-injury results with post-concussion results. This opinion amongst para sport concussion experts is in direct opposition to the expert consensus established for able-bodied athletes by the CISG. In their fifth consensus statement, the CISG acknowledged that while baseline testing may be useful, it is not necessary for interpreting post-injury scores (2). Their argument is that the clinical value of baseline testing when an athlete is well (i.e., not concussed) and subsequent follow-up (i.e., post-concussion) is currently not endorsed by scientific evidence and is neither validated in athletes in general nor in athlete subpopulations, such as athletes with impairments (53,63). On the contrary, the data from our study agrees with the CIPS group's position that routine baseline testing is essential in establishing a baseline reference point for the assessment of concussion symptoms in the future (16). It is also necessary to consider that para athletes with VI have pre-existing conditions that may affect the results of the baseline test, and that these athletes can exhibit symptoms at baseline akin to those typically observed post-concussion (i.e., blurred vision, sensitivity to light, balance problems, etc.) (53,66). It is of utmost importance for medical professionals to understand the full extent of the pre-existing conditions in athletes with VI, yet another reason for the increased provision of medical support staff in para sport. Due to the presence of pre-existing conditions in athletes with VI, it is more important for baseline testing to be conducted for athletes with VI than it is for able-bodied athletes. There is also evidence from our study to suggest that baseline testing may also be beneficial in the acute management of concussion and in making return-to-sport decisions for athletes with VI.

Despite unanimous consensus among experts on the importance of baseline testing for athletes with VI, concern was expressed with making baseline testing compulsory and systematically

implemented for internationally sanctioned para sports. The concern was that mandating baseline testing would stress volunteers and organizations without the necessary resources (e.g., medical personnel, financial means) to carry out baseline testing. There was added concern that burdening volunteers and organizations to carry out their own baseline testing would result in haphazard pre-participation examinations of poor quality. To allow for baseline testing data to be collected at least annually, provision of outside medical support staff for teams without their own would be required. In this way, baseline testing results and a detailed account of pre-existing conditions for every athlete would be available at both competitive and training environments.

The best method for capturing baseline testing data in para athletes is currently unknown. Findings from our study suggest that medical professionals are currently using a variety of methods to collect baseline testing data in athletes with VI. Most participants identified that they used the SCAT3/SCAT5 with VI athletes under their care while others indicated they have used the VOMS assessment and other unspecified balance tests, symptom screening tests, and visual tests (e.g., measuring pupillary dilation reflexes, etc.). In recognition of the lack of medical support staff in VI para sport (16), a standardized method of capturing baseline testing data and pre-existing conditions across all para athletes with VI could be beneficial. A standardized method of capturing baseline data in VI athletes would allow for outside medical professionals who would otherwise be unfamiliar with a given VI athlete to have an improved understanding of the athlete's pre-existing condition. Future research should be devoted to determining the best method for capturing baseline data and for documenting pre-existing conditions in athletes with VI to allow for this process to be standardized across all para athletes and sporting federations.

2.5.3 Assessment

While most experts recognized that the SCAT5 can be used to assess concussions in athletes with VI, some identified that modifications to the content and delivery of the SCAT5 may be required. Modifications mentioned by experts included modifying tasks that involve a visual component, asking the athlete to verbally rank the items of the SCAT5 symptom scale, and using speech apps/phones to help dictate the SCAT5 assessment to the athlete. These modifications are consistent with the CIPS group recommendation that the delivery of the SCAT5 may need to be altered, given the existing SCAT5 assumes certain 'normal' athlete functions to complete these assessments, such as the ability to see clearly (16,56).

Results from our study found that all seven experts directly involved in concussion assessment used the SCAT5 with VI athletes under their care. A concerning result, however, was that only three experts indicated they used additional concussion assessment tools to add to the clinical value of the SCAT5 (i.e., balance testing, the VOMS assessment, etc.). Concussion assessment guidelines emphasize that the SCAT5 should not be used in and of itself to make or exclude the diagnosis of a concussion (2,16). This is because an athlete may still have a concussion even if their SCAT5 is found to be normal (16). As such, clinicians are encouraged to inform their clinical decision with the help of a variety of concussion assessment tools that assess additional domains such as concussion symptom severity, clinical reaction time, changes in balance and gait from the athlete's normal, neurocognitive outcomes, and video footage of the suspected concussion injury if available (2,16). It is unclear as to why the remaining four experts failed to mention additional concussion assessment tools that could add to the clinical utility of the SCAT5. One possible reason could be that for certain experts, the SCAT5 has been sufficient in the diagnosis of concussion in athletes with VI. Another reason could be that other concussion assessment tools are not suitable for use in athletes with VI, and medical professionals

are hesitant to adapt these tools without first establishing the clinical validity of the adapted assessment tools.

Most experts (86%) who took part in our study agreed that the SCAT5 currently represents the most effective assessment tool available for the evaluation of suspected concussion. However, one expert disagreed with the previous statement with their reasoning being that the SCAT5 is too large and has added components without evidence of improved discriminatory value over previous SCAT versions. It should be recognized that in the elite competitive para sport environment, medical providers often have fewer than 10 minutes to complete first aid/emergency care priorities, conduct a concussion assessment, and come to a decision as to whether the athlete is safe to return to play (22). Considering the sideline assessment section of the SCAT5 takes at least 10 minutes to administer correctly (56), this could mean that it would be an unrealistic expectation for medical providers to complete the entire sideline SCAT5 assessment correctly during the allotted time. It is also worth recognizing that it may take longer than 10 minutes to administer the SCAT5 correctly in athletes with VI, as these athletes may require the use of speech apps to aid in the administration of the tool. Going forward, it would be worth identifying areas of the sideline SCAT5 that demonstrate the most clinical utility when assessing concussion in athletes with VI to understand whether it would be possible to create a shorter, validated, and clinically applicable to the field of play assessment tool for athletes with VI.

In terms of vestibular and oculomotor assessments, one expert from the current study explained that they measured pupillary dilation reflexes at baseline to assess for change after a possible head injury. Another stated they have eye tracking exams that are unique to each of their VI athletes and baseline balance testing videos that they can use to compare post-concussion testing results with. Given the VOMS assessment test measures domains such as smooth pursuits, horizontal and vertical saccades, near point convergence, gaze stability, and balance (95,96), VI athletes may not be able to perform

these assessment domains at baseline nor after a suspected concussion. As such, future research is needed to determine which domains of the VOMS assessment may demonstrate clinical utility in concussion assessment and return-to-sport decision-making in athletes with VI. Furthermore, research is needed to understand which components of the VOMS assessment may need to be modified for use in VI athletes.

Expert opinions were divided on the need to create entirely new assessment tools specifically for athletes with VI. In the second-round of the Delphi study, experts were leaning more towards the creation of new tools, with approximately 71% of experts finding the idea of new VI-specific assessment tools either helpful or urgently needed. The remaining participants were content with the use of current assessment tools with necessary modifications. Some of these necessary modifications were identified earlier and include verbally asking athletes to rank their concussion symptoms on the SCAT5, modifying visual tasks included in the SCAT5 and VOMS assessment, or omitting certain visual assessment domains entirely in the event an athlete is unable to perform the visual task. However, the issue with having to modify or omit certain visual assessment domains from existing assessment tools such as the SCAT5 or the VOMS is that these modifications may alter the validity of the tool. It could be the case that medical professionals are hesitant to use modified assessment tools due to their lack of validity in the detection of concussion, and perhaps why some experts endorse the creation of new tools over the modification of existing ones. Future research should invest in understanding what new assessment tools may need to look like for concussion assessment in athletes with VI.

2.5.4 Management and Return-to-Sport

Experts came to a consensus that management strategies remain largely unmodified from those recommended for use in able-bodied athletes, apart from having to adapt management protocols to suit the athlete's visual impairment if necessary. This finding aligns with the CIPS group who recommended

no variation from the standard acute management protocol endorsed by the CISG for athletes with VI (2,16). Regrettably, our study did not explicitly differentiate between the acute management of concussion and the management of persistent concussion symptoms. As such, some participants may have interpreted the question of whether they modify their management strategies as referring to acute management only, whereas others may have thought the question was referring to persistent concussion symptoms as well. For this reason, limited data was collected on the management of persistent concussion symptoms in athletes with VI. Going forward, further investigation into the management of persistent concussion symptoms in athletes with VI is needed to understand whether existing strategies (e.g., symptom-limited aerobic exercise, cognitive behavioural therapy, vestibular rehabilitation, etc.) may require modification for athletes with VI.

Consistent with guidelines on the return-to-sport process following concussion for able-bodied athletes, all seven experts in Round 2 agreed that an athlete with VI is safe to return to sport once they have successfully progressed through a sport-specific multi-staged return-to-sport concussion protocol without a recurrence of concussion symptoms (2,97). Experts from the current study recognized that no major modifications are needed to the return-to-sport process for athletes with VI. Some experts, however, suggested increasing the amount of time between each of the return-to-sport stages (i.e., over and above the 24-48 hour guideline) initially recommended by the CISG (2). Similarly, the CIPS group advised clinicians to consider whether para athletes may need a longer initial period of cognitive and physical rest prior to starting the return-to-sport protocol for impairment specific reasons, such as a history of previous central nervous system (CNS) injury or impaired CNS function at baseline (16). Presumably, the suggestion to increase the amount of time between return-to-sport stages is a precautionary one, given the lack of evidence demonstrating improved recovery for VI athletes when increasing the amount of time between return-to-sport stages.

One possible reason for extending the duration of time between return-to-sport steps could be that many of the signs and symptoms clinicians monitor during the return-to-sport process (e.g., dizziness, headache, blurred vision, and poor balance) may be pre-existing in VI athletes (16,28). As such, more time between steps may be needed to distinguish symptoms elicited during the return-to-process from baseline values in this group of athletes (16). Another reason could be that athletes with VI may experience increased cognitive and physical demands, when compared to able-bodied athletes, while recovering from concussion which may make it more challenging for them to interact with their environment (i.e., reading braille may take more cognitive effort than reading with normal sight) (98). A study conducted in a population of healthy, able-bodied children and young adults found that increased cognitive load was associated with a longer recovery from concussion (99,100). More research is needed to determine whether increases in cognitive load could exacerbate recovery from concussion in blind or visually impaired individuals. Future work should also be devoted to understanding whether increasing the amount of time between return-to-sport stages could improve concussion recovery in athletes with VI.

2.5.5 Education

There was consensus amongst experts that concussion education is extremely important for non-medically trained individuals. However, findings from our study suggest that there is minimal concussion education targeted to athletes, coaches, and the wider para sport population. As a result of a lack of education, experts felt that VI athletes, coaches, support personnel, and to some extent International Federations and/or event organizers tend to downplay the severity of concussion injuries. The tendency for athletes, coaches, and sport federations in para sport to downplay the severity of concussion injuries is consistent with previous studies (10,16,46). In a study by Wessels et al. (2012), when wheelchair basketball athletes were asked why they did not report their concussion incidents,

most participants reported they did not want to be taken out of the game, that they didn't think their concussion was serious, or that they did not know they had a concussion (46). The previous responses demonstrate a lack of awareness of the dangers of failing to report concussion symptoms and of the consequences of neglecting proper management of concussion injuries (46). Clearly, education on the severity of concussion injuries and the consequences of failing to address concussion injuries is needed amongst non-medical personnel in VI para sport.

In addition to education on the severity and potential consequences of concussions, experts from our study came to a consensus that recognizing concussion signs/symptoms, understanding the importance of a properly followed protocol in the event of head injury, and knowledge of concussion prevention strategies are also important education topics for non-medically trained individuals in VI para sport. Acknowledging the lesser availability of medical support staff for para athletes during training and competition (16), para athletes may need to be able to adequately recognize and respond to concussion symptoms on their own. Paradoxically, para athletes, coaches, and guides may be better positioned to recognize concussion symptoms when compared to medical professionals. Para athletes, coaches, and guides may be better equipped to notice subtle changes in an athlete's visual function, balance, or personality from normal considering athletes, coaches, and guides may have a deeper understanding of each other on a physical and psychological level when compared to medical professionals who are not usually on the sidelines. While there are concussion education topics that non-medically trained personnel do not need to understand (e.g., specific concussion assessment tools), at a minimum, para athletes, coaches, and guides should be able to recognize concussion symptoms and know how to respond appropriately.

2.5.6 Lack of Medical Support and After-Care

As demonstrated by the difficulty researchers faced when recruiting healthcare professionals for the present study and by the results obtained in our study, there is a systemic lack of on-site medical support in VI para sport. This finding is consistent with the Concussion in Para Sport group's observation that there is a lesser availability of specially trained medical personnel for para athletes in comparison to able-bodied athletes (16). While there is a lack of research quantifying how pervasive the lack of on-site medical staff is in VI para sport, one expert from the present study described that team physician access is considered a "resource privilege". In addition, all medical professionals who took part in the current study were from either North America or Europe. This observation suggests that there may be even fewer medical professionals with expertise in para sport in other continents such as Africa, Asia, Oceania, and South America. If there are little to no medical staff on-site to perform medical assessments, then there is a greater chance that VI athletes will continue to train and compete while injured, which could put athletes at risk of sustaining another concussion or a different life-threatening injury. It is also worth recognizing that if there is a lack of on-site medical support in elite VI para sport, then it is very likely there is an even greater absence of on-site medical support in recreational para sport. Investment in the provision of on-site medical support in both training and competitive environments in elite VI para sport at a minimum is critically needed to ensure the safety and well-being of VI para athletes. Further investment in the education of community health professionals and support for recreational sport activities would further improve the well-being of VI para athletes.

Experts from the current study came to a unanimous consensus that there is a lack of after-care in VI para sport in addition to the lack of on-site medical support. Concerningly, para athletes may be left to manage their concussion symptoms and return-to-sport on their own once they have stopped training and/or competing with their national team. In this way, it is likely that athletes may not adhere to their

return-to-sport protocol and may return to competitive sport with their domestic team earlier than advised by their national team physician. A premature return to sport could increase the risk for a second concussion injury, which has the potential to cause permanent brain damage or even death (101). This is another argument for increased education on the risks associated with a premature return to sport and the importance of a properly followed return-to-sport protocol.

2.5.7 Perspectives and Experiences of Medical and Scientific Experts in VI Para Sport

Participants were not in agreement on most of the statements from the final domain of the second-round survey. One possible reason for the differences in the experiences of medical and scientific experts from our study could be due to the differences in the perceived risk of concussive injuries across different VI para sports. Sports such as Blind Football and Para Alpine Skiing have documented high rates of concussion (8,9,17,41) and athletes from these sports may be more educated on the severe impacts of concussive injuries and may be more likely to disclose concussion symptoms. In contrast, athletes and coaches from a sport where concussive injuries are comparatively less likely, such as Para Nordic Skiing, may not disclose their symptoms to members of their team or on-site medical professionals simply because they are not educated on the acute symptoms consistent with concussion injuries. Another reason for the differences that were observed in the opinions of experts could be due to the differences in team dynamics. Some athletes may feel supported when disclosing concussion symptoms to their coaching and medical staff because there is an understanding amongst team members that the health and safety of the athlete matters most, while other athletes may feel they are under more pressure to continue to play and perform. Further investment in concussion education for all those involved in VI para sport would encourage the development of supportive sporting environments where the para athlete's health is of utmost priority and the athlete feels supported when disclosing concussion symptoms or other health concerns.

2.5.8 Additional Research Priorities

Experts reached a consensus that the validation of existing assessment tools is an important research priority going forward. Currently, none of the pre-existing assessment tools (e.g., SCAT5, ImPACT, mBESS, VOMS, etc.) have been tested for their validity or test-retest reliability when used in athletes with VI (16). The validity of concussion screening batteries is vital because concussions that go unreported or undetected for days or weeks after injury may worsen the severity of a brain injury, particularly when concussed individuals return to activities prematurely (102). Likewise, symptom scales should also provide measurement sensitivity and accuracy in symptom detection from the first point of contact and throughout the period of recovery so that return-to-sport decisions can also be informed by measurable improvements in symptom recovery (102).

A recent systematic review of the literature surrounding the validity and utility of the widely used Immediate Post Concussion Assessment and Cognitive Testing (ImPACT) in able-bodied athletes found that while convergent validity[4] was supported by the literature, evidence of predictive validity, diagnostic accuracy, and responsiveness was inconclusive (103). The same review found that the validity and utility of the ImPACT test was influenced by factors such as the testing environments, invalid baseline scores, exertion, and sleep prior to the test (103). These findings highlight the importance of examining the validity of commonly used assessment protocols to better understand if there are any VI para sport-specific factors that may threaten the validity of test scores.

Before validation studies of common assessment tools used in athletes with VI can be undertaken, normative data on how athletes with VI typically perform on assessment tools is required. A recent study found that para athletes reported an average of 5.0±5.4 symptoms (out of 22 symptoms) and an

[4] Convergent validity indicated whether the ImPACT test correlated highly or yielded similar results as other measures believed to measure the same construct (e.g., visual memory, verbal memory, reaction time, etc.).

average symptom severity score of 11.0±14.3 (out of 132) at baseline with the SCAT5 (66). More published baseline and post-concussion scores among athletes with VI will allow for a greater understanding of how athletes with VI typically perform on common assessment tools. In turn, data from these studies will allow for the comparison of scores with the goal of establishing convergent validity across different assessment tools.

2.5.9 Strengths of the Delphi Method

The Delphi technique was the method of choice for the current study for a variety of reasons. Firstly, the Delphi study technique allows for the solicitation and establishment of expert opinion while avoiding recruitment bias due to the participants' geographical location (104). This allowed us to solicit the opinions of experts from a range of locations including experts from countries in both North America and Europe. In addition, unlike other consensus-building methods, the Delphi technique does not require direct face-to-face interviews (104–106). Instead, an online survey technique allows the participant the flexibility to complete each round of the study at their own earliest convenience.

Another reason for utilizing the Delphi study technique was the anonymity the methodology affords its participants (104,107). Participant anonymity reduces the ability of the opinions of otherwise dominant individuals in the field of interest to artificially drive consensus, which is often a concern when using group-based processes to collect and synthesize information (88,108). Furthermore, the Delphi study is recommended in situations where there is incomplete knowledge, uncertainty, or a lack of evidence in the field being investigated (104,109). Given the minimal research and lack of evidence regarding best practices in concussion management for athletes with vision impairment, the Delphi study technique was considered an appropriate methodology for the current study.

2.5.10 Limitations of the Delphi Method

While there are several advantages to the Delphi study technique as discussed above, there are also various limitations. For instance, instead of using a random sample representative of a population of interest, the Delphi technique employs a limited number of 'expert' participants and there are controversies associated with the 'expert' label (87,104). For the current study, we made an effort to mitigate this limitation by defining our inclusion criteria for participation in the study from the outset. However, even with defined inclusion criteria, there is still debate over what constitutes an 'expert' in the field of concussion management in VI para sport. Knowledge in the field through a professional qualification (e.g., certified medical practitioner, registered physiotherapist, etc.) may be sufficient, but qualification does not ensure expertise (104). Likewise, the number of years a medical professional has been practicing is not always indicative of their level of expertise (104,110).

Many health-related Delphi studies have a relatively small sample size and recruit participants with particular knowledge of a condition (104). The first round of our Delphi study had a sample size of eight participants. While this sample size is within the range of typical sample sizes for health-related Delphi studies (i.e., 8-15 participants), it could be argued that the present study could have used a larger sample size to ensure the generalizability of opinions (87,104,111). To that effect, the opinions expressed by most participants in our study only reflect how concussion is assessed and managed for VI para sport teams with access to medical support. Consistent with the CIPS position statement on concussion in para sport, participants in the current study reported that many VI sports teams do not have access to their own medical support (16). It is crucial to recognize that there is an imbalance in the level of medical support available to VI athletes in para sport when interpreting the results from the current study.

While international sport organizations such as the IPC, IBSA, CBSA, and CIPS assisted the investigators in the recruitment of participants from a variety of different continents, all experts who participated in the study were from either Europe or North America. As participants were required to have sufficient English language proficiency to understand and complete the questionnaire, this inclusion criterion likely disproportionately attracted native English speakers to participate compared to non-native English speakers. Another reason for the lack of participants from continents such as Africa, Asia, Oceania, and South America could be that there are fewer qualified medical support personnel from these continents to begin with. As such, the results from this study reflect the opinions of healthcare professionals from Europe and North America only.

In Round 1, participants were asked to provide written answers to the 25 open-ended questions included in the questionnaire. Some written answers included the misspelling of words and unclear sentence structure, and the investigators interpreted these responses to the best of their ability. Moreover, there could be a discrepancy between the written answers that experts provided, and the concussion management practices experts engage in. That said, it is unclear why study participants would not give an accurate account of their concussion management practices given their anonymity in this study and that their association with their written responses is kept strictly confidential.

Another limitation of the Delphi technique is the amount of qualitative data that is generated after the first round of the study. The Classic Delphi study approach (i.e., open-ended questions in the first round) was used for the current study as opposed to a modified approach which typically involves the researcher identifying issues through either a literature review or through consultations with stakeholders (87,104). For the present study, the Classic Delphi study approach was chosen given the lack of evidence and available research on current assessment and management practices in VI para sport. While an abundance of data is generally a welcome scenario, the first round produced a large

number of statements which would have created a lengthy and time-consuming second-round questionnaire for participants (104). In the interest of retaining as many participants as possible for the second round and avoiding overburdening the expert panel with an overly lengthy questionnaire, the research team prioritized the inclusion of between 40-50 statements for the second round. A study by Trevelyan & Robinson (2015) encountered a similar issue of a large amount of qualitative data after the first round and upon reflection, suggested the use of fewer, well-focused open-ended questions or the use of a modified approach in developing the initial consensus statements (104).

Currently, there is little research concerning the optimal number of response categories for a Delphi study in Round 2 and onwards (104). Non-Delphi research studies have found that two, three, and four-point scales have poor reliability and discriminating power (112). For general survey-based studies, one study suggested that the optimal number of categories lies between four and seven (113). For the present study, we used a five-point Likert scale. The five-point Likert scale was chosen because it allowed participants to remain 'neutral' on a given statement if they had no opinion. One argument against the use of a midpoint is precisely that it allows participants to remain 'neutral' which could also be interpreted as if they "don't know" or that they are "undecided" on the matter (114). It is thought that this could affect the reliability and validity of results, in that the midpoint may serve as a "dumping ground" (115). However, in the second round of our Delphi study, we observed very few respondents selecting the 'neutral' option to begin with. Additionally, to differentiate between 'neutral' and 'uncertain' responses, we included a sixth response option for every statement in the second round which allowed participants to state they were "Uncertain" or "Unqualified to answer" a given statement.

2.5.11 Conclusion

Prior to the current study, concussion assessment and management practices in elite VI para sport were not well documented in the scientific literature. We found that in general, healthcare professionals in

VI para sport are using existing concussion assessment tools and management strategies originally developed for able-bodied athletes and adapting tools and strategies as necessary to VI athletes based on their visual impairment. There was strong agreement among experts that understanding the VI athlete's pre-existing condition and conducting baseline testing prior to the start of every season is vital to assess for any change after a possible head injury. Some experts suggested prescribing a longer period of initial rest or doubling the time between return-to-sport steps for athletes with VI. Experts disagreed on the need to create entirely new assessment tools for athletes with VI, however, some experts were open to the creation of shorter, clinically applicable sideline concussion assessment tests specific to athletes with VI. Validation of existing concussion assessment tools was identified as an important research priority. Future investment in the provision of on-site medical support and concussion education is critical for the improved recognition of concussion injuries in athletes with VI.

Chapter 3

Para Athlete and Coach Perspectives and Experiences with Concussion in Vision Impaired Para Sport

3.1 Abstract

Purpose

The purpose of this study was to understand the perspectives, experiences, and knowledge of elite athletes with vision impairment (VI) and coaches concerning concussion in VI para sport.

Methods

For this survey study, elite para athletes with VI and coaches were invited to participate. Participants were asked to independently complete a single web-based survey delivered through REDCap, a secure web application for building and managing online surveys (81). The survey consisted of a combination of multiple choice, Likert scale, Yes/No, and short-answer questions for a total of 40 to 52 questions. Questions covered the following topics: Demographics; Concussion incidence, recognition, response, assessment, and management; Return-to-sport; and Education. Analysis consisted of categorizing written responses and analyzing response frequencies.

Results

A total of 8 participants (athletes (n = 4); coaches (n = 4)) from elite VI para sport took part in the study. Participants were from a variety of VI para sports including Para Alpine Skiing, Para Athletics (Track & Field), Para Cycling, Para Judo, Para Nordic Skiing (Cross-country & Biathlon).

When asked how their medical team decides to investigate whether an athlete has sustained a concussion, three out of four athletes reported that they were uncertain. In contrast, all four coaches

identified that any significant impact to the head, face or neck would prompt an investigation from the medical team.

Two out of four athletes responded that they (or a teammate) sustained a concussion and did not report it to their coach or team. Reasons for not reporting or seeking medical attention after a suspected concussion included: “I didn’t think [the concussion] was serious”; “I thought I would get better on my own”; “time or money for something they already knew”; and “visual behaviours misinterpreted due to medical personnel’s lack of knowledge regarding blindness and/or low vision”.

None of the athletes were able to identify specific concussion assessment tools that medical professionals use to assess the severity of a suspected concussion injury. Two out of the four coaches were able to identify specific concussion assessment tools used by medical professionals, including the SCAT and the ImPACT tests.

In response to whether participants had previously received any form of concussion education, three out of four coaches said they had received concussion education, while only one out of three athletes received concussion education.

Conclusion

The results from this study suggest there are notable disconnects between elite VI para athletes and coaches perspectives and experiences regarding concussion. Athletes appear to be receiving less and poorer quality concussion education compared to coaches. Future education strategies should prioritize informing para athletes of the potential long-term consequences of concussion so athletes can make informed decisions regarding their participation in para sport.

3.2 Introduction

Elite para sport participation has come a long way since the Stoke Mandeville Games in 1948 which featured a total of 16 para athletes (116). The Tokyo 2020 Paralympic Games and Beijing 2022 Paralympic Winter Games both saw record numbers of para athletes with 4,403 and 564 competitors, respectively (45,117). With increased participation of para athletes, unfortunately, comes an increase in the number of injuries in para sport competition and training. The International Paralympic Committee (IPC) have conducted injury and illness surveillance studies for the last two decades at every major Paralympic Games event (6). These studies found that injuries to the head, face, and neck remain among the most prevalent of sports-related injuries, accounting for 10% of the total number of injuries at the Rio 2016 Paralympic Games (8). In some sports, such as Blind Football, injury rates are even higher, with 25% of acute injuries being to the head and neck at the London 2012 Games (14).

Sports-related concussion, a form of mild traumatic brain injury, is a prominent topic in sports medicine (118). While up to 90% of concussion symptoms are transient and typically resolve within 10 to 14 days after injury (119), athletes who sustain multiple concussions are at an increased risk of prolonged neurological consequences (120). Early medical intervention, management, and engagement in a return-to-sport protocol soon after a concussion injury is essential to limit the possibility of sustaining an additional concussion when the brain is still recovering from the initial injury (120). A recent concussion epidemiological study has shown that athletes with vision impairment reported a significantly higher incidence proportion and a significantly higher incidence rate of sports-related concussion compared to athletes in other impairment groups (10). These results suggest that concussions may be more likely and may occur more frequently in athletes with vision impairment compared to other impairment types.

To date, little attention has been given to the unique needs of para athletes when it comes to concussion injury risk reduction, education, and prevention (121). One study by Wessels et al. (2012) found 44% of wheelchair basketball athletes who sustained a sports-related concussion failed to report their concussion (46). Reasons for failing to report their concussion included not wanting to be taken out of the game, thinking the concussion was not serious, and not knowing it was a concussion (46). A recent review also explained that some athletes may not consider concussion a critical issue particularly because para athletes may already have to live with major trauma and other serious medical conditions (122). As a result, some para athletes may be less likely to take concussion injuries seriously and may be less likely to recognize a concussion and seek medical attention immediately after injury.

The purpose of the current study was to understand the perspectives, experiences, and knowledge of elite athletes and coaches concerning concussion in VI para sport. To the best of our knowledge, this study is the first to investigate athlete and coach perspectives and experiences with concussion in para sport. Recruitment for the current study was centered in elite-level para sport because elite para sport organizations tend to have administrative staff to facilitate the recruitment of para athletes and coaches for the purpose of research studies, compared to recreational para sport organizations. Another reason for targeting recruitment to elite-level athletes and coaches was that we expected elite athletes and coaches to be more informed regarding the risks of concussion injury when compared to recreational para sport athletes and coaches. Should the current study reveal that elite athletes and coaches have limited knowledge of the seriousness of concussion injuries, this would indicate that the recreational level is likely even less aware of the dangers of concussion.

3.3 Methods

3.3.1 Participants

Two groups of participants were recruited for this study: elite para athletes with VI and coaches of elite para athletes with VI. The population of para athletes with VI is relatively small in comparison to the able-bodied athlete population. It is estimated that there were approximately 772 para athletes with VI that competed in the Tokyo 2020 Paralympic Games and roughly 142 para athletes with VI that competed in the Beijing 2022 Paralympic Winter Games (45,117). In comparison, 11,420 able-bodied athletes competed in the Tokyo 2020 Olympic Games and 2,834 athletes competed in the Beijing 2022 Olympic Winter Games (123,124). The population data of para athletes with VI suggests that there are approximately 1,000 athletes with VI in the world who compete at the elite level. Assuming a 2% participation rate from elite para athletes, an approximate sample size of 20 athletes with VI was anticipated. A 2% participation rate was chosen considering our survey was delivered in English exclusively, and our inclusion criteria was strict in that it required athletes and coaches to have experienced concussion themselves or to have known someone who had. We anticipated recruiting a similar number of coaches to athletes in this study because apart from large team sports such as Blind Football or Goalball, other sports such as Para Alpine, Para Nordic, Para Judo and Para Cycling are individual sports where there is typically one coach per athlete.

Recruitment of elite para athletes with VI and coaches from VI para sports where the risk of concussion is documented to be highest (i.e., Blind Football, Goalball, Para Judo, Para Cycling, Para Swimming and Para Alpine Skiing) was prioritized (6,10). Participants were recruited with the help of representatives from the following para sport International Federations and International Organizations: World Para Alpine Skiing, World Para Nordic Skiing, World Para Athletics, World Para Swimming, IBSA Blind Football, IBSA Goalball, and IBSA Judo. Participants were also recruited from Great

Britain's VI Judo and VI Cycling teams, and the Canadian Blind Sports Association (CBSA) assisted with the recruitment of Canadian athletes with VI. The research team provided the representatives from the International Federations, International Organizations, and International VI sports teams with the recruitment letter and study information letter for the study. Representatives were requested to forward the recruitment letter and study information letter to para athletes with VI and coaches in their respective memberships. Recruitment of participants took place through email correspondence.

3.3.1.1 Inclusion Criteria

Participants were eligible for participation in the study if they met the following criteria:

- Current or former para athlete who is blind or visually impaired OR current or former coach of athletes in VI para sport,
- Have participated or have coached in a VI para sport sanctioned by the International Paralympic Committee,
- Either have sustained personally, or know someone (e.g., teammate, friend, another athlete) who has sustained a sports-related concussion in the past,
- Have sufficient English language proficiency to understand and complete a web-based survey in English,
- Be at least 16 years of age.

3.3.2 Study Procedure

Participants were asked to independently complete a single web-based survey delivered through REDCap, an electronic data capture tool hosted at the University of Waterloo, School of Optometry and Vision Science (81,91). This study received ethics clearance from the Office of Research Ethics at

the University of Waterloo (ORE #43072). Accessibility staff from the CBSA performed an accessibility check on the consent form and athlete/coach survey and determined both were accessible for athletes with VI and for coaches who may have a vision impairment.

3.3.2.1 Online Consent Form

Once a participant opened the link to the survey provided in the recruitment or study information letter, they were immediately taken to an online consent form. If the participant consented to participate, they were invited to complete either the athlete or the coach survey that followed. If consent was not provided, an appreciation message appeared thanking the participant for their consideration in participating in the study. In addition to consenting to participate in the study itself, participants were also asked whether they consented to having their anonymous quotations used in future publications and/or presentations. Participants could either consent or decline to consent to the use of their anonymous quotations and still partake in the athlete/coach survey.

3.3.2.2 Athlete/Coach Survey

The athlete/coach survey opened June 1st, 2021, and closed March 31st, 2022. After the participant consented to take part in the study, the survey then asked the participant whether they identified as an athlete with VI or as a coach of a VI para sport. The participant's selection determined whether they were directed to the athlete survey or the coach survey.

The surveys were administered anonymously, and participants were not asked for any identifying information. Demographic data was collected to better understand the profile of participants who completed the survey. Demographic data were analyzed separately from answers to concussion-specific questions. Participants could skip over any question(s) they did not wish to answer by leaving the appropriate question answer blank or by selecting the 'Prefer not to answer' option. If at any point the

participant wished to withdraw from the study, they could do so by closing the survey and exiting their web-browser. The estimated time for participants to complete the survey was between 30-45 minutes.

Both the athlete and coach surveys consisted of a combination of multiple choice, Likert scale, Yes/No, and short-answer questions for a total of 40 to 52 questions. The number of questions ranged from 40 to 52 questions because some questions were enabled with branching logic (i.e., skip logic). The branching logic prompted the participant to answer additional questions if the participant provided an answer that required further elaboration. The same questions were posed in both surveys, the only difference was how select questions were phrased for athletes as opposed to for coaches. For example, the question to an athlete read "Have you previously been medically diagnosed by a physician with a concussion?" while the question to a coach read "To your knowledge, has an athlete of yours ever been medically diagnosed by a physician with a concussion?". Questions covered different topics including the following: Demographics; Concussion incidence, recognition, response, assessment, management; Return-to-sport; and Education. The survey questions were developed based on a review of the literature on concussion in VI para sport and through consultation with experts from the IPC Medical Committee.

3.3.3 Analysis

Survey data were compiled in REDCap and exported as a CSV file to Microsoft Excel. For the demographic data, results were presented as a frequency and percentage of the total population of participants to ensure participant anonymity and confidentiality were maintained in the publication of results. For concussion-specific data, results were presented as frequencies out of the total number of responses. Short answer responses were categorized into themes, and representative quotes were included in the results section as originally worded (87). Only complete survey responses were included

in data analysis. The ‘Submit’ button at the end of the survey was required to be selected by the participant for the response to be considered a complete response.

3.4 Results

The athlete/coach survey was accessed a total of 18 times while the survey was active. Because the survey could be accessed anonymously, it is possible a single participant accessed the survey more than once. Assuming all participants accessed the survey only once, then 18 participants accessed the survey. Of the 18 participants who accessed the survey, 8 survey responses were completed and submitted (i.e., the participant selected the ‘Submit’ button at the bottom of the survey page). These 8 submitted survey responses were included in the analysis of results for the present study. The remaining 10 participants did not complete or submit the survey and as such, these responses were excluded from the analysis of results.

3.4.1 Population Demographics

Eight participants completed the study. Four participants were elite athletes with VI and the remaining four participants were coaches of elite athletes with VI. Table 3.1 describes the demographic characteristics of the participants who took part in the study, including their sex, gender identity, age, whether they are currently competing/coaching, their event category, and the continent they represent/represented in competition. Figure 3.1 illustrates the VI para sports that participants either trained/competed in or coached. Some athletes and coaches competed/coached in more than one sport.

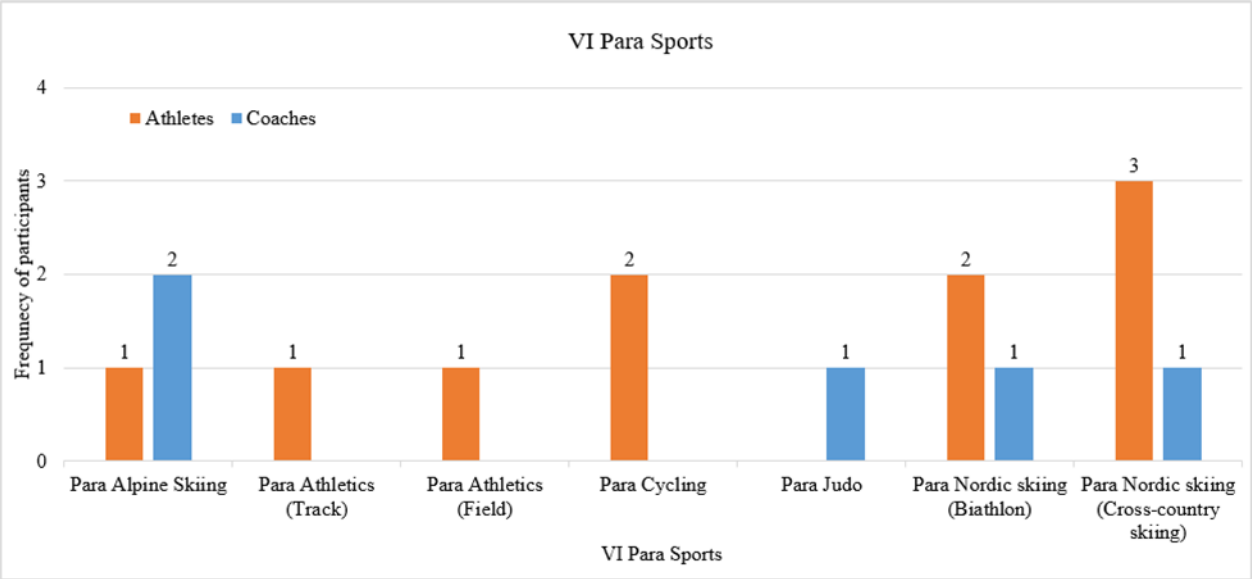

Figure 3.1: VI Para Sports represented by participants in the study. Note, some athletes and coaches reported participating in more than one sport.

Table 3.1: Demographic characteristics of participants.

	Athletes with VI (n = 4)		Coaches (n = 4)	
	N	**%**	**N**	**%**
Sex				
Female	4	100		
Male			4	100
Gender identity				
Woman	4	100		
Man			4	100
Age (years)				
25 - 34	2	50	1	25
35 - 44	1	25	2	50
45 - 54			1	25
55 - 64				
≥ 65	1	25		
Currently competing/coaching?				
Yes	2	50	4	100
Former	1	25		
Recently retired (≤ 5 years)	1	25		
Event category*				
Female	4	100	1	20
Male			3	60
Mixed			1	20
Continent				
Africa				
Asia	1	25	1	25
Oceania				
Europe	2	50	1	25
North America	1	25	2	50
South America				
*Each participant was able to select more than one event category if applicable (i.e., one coach selected both Female and Male event categories).				

3.4.2 Concussion Incidence and Seeking Medical Attention

One out of the four athletes in our study population said that they had previously been medically diagnosed by a physician with a concussion. When asked how many medically diagnosed concussions

they had sustained, the athlete answered 4. Another athlete said they were uncertain whether they had ever been medically diagnosed by a physician with a concussion. Three out of four athletes expressed that a teammate of theirs had previously sustained a sports-related concussion.

Two athletes suspected they had sustained a concussion previously but never received a medical diagnosis. When asked why they didn't see a medical professional after sustaining a suspected concussion, one athlete stated the following:

"I thought I would get better on my own."

Three out of four coaches reported that an athlete of theirs had previously been medically diagnosed by a physician with a concussion. In addition, three out of four coaches knew of an athlete they did not coach personally that had sustained a sports-related concussion in the past.

Additionally, one coach said an athlete of theirs suspected they had a concussion but never received a medical diagnosis. When asked why their athlete avoided getting a medical diagnosis for their suspected concussion, the coach explained:

"Not avoided, they didn't want to spend the time or money for something they already knew."

3.4.3 Concussion Recognition and Response

Overall, athletes with VI were more likely to report that medical professionals are less frequently on the sidelines at the Paralympic Games, International, and National competitions compared to the coaches (Figure 3.2). During training, all four athletes said medical professionals are either rarely or never on the sidelines, while two of the coaches in our study population said medical professionals are frequently on the sidelines. Both athletes and coaches agreed that that medical professionals are rarely or never on the sidelines while athletes are playing for fun or are off the field of play.

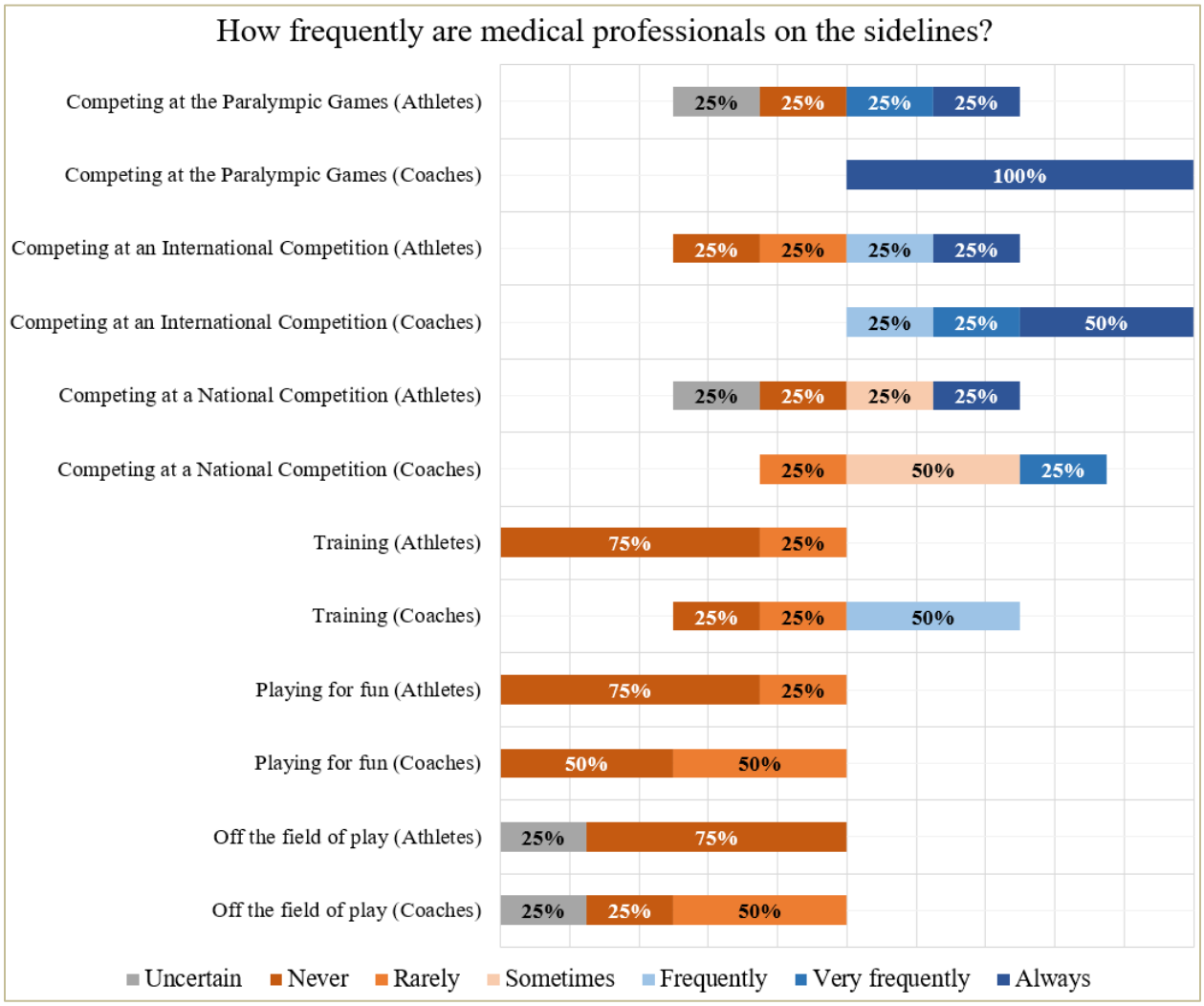

Figure 3.2: Athlete and coach perspectives on how frequently medical professionals are on the sidelines in various para sport settings.

When asked how their medical team decides to investigate whether an athlete has sustained a concussion, 3 out of 4 athletes were uncertain. In contrast, all four coaches identified that any significant impact to the head, face or neck would prompt an investigation from the medical team (Figure 3.3). One athlete stated the following in response to this question:

"We don't have [our] own medical team."

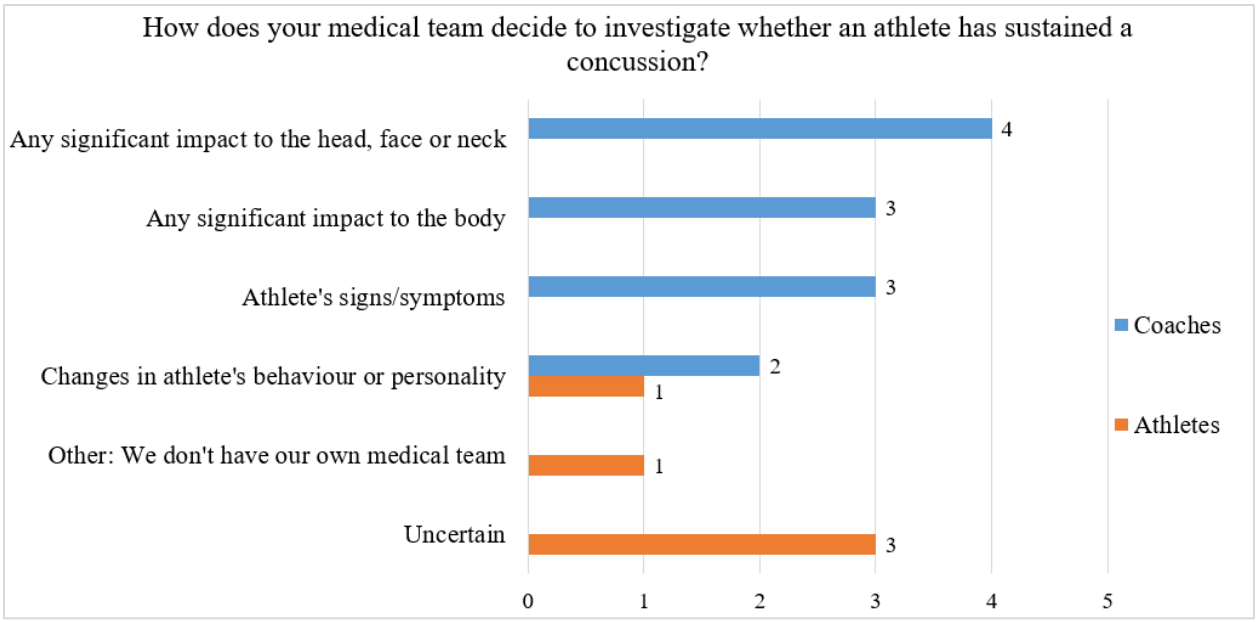

Figure 3.3: Athlete and coach perspectives and experiences on how their medical team decides to investigate whether an athlete has sustained a concussion.

Participants were then presented with the following scenario:

> *"Your teammate/athlete has just had a hard fall and has hit their head while training. They are slow to get up and seem confused/dazed. Someone without medical experience was there to witness the fall and suspects that they may have sustained a concussion. In your experience, what happens next?"*

In response to the scenario above, only one athlete recognized that the athlete should be taken for an assessment by a medical professional immediately after injury. The remaining athletes answered that the athlete should wait a few days before being assessed, or that nothing would happen unless the athlete had severe symptoms after injury. In contrast, all four coaches recognized that the athlete should

be taken for an assessment by a medical professional immediately after injury, with another 3 out of 4 athletes answering that the athlete should be removed from play immediately. These results are presented in Figure 3.4.

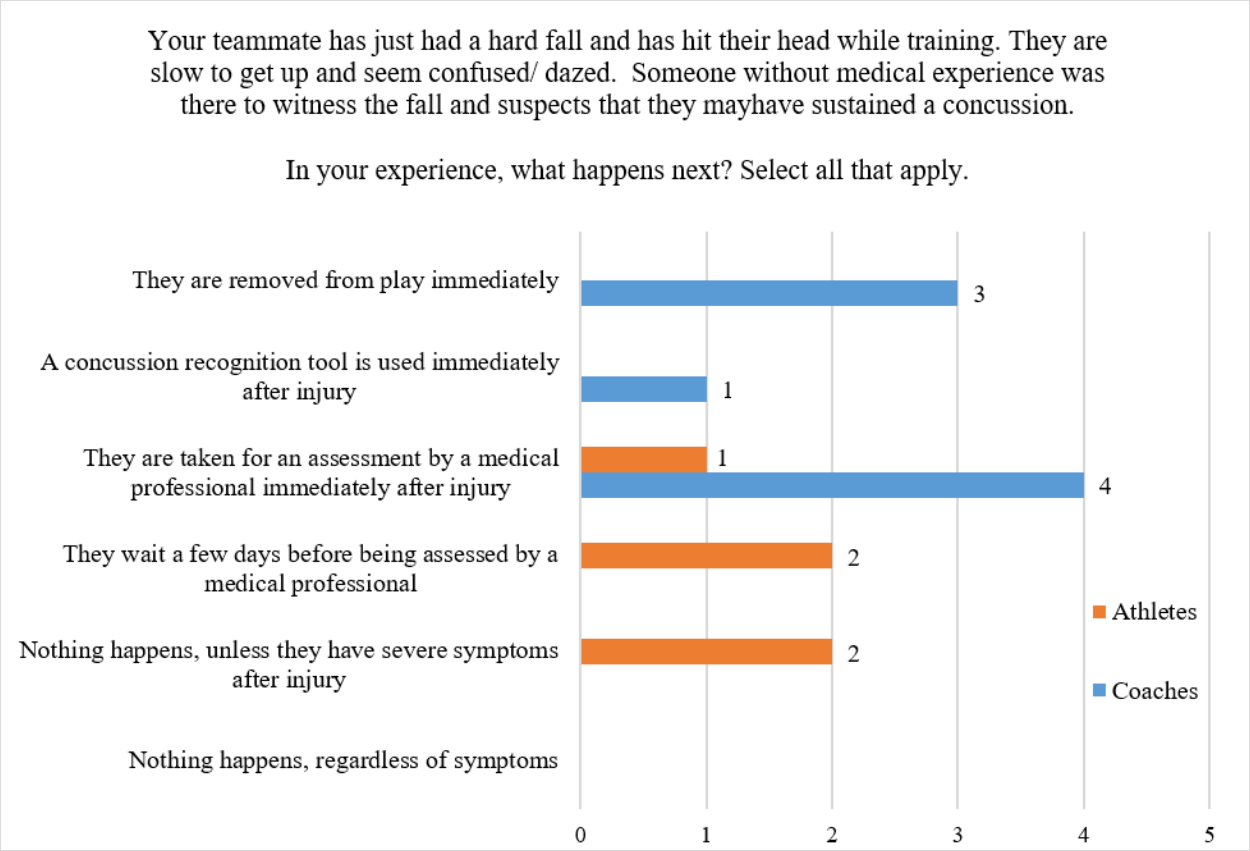

Figure 3.4: Athlete and coach responses to concussion recognition scenario question.

The following question asked whether athletes are encouraged to report sports-related concussions to their coaches and/or team. Results are illustrated in Figure 3.5. Athlete responses ranged from 'Uncertain' to 'Always'. Coach responses ranged from 'Rarely' to 'Always' with 3 out of 4 coaches indicating athletes are either 'Very Frequently' or 'Always' encouraged to report their sports-related concussions.

Two athletes responded that they (or a teammate) sustained a concussion and did not report it to their coach or team. When asked why they failed to report their concussion, one athlete gave the following response:

"Didn't think [the concussion] was serious."

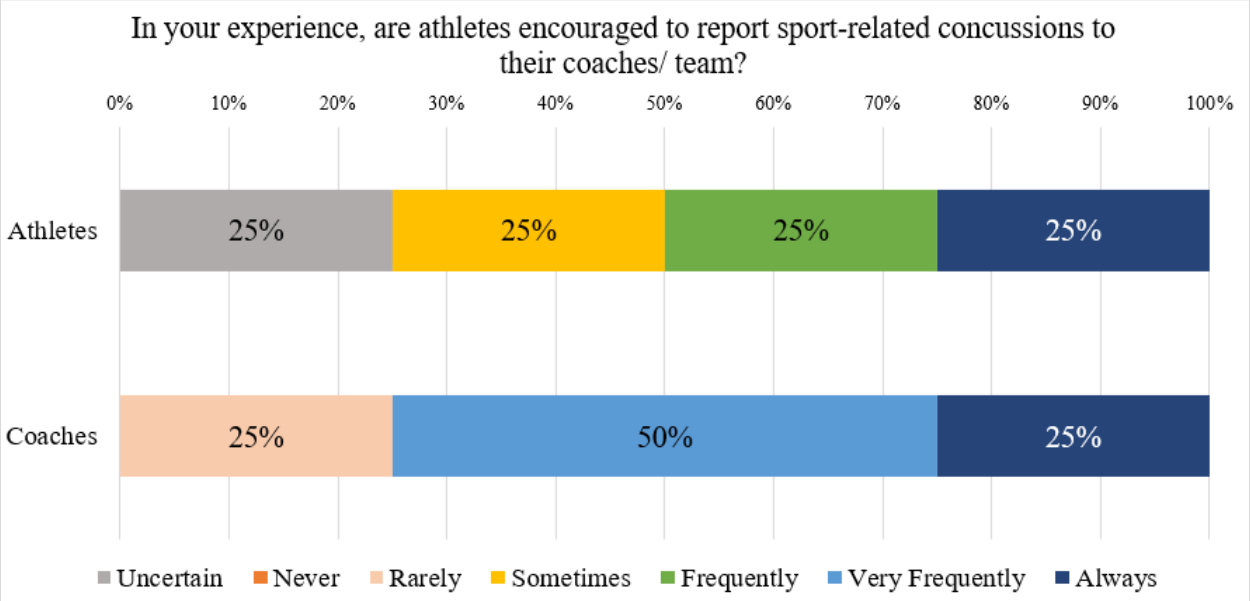

Figure 3.5: Athlete and coach perspectives on whether athletes are encouraged to report concussions to their coaches/team.

When asked whether participants knew of any challenges in recognizing and responding to concussions, two athletes answered with the following:

"Small team, little staff, no team care, usually our guide who has to fix things because coach is busy. Nystagmus also makes it hard to judge as a symptom."

"Eye movement and visual behaviours may be misinterpreted due to medical personnel's lack of knowledge regarding blindness and/or low vision."

A coach identified the following challenge in concussion recognition in athletes with VI:

> "Sometimes they are more confused after a crash just from vertigo or not knowing where they ended up. Not concussed, just specially confused."

3.4.4 Assessment

When asked who typically performs the preliminary concussion assessment if there are no medical professionals immediately available, athletes were more likely to say that the guide or the athlete themselves would perform the initial assessment. Coaches, on the other hand, were more likely to say that the coach or athletic trainer would carry out the preliminary concussion assessment. These results are presented in Figure 3.6.

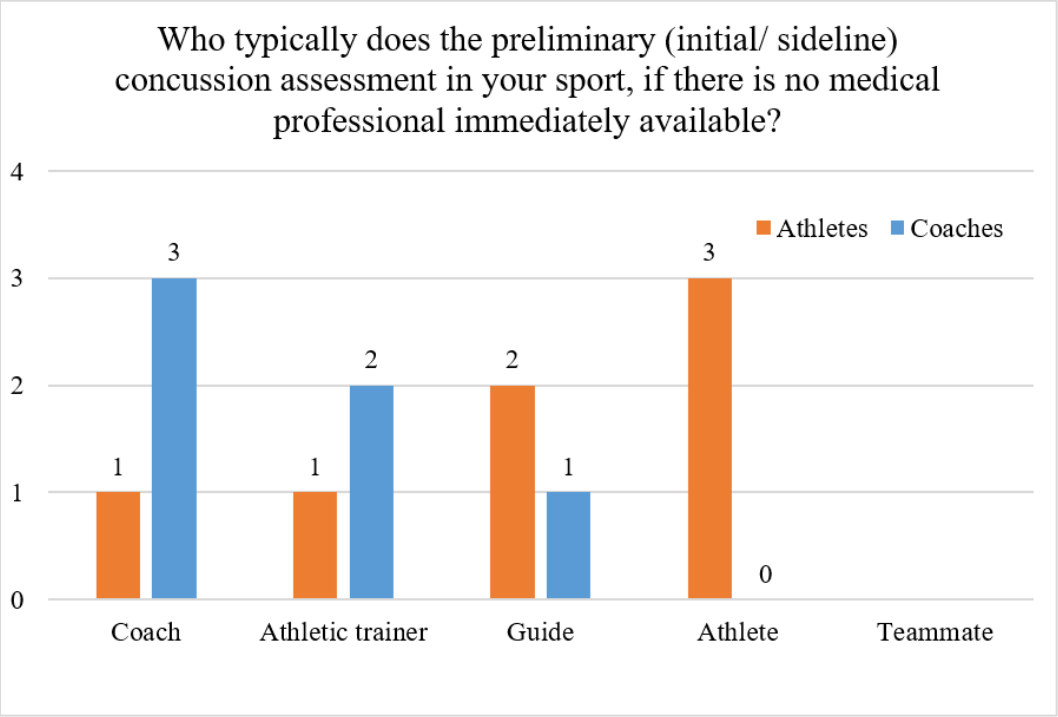

Figure 3.6: Athlete and coach responses in terms of who typically conducts the preliminary concussion assessment in the absence of medical professionals.

In response to what the initial/sideline assessment tests typically consist of, 3 out of 4 athletes and all four coaches responded with typical questions that are asked to the athlete after injury. One athlete responded that athletes are asked questions such as:

"Do you have a headache? What is your name? What day is it? Do you feel sick?"

When asked which medical professionals typically conduct the medical concussion assessment, 3 out of 4 athletes and all four coaches identified a variety of different medical professionals (Figure 3.7). The medical professionals selected most often by participants were team physicians, the athlete's physician, and emergency medical professionals. One athlete did not select any medical professionals and stated that their team did not have access to their own medical support.

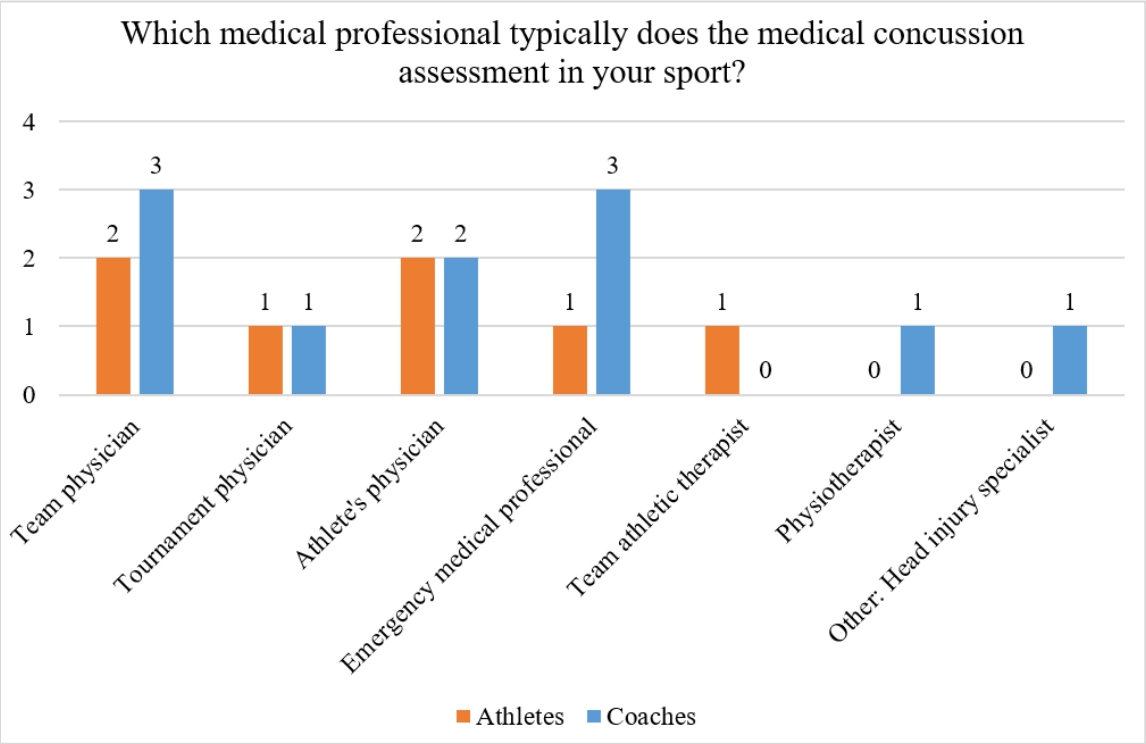

Figure 3.7: Athlete and coach responses in terms of who typically conducts the medical concussion assessment.

None of the athletes were able to identify specific concussion assessment tools that medical professionals use to assess suspected concussion injury. Two out of four coaches were able to identify specific concussion assessment tools used by medical professionals, which included the SCAT and ImPACT tests.

Two out of four athletes said they participated in baseline testing prior to training and competing in their sport (Figure 3.8). When asked whether medical professionals compare pre-injury baseline testing results with post-injury testing results, only one athlete said, ‘Yes’ while the other three either answered ‘No’, or ‘Uncertain’. One out of four coaches said their athlete participated in baseline testing prior to training and competing (Figure 3.8). However, three out of four coaches reported that medical

professionals do compare pre-injury baseline testing results with post-injury testing results when assessing suspected concussion in athletes with VI.

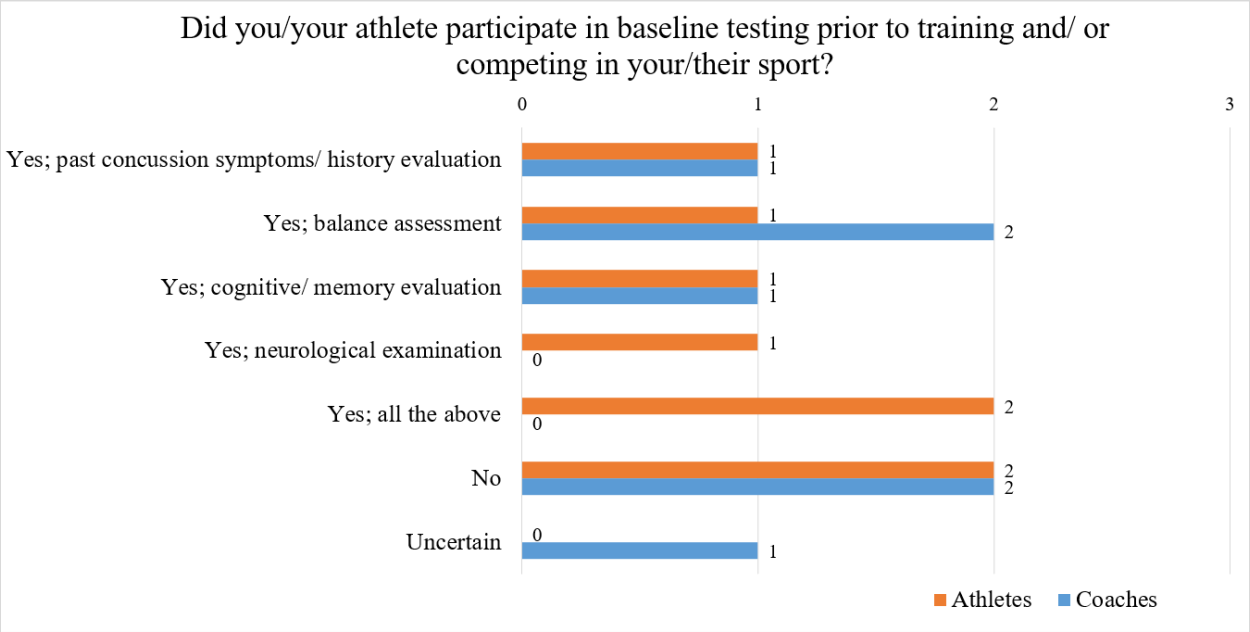

Figure 3.8: Athlete and coach responses to whether they/their athletes participated in baseline testing.

In terms of challenges in the assessment of concussion in athletes with VI, one coach gave the following response:

> "Many online tests are visual cues and [measure] response time, they need more [auditory cues] or [verbal] questions."

3.4.5 Management

When asked who typically develops the concussion management/treatment plan for athletes with VI, three athletes and three coaches selected a multidisciplinary team of medical experts, ranging from the

team's physician to team athletic therapists and physiotherapists (Figure 3.9). In terms of who helps the athlete through the recovery process of their concussion, three athletes and two coaches also recognized that athletes typically get extra support from their guides, coaches, and families.

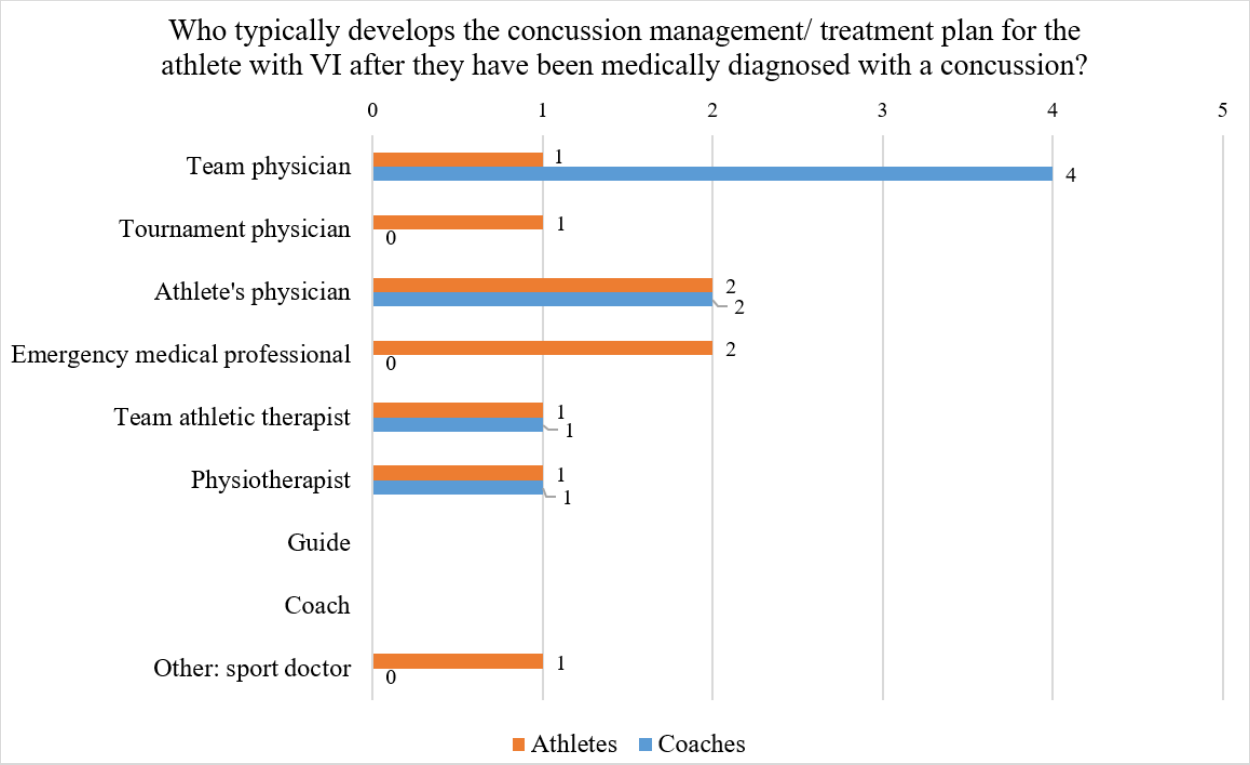

Figure 3.9: Athlete and coach responses in terms of who typically develops the concussion management/ treatment plan for athletes with VI.

In response to whether participants knew of any concussion management strategies that are used in VI para sport, two athletes and two coaches provided examples of protocols they were aware of. One athlete provided the following response:

"Rest, specific rehab, emotional support."

A coach provided the following example:

"Time off, minimal activity, minimal brain activity. Seen 2 occasions where eye treatment needed."

None of the coaches from the current study identified any challenges in the management of concussion in athletes with VI. Two athletes identified challenges they have experienced with one athlete detailing:

"Balance can be impacted; vertigo and disorientation may occur more frequently."

3.4.6 Return-to-Sport

When asked who typically determines when an athlete is safe to return to sport after sustaining a concussion, athletes gave a variety of answers which ranged from their own team physician to their coach (Figure 3.10). Two athletes also indicated that the athlete themselves would play a role in the return-to-sport decision making. As for the coach perspective, all four coaches indicated that the return-to-sport decision is made by the team physician with the help of other medical professionals. Contrary to the athlete responses, none of the coaches selected that coaches and athletes themselves would play a role in the return-to-sport decision.

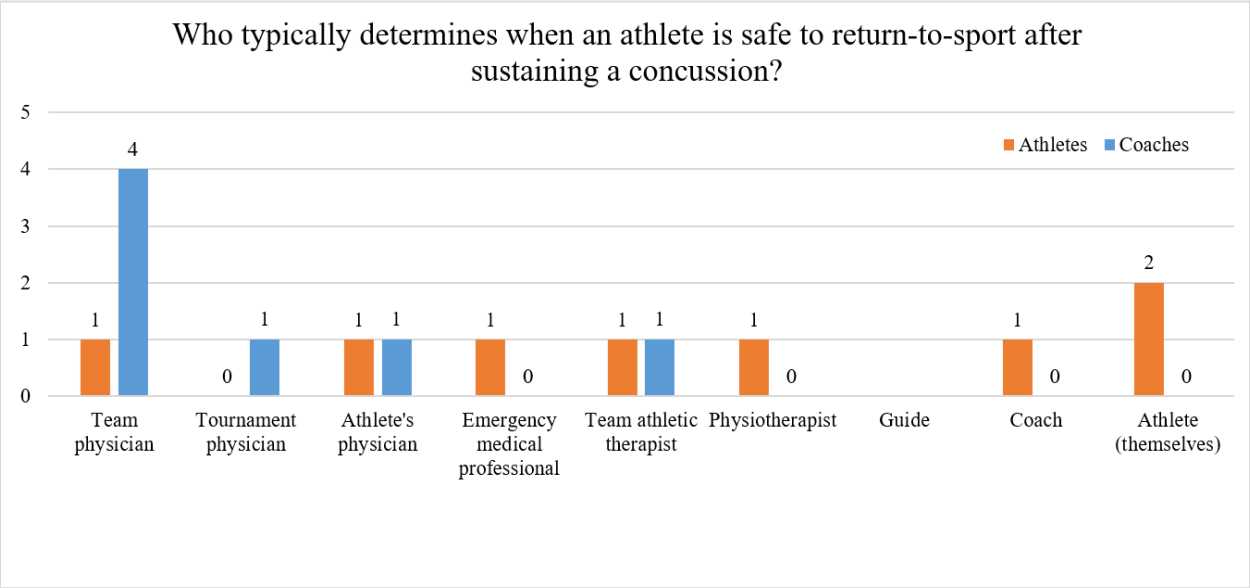

Figure 3.10: Athlete and coach responses to who typically determines when an athlete is safe to return-to-sport.

Participants gave a variety of answers when asked how athletes are determined safe to return to training and/or competing after sustaining a concussion (Figure 3.11). All three athletes who provided an answer to this question selected ‘When the athlete feels subjectively better’. In contrast, none of the coaches selected the ‘When the athlete feels subjectively better’ option. All four coaches selected a variety of responses ranging from ‘When concussion signs/symptoms are no longer present’ to ‘Strategies are case-by-case, dependent on the athlete’.

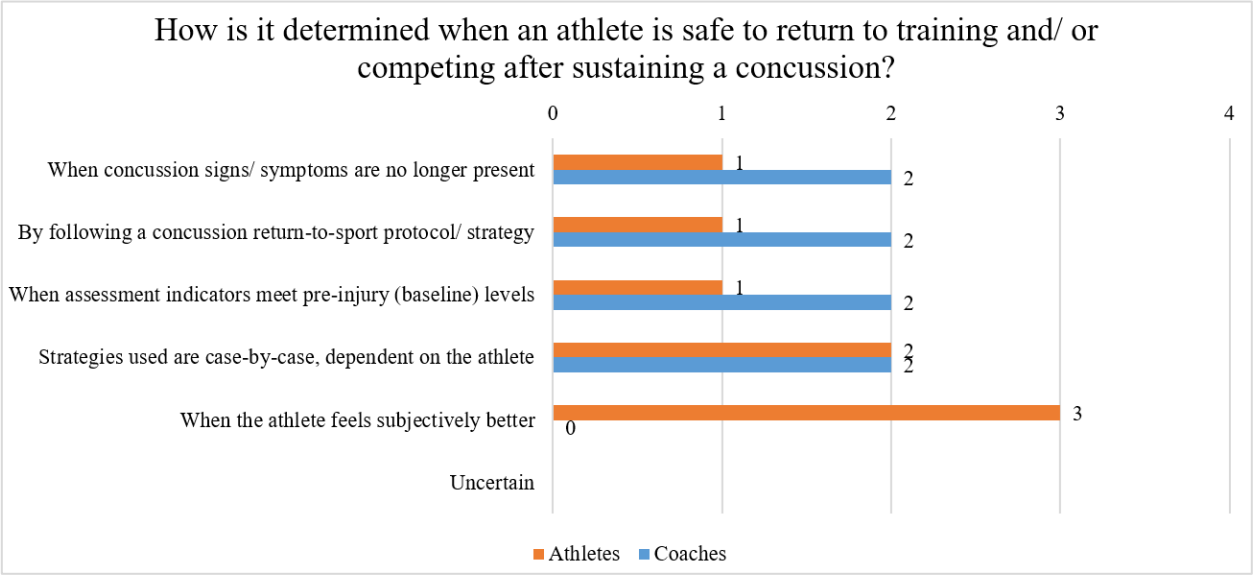

Figure 3.11: Athlete and coach responses to how athletes are determined safe to return to training and/or competing after sustaining a concussion.

In terms of return-to-sport protocols used in VI para sport, none of the athletes or coaches named any specific strategies. However, athletes and coaches had an idea of what medical professionals are considering when making return-to-sport decisions. One coach provided the following response:

> "Slow paced return, low rep, low volume, slowly build. Staying away from opportunities to reinjure until balance and technique return in full confidence."

In response to whether there are any challenges concerning return-to-sport for athletes with VI, one athlete responded with the following:

> "[The athlete] may not [be] sure about [their] recovery, [they] will not be certain about the training area."

A coach commented with the following:

"They tend to make contact with the ground more often when something happens, so their pace is sometimes even slower to keep impact minimal."

3.4.7 Concussion Education

When asked how important it is for different parties involved in VI para sport to be educated on concussion recognition, assessment, management, return-to-sport, and prevention, both athletes and coaches agreed that concussion education is most important for healthcare professionals and coaches (Figure 3.12). Athlete and coach opinions differed slightly when considering the importance of concussion education amongst athletes, guides, and trainers. One out of the three athletes that participated in this question answered that concussion education is 'of little importance' for athletes and guides. In contrast, none of the coaches rated concussion education 'of little importance' for athletes and guides.

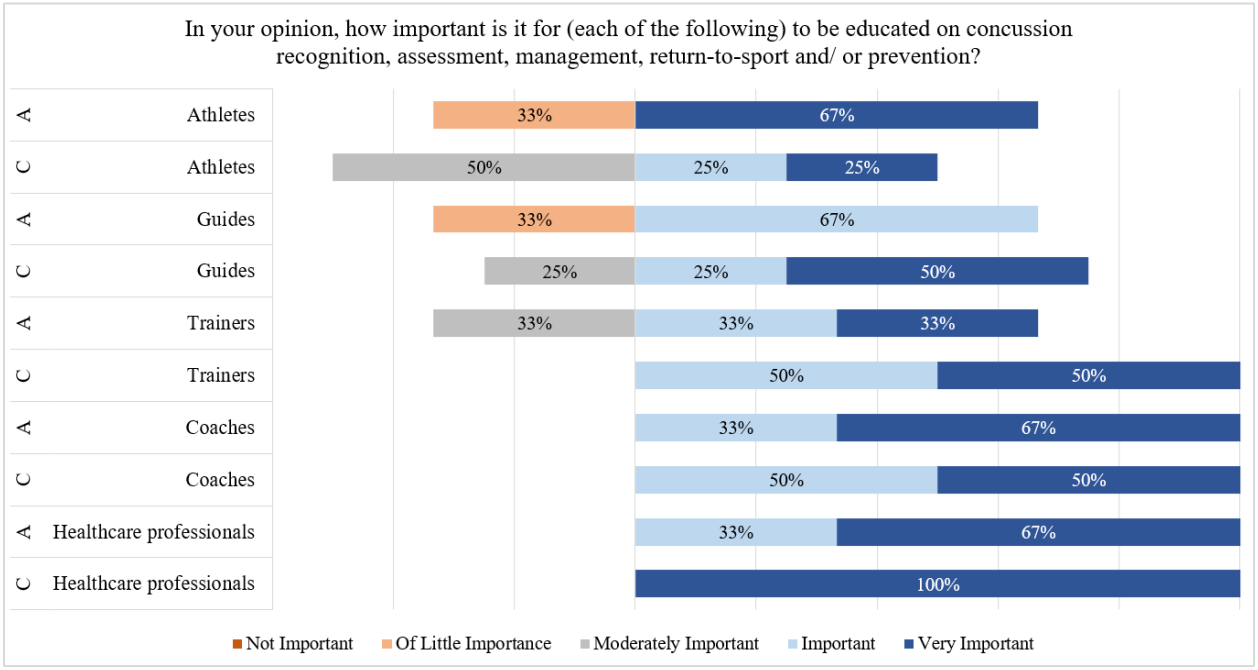

Figure 3.12: Athlete and coach perspectives on the importance of concussion education for healthcare professionals, coaches, trainers, guides, and athletes.

Note: A = athlete responses; C = coach responses.

In response to whether participants had previously received any form of concussion education, three out of four coaches said they had received concussion education, while only one out of three athletes had (Figure 3.13). All three coaches received education pertaining to concussion recognition. The only athlete who received concussion education indicated that their education consisted of all the above concussion topics mentioned.

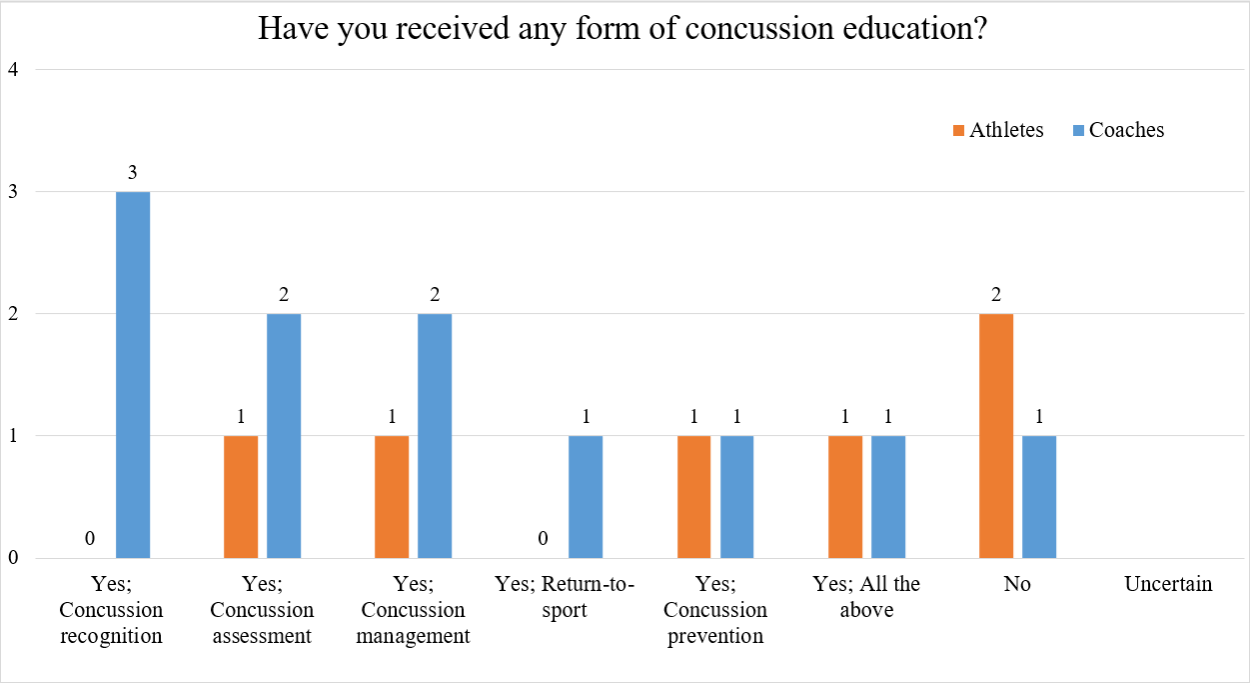

Figure 3.13: Athlete and coach responses to whether they received any form of concussion education.

The quality, accessibility, satisfaction, and relevance of the concussion education received was also different between athletes and coaches. The only athlete who received concussion education rated it below average in quality, moderately accessible, not relevant at all, and said they were not satisfied with the education they received. Comparatively, all three coaches who received concussion education rated the quality of the education average to above average, the accessibility of the education accessible to very easily accessible, the relevance of the education moderately relevant to very relevant, and said they were either satisfied or very satisfied with the education they received.

All three coaches received education in the format of online courses or modules (Figure 3.14). One coach added that they were tested on their knowledge with online quizzes, while another responded

that they learned from working directly with their team physician. The only athlete that received concussion education answered that the education was in the format of resources received by email.

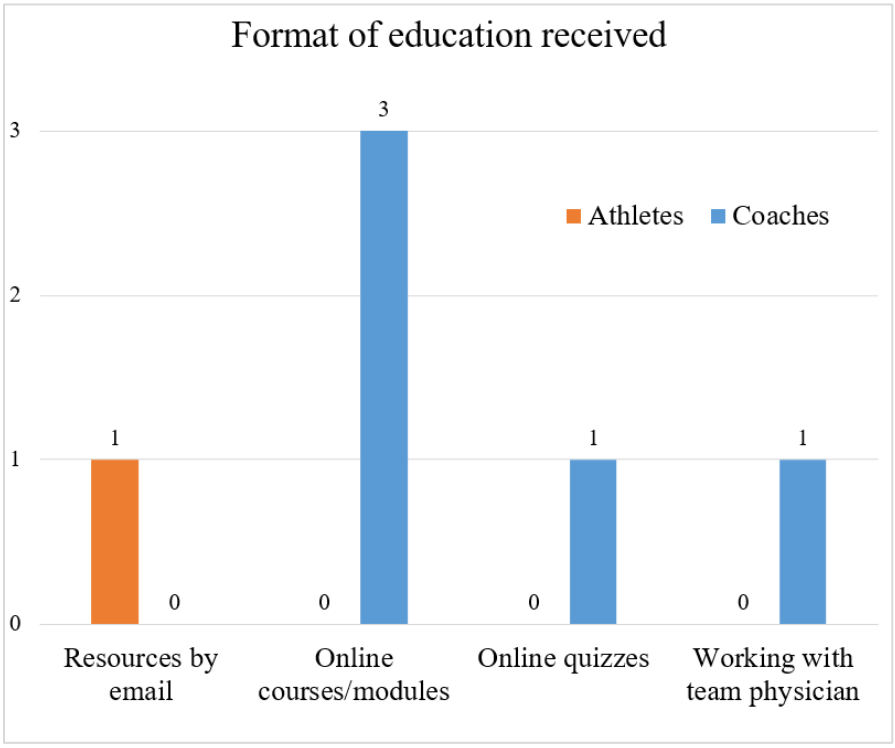

Figure 3.14: Athlete and coach responses to the format of concussion education they received.

Lastly, when asked if participants found any challenges concerning concussion education for athletes with VI, one athlete and coach held similar perspectives that there is minimal concussion education for athletes with VI. One athlete responded with the following:

"Education needs to be more relevant and accessible to people with VI."

Another athlete had a different perspective on concussion education for athletes and provided the following comment:

> "Never heard of [concussion education for athletes with VI], so it sounds to me like it does not exist. It also makes it hard for me to judge if this is important or not."

3.5 Discussion

The purpose of the current study was to explore the perspectives, experiences, and knowledge of elite athletes and coaches concerning concussion in VI para sport. Notable differences were observed between athletes with VI and coaches in terms of their knowledge and appreciation of the seriousness of concussion injuries. Coaches were generally more informed on aspects of concussion recognition, assessment, management, and return-to-sport compared to athletes with VI. Athletes reported receiving fewer education resources compared to coaches, and those that did receive concussion education rated it below average in quality, relevance, and accessibility. Some athletes were also unable to recognize the importance of being educated on concussion, which strongly suggests that education on the potential long-term consequences of successive concussion injuries is needed for athletes with VI.

A study by Wessels et al. (2012) surveyed 263 wheelchair basketball athletes and found that 44% of those who experienced a concussion did not report their concussion (46). When asked why participants did not report their concussion, the most common reason reported was that they did not want to be taken out of the game (67%) (46). The next two most common reasons were because participants did not think their concussion was serious (50%), and that participants did not know they were suffering from a concussion (50%) (46). Similarly, when athletes from the current study were asked why they did not report their concussion, one athlete believed they would get better on their own while the other didn't think their concussion was serious. Also from the present study, one coach reported that an athlete of theirs had sustained a concussion but chose not to seek a medical diagnosis because they didn't want to spend the time or money for something that they already knew. These results demonstrate a lack of appreciation of the seriousness of a concussion injury and of the

consequences of neglecting proper management (46). Clearly, more education on the potential long-term consequences of concussion is needed for athletes and coaches in VI para sport (125). Athletes and coaches should also be informed of the potential life-threatening decision they are making when choosing to either conceal concussion symptoms, or when failing to seek medical attention.

Based on the results from the current study, athletes are generally less aware of how to identify and respond to a suspected concussion injury compared to coaches. The difficulty athletes face in knowing how to respond to a suspected concussion is presumably due to a lack of education in terms of how to respond to concussion injuries. Another aspect to consider is that compared to able-bodied sport, it may be more difficult to identify whether an athlete is suffering from a concussion due to the tendency for pain to be normalized in para sports (77). In a study by Fagher et al. (2016) which investigated Swedish para athletes' perceptions of their experiences of sports-related injuries, there was a reoccurring theme of pain being seen as something that belongs to para sport (77). While there was the understanding among athletes that pain should be seen as a warning for a more serious injury, many athletes confessed to training and competing even though they were experiencing pain (77). Para athletes also acknowledged that pain persisted in their daily lives outside of sport, and that impairment specific factors such as wheelchair use and poor posture contributed to their pain (77). The previous findings suggest that para athletes may be more likely to play through concussion symptoms because pain is intrinsically linked to their daily lives both in and outside of their sport. Going forward, athletes should be educated on how to recognize and respond to a concussion in the event there are no medical or coaching support staff on the sidelines.

Results from the current study suggest that coaches tend to receive more education on concussion recognition, assessment, management, return-to-sport, and prevention than athletes with VI do. Given the lesser availability of on-site medical support in VI para sport in general (16), it is reassuring to know

that several coaches have completed training in concussion recognition and would know how to conduct an initial sideline screen for concussion in the absence of medical support. However, it is concerning that only one out of the three athletes who participated in the education section of the survey indicated that they had received concussion education. Even more alarming was that the athlete rated their concussion education below average in quality, moderately accessible, not relevant, and that they were unsatisfied with the education they received. The above results are a clear indication that relevant and accessible concussion education targeted to athletes with VI is needed.

In our study, some athletes regarded concussion education as important for themselves, whereas others were unable to see the value of concussion education for athletes. Understanding athlete preferences in terms of the content and delivery of the education they will receive may be required to create education that athletes would be more likely to engage with. A recent study by Kroshus & Baugh (2016) found that most U.S. collegiate-level athletes wanted education to include information on the symptoms of concussion (89.0%), information about the possible long-term consequences of concussions (84.5%), the impact of concussions on athletic (87.0%) and academic performance (86.1%), and education about the importance of reporting concussion symptoms (82.6%) (125). Additionally, athletes from the same study preferred their concussion education to be delivered by their athletic trainer (83.1%), but many also wanted a physician (54.5%) or their coach (40.9%) to be involved in the concussion education process (125). Furthermore, over half of the athletes surveyed preferred their education delivered in the form of a lecture (57.4%) or video (54.0%), with fewer athletes preferring the information in the form of a written handout (28.7%) or as online materials (13.0%) (125). Understanding para athlete and coach preferences in terms of the content and delivery of concussion education is a necessary first step toward creating relevant and accessible educational

materials for these populations. Future research should explore the preferences of para athletes with VI and coaches when it comes to concussion education content and delivery.

Athletes and coaches in the present study recognized the nuances in concussion sustainment, response, assessment, and recovery that are unique to para sport and to athletes with vision impairment. For instance, one athlete shared that their team had few staff members to assist athletes in the event of an injury, and the first responder to an injury is often the athlete's guide. While the athlete's guide is likely to understand the athlete better than anyone and would be able to recognize a change in the athlete's behaviour (i.e., which could be indicative of a concussion injury), it is also possible that the guide is not trained in concussion recognition or response and would not know how to respond appropriately. Additionally, two athletes recognized that conditions such as nystagmus and other conditions causing irregular eye movements and visual behaviours may be misinterpreted by some medical professionals due to a lack of knowledge regarding blindness and low vision. Going forward, medical professionals should be required to complete education on visual impairments and low vision conditions to ensure athletes are not being misdiagnosed for a concussion because of their underlying visual conditions. One coach acknowledged the limitations of online concussion assessment tests in that most rely on visual cues and measuring response time, which may be difficult to use with VI athletes. The inclusion of more noise-related or question-answer elements in mainstream concussion assessment tools should be considered going forward so that these assessment tools can be used to assess concussion in athletes with VI. Lastly, another athlete recognized that balance can be impacted at baseline, and vertigo and disorientation may occur more frequently in athletes with VI. It is critical for medical professionals to be aware of any balance issues, vertigo, or disorientation at baseline so that assessment and management strategies can be appropriately adapted for athletes with VI.

3.5.1 Limitations

Findings from the current study were limited due to the small number of participants. As mentioned previously, it is estimated that roughly 1,000 athletes with VI participated in the most recent Paralympic and Winter Paralympic Games globally (45,117). While recruitment was conducted on a global scale, it is possible that the inclusion criteria for participation in the study were overly stringent. It is likely that the combination of a small target population, the inclusion requirement for athletes and coaches to be proficient in English, and the requirement for participants to have concussion experience limited the target population to a couple hundred eligible participants worldwide. In addition, one athlete participant chose to leave questions pertaining to return-to-sport and concussion education blank. As a result, all athlete responses from both these sections of the survey are out of three as opposed to four athlete responses.

It is suspected that the lack of participation by athletes and coaches in the present study could have also been due to the general lack of concussion education amongst sports administrators. The research team relied on the assistance of sports administrators from various international sport federations and organizations to circulate the athlete/coach survey electronically amongst their athlete and coach contacts. However, on occasion, we received responses from sports administrators claiming that concussion was not an issue in their para sport and as a result, they didn't recognize the value of circulating our survey. Despite our efforts to follow up with sport administrators to explain that the goal of our study was to understand athlete and coach perspectives, experiences, and knowledge surrounding concussion, some sports administrators failed to follow up. The lack of engagement from some sports administrators on the topic of concussion suggests that their knowledge of concussion may also be limited. Going forward, concussion education strategies should be tailored to sports administrators as well because they too represent a key stakeholder group in para sport.

Recent epidemiological research has shown that concussion risk is highest amongst the following VI para sports: Blind Football, Goalball, Para Cycling, Para Judo, and Para Alpine Skiing (6,10,14). Despite best efforts, researchers were unable to recruit athletes or coaches from Blind Football or Goalball. We suspect the lack of participation seen from Blind Football and Goalball athletes was due to the tendency for athletes from these two sports to have the most severe vision impairments (i.e., most are classified as B1 with a visual acuity of worse than 2.6 LogMAR or no light perception whatsoever), which would have made our survey difficult to complete for these athletes. With the recruitment of athletes and coaches from Blind Football and Goalball, this study would have represented a more accurate account of the perspectives, experiences, and knowledge of athletes and coaches concerning concussion amongst VI para sports with the highest risk of concussion injury.

Another limitation of the present study was the design of the survey. While a representative from the CBSA determined that both the consent form and athlete/coach survey were accessible for individuals who are blind or visually impaired, it could have been the case that participants had difficulty completing and submitting the survey due to accessibility issues. Granted that assistive reading technologies for blind and visually impaired individuals (e.g., Job Access With Speech (JAWS) screen readers, ElBraille devices, Refreshable Braille Displays, Smartphone-Based Assistive Technology, etc.) have never been more available and accessible to the public than they are today, it is possible that older assistive technologies were not compatible with the REDCap survey design interface. This could explain why up to ten potential survey participants were unable to complete and successfully submit their survey responses. It is also possible that the survey length was too long and may have discouraged participants from completing the entire survey. Finally, the current study was that the survey title, “Concussion Management in Blind and VI Para sport” could have introduced a

bias toward attracting athletes with VI and coaches who felt more qualified or motivated to answer questions regarding concussion.

3.5.2 Conclusion

Noticeable differences exist between elite VI para athletes and coaches concerning their perspectives and experiences on concussion in almost every aspect studied. Coaches were found to be generally more well informed on concussion than athletes. This is not surprising since our study suggests that athletes with VI appear to be receiving less and poorer equality education about concussion compared to coaches. A lack of concussion education amongst VI athletes could explain why athletes are less inclined to be knowledgeable about concussion recognition and less concerned about the importance of early intervention after a suspected concussion injury. Future research should continue to understand the perspectives and experiences of athletes and coaches with concussion in VI para sport. Better understanding of athlete and coach perspectives concerning concussion injuries will encourage the development of targeted prevention strategies and relevant educational resources that athletes and coaches will be more likely to engage with in the future.

Chapter 4
Discussion, Limitations, and Future Directions

4.1 Discussion

Results from our studies demonstrate that concussion injuries in VI para sport are of significant concern. While recommendations for a concussion standard of care were recently developed by members of the Concussion in Para Sport group (16), there is an absence of understanding in terms of how concussions are currently being assessed and managed in elite VI para sport. Our study found that medical professionals are adapting pre-existing able-bodied assessment tools and management strategies as necessary for use in athletes with VI. Above all, medical professionals highlighted the importance of understanding your VI athlete's pre-existing condition and of conducting annual baseline testing. Alarmingly, athletes were found to be generally uneducated about the seriousness of concussion injuries and how to recognize if a concussion has occurred. The former finding is particularly troublesome given the reported lack of on-site specially trained medical support in VI para sport. Considering how little is understood about concussions in VI para sport, research efforts should be focused on understanding how athletes with VI experience concussion, including how they typically perform on common assessment tools, what is involved in their concussion management, and how they recovery from their injuries. In addition, preventative measures should continue to be implemented to reduce the likelihood of concussion in VI para sport. Lastly, concussion education efforts should prioritize informing para athletes of the potential long-term consequences of concussion to ensure athletes are well-informed of the risks of participating in their para sport.

Recent injury epidemiology studies suggest that the risk of concussion injury may be greater in sports for athletes with VI when compared to able-bodied sports (10). One reason the risk of concussion is suspected to be higher for athletes with VI is because many VI sports involve the use of eye shades

to ensure fair competition (12,13). As a result, athletes in sports such as Blind Football or Goalball have no light perception whatsoever and are at a high risk of colliding with other athletes and objects (6). The suspected increased risk of concussion among certain athletes with VI raises the important, yet difficult, question of whether para sports such as Blind Football, Goalball, or Para Alpine Skiing should be allowed to continue. On the one hand, one could argue that the requirement for athletes to wear eye shades is an example of how these para sports could be considered more dangerous than their able-bodied counterparts. However, it is also necessary to consider the importance of inclusion in sport and the ability for sport to create a sense of belonging within a population. It is important to remember that athletes with VI have put in countless hours to perfect their techniques and to perform at the top of their game. To remove para sports from the lives of athletes with VI would deny these athletes the sense of community and fulfillment that they get from participating in sport. Moreover, able-bodied sports such as American football, ice hockey, and rugby are extremely dangerous and high-risk for concussion injuries, yet these sports are still allowed to take place. While it is valid to acknowledge that participation in para sports may pose different risks to athletes than participation in able-bodied sport, participation in all sport (para or able-bodied) can be dangerous. It is also important to recognize that it is possible to make para sports safer, as we will discuss in a subsequent paragraph.

Most experts who took part in our Delphi study considered the validation of existing concussion assessment tools (i.e., the SCAT5) to be an important research priority going forward. Before we can validate pre-existing assessment tools for use in athletes with VI, we would argue that there must be a solid understanding of how athletes with VI typically perform on existing concussion assessment tools such as the SCAT5. Currently, there is minimal published data exploring how athletes with VI typically perform on concussion assessment tools. A recent study captured normative baseline SCAT5 scores for 58 healthy Paralympic athletes and found that athletes reported an average of 5.0 ± 5.4 out of 22.0

symptoms and reported an average symptom severity score of 11.0 ± 14.3 out of 132.0 at baseline (66). However, impairment types of the para athletes who took part in the above study were not taken into consideration in the analysis of average baseline SCAT5 symptom scores. Going forward, future research should collect normative data for baseline and post-injury SCAT5 performance specific to impairment type. In this way, we can begin to understand how athletes with different visual impairments typically perform on different sections of the SCAT5. With enough understanding of how athletes with VI typically perform on commonly used assessment tools, we can then begin to validate these tools for use in athletes with VI.

While our survey studies did not explicitly ask participants to comment on preventative measures that could reduce the occurrence of concussions in para sport, preventative measures are important to develop and consider for implementation. As an example, the introduction of softshell helmets in high-risk para sports as a preventative measure is a logical first step. Currently, helmets are not worn by all para athletes in Blind Football, Goalball, or Para Judo. Given the lack of available evidence recommending protective equipment for the prevention of concussion in para sport, the IBSA initiated a study on the feasibility of softshell helmets in Blind Football. Should softshell helmets reduce the occurrence of concussions in Blind Football, these helmets could also be considered in VI para sports such as Goalball or Para Judo. Another potential preventative measure could be the introduction of sensors in para sport. These sensors could be integrated into the athlete's equipment and into objects that are part of the field of play (e.g., goalposts, the ball, barricades, walls, etc.). If an athlete were to come within a certain distance of an obstacle or another athlete, an alarm could sound to inform the athlete of the impending collision risk. This would tell the athlete that they need to change course or proceed with caution to avoid potential head-to-head contact with the athlete or object. In addition, the oncoming hazards could give off different sound frequencies so that the athlete would be able to

differentiate between different types of hazards. Lastly, another preventative measure to consider could be training cervical strength and proprioception in athletes with VI (18,126). Previous studies have found that increased neck strength and muscle activation results in reduced head movement following a standardized impact (127). A follow-up study found that athletes with stronger necks were less likely to sustain a concussion (126). Going forward, the above prevention strategies should be carefully considered and implemented in the hope that one of them, or a combination of them, can reduce the occurrence of concussions in para athletes with VI.

Perhaps the biggest take-away from both of our survey studies were the disparities in concussion education across different stakeholders in VI para sport. Results from our studies suggest that para athletes with VI appear to be receiving minimal education regarding concussion. Coaches appear to be more educated on concussion compared to athletes, yet some coaches failed to see the urgency in seeking medical attention after a suspected head injury. Medical professionals, while generally as educated as they can be given the lack of understanding we have on concussion in para sport, were reported to sometimes misinterpret visual behaviours of athletes with VI due to their lack of knowledge regarding blindness and/or low vision. Sport administrators may also require concussion education, given the difficulty investigators faced in circulating the athlete/coach survey amongst certain international sport federations and organizations. Going forward, all stakeholders involved in para sport should be informed of the potential life-threatening consequences of concussion injuries. It should be understood by all that concussion recognition is a collective responsibility that should not fall on the shoulders of any one group in sport to manage, especially given the lack of on-site medically support in para sport. Most importantly, education should be relevant and accessible for each stakeholder group. Future research should explore the preferences of athletes, coaches, sport administrators, and medical professionals when it comes to concussion education content and delivery. If the concussion education

is designed with key stakeholder perspectives in mind, there is a higher chance that participants will actively engage with and learn from the education they receive.

4.2 Recommendations Going Forward

The following is a list of recommendations for para sport governing bodies, including the IPC and IBSA, to consider for implementation:

1. The development and implementation of a standard protocol to investigate all significant impacts to the head or body at all sanctioned competitive events.
2. The provision of impartial medical support staff at sanctioned events where the risk of concussion injury is high.
3. A standardized method of capturing baseline testing data for all athletes with VI at least annually.
4. The provision of baseline testing results and a detailed explanation of pre-existing conditions for every athlete with VI at all sanctioned events.
5. Proof of completion of mandatory education on visual impairments and low vision for all medical personnel involved in concussion assessment of athletes with VI at events.
6. Proof of completion of mandatory concussion education for athletes, coaches, and sports administrators at sanctioned competitive events.

4.3 Limitations

Both the Delphi study and athlete/coach survey study encountered issues in terms of sample size and participant recruitment. For health-related Delphi studies, the sample size recommendation for a homogenous sample of experts lies anywhere between 8 – 15 participants (87,104,111). Round 1 of the

Delphi study met the previous outlined recommendation with a sample size of eight participants. However, the sample size in Round 2 fell slightly below what is recommended with a total of seven participants. It is possible that the lack of medical personnel specifically trained in para sport could have contributed to the difficulty we faced in the recruitment of healthcare professionals for the Delphi study. Additionally, many of our study participants were involved in providing medical support to teams at the Tokyo 2020 Paralympic Games, which were initially canceled and then rescheduled due to the COVID-19 pandemic. The rescheduling of the Games would have also had an impact on the availability of participants for our study.

The athlete/coach survey study experienced difficulties regarding the recruitment of eligible participants. Only four athletes with VI and four coaches successfully completed the survey. The lack of statistical power due to small sample size limited the possibility to determine whether there was a statistically significant difference between athlete and coach responses. It is likely that the sample size obtained was the result of several factors including: the small target population of elite athletes and coaches in VI para sport; the study inclusion requirement for athletes and coaches to have sufficient English language proficiency to understand and complete the survey in English; the requirement for athletes and coaches to have either personally sustained a concussion, or to have known someone who had sustained a sports-related concussion in the past; and the survey being released around the time of the Tokyo 2020 Paralympic Games, which were initially canceled and then rescheduled due to the COVID-19 pandemic. To improve upon the present study design, future studies should consider recruiting elite athletes and coaches without the requirement for them to have had a personal experience with a concussion or to have known someone who had. It would also be worth repeating the study in athletes and coaches participating in VI para sport at a recreational level for a broader sample and to determine differences between elite and non-elite VI para athletes and coaches.

4.4 Future Directions

In terms of concussion assessment, existing tools such as the SCAT5 appear to be generally effective at detecting concussion in athletes with VI. However, it is worth exploring whether modifications to the delivery of the SCAT5 may aid in the diagnosis of sports-related concussions in the VI para sport environment. Other common assessment tools such as the VOMS and the ImPACT tests should also be examined going forward to determine if they would be suitable for assessing concussion in athletes with VI. Given that athletes appear to be the most uninformed regarding concussion in general, future education strategies should emphasize the potential long-term consequences of concussion. Athletes should be informed of the potential long-term psychiatric and psychological outcomes (e.g., depression, anxiety, substance use, behavioural changes, neurodegenerative changes, etc.) of repeated concussion events so that they understand the significance of failing to report concussion symptoms and of neglecting concussion injury protocol (128). Further investigation into persistent concussion symptoms in athletes with VI is also needed to understand whether existing strategies (e.g., symptom limited aerobic exercise, cognitive behavioural therapy, etc.) may require modification for athletes with VI.

4.5 Conclusions

As in able-bodied sport, sports-related concussions are commonplace in para sport. However, there is limited understanding of best practices in concussion assessment and management for athletes with VI. In general, healthcare professionals in VI para sport are adapting existing able-bodied assessment tools and management strategies as necessary for use in athletes with VI based on their specific impairment. Given the significant overlap between symptoms associated with pre-existing visual conditions and acute concussion symptoms in athletes with VI, extra attention is needed in the recognition of concussion in this population of athletes. Understanding an athlete's pre-existing condition and conducting baseline testing at least annually is vital in this population of athletes. Future investment in

the provision of on-site medical support in both training and competitive environments in elite VI para sport is needed to ensure the safety and well-being of VI para athletes.

Before the development of our survey study, our knowledge of the perspectives and experiences of elite VI para sport athletes and coaches regarding concussion were non-existent. The results from our athlete/coach study suggest that there is a notable disconnect of perspectives and experiences regarding concussion between elite athletes and coaches. Athletes also appear to be receiving less and poorer quality education about concussion compared to coaches. Future education strategies should prioritize informing para athletes of the potential long-term consequences of concussion, so they understand the significance of failing to report concussion symptoms and of neglecting concussion injury protocol.

References

1. Lexell J, Frontera WR. Para Sport and Paralympic Sport: The Start of a New Journal Section. Am J Phys Med Rehabil. 2020;99(11):975–6.

2. McCrory P, Meeuwisse W, Dvorak J, Aubry M, Bailes J, Broglio S, et al. Consensus statement on concussion in sport—the 5 th international conference on concussion in sport held in Berlin, October 2016. Br J Sports Med [Internet]. 2017 Apr 26;51(11):bjsports-2017-097699. Available from: https://bjsm.bmj.com/lookup/doi/10.1136/bjsports-2017-097699

3. Harmon KG, Drezner JA, Gammons M, Guskiewicz KM, Halstead M, Herring SA, et al. American Medical Society for Sports Medicine position statement: concussion in sport. Vol. 47, British journal of sports medicine. 2013. p. 15–26.

4. Gardner RC, Yaffe K. Epidemiology of mild traumatic brain injury and neurodegenerative disease. Vol. 66, Molecular and Cellular Neuroscience. Academic Press Inc.; 2015. p. 75–80.

5. Theadom A, Starkey N, Dowell T, Hume PA, Kahan M, McPherson K, et al. Sports-related brain injury in the general population: An epidemiological study. J Sci Med Sport. 2014 Nov 1;17(6):591–6.

6. Kissick J, Webborn N. Concussion in Para Sport. Phys Med Rehabil Clin N Am. 2018;29(2):299–311.

7. Derman W, Schwellnus M, Jordaan E, Blauwet CA, Emery C, Pit-Grosheide P, et al. Illness and injury in athletes during the competition period at the London 2012 Paralympic Games: Development and implementation of a web-based surveillance system (WEB-IISS) for team medical staff. Br J Sports Med. 2013;47(7):420–5.

8. Derman W, Runciman P, Schwellnus M, Jordaan E, Blauwet C, Webborn N, et al. High precompetition injury rate dominates the injury profile at the Rio 2016 Summer Paralympic Games: A prospective cohort study of 51 198 athlete days. Br J Sports Med. 2018;52(1):24–31.

9. Derman W, Runciman P, Jordaan E, Schwellnus M, Blauwet C, Webborn N, et al. High incidence of injuries at the Pyeongchang 2018 Paralympic Winter Games: a prospective cohort study of 6804 athlete days. Br J Sports Med. 2020;54(1):38–43.

10. Lexell J, Lovén G, Fagher K. Incidence of sports-related concussion in elite para athletes – a 52-week prospective study study. Brain Inj. 2021 Jul 3;35(8):971–7.

11. Fagher K, Jacobsson J, Timpka T, Dahlström Ö, Lexell J. The Sports-Related Injuries and Illnesses in Paralympic Sport Study (SRIIPSS): a study protocol for a prospective longitudinal study. 2016;1–10.

12. International Blind Sports Federation. IBSA Classification Rules [Internet]. 2018 [cited 2022 Sep 27]. Available from: https://ibsasport.org/wp-content/uploads/2020/07/IBSA-Classification-rules-2018.pdf

13. International Paralympic Committee. History of Blind Football [Internet]. [cited 2022 Sep 27]. Available from: https://www.paralympic.org/blind-football/about

14. Webborn N, Cushman D, Blauwet CA, Emery C, Derman W, Schwellnus M, et al. The Epidemiology of Injuries in Football at the London 2012 Paralympic Games. PM and R. 2016;8(6):545–52.

15. Magno E Silva MP, Morato MP, Bilzon JLJ, Duarte E. Sports injuries in Brazilian blind footballers. Int J Sports Med. 2013;34(3):239–43.

16. Weiler R, Blauwet C, Clarke D, Dalton K, Derman W, Fagher K, et al. Concussion in para sport: The first position statement of the Concussion in Para Sport (CIPS) Group. Br J Sports Med. 2021;55(21):1187–95.

17. Willick SE, Webborn N, Emery C, Blauwet CA, Pit-Grosheide P, Stomphorst J, et al. The epidemiology of injuries at the London 2012 Paralympic Games. Br J Sports Med. 2013;47(7):426–32.

18. Fitzpatrick D, Thompson P, Kipps C, Webborn N. Head impact forces in blind football are greater in competition than training and increased cervical strength may reduce

impact magnitude. Int J Inj Contr Saf Promot [Internet]. 2021;28(2):194–200. Available from: https://doi.org/10.1080/17457300.2021.1905667

19. Weiler R, Verhagen E, Taylor A, Ahmed OH. Monitoring the beautiful adapted game: a 3-year prospective surveillance study of injuries in elite English Para football. Science and Medicine in Football [Internet]. 2021;00(00):1–6. Available from: https://doi.org/10.1080/24733938.2021.1984556

20. IBSA Football Committee. IBSA Blind Football Temporary Concussion Substitution Policy [Internet]. 2020 [cited 2022 Sep 27]. Available from: https://blindfootball.sport/wp-content/uploads/2021/05/IBSA-Blind-Football-Temporary-Concussion-Substitution-policy.pdf

21. Ahmed O WR. Rolling out a new policy on the big stage - the introduction of Temporary Concussion Substitutions at the Tokyo Paralympic Games [Internet]. BMJ Open Sport & Exercise Medicine Blog. 2021 [cited 2022 Sep 27]. Available from: https://blogs.bmj.com/bmjopensem/2021/09/01/rolling-out-a-new-policy-on-the-big-stage-the-introduction-of-temporary-concussion-substitutions-at-the-tokyo-paralympic-games/

22. Ahmed FOH, Fulcher M, Malone D, Lopez CMY, Rho ME, Strojna A. THE INTRODUCTION OF TEMPORARY CONCUSSION SUBSTITUTIONS IN DISABILITY FOOTBALL : ARE WE ‘ HEADED ’ IN THE RIGHT DIRECTION ? In an exceptional working environment you need exceptional representation In these exceptional times you need exceptional support Th. 2020;13–6.

23. International Federation of CP Football. IFCPF unveils new Temporary Concussion Substitution (TCS) Policy [Internet]. 2019 [cited 2022 Sep 27]. Available from: https://www.ifcpf.com/news/ifcpf-unveils-new-temporary-concussion-substitution-%28tcs%29-policy

24. International Blind Sports Federation. About Goalball: Overview [Internet]. [cited 2022 Sep 27]. Available from: https://goalball.sport/about-goalball/overview/

25. Zwierzchowska A, Rosołek B, Celebańska D, Gawlik K, Wójcik M. The prevalence of injuries and traumas in elite goalball players. Int J Environ Res Public Health. 2020;17(7):1–7.

26. Aravena C, Fontanilla M, Barrı M. Injuries and Illness Prevalence Prior to Competition in Goalball Players. 2019;113(5):443–51.

27. Connor Jr. JL LJDLA. Adaptive Combative Sports (Judo, Boxing, Wrestling, Mixed Martial Arts). In: de Luigi AJ, editor. Adaptive Sports Medicine. Springer International Publishing; 2018. p. 333–42.

28. Fagher K, Hassan Ahmed O, Pernheim N, Varkey E. Prevalence of sports-related injuries in paralympic judo: An exploratory study. J Sci Med Sport [Internet]. 2019;22(8):902–6. Available from: https://doi.org/10.1016/j.jsams.2019.03.005

29. International Blind Sports Federation. IBSA Judo Classification Rules [Internet]. 2021 [cited 2022 Sep 27]. Available from: https://www.judoontario.ca/_files/ugd/4e882e_ed2ff5ef789b4ccbaf741f26f223a367.pdf/

30. Kim KS, Park KJ, Lee J, Kang BY. Injuries in national Olympic level judo athletes: An epidemiological study. Br J Sports Med. 2015 Sep 1;49(17):1144–50.

31. Judo Channel. Judo terms : Tachi-waza [Internet]. [cited 2022 Sep 27]. Available from: https://www.judo-ch.jp/english/dictionary/terms/tatiwaza/

32. Judo Channel. Judo terms : Ne-waza [Internet]. [cited 2022 Sep 27]. Available from: https://www.judo-ch.jp/english/dictionary/terms/newaza/

33. Gordon AH, de Luigi AJ. Adaptive Cycling. Curr Sports Med Rep. 2020;19(7):266–71.

34. Canadian Paralympic Committee. Para Cycling [Internet]. [cited 2022 Sep 27]. Available from: https://paralympic.ca/paralympic-sports/para-cycling

35. Hanief YN, Umar F. The characteristics of Indonesian para-cycling athletes' injuries. Advances in Rehabilitation. 2020;34(3):37–46.

36. Clarsen B, Pluim BM, Moreno-Pérez V, Bigard X, Blauwet C, del Coso J, et al. Methods for epidemiological studies in competitive cycling: An extension of the IOC consensus statement on methods for recording and reporting of epidemiological data on injury and illness in sport 2020. Br J Sports Med. 2021;55(22):1262–9.

37. World Para Swimming. History of Para Swimming [Internet]. [cited 2022 Sep 27]. Available from: https://www.paralympic.org/swimming/about

38. Magno E Silva M, Bilzon J, Duarte E, Gorla J, Vital R. Sport injuries in elite paralympic swimmers with visual impairment. J Athl Train. 2013;48(4):493–8.

39. World Para Swimming. Classification in Para Swimming [Internet]. [cited 2022 Sep 27]. Available from: https://www.paralympic.org/swimming/classification

40. Juriga BJ YYDLA. Adaptive Alpine Skiing and Para-snowboarding. In: de Luigi AJ, editor. Adaptive Sports Medicine. Springer International Publishing; 2018. p. 251–99.

41. Derman W, Schwellnus MP, Jordaan E, Runciman P, van de Vliet P, Blauwet C, et al. High incidence of injury at the Sochi 2014 Winter Paralympic Games: A prospective cohort study of 6564 athlete days. Br J Sports Med. 2016;50(17):1069–74.

42. Derman W, Blauwet C, Webborn N, Schwellnus M, van de Vliet P, Lazarovski D. Mitigating risk of injury in alpine skiing in the Pyeongchang 2018 Paralympic Winter Games: The time is now! Br J Sports Med. 2018;52(7):419–20.

43. Blauwet C, Webborn N, Kissick J, Lexell J, Stomphorst J, van de Vliet P, et al. When van Mechelen's sequence of injury prevention model requires pragmatic and accelerated action: The case of para alpine skiing in Pyeong Chang 2018. Br J Sports Med. 2019;53(22):1391–2.

44. Fagher K, Dahlström Ö, Jacobsson J, Timpka T, Lexell J. Prevalence of Sports-Related Injuries and Illnesses in Paralympic Athletes. PM and R. 2020;12(3):271–80.

45. International Paralympic Committee. Tokyo 2020 sets the record for the most athletes and women at a Paralympic Games [Internet]. 2021 [cited 2022 Sep 27]. Available

from: https://www.paralympic.org/news/tokyo-2020-sets-record-most-athletes-and-women-paralympic-games

46. Wessels KK, Broglio SP, Sosnoff JJ. Concussions in wheelchair basketball. Arch Phys Med Rehabil [Internet]. 2012;93(2):275–8. Available from: http://dx.doi.org/10.1016/j.apmr.2011.09.009

47. Aubry M, Cantu R, Dvorak J, Graf-Baumann T, Johnston K, Kelly J, et al. Summary and agreement statement of the First International Conference on Concussion in Sport, Vienna 2001. Physician and Sportsmedicine. 2002;30(2):57–63.

48. McCrory P, Meeuwisse WH, Aubry M, Cantu RC, Dvorák J, Echemendia RJ, et al. Consensus Statement on Concussion in Sport-The 4th International Conference on Concussion in Sport Held in Zurich, November 2012. PM and R. 2013;5(4):255–79.

49. McCrory P, Meeuwisse W, Johnston K, Dvorak J, Aubry M, Molloy M, et al. Consensus statement on Concussion in Sport-The 3rd International Conference on Concussion in Sport held in Zurich, November 2008. J Sci Med Sport. 2009;12(3):340–51.

50. McCrory P, Johnston K, Meeuwisse W, Aubry M, Cantu R, Dvorak J, et al. Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004. Br J Sports Med. 2005;39(4):196–204.

51. McQuivey KS, Moore ML, Pollock JR, Hassebrock JD, Patel KA, Chhabra A. Top-100 Most-Cited Sports-Related Concussion Articles Focus on Symptomatology, Epidemiology, and Demographics. Arthrosc Sports Med Rehabil. 2021 Dec 1;3(6):e1585–97.

52. Bull A. New paper launches attack on ‘biased’ sport concussion consensus process [Internet]. Guardian News & Media Limited. 2021 [cited 2022 Nov 21]. Available from: https://www.theguardian.com/sport/2021/oct/20/new-paper-launches-attack-on-biased-sport-concussion-consensus-process

53. Weiler R, van Mechelen W, Fuller C, Ahmed O, Verhagen E. Do neurocognitive scat3 test scores differ between non-concussed national footballers living with and without disability? a cross-sectional study. Br J Sports Med. 2017;51(11):A75.1-A75.

54. Griffin S, West LR, Ahmed OH, Weiler R. CONCUSSION KNOWLEDGE, ATTITUDES, AND BELIEFS AMONGST SPORTS MEDICINE PERSONNEL AT THE 2015 CEREBRAL PALSY FOOTBALL WORLD CHAMPIONSHIPS. Br J Sports Med. 2017 Feb;51(4):325.1-325.

55. Echemendia RJ, Meeuwisse W, McCrory P, Davis GA, Putukian M, Leddy J, et al. The Sport Concussion Assessment Tool 5th Edition (SCAT5): Background and rationale. Br J Sports Med. 2017 Jun 1;51(11):848–50.

56. Echemendia RJ, Meeuwisse W, McCrory P, Davis GA, Putukian M, Leddy J, et al. The Sport Concussion Assessment Tool 5th Edition (SCAT5). Br J Sports Med [Internet]. 2017 Apr 26;51(11):bjsports-2017-097506. Available from: https://bjsm.bmj.com/lookup/doi/10.1136/bjsports-2017-097506

57. Echemendia RJ, Broglio SP, Davis GA, Guskiewicz KM, Hayden KA, Leddy JJ, et al. What tests and measures should be added to the SCAT3 and related tests to improve their reliability, sensitivity and/or specificity in sideline Concussion diagnosis? A systematic review. Br J Sports Med. 2017;51(11):895–901.

58. Echemendia RJ, Meeuwisse W, McCrory P, Davis GA, Putukian M, Leddy J, et al. The Concussion Recognition Tool 5th Edition (CRT5): Background and rationale. Br J Sports Med. 2017 Jun 1;51(11):870–1.

59. Davis GA, Purcell L, Schneider KJ, Yeates KO, Gioia GA, Anderson V, et al. The Child Sport Concussion Assessment Tool 5th Edition (Child SCAT5): Background and rationale. Br J Sports Med. 2017;51(11):859–61.

60. West LR, Griffin S, Weiler R, Ahmed OH. Management of concussion in disability sport: A different ball game? Br J Sports Med. 2017;51(14):1050–1.

61. Centers for Disease Control and Prevention. Heads up: FAQs about baseline testing. [Internet]. [cited 2022 Dec 10]. Available from: https://www.cdc.gov/headsup/basics/baseline_testing.html.

62. Tsao JW, Vermetten E. Neurocognitive Testing in Concussion Management. 2015;1–12.

63. King D, Brughelli M, Hume P, Gissane C. Assessment, management and knowledge of sport-related concussion: Systematic review. Vol. 44, Sports Medicine. Adis International Ltd; 2014. p. 449–71.

64. Pasqualotto A, Lam JSY, Proulx MJ. Congenital blindness improves semantic and episodic memory. Behavioural Brain Research. 2013 May 1;244:162–5.

65. King AJ. Crossmodal plasticity and hearing capabilities following blindness. Vol. 361, Cell and Tissue Research. Springer Verlag; 2015. p. 295–300.

66. Zdziarski L, Pierpoint L, Taylor D, Donaldson A, Moreau W, Nabhan D. Normative Baseline SCAT5 Scores in a Population of United States Paralympic Athletes. Br J Sports Med. 2020;54(Suppl 1):A1–173.

67. Piedade SR, Hutchinson MR, Ferreira DM, Cristante AF, Maffulli N. The management of concussion in sport is not standardized. A systematic review. J Safety Res [Internet]. 2021;76:262–8. Available from: https://doi.org/10.1016/j.jsr.2020.12.013

68. Burton H, Snyder AZ, Conturo TE, Akbudak E, Ollinger JM, Raichle ME. Adaptive Changes in Early and Late Blind: A fMRI Study of Braille Reading. J Neurophysiol [Internet]. 2002;589–607. Available from: www.jn.org

69. Sadato N, Pascual-Leone A, Grafman J, Ibanez V, Deiber MP, Dold G, et al. Activation of the primary visual cortex by Braille reading in blind subjects. Nature. 1996 Apr 11;380:526–8.

70. Canadian Blind Sports. Post-concussion guidelines: Return to school considerations for students who are blind or visually impaired. [Internet]. [cited 2022 Dec 10]. Available

from: http://canadianblindsports.ca/wp-content/uploads/2021/06/0515_EN_Return-to-School-Considerations-document.pdf

71. Canadian Blind Sports. Concussion and Visual Impairments. [Internet]. [cited 2022 Dec 10]. Available from: http://canadianblindsports.ca/resources/concussion-and-visual-impairments/

72. Provincial Resource Centre for the Visually Impaired. The Expanded Core Curriculum. [Internet]. [cited 2022 Dec 10]. Available from: https://prcvi.org/resources/the-expanded-core-curriculum/

73. Canadian Blind Sports. Concussion return-to-work considerations for employees who are blind or visually impaired [Internet]. [cited 2022 Dec 10]. Available from: http://canadianblindsports.ca/wp-content/uploads/2021/06/0515_EN_Return-to-Work-Considerations-document.pdf

74. Canadian Blind Sports. Concussion return-to-sport considerations for athletes who are blind or visually impaired [Internet]. [cited 2022 Dec 10]. Available from: http://canadianblindsports.ca/wp-content/uploads/2021/06/0610_EN_Return-to-Sport-Considerations-Document.pdf

75. da Silva ES, Fischer G, da Rosa RG, Schons P, Teixeira LBT, Hoogkamer W, et al. Gait and functionality of individuals with visual impairment who participate in sports. Gait Posture. 2018 May 1;62:355–8.

76. Sánchez-González MC, Gutiérrez-Sánchez E, Sánchez-González JM, Rebollo-Salas M, Ruiz-Molinero C, Jiménez-Rejano JJ, et al. Visual system disorders and musculoskeletal neck complaints: a systematic review and meta-analysis. Vol. 1457, Annals of the New York Academy of Sciences. Blackwell Publishing Inc.; 2019. p. 26–40.

77. Fagher K, Forsberg A, Jacobsson J, Timpka T, Dahlström Ö, Lexell J. Paralympic athletes' perceptions of their experiences of sports-related injuries, risk factors and preventive possibilities. Eur J Sport Sci. 2016 Nov 16;16(8):1240–9.

78. Fagher K. Sports-related injuries and illnesses in Paralympic athletes (PhD Academy Award). Vol. 55, British Journal of Sports Medicine. 2021. 237–238 p.

79. Parachute Canada. Concussion protocol resources for sport organizations [Internet]. [cited 2022 Dec 10]. Available from: https://www.parachutecanada.org/en/professional-resource/concussion-collection/concussion-protocol-resources-for-sport-organizations/

80. Babul S. Concussion Awareness Training Tool: About CATT Online [Internet]. [cited 2022 Dec 10]. Available from: https://cattonline.com/about/

81. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)-A metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform. 2009 Apr;42(2):377–81.

82. Herring SA, Cantu RC, Guskiewicz KM, Putukian M, Kibler W ben. Concussion (Mild Traumatic Brain Injury) and the team physician: A consensus statement-2011 update. Med Sci Sports Exerc. 2011 Dec;43(12):2412–22.

83. Parachute. Canadian Guideline on Concussion in Sport. 2017.

84. Ferris LM, Kontos AP, Eagle SR, Elbin RJ, Collins MW, Mucha A, et al. Utility of VOMS, SCAT3, and ImPACT Baseline Evaluations for Acute Concussion Identification in Collegiate Athletes: Findings From the NCAA-DoD Concussion Assessment, Research and Education (CARE) Consortium. American Journal of Sports Medicine. 2022;50(4):1106–19.

85. Giza CC, Kutcher JS, Ashwal S, Barth J, Getchius TSD, Gioia GA, et al. Summary of evidence-based guideline update: Evaluation and management of concussion in sports: Report of the Guideline Development Subcommittee of the American Academy of Neurology. Neurology. 2013 Jun 11;80(24):2250–7.

86. Junge A, Langevoort G, Pipe A, Peytavin A, Wong F, Mountjoy M, et al. Injuries in team sport tournaments during the 2004 Olympic Games. Vol. 34, The American journal of sports medicine. 2006. p. 565–76.

87. Keeney S, Hasson F, McKenna H. The Delphi Technique in Nursing and Health Research. First. Vol. p. 208. Oxford: Wiley-Blackwell ; 2011.

88. Hsu CC. The Delphi Technique: Making Sense Of Consensus. 2007;12(10).

89. Delbecq AL, van de Ven AH, Gustafson DH. Group Techniques for Program Planning: A Guide to Nominal Group and Delphi Processes. Glenview, IL: Scott, Foresman, and Co. 1975 Jul;

90. Moore CM. Group techniques for idea building. Group techniques for idea building. Thousand Oaks, CA, US: Sage Publications, Inc; 1987. 143 p. (Applied social research methods series, Vol. 9.).

91. Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L, et al. The REDCap consortium: Building an international community of software platform partners. Vol. 95, Journal of Biomedical Informatics. Academic Press Inc.; 2019.

92. Custer RL, Scarcella JA, Stewart BR. The modified Delphi technique-A rotational modification. Journal of Vocational and Technical Education. 1999;15(2):50–8.

93. Ravensbergen HJCR, Mann DL, Kamper SJ. Expert consensus statement to guide the evidence-based classification of Paralympic athletes with vision impairment: A Delphi study. Br J Sports Med. 2016;50(7):386–91.

94. Zetterlund C, Lundqvist LO, Richter HO. Visual, musculoskeletal and balance symptoms in individuals with visual impairment. Clin Exp Optom. 2019 Jan 1;102(1):63–9.

95. Seidman DH, Burlingame J, Yousif LR, Donahue XP, Krier J, Rayes LJ, et al. Evaluation of the King-Devick test as a concussion screening tool in high school football players. J Neurol Sci [Internet]. 2015;356(1–2):97–101. Available from: http://dx.doi.org/10.1016/j.jns.2015.06.021

96. Mucha A, Collins MW, Elbin RJ, Furman JM, Troutman-Enseki C, Dewolf RM, et al. A brief vestibular/ocular motor screening (VOMS) assessment to evaluate concussions: Preliminary findings. American Journal of Sports Medicine. 2014;42(10):2479–86.

97. Schneider KJ, Leddy JJ, Guskiewicz KM, Seifert T, Mccrea M, Silverberg ND, et al. Rest and treatment / rehabilitation following sport-related concussion : a systematic review. 2017;(3):930–4.

98. Pigeon C, Li T, Moreau F, Pradel G, Marin-Lamellet C. Cognitive load of walking in people who are blind: Subjective and objective measures for assessment. Gait Posture. 2019 Jan 1;67:43–9.

99. Brown ANJ, Mannix RC. Effect of Cognitive Activity Level on Duration of Post-Concussion Symptoms. 2014;133(2):2–7.

100. Gupta A, Summerville G, Senter C, Summerville G, Senter C. Treatment of Acute Sports-Related Concussion. 2019;117–23.

101. Wetjen NM, Pichelmann MA, Atkinson JLD. Second impact syndrome: Concussion and second injury brain complications. Vol. 211, Journal of the American College of Surgeons. 2010. p. 553–7.

102. Lecci L, Williams M, Taravath S, Frank HG, Dugan K, Page R, et al. Validation of a concussion screening battery for use in medical settings: Predicting centers for disease control concussion symptoms in children and adolescents. Archives of Clinical Neuropsychology. 2021;35(3):265–74.

103. Alsalaheen B, Stockdale K, Pechumer D, Broglio SP. Validity of the Immediate Post Concussion Assessment and Cognitive Testing (ImPACT). Vol. 46, Sports Medicine. Springer International Publishing; 2016. p. 1487–501.

104. Trevelyan EG, Robinson N. Delphi methodology in health research: How to do it? Eur J Integr Med [Internet]. 2015;7(4):423–8. Available from: http://dx.doi.org/10.1016/j.eujim.2015.07.002

105. Murphy MK, Sanderson C, Black NA, Askham J, Lamping DL, Marteau T, et al. Consensus development methods, and their use in clinical guideline development [Internet]. Vol. 2, HTA Health Technology Assessment NHS R&D HTA Programme Health Technology Assessment. 1998. Available from: www.hta.ac.uk/htacd.htm

106. McKenna DPM DipN Rh HP, RGN AdvDipEd RNT N. The Delphi technique: a worthwhile research approach for nursing? Vol. 19, lournal of Advanced Nursing. 1994.

107. Goodman CM. 729-734 RGN DNCert Lecturer in Nursing Research, North West Thames Regional Health Authority. Vol. 12, Journal oJ Advanced Nursing. GOODMAN CM; 1987.

108. Dalkey NC. THE DELPHI METHOD: AN EXPERIMENTAL STUDY OF GROUP OPINION md falfUtlAtiOH I »00 MS'S St • SANIA MONK*. CAl » O » N I A • «040*. 1969.

109. Powell C. The Delphi technique: Myths and realities. Vol. 41, Journal of Advanced Nursing. 2003. p. 376–82.

110. Baker J, Lovell K, Harris N. How expert are the experts? An exploration of the concept of "expert" within Delphi panel techniques. Nurse Res. 2006;14(1):59–70.

111. Skulmoski GJ, Hartman FT, Krahn J. The Delphi Method for Graduate Research The Delphi Method for Graduate Research 2. Vol. 6, Journal of Information Technology Education. 2007.

112. Preston CC, Colman AM. Optimal number of response categories in rating scales: reliability, validity, discriminating power, and respondent preferences [Internet]. Available from: www.elsevier.com/locate/actpsy

113. Lozano LM, García-Cueto E, Muñiz J. Effect of the number of response categories on the reliability and validity of rating scales. Methodology. 2008;4(2):73–9.

114. W Raaijmakers QA, van Hoof A, M A Verbogt TF, M Vollebergh WA. ADOLESCENTS' MIDPOINT RESPONSES ON LIKERT-TYPE SCALE ITEMS: NEUTRAL OR MISSING VALUES? *. International Journal of Public Opinion Research.

115. Tsang KK. The use of midpoint on Likert scale: The implications for educational research. Hong Kong Teachers' Centre Journal. 2012;11:121–30.

116. International Paralympic Committee. Paralympics History [Internet]. [cited 2022 Oct 21]. Available from: https://www.paralympic.org/ipc/history#:~:text=On%2029%20July%201948%2C%20the,who%20took%20part%20in%20archery.

117. International Paralympic Committee. Record number of female Para athletes set for Beijing 2022 Paralympic Winter Games [Internet]. 2022 [cited 2022 Oct 2]. Available from: https://www.paralympic.org/feature/record-number-female-para-athletes-set-beijing-2022-paralympic-winter-games

118. Richard J, Lin YS, Wernet L, Kasitinon D, Royston A, Bristow K, et al. Is the King-Devick Test a Reliable Tool in Wheelchair Athletes? A Preliminary Prospective Study in Wheelchair Basketball. Clinical Journal of Sport Medicine. 2022 Mar 1;32(2):E134–8.

119. Permenter CM, Fernández-de Thomas RJ, Sherman A l. Postconcussive Syndrome. 2022.

120. Kroshus E, Baugh CM, Hawrilenko MJ, Daneshvar DH. Determinants of Coach Communication About Concussion Safety in US Collegiate Sport. Annals of Behavioral Medicine. 2015 Aug 22;49(4):532–41.

121. Blauwet C, Lexell J, Derman W, Idrisova G, Kissick J, Stomphorst J, et al. The Road to Rio: Medical and Scientific Perspectives on the 2016 Paralympic Games. PM and R. 2016 Aug 1;8(8):798–801.

122. Kissick J, Webborn N. Concussion in Para Sport. Aspetar Sports Medicine Journal (Paralympic Athletes Targeted Topic). :156–61.

123. International Olympic Committee. Olympic Games Tokyo 2020: About the Games [Internet]. 2022 [cited 2022 Oct 2]. Available from: https://olympics.com/en/olympic-games/tokyo-2020

124. International Olympic Committee. Olympic Winter Games Beijing 2022: About the Games [Internet]. 2022 [cited 2022 Oct 2]. Available from: https://olympics.com/en/olympic-games/beijing-2022

125. Kroshus E, Baugh CM. Concussion Education in U.S. Collegiate Sport: What Is Happening and What Do Athletes Want? Health Education and Behavior. 2016;43(2):182–90.

126. Collins CL, Fletcher EN, Fields SK, Kluchurosky L, Rohrkemper MK, Comstock RD, et al. Neck Strength: A Protective Factor Reducing Risk for Concussion in High School Sports. Journal of Primary Prevention. 2014 Oct 1;35(5):309–19.

127. Eckner JT, Oh YK, Joshi MS, Richardson JK, Ashton-Miller JA. Effect of neck muscle strength and anticipatory cervical muscle activation on the kinematic response of the head to impulsive loads. American Journal of Sports Medicine. 2014 Mar;42(3):566–76.

128. Finkbeiner NWB, Max JE, Longman S, Debert C. Knowing what we don't know: Long-term psychiatric outcomes following adult concussion in sports. Vol. 61, Canadian Journal of Psychiatry. SAGE Publications Inc.; 2016. p. 270–6.