Fall 2015

A Systematic Review of Smartphone Applications for Parent, Coach, and Referee Sideline Concussion Symptom Identification and Intervention in Youth Soccer

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December 2015

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Acknowledgements

First and foremost, I would like to say Thank You to all of the members of my CE Committee, Dr. Nikki Rogers, Dr. Sara Paton, and Dr. John McAlearney, for their long-standing support, dedication, and sincere desire for my personal success during the conduct of this project. And I would like to personally acknowledge their personal time, effort, and perseverance on contributing to the success of this project. God Bless you all for your care and belief in my success.

Next, I can't adequately express, in so few words, how much I am appreciative and grateful to Dr. Nikki Rogers for EVERYTHING that she has contributed, produced, motivated, and challenged me, during every stage of this project and during my tenure as a WSU MPH Program candidate. Your guidance, motivation, direction, and focus were instrumental to my educational success. Thank You.

And Thank You to ALL of the WSU MPH Program Staff for their "re-dedication" and "re-commitment" to ensuring the educational success and achievement of their program's students.

Lastly, I would like to express my love and gratitude to all of my children (Bryan, Gabrielle, Kirsten, Timothy, and Alyssa) and my wife (Christine) for their long-time support and personal sacrifices throughout this educational achievement. I love you all dearly.

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Abstract

BACKGROUND: It is the collective responsibility of coaches, referees, and parents to identify the signs and symptoms of a concussion, assess a player's acute medical condition, and report their observations. Increasing concussion awareness and empowerment of these entities is critical to ensure that concussions are properly managed, risk is reduced, and effects are mitigated. OBJECTIVE: The purpose of this review was to provide youth soccer organizations and relevant parties with the most relevant, factual evidence-based smartphone applications for recognizing the signs and symptoms of concussions in youth sports. METHODS: An evidence-based standard for concussion symptoms and identification was identified from the Centers for Disease Control and Prevention's HEADS UP to Youth Sports website. This baseline info was used to evaluate smartphone application's degree of complete and accurate information about the signs and symptoms of concussion. A keyword search on Apple's 'App Store' was performed to identify sideline concussion evaluation applications. Seven criteria were developed to evaluate the applications for meeting security and performance standards. RESULTS: The 'concussion' keyword search yielded forty-seven (47) smartphone applications for review and evaluation. These applications were screened against the seven criteria: eight met all criteria. A detailed review of each of the eight applications was performed, noting strengths and weaknesses. Four of the eight applications were deemed "recommended". CONCLUSION: The four applications that met the objective were recommended for download by youth sport parents, referees, coaches and players: Concussion Smart (v 1.2), Concussion Coach (v 1.0.1), Concussion Management (v 1.0), and Concussion Awareness (v 1.0.0).

Keywords: Sports Injuries, Traumatic Brain Injury, Team Sports

Preface

Imagine this scenario: a nine-year old soccer player dribbles down the soccer field and is about five yards from scoring a goal when he gets ‘blindsided’ by a charging opposing player. This causes him to lose his balance and land headfirst onto the grassy field. The child stumbles when trying to regain his footing and then falls back to the ground. Within a few seconds, he gets up and trots off the field. During this event, no referee or parent intervention takes place to stop the play of the game. When returning to the sideline, the player’s teammates applaud his toughness and encourage him to ‘get that one back’. The coach questions him, “Are you good?” The player responds with “Good to go coach. Just shook it off.” Within five minutes of his head contacting the ground with force, the coach sends the player back in to the game.

This realistic scenario highlights many concerns that arise when dealing with possible concussion risk identification, self-assessment, and triage involving youth athletes. Coaches have traditionally been trained to note that the fundamental principle of “fair play” was violated by the charge by the opposing player. A concern that has only recently come into the public consciousness is that the fallen player displayed physical signs and symptoms of a possible injury known as *concussion*. The headfirst slam against the ground was the first identification marker, followed by an unsuccessful attempt to regain his footing (stumbling), the second identification marker.

Another major concern in this scenario is the lack of a proper concussion assessment performed to evaluate the child’s potential injury, the response of the other players, and the player’s immediate return to the field. As described in this scenario, the other players encouraged the fallen child to continue to play and made suggestions to ‘play harder’: this type of encouragement is counterproductive to his health and well-being and values play over proper

injury assessment and recovery (if needed). The coach's lack of awareness of both the potential injury and the subsequent signs and symptoms of the player's urgent medical condition is typical of practices prior to the 21st century (Ezell, 2013).

In this scenario, the coach and referees failed to ensure that the game was stopped and that proper medical treatment and support was provided to the player. The coach's return to play approval illustrates a lack of understanding of the significance of a concussion and could result in further aggravation/exacerbation of the injury itself. In addition, the risk of second impact syndrome, a more serious and life-threatening condition resulting from a potential secondary traumatic brain injury without adequate rest and recovery, is amplified by the coach's approval of the player's immediate return to play.

This scenario paints a picture of how concussions can go unreported due to a lack of understanding of the signs and symptoms of a concussion. Another concern is that children may not be able to properly or clearly express or describe the mental and physical effects of an on-field head injury. It is the collective responsibility of coaches, referees, and parents to be able to identify the signs and symptoms of a concussion, to be able to assess a player's acute medical condition, seek appropriate medical treatment given the triaged signs and symptoms of the traumatic event, and accurately report the findings to medical staff and caregivers. Increasing awareness and empowerment of coaches, referees, and parents is critical to ensure that concussions are medically managed, that second impact syndrome risk is eliminated, and that the effects of a concussion are proactively mitigated.

A Systematic Review of Smartphone Applications for Parent, Coach, and Referee Sideline Concussion Symptom Identification and Intervention in Youth Soccer

In the mid to late 1990s, after several investigations into the effects of concussion on its players, the NFL Retirement Board acknowledged the dangers of multiple concussions on its players' lifetime health through a 1999 disability ruling on one of those investigations (Ezell, 2013). The significance of this ruling and its findings would help shape the dialogue of concussions in sports, not just at the professional level, but through all levels of competitive play including youth sports. In addition, the findings on the NFL players' histories and health concerns not only brought about an awareness in how to shape the sport itself, but would also become the only medical condition that would lead to state legislation. In 2009, the Lystedt Law was passed by Washington State legislature requiring concussion awareness and management policy in youth sports (Ezell, 2013; Gibson, Herring, Kutcher, & Broglio, 2015).

Covassin, Elbin, and Sarmiento (2012) report approximately 45 million American youth play some form of organized and recreational sports. Sports-related injuries, including concussions, are common: 65% of athletes seen in US emergency rooms for sports-related injuries are between the ages of 5 and 18 years old. A concussion is a 'mild' form of traumatic brain injury (e.g. MTBI) and the Centers for Disease Control & Prevention (CDC) define it in the following way:

> Mild traumatic brain injury or MTBI—also called concussion, minor head injury, minor brain injury, minor head trauma, or minor TBI—is one of the most common neurologic disorders. It occurs when an impact or forceful motion of the head results in a brief alteration of mental status, such as confusion or disorientation, loss of memory for events immediately before or after the injury, or brief loss of consciousness (Centers for Disease Control & Prevention [CDC], 2010, p. 7).

While various forms of traumatic brain injuries are defined and range in severity and effects from 'mild' to 'severe', the CDC captures and publishes emergency department (ED) data

on all forms of traumatic brain injury without segregating the data by severity levels. As a direct result of this lack of segregating the data, the 'true' number of youth sports related concussions (MTBI) cannot be determined from CDC data. However, the U.S. Consumer Product Safety Commission's National Electronic Injury Surveillance System – All Injury Space Program (NEISS-AIP) provides ED visit concussion data for youth (ages 10 to 19) that are broken down by cause of injury, e.g. sports or recreation related. CDC staff analyzed the data from the 2001-2009 NEISS-AIP and reported that the number of sports or recreation related ED visits for TBI amongst youth increased by 62% between 2001-2009, while the overall TBI rate only increased by 57% (Gilchrist, Thomas, Xu, McGuire, & Coronado, 2011). The authors state that these statistics might reflect a combination of one, or more, of the following: an increase participation rate in sports or recreation, an increased incidence of TBI, or the more likely increased 'awareness' on early diagnosis of TBI.

As reflected in these statistics on increased ED visits, public awareness on concussions in youth sports has grown since the NFL's forced recognition of lifetime concussion damage. Public health must take an active role in this discussion by providing educational tools and literature that can describe the signs and symptoms of concussions and how to assess players suspected of having a concussion. One such educational tool is a smartphone application. Smartphone applications are flexible and readily available to those that would have a need for it, i.e. parents, coaches, and referees.

Purpose Statement

The purpose of this systematic review was to provide youth soccer organizations and all relevant parties, including coaches, referees, and parents of youth soccer athletes, with the most relevant, factual evidence-based smartphone applications for recognizing the signs and

symptoms of concussions in community youth (less than high school age) sports. This purpose was achieved by reviewing and comparing smartphone applications developed for parent and coach sideline identification and self-assessment of juvenile concussion injuries based on a comparison with a traditional evidenced-based standard. The focus on youth was due to the recognition that pre-high school athletes are at higher risk of concussion than their counterparts and take longer to recover (Ezell, 2013; Gibson et al., 2015; Pfister, Pfister, Hagel, Ghali, & Ronksley, 2015).

Literature Review

Public Health Burden

The Centers for Disease Control and Prevention (CDC) is the national agency dedicated to preventing disease and injury by promoting healthy lifestyles through public awareness, educational programs, policy, administrative services, and research (CDC Foundation, 2016). The CDC supports research and education on Traumatic Brain Injury through the National Center for Injury Prevention and Control (CDC, 2015a). According to the CDC, an estimated 1.5 million Americans sustain a TBI annually; 50,000 die from these injuries and 80,000 to 90,000 experience onset of long-term disability, resulting in a cumulative estimate of 5.3 million Americans with permanent disability due to TBI (CDC, 2010). Further, the report notes that almost 75% of these injured persons actually have a mild traumatic brain injury (MTBI). A more elusive number is the total number of patients that go untreated. The report suggests that as many as 381,000, or 25%, receive no medical care for their head injuries.

As awareness to this public health issue has grown since 1999, so too has the number of US emergency department visits. From 1997 to 2007, concussion reporting more than tripled, and greater than forty percent of the concussions diagnosed in the emergency department during

that timeframe were sports related (Merkel & Molony, 2012). Gourley, McLeod, and Bay (2010) show that the concussion incidence rate is different among age groups: they report that concussions account for 8.9% of all athletic injuries in high school, but that number is only 3% to 8% for children under the age of 16 years. These rates are corroborated by a separate study by Gessel, Fields, Collins, Dick, and Comstock (2007) and comparable to the 9% reported in a high school surveillance study (Comstock, Yard, Knox, & Mauring, 2006). Langlois, Rutland-Brown, and Wald (2006) estimated that the actual incidence of sport related concussion lies somewhere in a range between 1.6 and 3.8 million injuries annually. Although this seems like a rather wide range, closer approximations are difficult due to underreporting (CDC, 2010; McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004).

Although youth athletes have a smaller incidence rate (3-8%) than high school athletes (9%), youth athletes are more susceptible to concussions and concussions are more dangerous at their stage of physical and brain development. Their larger head to body size ratio and weaker neck muscles make youth athletes more susceptible to concussion. In addition, their brains are at an earlier stage of development than high school athletes and so, a concussion can have a longer, more profound and dangerous impact on their mental health and development (Ezell, 2013; Gibson et al., 2015; Pfister et al., 2015).

Incidence

Injury prevention in sports is a major public health issue. According to the CDC, 20% of the 1.5 million TBIs diagnosed in the United States in 1991 were sports-related (CDC, 2010). Concussion treatment was primarily treated as out-patient based care. However, recent CDC statistics show that the incidence of hospitalizations occurring from these injuries has steadily declined while emergency department visits has almost doubled (216 to 392 per 100,000). These

incidence numbers reflect the general population, but examination of these numbers against the reported incidence within the youth age demographics (<19yrs) shows that youth make up a greater percentage of the population incident rate. Ahmann (2013) reported almost a 160% increase, between 2001 and 2009, in the incidence rate in emergency department visits due to concussion.

Breaking down concussion incidence by sport shows that certain sports that have greater types and magnitudes of physical contact, whether intentional or unintentional, and produce the greatest risk of concussion incidence. According to Ahmann (2013), U.S. male athletes at both the high school and college levels playing football, ice hockey, lacrosse, or wrestling have the greatest risk and reported rates of concussions. U.S. female athletes playing soccer, lacrosse, or basketball have the greatest risk and reported rates of concussions (Ahmann, 2013). Labella (2014) reported that concussion rates are highest amongst boy's football and girls' soccer. She provides the specifics of these incident rates by using the concept of Athlete Exposures (AE), means that an athlete participates in an activity where there is the potential (exposure) for an injury.

The High School RIO, an internet-based sports injury surveillance system developed at the Colorado School of Public Health, provides food for thought for the discussion on youth sport concussion incidence. In collaboration with the Columbus Children's Hospital, Comstock and colleagues (Comstock et al., 2006) performed a surveillance of injuries sustained by U.S. athletes of 100 independent high schools across the country during the 2005-2006 academic school year. Their incidence rate findings are comparable and corroborate LaBella's (2014) findings of Athlete Exposures. However, Comstock, Yard, Knox, and Mauring (2006) go a step further and breaks down the incidence rates amongst the level of play (practice or competition)

when describing the incidence results. This added information helps to delineate whether level of play has any impact on measured results and provides a greater understanding of where the greatest risk for injury occurs. As shown in Table 1, Comstock and colleagues' (2006) findings support the fact that although practice has a greater number of AEs, the injury rate is higher during competitive play.

Table 1. *Rate of Injury by Sport*

Sport	**# Injuries**	**# Exposures**	**Injury Rate (per 1,000 Athlete Exposures [AE])**
Overall total	4,350	1,730,764	2.5
Competition	2,240	484,265	4.6
Practice	2,110	1,246,499	1.7
Boys' football total	1,880	431,242	4.4
Competition	992	82,059	12.1
Practice	888	349,183	2.5
Boys' soccer total	372	153,400	2.4
Competition	208	49,294	4.2
Practice	164	104,106	1.6
Girls' soccer total	334	141,581	2.4
Competition	226	43,415	5.2
Practice	108	98,166	1.1

Source: Comstock et al., 2006

Concussion Causes

While the CDC's definition of a concussion focuses primarily on the physical trauma of a head injury, LaBella's (2014) definition focuses on the results of the functions that become

impaired and brain processes that are impacted by the trauma. A concussion develops when there is a blunt force trauma (physical) to the head which has a direct impact and subsequent impairment on brain functionality, whether for the short term or long term. Many types of events or actions can cause a concussion. Comper (2005) identified several causes of MTBI and the main causes were related to motor vehicle accidents and intentional or unintentional falls to the ground. He also identifies *sports and recreational injuries* as another cause in his review. In any case, not all blunt force traumas actually produce impairment to the brain, which is an important aspect or requirement for a concussion to have occurred.

Focusing now on the causes of concussions in sports, Gessel and colleagues (2007) generalizes that contact sports is more likely than non-contact sports to produce concussions amongst high school players. The authors then refine their generalization by specifying full-contact sports (wrestling and football) and partial-contact sports (soccer and basketball) as having the highest concussion incidence rates.

The youth soccer activities most associated with causing a concussion are described in Table 2 and are taken from a study by Gessel and colleagues (2007) from the High School Sports –Related Injury Surveillance Study: U.S., 2005-2006 School Year. The data show that the activity that leads to the highest rate of concussion, amongst both genders, was ‘heading the ball’. However, it should be noted that while the proportion appears to be the same, there is a large difference in the actual number of concussion injuries; women had a larger number of sustained concussion injuries (Gessel et al., 2007). Data reported by Faude, Rößler, and Junge (2013) and the American Academy of Pediatrics (AAP) corroborate Gessel’s findings. Faude and colleagues (2013) groups the individual activities into a generalization that 40 to 60% of all concussion injuries are due to contact with another player’s head, elbow, or foot. The AAP

reported that 47% of college athlete concussion injuries are a result of the same type of contact. (American Academy of Pediatrics [AAP], 2010)

Table 2. *Youth Soccer Activities Leading to a Concussion* (Gessel et al., 2007)

Male		**Female**	
Activity	Rate	Activity	Rate
Heading ball	40.5%	Heading ball	36.7%
Defending	20.5%	Defending	15.1%
General Play/Other	10.6%	Chasing Loose Ball	11.7%
Receiving Pass	10.5%	General Play/Other	8.5%

Interestingly enough, what Faude and colleagues (2013) and the AAP both described is unintentional contact of the head with another object, such as the head contact was made with another player due to accidental reasons, such as falling to the ground or when two players' heads bump into each other when trying to make a heading play on the soccer ball, etc. However, Gray, Bain, and Willis (2009) scrutinizes the 'accidental' aspect of the injuries to only injuries when the head and neck are not stabilized, i.e. braced for impact. Faude and colleagues (2013) further their point about causes of this type of injury and the environment that are conducive for by suggesting that greater attention needs to be paid to differentiating the timeframe for when concussions occur; in this case, did it occur during match play, scrimmage, or practice. Reviewing this research suggests that there is a higher rate of injuries occurring during actual game play versus practice, or scrimmage, play. Gessel and colleagues' (2007) findings confirm Faude and colleagues' (2013) research regarding concussion incident rates amongst AEs in his study.

Effects/Impacts

Short-term effects.

In the short term, the identified symptoms of the concussion represent the acute effects. Specific acute effects affecting youth athletes include impaired verbal skills, decreased cognitive adaptability, and reduced mental aptitude/learning (Johnson, 2012). Ahmann (2013) reports that repeat concussions will become more severe in athletes and have a longer recovery period. Although rare, the most severe short-term effect of a concussion is death (American Association of Neurological Surgeons [AANS], 2014).

Death is a possible short-term effect from a concussion through a condition known as Second Impact Syndrome (SIS). Johnson describes this condition as "a rare neurological condition involving catastrophic diffuse cerebral swelling and brain herniation." (Johnson, 2012, p. 181). He goes on to suggest that mortality as a result of this condition is almost certain to occur within a matter of minutes of the event. However, Amberg (2012) brings that certainty of mortality down to 50% but notes that survivors will almost certainly become disabled.

Long-term disability.

One long-term health impact stemming from multiple concussion events is a condition known as Chronic Traumatic Encephalopathy (CTE). CTE has been identified as a precursor for the onset of several psychological conditions such as "early dementia, depression, suicide, disinhibition and erratic behavior, and motor neuron disease" (Johnson, 2012, p. 181). LaBella's (2014) findings corroborate Johnson's findings on the identification of dementia and depression as long-term effects of concussions.

Recent research indicates that CTE doesn't begin at the professional sport level: it is an accumulative degenerative process, starting early in life. Johnson (2012) cites an example of an

incipient CTE autopsy in an 18-year-old football player with a history of concussions. He concluded that "studies of football athletes in their 20s with no history of concussion also reveal evidence of the deposition of Tau proteins indicative of CTE, suggesting that playing youth and school football has a role in CTE" (Johnson, 2012, p. 181). However, Ahmann (2013) highlights the emergent state of CTE research by stating "whether repetitive head impacts and multiple concussions sustained in youth lead to long term neurodegenerative disease, such as chronic traumatic encephalopathy (CTE), remains unclear" (Ahmann, 2013, p. 312).

Awareness/Symptoms

Considering the possible life-altering ramifications of an unidentified/unreported concussion in youth athletes, concussion symptoms identification and awareness need to become the staples of any educational /intervention program. It is the responsibility of all vested parties, including athletes, parents, coaches, referees, and any trained medical staff to be aware of concussion symptoms and immediate intervention is provided to youth athletes, if a possible concussion is suspected. It is also public health professionals' responsibility to ensure that concussion awareness and education is provided to the community and sports organizations. Gourley et al. (2010) highlights the importance of concussion symptoms identification awareness and education by all vested parties by pointing out that many sports organizations don't employ on-site medical staff or sports trainers.

Bringing awareness to this topic through educational programs, use of hand-out materials, smartphone applications, and required training programs of all vested parties will help to avoid a lack of awareness on the subject and will allow multiple entities to be able to assist in the identification of a concussion. This will help combat a statistic that Covassin et al. (2012) identified: when only 61% of coaches were able to correctly identify the signs and symptoms of

a concussion and even acknowledged that there were some misunderstandings about several of the symptoms. Rivara et al. (2014) found that the majority of high school athletes, despite awareness on concussions, continued to practice or play while symptomatic for concussion, and 40% did not inform coaches about their symptoms. However through educational programs on concussion symptom identification and awareness, typical responses by the athletes tend to be more proactive. This was corroborated by Doherty-Restrepo, Lascano, and Ahouse's (2012) finding that 72% of high school players who underwent concussion education agreed that they would proactively inform coaching staff about concussion, whereas only 36% of players without education said they would proactively report their injury.

Methods

The objective of this paper was to provide parents, coaches, and referees with the most relevant, factual based smartphone applications for recognizing the signs and symptoms of concussions in youth athletes. Considering that objective, the existing literature reviewed and referenced above includes several prominent public/private health care organizations including, but not limited to, the CDC and the AAP.

Based on the author's understanding that the CDC and the AAP both review and publish fact-based evidence to support their healthcare recommendations, their selection for and subsequent review of their published literature on youth concussions was the main criterion used in their selection for this analysis. In addition, the author's role as a youth soccer coach has provided familiarity with the CDC's HEADS UP Concussion in Youth Sports initiative, as their online concussion training is a key requirement for youth coaching and their handouts on the subject are distributed to parents for review before their acceptance into the youth soccer program. The search for fact-based evidence on youth concussions focused on reviewing these

two entity's published literature on the subject and considered the needs of our target audience. The needs of our target audience (i.e. parents, coaches, and referees) include fact-based evidence that is both easy to read, easy to use, and is comprehensive in symptom identification.

In order to accomplish this focused review of each healthcare organization's published literature on the subject, a search of their website using their own web search tool was performed using the keywords "concussion in youth sports". The results from this web search are detailed below.

Centers for Disease Control and Prevention (CDC)

The search yielded many links to resources within the CDC's website. The first link redirected to their "HEADS UP to Youth Sports" page (Centers for Disease Control & Prevention, 2015b). In this page, there were resource links for each of the vested entities in this discussion, including parents, coaches, officials, and even the athletes themselves. Upon clicking on each one of the provided entity resource links, the website was redirected to a new webpage with several customized educational materials written specifically for each of our target audiences (parents, coaches, players) in a variety of formats.

American Academy of Pediatrics (AAP)

The search yielded three links to resources within their website. The first link redirected to a pdf document called *Concussion Management: Return to Play* (AAP, 2015a). The second link redirected to the AAP's educational website healthychildren.org with information on sports-related concussion (AAP, 2015b) and the third link redirected to a pdf document titled *Protecting School-Age Athletes from Sport-Related Concussion Injury* (AAP, 2010).

The first link was a resource covering a variety of concussion topics including facts, state law progress, and three more topic resource webpage links. The first of these resource links

redirected to the AAP Clinical Report – Sports-Related Concussion in Children and Adolescents (Halstead & Walter, 2010). The second of these resource links redirected to the AAP Clinical Report – Returning to Learning Following a Concussion (Halstead et al., 2013). The third of these resource links was a dead link (e.g. went nowhere.) These two working resources listed signs and symptoms of concussions, appropriate for youth in table format. The second link to the partner website provided good information about the signs and symptoms of concussion in a table format, but split the table into two columns, with each column is devoted to an entity (parents/guardians or athlete). The third link was a limited value resource document, because there is limited information on the discussion point of signs and symptoms.

CDC vs. AAP (Selection)

Upon thorough review of both of the entities' websites, materials, and resource links, while aligning with the purpose of this report, there was a vast difference in approach, design, and language in which the materials were written and developed. Both entities took their own approach toward discussing and identifying the subject with no overlap and/or partnership on the subject. Both provided rather recently dated resources, with the exception of the hardcopy material that the AAP provided. AAP's handouts more dated when compared against the CDC's handouts. AAP provided documents written in a format and level of language suited for an adult with a high level of health literacy and with a clinical background. Their partner website (healthychildren.org) is written in a language that is accessible to the target audience and that provides and met the objectives of two of the four vested parties, i.e. parents and athletes. In stark contrast, the CDC provided materials and resources that met all of the criteria of this target audience and is well written and easy to follow and understand, at a lower level of intelligence

when compared to the AAP. Both provided very valuable and resourceful signs and symptoms information that are very comparable to each other with limited differences in findings.

Based on this analysis, the preferred entity to evaluate the youth sports organizations against was the CDC.

Smartphone Application Search and Evaluation

In order to determine and review all of the potential smartphone applications available, the author conducted a keyword search using the Apple 'App Store' application found on all Apple smartphones, e.g. Apple IPhone (https://support.apple.com/en-us/HT204266). The App Store provides a search feature on keywords to deliver all associated smartphone applications based off that keyword search. For this application review, the keyword "concussion" was used since the keywords "concussion in youth sports" would yield too few results for comparison; in addition, using the broader "concussion" keyword would also eliminate any applications that are returned only as a result of the keyword "youth".

There were seven criteria developed and utilized to evaluate the identified application (Table 3). Each of the seven criteria has a distinct role to help eliminate applications that either don't meet our target audience's needs or could provide an unsafe, unsecure, or broken application on their smartphone. In addition, these seven criteria were designed to ensure that the application provides the necessary minimum requirements of having defined concussion signs and symptoms, but will also provide the added capability of concussion intervention via a concussion assessment tool. Expanding on the description of the seven criteria in Table 3, below is a more defined summary of each criteria. If the application failed to meet minimally essential functions or had privacy concerns, the application was removed from further consideration and review.

Table 3. *Criteria Used to Evaluate Sideline Concussion Applications*

Criterion #	Criteria
Criterion #1	Paid
Criterion #2	Function (Gaming, Digital Warning System, Recovery Tool, Company Customer Service, Company Communication Tool, Concussion Monitoring System)
Criterion #3	Operational Status (Application Error, Application Locks Up)
Criterion #4	Accessibility (Must have a separate/online account, Not for public use, App cannot be configured w/o online account and website is down, must have a company ID, must have an activation code)
Criterion #5	Self-Assessment Included
Criterion #6	Application Permissions/Privacy Concerns, Location Tracking (Possible information to be sent to PAR. Advertising/banners. Sets Location to 'Always' by default for no reason)
Criterion #7	Application Function Missing (Missing concussion education/info for parents)

Note: If criterion was met, the application was removed from further consideration.

Criterion #1 eliminates the need to purchase the application through the App Store. Criterion #2 ensures that the application provides the minimally essential function of concussion signs and symptom identification as its primary function rather than it being developed more as a game or a warning system as an example. Criterion #3 ensures that the application actually works as intended by loading and executing on the smartphone without any application or system errors. Criterion #4 identifies that the application acts as a standalone app, e.g. which doesn't require any external setup or configuration or registration in order to use the app. Criterion #5 aligns with the target audience's benefit of an application that can provide concussion intervention for the athlete. Criterion #6 ensures that application permissions and privacy

concerns are addressed and that the end user has the authority to configure and/or setup the application to operate and execute as how they would like it according to their preferences. Criterion #7 required that the primary function of concussion education be provided to the target audience.

Results

Concussion Applications Found

The ‘concussion’ keyword search conducted on November 12, 2015 yielded forty-seven (47) smartphone applications for possible review and evaluation. This result list of 47 possible applications was screened against the established criteria (described in Table 3) that ensures that the application meets certain technical and functional standards, including but not limited to accessibility, operability, and security.

Concussion Applications That Did Not Meet Criteria

The forty-seven (47) applications found in the initial search are listed in Table 4, along with their reasons for being removed from further evaluation. For example, the CDC HEADS UP Concussion and Helmet Safety application was removed for further evaluation in this systematic review due to the fact that it didn’t include a self-assessment function. The applications highlighted in green represent the applications that were accepted for further evaluation. By using these seven criteria, the initial result list of 47 applications was paired down to eight applications.

Table 4. *Reasons for Concussion Applications Removed from Further Evaluation*

	Application Screen Out Criterion						
Application (version)	Paid	Function[1]	Operational Status[2]	Accessibilty[3]	Self-Assessment Included	Privacy Concern(s)[4]	Missing education info[5]
Concussion Smart (v 1.2)							
Play It Safe Concussion Assessment (v1.3)	**X**						
Concussion Recognition & Response: Coach & Parent Version (v 1.2.2)						**X**	
CDC HEADS UP Concussion and Helmet Safety (v 1.0)					**X**		
MedZam Concussion Assessment Exam Test Tool (v 2.1)			**X**				
Concussion Coach (v 1.0.1)							
Concussion Quick Check (v2.2)					**X**		
Concussion Assessment & Response: Sport Version (v 1.1)	**X**						
Sway - Balance/Reaction Time/Concussion Management (v 2.1.1)				**X**			
Return2Play for Concussion (v1.5)	**X**						
USA Football (v 3.1)					**X**		
SCAT2 (v 1.0)	**X**						
Coach Safely by Inova (v 1.1)							
Concussion Boxing (v 1.08)		**X**					
Concussion Management (v 1.0)							
Sideline ImPACT (v 1.0)	**X**						
Mobile ImPACT Customer Center (v 1.5.3)	**X**						
Concussion Education Tool (v 1.1)							
Braincheck Concussion (v 1.1)				**X**			
Memorial Hermann IRONMAN Sports Medicine Institute (v 1.3)					**X**		
World Rugby Concussion Management (v 1.4.1)							
Spot Light Concussion Tracking System (v 1.0.2)				**X**			
XLNTBrain Mobile (v 1.8.3)				**X**			

Table 4. *Reasons for Concussion Applications Removed from Further Evaluation* (Cont'd)

	Application Screen Out Criterion						
Application (version)	Paid	Function[1]	Operational Status[2]	Accessibilty[3]	Self-Assessment Included	Privacy Concern(s)[4]	Missing education info[5]
Concussion Awareness (v 1.0.0)							
ICEdot (v1.2)		X					
BrainKit: TaskPlanner		X					
Concussion2 (v2.0)			X				
ImPACT Passport (v1.1)				X			
Canada MICC (Mobile imPACT Customer Center)(v1.5.3)		X					
Triax SIM-P (v1.5)					X		
Traumatic Brain Injury (TBI)(v1.10)	X						
Shockbox (v1.2.143)							X
Neurology Advisor (v1.3.1.108)					X		
Brain Injury Strong Mind Puzzles (v1.2)	X						
Jolt Sensor (v1.19)				X			
HEADWays (v1.0)							
BIAMD (v1.50.68.122)		X					
James E Gilbert MD (v1.0)		X					
Bird Shredder - Sail through the gap to avoid disaster (v1.0)		X					
SKYi Remote (v1.0)		X					
Headache Relief Hypnosis - Naturally Soothe & Relieve Headache Pain (v2.0)	X						
InVici-BULL Shockbox (v1.0.145)	X						
Play On (v1.2)				X			
Health Matters - Quiz and Trivia: Full Answer (v1.0)	X						

Notes: 1. Gaming, Digital Warning System, Recovery Tool, Company Customer Service, Company Communication Tool, Concussion Monitoring System). 2. (Application Error, Application Locks Up). 3. Must have a separate/online account, not for public use, App cannot be configured w/o online account and website is down, must have a company ID, must have an activation code. 4. Application Permissions/Privacy Concerns, Location Tracking (Possible information to be sent to PAR. Advertising/banners. Sets Location to 'Always' by default for no reason. 5. Application Function Missing (Missing concussion education/info for parents).

CONCUSSION RECOGNITION IN YOUTH SOCCER 24

Review of Applications Meeting All Criteria

A comprehensive review of the eight (8) applications that were selected for further evaluation was completed and is presented below. Each application was detailed considering a variety of characteristics such as navigation, readability, ease of use, and to differentiate these applications from each other, as well as ensure that all vested parties can utilize these applications. A synopsis of each of the application's strengths and weaknesses was also provided to help identify the key characteristics of each of the applications.

Concussion Smart (v 1.2).

This simple-to-use app provides a very user-friendly swipe to access interface that allows for quick forward and backward navigation. In addition, the color-coded features make it easy to identify the current function. The language is easy to read and understand. The provided features give a complete tool to perform a review of concussion related information, perform an actual concussion assessment/examination, and understand the importance of Return to Play guidelines. It is designed for use by parents, coaches, and players alike without requiring strong health literacy. The concussion assessment/examination function provides three different levels of assessment, both from a clinical background and both as a parent. Finally, this tool correctly listed 22 signs and symptoms of concussion; 18 of these (81%) also appear on the CDC's signs and symptoms checklist.

Strengths: Easy to use, simple interface, wealth of information, quick assessment, and forward/backward navigation.

Weaknesses: None

Concussion Coach (v 1.0.1).

This is a simple-to-use app that is designed to be used by the player for assessing/triaging a concussion, all the way through managing and tracking concussion history. However, others, such as parents or coaches, can use this also as a diagnostic tool for sideline reporting due to the information provided and types of tests that can be performed. Because it is a complete diagnostic tool, users can track concussion history and self-report this information to a health care provider. In addition, the tool is really well designed to provide concussion management and support. Considering this tool is designed for not just concussions, but also PTSD, this tool is really well created. The language is easy to read and understand. This tool is designed without requiring a health literacy background. Finally, this tool correctly listed 16 signs and symptoms of concussion; 14 of these (88%) also appear on the CDC's signs and symptoms checklist.

Strengths: Complete Diagnostic Tool, pictures, Access to Resources & Support, Well Organized.

Weaknesses: No Backwards Navigation, Enables Cellular Data to be used by default.

Coach Safely by Inova (v 1.1).

This is a simple-to-use app that is designed to be used by a parent for assessing a concussion by reviewing signs and symptoms both observed and reported. The assessment tool provides the parent with easy to ask questions and helpful commands. The other features make it easy to find and locate a doctor. The language is easy to read and understand. This tool is designed without requiring a health literacy background. Finally, this tool correctly listed 20 signs and symptoms of concussion; 20 of these (100%) also appear on the CDC's signs and symptoms checklist.

Strengths: Simple to Use interface, self-assessment feature which includes both questions and actions, and provides a feature to find nearest emergency room or hospital.

Weaknesses: Limited features, allows location (tracking) services to be enabled, and designed to locate only Inova health care providers.

Concussion Management (v 1.0).

This is an entertaining app that has both simplicity in design and functional features that make it a complete app for parents, coaches, and players. I view this app as both a resource, as well as an educational tool. Included in this app is access to content rich literature, videos, and even learning quizzes. Learning and education was clearly the main driver in the design of this app. Also, the non-concussion tools which include, but not limited to note taking, sending email, voice recording, and photo taking/sharing features, really enhance the usefulness of this app, even beyond the scope of the app. The language is easy to read and understand. This tool is designed without requiring a health literacy background. Finally, this tool correctly listed 24 signs and symptoms of concussion; 20 of these (83%) also appear on the CDC's signs and symptoms checklist.

Strengths: Easy to use, plethora of apps, integrated use of varying formats of information, entertaining, and easy to navigate.

Weaknesses: Automatically enables some security/privacy concerns.

Concussion Education Tool (v 1.1).

This is a very simple app with features limited to only self-assessments. However, the audience of the app includes both parents, coaches, and physician trainers, and the functions provided to each audience are unique and different, which makes this a flexible app. Focusing on the parent functions, the information is not exactly easy to read, due to size/font choices, but is

easy to understand. In addition, there is no background to it and the color choice makes it hard to be interested in using. It gives minimum information, but does provide a self-assessment tool. Finally, this tool correctly listed 25 signs and symptoms of concussion; 21 of these (84%) also appear on the CDC's signs and symptoms checklist.

Strengths: Designed for multiple audiences, and simple to use.

Weaknesses: Limited features, poor background/color choices, and not easy to read text.

World Rugby Concussion Management (v 1.4.1).

This is a really well-designed app with many useful features that encompass all aspects of concussion management from self-assessment to return to play. This app is designed for all parties to include parents, coaches, and referees. The app interface is colorful and well-organized. The app provides a variety of functional tools that include videos and a pocket guide. The information is well written and the language is easy to read and understand. This tool does not require strong health literacy. Finally, this tool correctly listed 17 signs and symptoms of concussion; 17 of these (100%) also appear on the CDC's signs and symptoms checklist.

Strengths: Easy to use, wealth of information, developed for multiple audiences, and exactly matches CDC's concussion signs and symptoms list.

Weaknesses: Short list of more signs and symptoms.

Concussion Awareness (v 1.0.0).

This is a feature-rich app that allows the user to switch from adult-mode to a child mode, which changes the content and appearance of the displayed information. It adapts the material to the user's literacy level. The adult-mode is parent-friendly with information about concussion signs and symptoms. This app integrates different formats of information, including text and video, to deliver its message. The app is geared toward hockey, which affects the presented

information and associated recommendations. The information is both easy to read and easy to understand. This app doesn't require a health literacy background. Finally, this tool correctly listed 18 signs and symptoms of concussion; 14 of these (78%) also appear on the CDC's signs and symptoms checklist.

Strengths: Simple to use, use of literacy modes (parent versus adult), integrated use of multiple formats (text, video, stories), eye-catching background, and wealth of information.

Weaknesses: Use of a lot of hockey-based information.

HeadWays.

This is a simple app in both design and content. It provides the information in a format for use by the player, rather than the parent. However, parents can use the tool by simply realizing that the questions are framed for the youth player. The tool has a lot of good information and is a useful educational tool. The information is both easy to read and easy to understand. This app does not require a health literacy background. Finally, this tool correctly listed 8 signs and symptoms of concussion; 8 of these (100%) also appear on the CDC's signs and symptoms checklist.

Strengths: Simple to use, easy backward and forward navigation, and good educational tool.

Weaknesses: Weak/low on listing of concussion signs and symptoms, and limited features.

Concussion Application Recommendation

Based on the detailed application reviews above, and considering the intent and purpose of this concussion application review, it became apparent that four (4) of these applications really 'stood out' when viewed against each of the eight (8) applications that were selected for

detailed analysis. These four applications are: Concussion Smart (v 1.2), Concussion Coach (v 1.0.1), Concussion Management (v 1.0), and Concussion Awareness (v 1.0.0).The analysis factors that led to the recommendation of these four (4) apps included simple design, multi-functional, easy-to-use interface, multi-formats (text, video, web, articles, etc.) and strong evidenced-based content.

Discussion

Sustaining a single concussion is a serious medical concern and should be treated as such. Proper response to a suspected concussion includes immediate removal from the field of play, evaluation by trained or certified medical staff, and mental rest. If this proper response is provided to the player, a concussion can easily be recovered from within a span of a few weeks. However, this single event can become even more serious, even deadly, if the player goes back onto the field too soon or never comes off the field of play and sustains a secondary concussion (SIS).

Public health professionals need to be cognizant and become advocates for youth sports concussion awareness and treatment, because the long term effects of increased concussion awareness and treatment will have broad financial and resource impacts on the broader community and health care system (CDC, 2010).

The results of this review may be of particular interest for sports organization that are not associated with school systems: they have relatively lesser oversight, fewer regulations and less-developed policy compared with school-sponsored sports. Community sports organizations have less regulation and have less guidance in how they manage their programs and potential concussion incidents. Giannotti, Al-Sahab, McFaull, and Tamim's (2010) Canadian study

showed that unorganized soccer play has a higher rate of concussion injury than organized soccer play, which led to greater hospital admission rates.

By having one of the four identified recommended concussion applications, parents, coaches, or referees will have access to an evidence-based smartphone application that they can trust and reference with confidence to make informed decisions. This confidence stems from the fact that the application's content has been compared to an established, evidenced-based standard, thereby allowing the target audience to reference clinical fact-based information. In addition, the application has been technically screened, through the use of seven criteria to conform to standards of simplistic design, multi-functionality, and ease of use-characteristics, amongst others; thereby allowing the target audience to read and easily understand the content of the application and as well as have confidence that the application is safe for their smartphone.

While concussion fact-based evidence is readily available in many formats such as paper handouts, pamphlets, flyers, instructional audio or video, and websites, having one of these four applications readily available on a smartphone allows immediate access to the content necessary to help identify, assess, and triage a player for a sports-related concussion. Smartphone applications are portable and require no advance planning beyond installation. Applications can easily be retrieved and accessed in very simple steps; whereas gaining access to other content formats such as audio or video or even pamphlets, will require pre-planning and checks for functionality (e.g. Android smartphones don't play some internet video). Also, because applications can be easily added or removed from a smartphone, it is a quick action to get an app installed. Applications can easily be installed on multiple people's smartphones and this makes it easy for multiple people (e.g., coaches, parents, referees) to have access to the same information

at any point in time. This flexibility overcomes many obstacles/barriers to information dissemination using traditional methods such as distribution of handouts and pamphlets.

From the viewpoint of a public health professional, smartphone applications are an educational and awareness tool that provides a new platform for disseminating public health data and information on concussions. In contrast to the traditional methods of information dissemination of brochures or pamphlets, etc., this platform is dynamic and flexible and can be uniquely adapted to meet the needs of the target audience. In fact, the CDC has its own no-cost smartphone application available for personal use. It has many features that distinguish it from private and/or other public applications, including specific audience content for players, parents, coaches, and referees. However, during this systematic review, it was noted that their application did not include the essential function of allowing players to perform a self-assessment, so it was removed from further evaluation.

The four smartphone applications are readily available and free for iPhone users to download and are designed to perform the essential functions of concussion symptom identification, self-assessment, and triaging. By choosing one of them, youth sport parents, coaches, and referees will be able to intervene on behalf of the players. This is particularly useful for practice session: there is a limited likelihood that trained medical personnel will be in attendance at sports practice or scrimmage, where there are more exposures to concussion events. At sporting games or events, there is a stronger likelihood of concussion due to the level of play of the competition and actions of the players involved which are different than at a sports practice or scrimmage. The cause of most sustained concussions in soccer, regardless of gender, is “heading the ball”, an advanced skill that is not taught during recreational youth training that is allowed only during competitive play.

Concussions do not develop from every exposure to competitive actions. The recommended smartphone applications will allow vested parties to help identify when the observed signs and symptoms translate into a genuine medical concern. The recommended applications facilitate informed decisions and are less dependent upon other vested parties' intervention, including the player themselves. This objectivity takes the decision-making out of the hands of the players that may want to avoid being removed from competitive play despite displaying the signs and symptoms of a concussion.

Strengths

One of this manuscript's strengths is the author's role as both a parent and coach for a youth sport organization. Considering this paper's target audience includes both of those roles, the author was able to consider the two entities' perspectives when evaluating the applications. Another important point about the author is his combined educational background in Information Technology (IT) and public health. This diverse educational background and his years of job experience in IT allow the author a unique perspective on how IT can shape public health discussions. One of the author's personal goals with having this diverse background is how to best utilize it for the benefit of public health.

Limitations

The author's research had several limitations. The decision to only evaluate only the CDC's and the AAP's offerings for the concussion signs and symptoms comparison standard limited the pool of viable research organizations which could provide this type of information. This decision was based on the author's familiarity with how, what, and when they maintain and publish their articles and statistics. Other public or private organizations, such as the American

Medical Association, World Health Organization, Ohio Department of Health, or the Institute of Medicine could have standards that could have been considered for selection.

In fact, another limitation in this paper was the decision to scope the target audience of this paper to youth sports. This decision would impact the type, quantity, and detail of concussion research materials, resources, and statistics. In comparison to concussion research on young adults and older sports, youth sports concussion research is not as refined and the quantity is ‘smaller’ in terms of size or depth. Considering that public awareness on concussions is relatively new, and initial focus was on the adverse health effects of sports professional, youth sports concussion research is still early in development.

Other noteworthy limitations of this research are embodied in the results of the application listing that were developed during this systematic application review. Those limitations include: 1) Selection amongst only Apple smartphone applications versus the use of Android ‘Play Store’ applications; 2) Use of the single word ‘concussion’ in the keyword search without MTBI and 3) use of seven criteria to limit and scope the results of the application findings.

Future Research

Future research ideas can easily be developed from some of the limitations described in this paper. Future research could use this paper’s methodology to evaluate the sideline assessment tools from other organizations.

The seven (7) criteria used in the methodology section of this paper were intended to reduce the number of initial application listing results to a manageable level. The most limiting criterion used in the initial application listing results was whether the application was a free or paid application for download. Future research could consider removing that as a criterion to

allow for more applications to be considered in the initial application listing. Another research suggestion on this criterion would be to develop another study that focuses only on all paid applications. This future research could then be compared to the findings of this research to see if there is any "added" value to paying for these applications.

Another future research consideration would be to evaluate the Android 'Play Store' to see if it contains any similar, different, or unique concussion applications when compared to the Apple 'App Store' using the same methodology. This would result in a list including applications supported on both smartphone device platforms.

Conclusion

By having access to and utilizing these smartphone applications, a vested party has access to signs and symptoms information instantaneously and thereby can intervene in a suspected concussion event. Upon removal from the field of play, these smartphone applications can help parents, coaches, referees, or even trained medical staff takes proper measures and perform on-site evaluations of players; thereby aiding in early intervention and limiting medical emergency resources to only when it becomes apparent that a concussion event has occurred. While the smartphone application cannot and should not be used as the sole decision maker, it does provide the proper framework and information necessary to make balanced decisions, between the health and well-being of the player and effective use of medical emergency resources, as well as personal time and financial resources.

As Ahmann (2013) noted, current statistics on the 160 % increase on the number of ED visits for suspected concussions show that medical emergency resources, such as ED visits, are the first aid response to concussion events to determine if a player has actually sustained a concussion. By using these smartphone applications as a sideline first aid tool, there is an

expectation that those ED visit percentages would adjust to a number that more accurately reflects the number of actual concussions requiring medical intervention. The expectation is that these smartphone applications will aid parents, coaches, and referees in making informed decisions: 1) whether the player shows signs and symptoms of a suspected concussion and thereby reduces the likelihood of using ED visits as a first aid/triage tool only, and 2) limiting 'knee jerk' reactions of overcautious entities seeking ED treatment when there is no clinical evidence to support that a player is suffering from the effects of a concussion.

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Appendix A. List of Competencies Met in CE

Tier 1 Core Public Health Competencies

Domain #1: Analytic/Assessment Skills
Applies ethical principles in accessing, collecting, analyzing, using, maintaining, and disseminating data and information
Uses information technology in accessing, collecting, analyzing, using, maintaining, and disseminating data and information
Selects valid and reliable data
Identifies gaps in data
Collects valid and reliable quantitative and qualitative data
Describes public health applications of quantitative and qualitative data
Uses quantitative and qualitative data
Describes assets and resources that can be used for improving the health of a community (e.g., Boys & Girls Clubs, public libraries, hospitals, faith-based organizations, academic institutions, federal grants, fellowship programs)
Describes how evidence (e.g., data, findings reported in peer-reviewed literature) is used in decision making
Domain #2: Policy Development/Program Planning Skills
Identifies current trends (e.g., health, fiscal, social, political, environmental) affecting the health of a community
Gathers information that can inform options for policies, programs, and services (e.g., secondhand smoking policies, data use policies, HR policies, immunization programs, food safety programs
Describes implications of policies, programs, and services
Domain #3: Communication Skills
Identifies the literacy of populations served (e.g., ability to obtain, interpret, and use health and other information; social media literacy)
Communicates in writing and orally with linguistic and cultural proficiency (e.g., using age-appropriate materials, incorporating images)
Suggests approaches for disseminating public health data and information (e.g., social media, newspapers, newsletters, journals, town hall meetings, libraries, neighborhood gatherings)
Domain #4: Cultural Competency Skills
Addresses the diversity of individuals and populations when implementing policies, programs, and services that affect the health of a community
Domain #5: Community Dimensions of Practice Skills
Recognizes relationships that are affecting health in a community (e.g., relationships among health departments, hospitals, community health centers, primary care providers, schools, community-based organizations, and other types of organizations)
Provides input for developing, implementing, evaluating, and improving policies, programs, and services
Uses assets and resources (e.g., Boys & Girls Clubs, public libraries, hospitals, faith-based organizations, academic institutions, federal grants, fellowship programs) to improve health in a community
Informs the public about policies, programs, and resources that improve health in a community
Domain #6:Public Health Sciences Skills
Retrieves evidence (e.g., research findings, case reports, community surveys) from print and electronic sources (e.g., PubMed, Journal of Public Health Management and Practice, Morbidity and Mortality Weekly Report, The World Health Report) to support decision making
Describes evidence used in developing, implementing, evaluating, and improving policies, programs, and services
Domain #7: Financial Planning and Management Skills
Describes government agencies with authority to impact the health of a community
Domain #8: Leadership and Systems Thinking Skills
Incorporates ethical standards of practice (e.g., Public Health Code of Ethics) into all interactions with individuals, organizations, and communities
Describes the ways public health, health care, and other organizations can work together or individually to impact the health of a community
Contributes to development of a vision for a healthy community (e.g., emphasis on prevention, health equity for all, excellence and innovation)

Concentration Specific Competencies

Public Health Management
Know effective communication strategies used by health service organizations
Be capable of applying decision-making processes
Have an understanding of effective mentoring methods
Be able to determine how public health challenges can be addressed by applying strategic principles and management-based solutions
Detailed knowledge of public health laws and regulations