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What Definition Is Used to Describe Second Impact Syndrome in Sports? A Systematic and Critical Review

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Abstract

Concern about what has been termed, "second impact syndrome" (SIS) is a major factor determining return-to-play decisions after concussion. However, definitions of SIS vary. We used Scopus to conduct a systematic review and categorize the definitions used to describe SIS. Of the 91 sources identified, 79 (87%) clearly specified that SIS involved either cerebral edema or death after a concussion when a prior concussion had not resolved. Twelve articles (13%) could be interpreted as merely the events of two consecutive concussions. Among the articles that listed mortality rates, nearly all (33/35, 94%) said the rate of death was "high" (*e.g.*, 50% to 100%). Our review found that most articles define SIS as a syndrome requiring catastrophic brain injury after consecutive concussive episodes. Given that it is unclear how common it is to have a second concussion while not fully recovered from a first concussion, the actual mortality rate of SIS is unknown.

> "Most controversies would soon be ended, if those engaged in them would first accurately define their terms, and then rigidly adhere to their definitions." Tryon Edwards, American theologian (1809–1894)(28)

Introduction

Concussions, generally described as a traumatically induced disturbance of brain function involving a complex pathophysiological process, are a major concern in a number of contact and collision sports and have assumed increasing prominence in sports medicine. Researchers from the CDC estimate that between 1.6 and 3.8 million sports related concussions occur in the United States each year (52). There is worry about both acute and chronic ramifications of concussions, especially if repetitive (37). Those involved in athlete care must decide when athletes may return to play after a concussion. Among the factors influencing this decision is the desire to avoid "second impact syndrome" (SIS), a poorly defined term that is not universally accepted.

SIS is a controversial issue with some questioning its existence in sports-related injuries (63,65). The mechanisms are theoretical. The purpose of this article is not to rehash the debate on its existence nor the theoretical mechanisms. Rather, we are interested in reviewing the definitions that have appeared in the peer-reviewed literature when discussing the possible syndrome.

The impetus for this study came after one of the authors (S.D.S.), a parent of youth soccer players, attended a concussion education program before the players received preseason baseline neurocognitive testing as part of a concussion management system. The parents were told that part of the reason for the neurocognitive testing was to prevent SIS. The instructor informed the parents that SIS was defined as a concussion suffered by an individual who has had a recent concussion that has not completely resolved. The instructor went on to say that the mortality rate associated with SIS was "about 50%." Similar references to SIS regularly occur in both the lay and medical literature, often used as a warning to avoid contact after a sports-related concussion (61).

Depending on the definition of SIS, the risk and ramifications may vary widely, affecting personal and public health decisions. How likely is it that an athlete who is still recovering from a previous concussion suffers a second

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concussion? The answer is unknown, but probably occurs with some regularity. Consider that concussion is a common sports-related injury (recently estimated at 13.2% of all sports injuries in 20 different high school sports) (58), often unreported (estimates are that as many of 50% of concussions are not reported) (62), and many (10% to 20%) last beyond a week (57). Thus, it is likely that many youth sport participants experience a concussion when a prior concussion has not resolved. Because concussions are common, and second concussions while still symptomatic likely occur with some regularity, it is incomprehensible that a concussion atop of an unresolved primary concussion results in death "50% of the time." The primary purpose of this study was to systematically review the literature that includes a definition of sports-related SIS with the goal of more clearly defining the concept. Secondarily, we reviewed the sources for the mortality rates cited by the studies.

Methods

To identify articles that defined SIS, our author team formulated the literature search parameters. Our biomedical librarian (J.K.) searched Scopus on December 29, 2014 (Scopus is an interface that allows searches of both Medline, 1946-December 29, 2014 and Embase, 1946-December 29, 2014), to identify all articles that mentioned, "second impact syndrome" or "recurrent traumatic brain injury" in the title or abstract, or were indexed as containing MeSH or Embase terms on the concept "second impact syndrome." No limits were applied to any searches and both keywords and indexing terms (when available) were used. The complete search strategy for Scopus was *TITLE-ABS-KEY("second impact syndrome") OR TITLE-ABS-KEY("recurrent traumatic brain injury")*. Three additional authors (J.W., R.S., M.H.) examined reference lists of included articles, articles citing included articles and review articles to identify additional articles and books, which were then screened for inclusion. Conference abstracts were not reviewed.

Articles and books were included if they used the term "second impact syndrome" and provided what seemed to be a definition or cited a definition from another source. To decide on what the articles used as a definition, articles were searched for the letters "defin" to capture the words "define," "defined" and "definition." If none of these terms were present, our reviewers made best estimates based upon other terminology, for example, "second impact syndrome is…". Only English-language sources were included. All reports of SIS were eligible regardless of patient age. Definitions in sources unrelated to sports or in journalistic/newspaper sources were excluded. All article screening and data extraction were performed individually by three authors and disagreements resolved by consensus or examination by a fourth author.

Definitions and mortality rates were extracted from each article and categorized to measure the prevalence of different definitions and reported mortality rates.

Results

The literature searches identified 144 articles with an additional eight articles and one textbook identified through examination of references or citing articles (Fig.). Ninety-one articles met inclusion criteria.

Definition of SIS

As seen in the Table, of the 91 sources, 80 (88%) clearly specified that SIS involved either cerebral edema or death after a second concussion when a prior concussion had not resolved. As an example, Schunk and Schutzman (82) wrote, "Second-impact syndrome refers to a very rare, but usually fatal diffuse cerebral edema as a consequence of a mild head injury. This term is applied typically when an athlete develops diffuse cerebral edema from a second head injury while still symptomatic from a first concussion." Of note, only a few studies noted that the concussions must occur within a certain time period, generally in the range of a few weeks" (26,33,85,97).

Twelve articles (13%) included a statement where the definition could be interpreted as merely two consecutive concussions, that is, a concussion in an individual who has had a prior concussion that has not completely resolved. In these articles, many had the following statement, "The second impact syndrome has been defined as occurring when an athlete who has sustained an initial head injury, most often a concussion, sustains a second injury before symptoms associated with the first have fully cleared" (64,91,92,95). These articles generally led back to a 1995 article by Cantu (20) which, interestingly, did not have the term "define" or any related term in the description. While these articles contain the above statement, they all subsequently describe the sequela of more serious brain injury (generally, cerebral edema). Of note, a 1992 article by Cantu (18) presented a definition that was less ambiguous as follows: "rapid brain swelling and herniation following a second head injury."

Mortality Rates

Mortality rates were mentioned in 35 of the 91 articles (38%). The vast majority were review articles repeating rates cited by case reports. Four manuscripts described these cases and discussed causes of death (20,40,69,95). Among the articles that listed mortality rates, nearly all (33/35, 94%) said the rate of death was either "high," "about 50%," "50% to 100%," or "100%."

Discussion

The main purpose of this study was to describe the definition of SIS by systematically reviewing the peer-reviewed literature. Secondarily, we reported the mortality rates listed within these articles. Most articles defined SIS as a syndrome requiring catastrophic brain injury (*e.g.*, cerebral edema) in a person who suffers a head trauma while still recovering from the effects of a recent concussion. There were a small number of articles that could be interpreted as merely involving a second concussion when a first concussion had not resolved.

How SIS Is Defined: Historical Origins and Controversy

Our review found an interesting sequence of interpretations that may provide insight into some of the discrepancy and confusion. The term, "second impact syndrome" can be traced back to 1984 when Saunders and Harbaugh wrote an article entitled, "The Second Impact in Catastrophic Contact-Sports Head Trauma" (81). The article described a case report of a football player who died 4 d after suffering a head injury. He had returned to play on the day of death, whereby he collapsed

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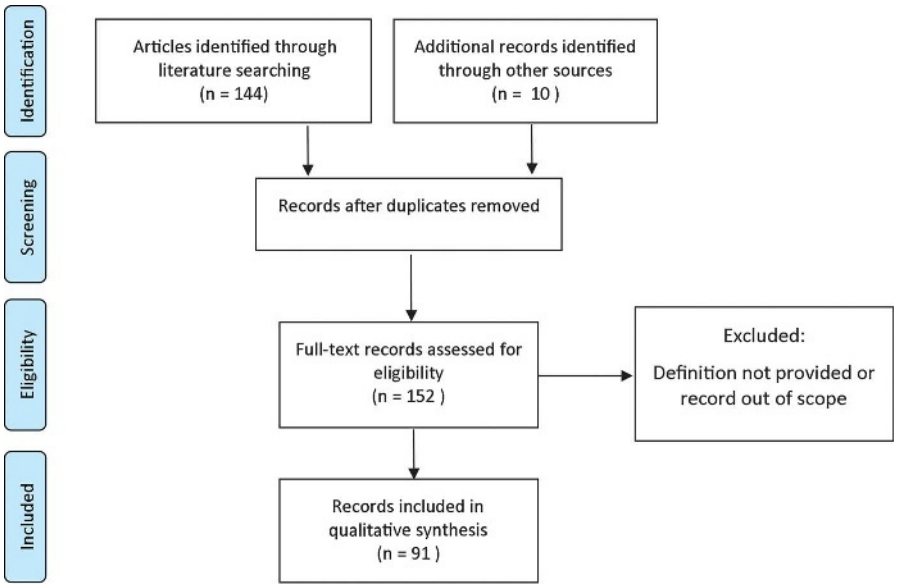


Figure: PRISMA flow diagram.

and died after a presumed second head injury. Although they never used the exact phrase, "second impact syndrome," Cantu in 1992 (18) and subsequently in several other articles (3,14,15,19) attributed to Saunders and Harbaugh the phrase, "the second impact syndrome of catastrophic head injury." Subsequently, others removed the phrase "of catastrophic head injury," and shortened the term to merely "second impact syndrome," occasionally without immediate mention that the second head injury causes a catastrophic outcome.

Why might someone interpret the definition of SIS to be merely the events of two concussions without the requirement of significant brain damage? While our review found this interpretation to be in the minority, a close read of these articles reveals how one could come to this conclusion. Consider the following statement taken from a 2005 review article, "The second impact syndrome has been defined as a sustained head injury after an initial head injury, usually a concussion, where symptoms associated with the first injury have not fully cleared" (92). The following sentence states, "It has been postulated that this second impact leads to rapid development of cerebral vascular congestion and increased intracranial pressure, resulting in brainstem herniation and death" (92). A literal interpretation of the first sentence without consideration of the next sentence might lead one to believe that it is merely the events of two consecutive concussions.

However, definitions often require context and interpretation beyond a single sentence. In addition, there may be some misunderstanding of the word, syndrome. In medicine, a "syndrome," defines an *outcome* when a number of signs and symptoms occur together (*e.g.*, "patellofemoral syndrome" or "shoulder impingement syndrome"). This is consistent with the definitions of SIS that involved catastrophic brain injury (*e.g.*, cerebral edema) with or without death after a second concussion.

While trying to settle on a definition of SIS, it is essential to understand that some question the existence of a unique syndrome of second impacts as any concussion can result in brain edema and death (63). In 1998, McCrory and Berkovic reviewed 17 published cases attributed to SIS. However, there was no evidence of a second impact in the majority of the cases (65).

Death Associated With SIS

What about the rate of death associated with SIS? The high death rates come from case reports of severe outcomes. For example, in 1995, Cantu (20) described six case reports of death (one from ice hockey and five from boxing) that

Table.
Categorization of articles defining "second impact syndrome."

A second concussion[a] (n = 12)	(20,35,101),(64)D,(63)D,(95)D,(65)D,(91)D,(92)D,(51)D,(72)D,(15)
A second concussion[a] with edema +/−death (n = 71)	(30,33,66), (78), (25), (7,19), (84), (93), (45), (26), (90), (87), (98), (89), (82), (75), (1), (83), (44), (99), (73), (11), (41), (86), (22), (85), (31), (34), (4), (40), (94), (55), (59), (17), (29), (12), (2), (32), (100), (10), (23), (16), (97), (47), (5), (36), (48), (71), (21), (77),(8)D, (49), (56), (27), (70), (46), (68,80), (96), (69), (42),(76)D, (43), (3,6,14,18,38,60,79)
A second concussion[a] resulting in death (n = 8)	(88),(50)D, (24), (67), (54), (74)D, (53), (13)

[a]The second concussion occurs when a first concussion has not resolved.

"D" signifies that the word "define" or "definition" was specifically used for SIS.

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apparently resulted from minor head trauma in athletes who may have had symptoms from a previous concussion. Thus, a death rate of 100%. In 2006, Mori reviewed published papers with reports of "severe sports related head injury" (69). There were eight cases with CT scans. All eight had cerebral edema and two died; a 25% death rate. Of interest, in Jordan's report of 316 cases of traumatic brain injury in boxers, there was one death (40).

If one were to follow the articles that define it as "death" after two consecutive concussions, then, by definition the rate of death would be 100%. Taking the most common definition with the outcome being cerebral edema with or without death, the death rate is unknown, and likely unknowable. To our knowledge, no one has ever tracked random cases of cerebral edema after single or consecutive concussions. When 2 impacts occur in very close succession (during the same game or within a few days), it is impossible to determine whether it was the initial injury that may have given rise to the catastrophic consequences.

The Importance of an Accurate Definition

This issue would not be important if it were not affecting decision making in the field of sports medicine. However, it is. The vignette that led to this review is likely not an isolated incident. A public advertisement from a major sports medicine unit has a headline that states, "A second hit could be the last." It then states, "Second impact syndrome, when someone incurs a second concussion while still recovering from the initial injury, may result in rapid brain swelling that's often fatal" (61). Advertisements like this instill fear in the public and concussion testing has assumed a high profile. If occult brain injury puts a child at risk for death should further injury occur, and if neurocognitive testing can detect occult brain injury, then it follows that demand for more frequent and advanced methods of testing will continue to grow.

There is further concern that repetitive concussions may lead to chronic traumatic encephalopathy (CTE) (66), an irreversible brain injury, although there are others who believe that the epidemiology does not clearly establish the concussions as the causative factor (39). There is evidence from both clinical studies and animal models that head injury in a concussed brain may prolong symptoms and neurocognitive recovery (9,37). As summarized by Harmon et al. (37), a concussion decreases cognitive ability and reaction time, theoretically increasing the risk of subsequent injury, including another concussion.

Strengths and Limitations

Our librarian-designed search allowed us to systematically locate scholarly articles on SIS. Like all searches, there is the potential for missing articles. Articles that did not have "second impact syndrome" in either the title, abstract or indexing terms may have not been located. We sought to include articles picked up by references of our search to minimize missed articles. Another limitation is the imprecision of definitions within the articles and difficulty determining which elements were stated and which were merely implied. In an effort to minimize bias, all retrieved articles were independently screened and had their definitions extracted by multiple reviewers.

Conclusion

Our systematic review on the definition of SIS found that the vast majority of articles define SIS as a syndrome requiring catastrophic brain injury (*e.g.*, cerebral edema) in a person who suffers a head trauma while still recovering from the effects of a recent concussion. The definition does not include diffuse cerebral edema resulting from a single significant impact. It is unlikely that we will ever know the true mortality rate from SIS because that would entail knowing an estimate of the number of concussed participants who developed cerebral edema and who had been playing with an unresolved previous concussion. There are many reasons that parents, coaches, and health care providers should seek to reduce the risk of sports-related concussions, and disallow a concussed athlete to return to play in a sport with a high risk of head injury. It is not necessary to instill unsubstantiated fear. We must align public health messages with the proper definition and, to the best of our ability, the actual rate of serious consequences.

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