



Review Article (Meta-analysis)

Service Delivery Models for the Management of Pediatric and Adolescent Concussion: A Systematic Review



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KEYWORDS

Brain concussion;
Delivery of health care;
Health care costs;
Post-concussion syndrome;
Rehabilitation

Abstract *Objective:* To examine the current peer-reviewed literature on pediatric concussion and mild traumatic brain injury (mTBI) service delivery models (SDMs) and relevant cost analyses.

Data Sources: PubMed, Embase (Elsevier), CINAHL Plus (EBSCO), APA PsycINFO (EBSCO), and Web of Science Core Collection, limited to human trials published in English from January 1, 2001, to January 10, 2022.

Study Selection: Included articles that (1) were peer-reviewed; (2) were evidence-based; (3) described service delivery and/or associated health care costs; and (4) focused on mTBI,

List of abbreviations: ED, emergency department; JBI, Joanna Briggs Institute; mTBI, mild traumatic brain injury; PCP, primary care provider; PPCS, persistent postconcussive symptoms; RTP, return-to-play; SDM, service delivery model; SMART, Self-management Activity Restriction and Relaxation Training; SRC, sport-related concussion.

Supported by UBMD Concussion Management Clinic (Buffalo, NY) and GF Strong Adolescent Complex Concussion Clinic, Vancouver BC, Canada. Disclosures: Dr John Leddy has a financial relationship with Highmark Innovations, 360 Concussion Care, Neuronasal, and Quadrant Biosciences. The other authors have nothing to disclose.

Cite this article as: Arch Rehabil Res Clin Transl. 2022;4:100221

<https://doi.org/10.1016/j.arrct.2022.100221>

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concussion, or postconcussion symptoms of children and adolescents. Studies describing emergency department–based interventions, adults, and moderate to severe brain injuries were excluded.

Data Extraction: The initial search resulted in 1668 articles. Using Rayyan software, 2 reviewers independently completed title and abstract screening followed by a full-text screening of potentially included articles. A third blinded reviewer resolved inclusion/exclusion conflicts among the other reviewers. This resulted in 28 articles included.

Data Synthesis: Each of the 28 articles were grouped into 1 of the following 3 categories: generalist-based services (7), specialist-based services (12), and web/telemedicine services (6). One article discussed both generalists and specialists. It was clear that specialists are more proactive in their treatment of concussion than generalists. Most of the research on generalists emphasized the need for education and training. Four studies discussed costs relevant to SDMs.

Conclusions: This review highlights the need for more discussion and formalized evaluation of SDMs to better understand concussion management. Overall there is more literature on specialist-based services than generalist-based services. Specialists and generalists have overarching similarities but differ often in their approach to pediatric concussion management. Cost analysis data are sparse and more research is needed.

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Pediatric concussion is a major public health concern and is a common reason for emergency department (ED) visits.¹ It is estimated that between 1.1 and 1.9 million sports and recreational concussions occur in children in the United States yearly.² About 25%-30% of pediatric patients take longer than 4 weeks to recover, and nearly 14% are still symptomatic 3 months after injury.³ Some studies have reported that up to 2% of concussed children continue to have symptoms 1 year post injury,³ while others suggest that 10%-20% of patients report symptoms years after initial injury.⁴ Those who take longer than 4 weeks to recover are considered to have persistent postconcussive symptoms (PPCS).⁴ PPCS have been associated with poor educational, social, and developmental outcomes in pediatric patients.^{5,6} Concussions frequently cause physical, social, and emotional symptoms that affect academic, athletic, and social performance.⁷ In addition, the cost of care associated with concussion may increase financial stress on the child's family.⁸

As far as we know, there is a lack of systematic comparison of concussion service delivery models (SDMs) and their associated costs. In 2001, the first International Consensus Statement on Concussion in Sport established one of the first concussion management guidelines.⁹ Since then, management protocols for acute and persistent concussion have evolved. Despite the development of concussion assessment and management tools, their application within clinical care pathways are rarely well described in the literature and, to our knowledge, have never been systematically analyzed or classified. Considering the diversity in concussion management and assessment strategies among clinics,¹⁰⁻¹² it would be beneficial to describe and compare SDMs so that clinicians and researchers can tailor assessments and interventions to specific patient needs. Cost of service may be a significant factor within SDMs and is therefore included in this review.

This systematic review analyzes concussion SDMs in pediatric populations and proposes concussion SDM categories. A categorization system for SDMs will allow clinicians and researchers to describe and compare management

strategies with greater precision. Categorization of concussion SDMs and increased efforts to describe SDMs within clinical studies will likely reduce unwarranted practice variation in concussion care. We also aim to evaluate the literature pertaining to the costs associated with different pediatric concussion SDMs. For many children and adolescents with concussion the point of entry is the ED; however, we elected to exclude ED research because our focus was on models of service delivery aimed at continuous care in the community.

Methods

Literature search procedures

This systematic review was registered with PROSPERO (ID: CRD42021232323) on April 30, 2021, and follows Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines. The following databases were included in the search: PubMed, Embase (Elsevier), CINAHL Plus (EBSCO), APA PsycINFO (EBSCO), and Web of Science. Searches were limited to human trials published in English in 2001 or later. We selected 2001 as our initial time point because it marks the first International Concussion in Sport Consensus Conference, an important turning point in research on sport-related concussion (SRC). Databases were selected to optimize the inclusion of relevant literature. Search strategies were developed with assistance from a health sciences librarian (M.L.Z.). Search terms were identified by examining pertinent literature from preliminary searches and extracting key words and controlled indexing vocabulary (eg, Medical Subject Headings of the National Library of Medicine and Emtree terms) (table 1). Electronic searches were carried out on February 19, 2021. A repeat search was done on January 10, 2022, to ensure the most up-to-date literature was captured. Only studies published between

Table 1 Search terms

Search Database	Search Strings
CINAHL Plus	TI concussion* OR AB concussion* OR TI mild traumatic brain injur* OR AB mild traumatic brain injur* OR TI sports related concussion* OR AB sports-related concussion* OR TI brain concussion* OR AB brain concussion* OR TI persistent post concussive symptom* OR AB persistent post concussive symptom* AND TI service delivery model* OR AB service delivery model* OR TI health care cost* OR AB health care cost* OR TI health care cost* OR AB health care cost* OR TI interdisciplinary model* OR AB interdisciplinary model* OR TI medical model* OR AB medical model* OR TI biopsychosocial model* OR AB biopsychosocial model* OR (MM "Brain Concussion+") OR (MM "Postconcussion Syndrome") AND (MM "Health Care Costs+") OR (MM "Health Care Delivery, Integrated") OR (MM "Health Care Delivery+") OR (MM "Decision Support Systems, Clinical") OR (MM "Models, Biological") OR (MH "Models, Psychological+") OR (MM "Models, Theoretical+")
Embase	'mild traumatic brain injur*':ab,ti OR concussion*:ab,ti OR 'sports-related concussion*':ab,ti OR 'brain concussion*':ab,ti OR 'persistent post concussive symptom*':ab,ti AND 'service delivery model*':ab,ti OR 'health care cost*':ab,ti OR 'health care cost*':ab,ti OR 'interdisciplinary model*':ab,ti OR 'medical model*':ab,ti OR 'biopsychosocial model*':ab,ti, OR('brain concussion'/exp OR 'postconcussion syndrome'/exp AND 'health care delivery'/exp OR 'interdisciplinary care'/exp OR 'biopsychosocial model'/exp AND (2001:py OR 2002:py OR 2003:py OR 2004:py OR 2005:py OR 2006:py OR 2007:py OR 2008:py OR 2009:py OR 2010:py OR 2011:py OR 2012:py OR 2013:py OR 2014:py OR 2015:py OR 2016:py OR 2017:py OR 2018:py OR 2019:py OR 2020:py OR 2021:py) AND 'human' /de)
PubMed	(mild traumatic brain injur*[Title/Abstract] OR concussion*[Title/Abstract] OR sports-related concussion*[Title/Abstract] OR brain concussion*[Title/Abstract] OR persistent post concussive symptom*[Title/Abstract]) OR ("Brain Concussion/classification" [MeSH Terms] OR "Brain Concussion/complications" [MeSH Terms] OR "Brain Concussion/diagnosis" [MeSH Terms] OR "Brain Concussion/rehabilitation" [MeSH Terms] OR "Brain Concussion/therapy" [MeSH Terms] OR "Post-Concussion Syndrome/classification" [MeSH Terms] OR "Post-Concussion Syndrome/complications" [MeSH Terms] OR "Post-Concussion Syndrome/diagnosis" [MeSH Terms] OR "Post-Concussion Syndrome/rehabilitation" [MeSH Terms] OR "Post-Concussion Syndrome/therapy" [MeSH Terms])) AND ((service delivery model*[Title/Abstract] OR health care cost*[Title/Abstract] OR health care cost*[Title/Abstract] OR interdisciplinary model*[Title/Abstract] OR medical model*[Title/Abstract] OR biopsychosocial model*[Title/Abstract]) OR ("Health Care Costs"[Mesh] OR "Delivery of Health Care" [MeSH Terms] OR "Interdisciplinary Studies" [MeSH Terms] OR "Decision Modeling" OR "Models, biopsychosocial" [MeSH Terms])) Filters: Humans, English, from 2001 - 2022
PsycInfo	TI mild traumatic brain injur* OR AB mild traumatic brain injur* OR TI concussion* OR AB concussion* OR TI sports-related concussion* OR AB sports-related concussion* OR TI brain concussion* OR AB brain concussion* OR TI persistent post concussive symptom* OR AB persistent post concussive symptom* AND TI service delivery model* OR AB service delivery model* OR TI health care cost* OR AB health care cost* OR TI biopsychosocial model* OR AB biopsychosocial model* OR TI service delivery model* OR AB service delivery model* OR TI medical model* OR AB medical model* OR TI interdisciplinary model* OR AB interdisciplinary model* OR MA "Brain Concussion" AND (((DE "Health Care Delivery") OR (DE "Health Care Costs")) OR (DE "Interdisciplinary Treatment Approach")) OR (MA "Medical Model") OR (MA "Biopsychosocial Approach")
Web of Science	TOPIC: (mild traumatic brain injur*) OR TOPIC: (concussion*) OR TOPIC: (brain concussion*) OR TOPIC: (persistent post concussive symptom*) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=2001-2021 AND TOPIC: (service delivery model*) OR TOPIC: (health care cost*) OR TOPIC: (health care cost*) OR TOPIC: (interdisciplinary model*) OR TOPIC: (medical model*) OR TOPIC: (biopsychosocial model*) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=2001-2021

Abbreviation: MeSH, Medical Subject Headings of the National Library of Medicine.

February 19, 2021, and January 10, 2022, were captured in the second search. We followed the same process of blinded review followed by full article review, which resulted in inclusion of 8 additional articles.

Article selection

Criteria for inclusion

Studies included were (1) peer-reviewed; (2) evidence-based, that is, included data on use and aspects of service

outcomes; (3) about service delivery, service delivery models, and/or analysis of concussion care costs; and (4) about mild traumatic brain injury (mTBI), concussion, or postconcussion symptoms in pediatric or adolescent (ages 0-21 years) populations.

Criteria for exclusion

Studies were excluded when (1) participants were adults; (2) participants had moderate or severe traumatic brain injury or nontraumatic brain injuries; (3) they were pharmaceutical or clinical drug trials; (4) they were imaging

research; (5) the emphasis was complications of concussion such as posttraumatic stress disorder; (6) they were ED-based research; (7) the study duplicated another published study; (8) the research was unpublished, non-peer-reviewed, or not a full text; and (9) the study was unavailable in English.

Data extraction

A total of 1668 articles was extracted, 177 of which were duplicates. Reviewers (B.W., J.P.) experienced in concussion and models of care independently screened 1491 titles and abstracts using Rayyan software.¹³ Articles were included if 2 reviewers (B.W., J.P.) chose to include them. If an article was included by one reviewer and excluded by the second, a third experienced clinician/reviewer (J.M.) independently appraised the article. The initial screening resulted in 1439 articles being excluded. The residual 52 articles moved into a full-text screening. The review process described above was repeated, that is, 2 independent reviewers with a third to resolve conflicts. This resulted in the final 28 articles included in the review. All included articles were then openly discussed by the research team to ensure consensus was achieved. Additionally, all articles were evaluated using the appropriate Joanna Briggs Institute (JBI) Quality Assessment tool. The JBI Quality Assessment tool¹⁴ was chosen because of the breadth of study designs among the included articles (fig 1).

Results

After initial and updated screening, 28 articles met inclusion criteria and all met JBI Quality Assessment inclusion criteria. After a thorough assessment of all 28 articles, the research team identified 3 concussion SDM types. The proposed pediatric concussion SDM types are generalist-based services (7), specialist-based services (12), and web/telemedicine-based services (6). One article was included in both Generalist and Specialist-Based models. Categorizations are described below. Four of the included articles discussed cost of concussion care (table 2).

Generalist-based services

We defined generalist-based services as services provided by primary care providers (PCPs) who treat children or adolescents. PCPs include but are not limited to general practitioners, family physicians, sports medicine physicians, and pediatricians.^{15,16} These clinicians are not usually specialists in the treatment of concussion. Clinicians within this model serve as the entry point to primary care. Of 28 articles, 7 fit into this category (see table 1). Two articles included multiple physician types; however, the majority of those physicians met classification as generalists.^{17,18}

The study by Arbogast et al¹⁹ suggested that insufficient time and training may limit adoption of best practices in concussion management among PCPs. This study aimed to increase the adoption of the vestibular/oculomotor examination as well as return-to-play (RTP) and return-to-learn

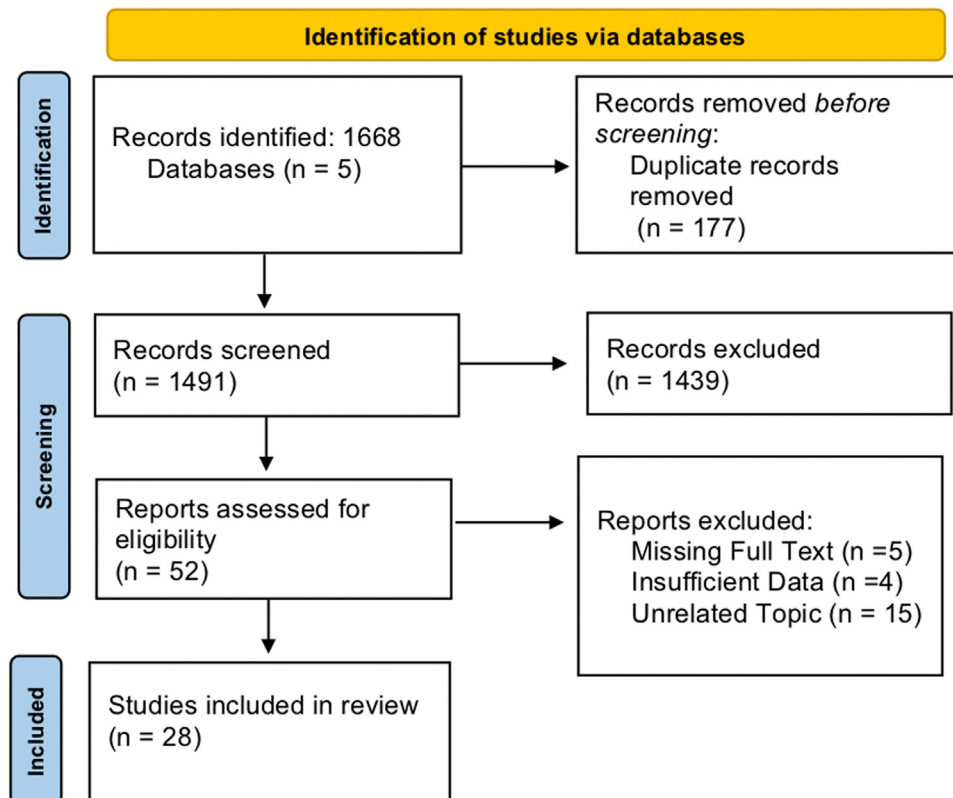


Fig 1 Preferred Reporting Items for Systematic Reviews and Meta-analyses flow diagram. This figure includes data from both the primary and secondary searches.

guidelines. Local PCPs completed a needs assessment and were then asked to use a clinical support decision tool (Smart-Set). The authors reported an increase in the use of the vestibular/oculomotor examination from approximately 2% preintervention to 71% post intervention. Documented discussion of return-to-learn and RTP guidelines increased from 19% to 73%. This study provided evidence for the value of disseminating detailed concussion management guidelines to PCPs. The authors suggested that insufficient training of PCPs may result in excessive referrals to specialists and patient care that is not evidence based.

Kinnaman et al¹⁸ highlighted the dearth of literature on concussion management practices among generalists. PCPs who treat pediatric concussions were surveyed on their use of concussion practice guidelines and medication prescription patterns. Eighty-four percent of PCPs reported using a concussion management tool such as the Sports Concussion Assessment Tool or using the Concussion in Sport Group Guidelines. Approximately 89% of respondents reported recommending over-the-counter medications or prescription medications for concussed patients.

Taylor et al²⁰ addressed knowledge gaps in primary care that could lead to unnecessary referrals to specialists and ED visits. The authors developed and assessed the effectiveness of an educational intervention to improve concussion awareness and enhance patient management by PCPs. The researchers hypothesized that a targeted, provider-focused intervention would improve adherence to consensus-based concussion care and ultimately improve health outcomes. The intervention increased compliance with the recommended management approach from 3.6% of cases prior to implementation to 28.1% after. This study also highlighted the value of education and clinical guidance for generalists. Cools et al²¹ completed a retrospective chart review to evaluate the completeness of concussion documentation and evaluation, use of standardized assessment tools, and return-to-sport and -school guidelines. Cognitive testing was not used in 86.5% of cases, symptom checklists were not used in 94% of cases, and roughly 85% of providers did not document inquiring about emotional symptoms, sleep disturbances, or neck pain. The authors concluded that professional education, development of clinical care pathways, and Electronic Medical Record-embedded clinical tools should help improve concussion management by PCPs.

Butler et al²² focused their retrospective chart review on the use of standardized concussion tools (such as Acute Concussion Evaluation form and a return-to-school letter) for providing guidance on cognitive rest and gradual return-to-school instructions in an outpatient pediatric PCP clinic. Only 44% of pediatric PCPs documented the use of a standardized tool for concussion management. Use of a standardized tool led to higher frequency of a documented care plan and discharge instruction specific to cognitive rest. The authors concluded that increased use of concussion tools to guide cognitive rest will improve adherence to recommendations and ultimately improve recovery times.

A qualitative study by Daugherty et al²³ described the opinion of PCPs in rural communities on the Centers for Disease Control and Prevention's evidence-based guidelines on pediatric mTBI. PCPs were concerned that the Centers for

Disease Control and Prevention guidelines were lengthy and nonspecific to rural communities. Many rural PCPs also reported a lack of support from specialists.

Finally, the article by Feyissa et al¹⁷ was classified as both a generalist-based services and a specialist-based services article because of its unique model. They assessed the effectiveness of a comanagement model between PCPs (generalists) and neurologists (specialists). The authors hypothesized that a comanagement model would enable patients to receive earlier treatment, recover faster, and avoid costs associated with specialty care. PCPs were able to bill more for comanaged care than their regular visits and believed the comanagement model improved care coordination. Overall this study suggests the feasibility and benefit of a comanaged model between generalists and specialists.

Specialist-based services

We defined specialist-based services as those provided by clinicians who have a focus on treating children and adolescents with concussion.^{15,16} Specialists generally have advanced education and intensive training giving them an expert understanding of concussion and related conditions. Specialists include neurologists, physiatrists, sports medicine physicians, and others with specialized training in mTBI. Many specialists work in integrated multidisciplinary or interdisciplinary teams, often in tertiary care centers. There were 12 articles that described specialist-based services (see [table 1](#)). The focus of most articles within this group is improved patient outcomes, effective treatment modalities, effective service delivery, cost-effectiveness, and increased accessibility of services.

While the articles describing generalist services were more often focused on the educational needs of the providers, articles on specialist services focused on interventions within SDMs. The specialist interventions were most often delivered in tertiary care environments to individuals with PPCS. Specialists were more likely to prescribe active treatments vs generalists, who emphasized passive approaches to care such as strict rest or the use of medications. Five of 12 specialist-based articles focused on aerobic exercise interventions. A randomized controlled trial of community-based concussion clinics published by Leddy et al²⁴ in 2019 revealed the effectiveness of personalized aerobic exercise based on a systematic assessment of each individual's degree of exercise intolerance within 10 days of injury. Early aerobic exercise treatment significantly reduced recovery time when compared with a placebo-like stretching exercise regimen. A second study by Leddy²⁵ in 2021 compared aerobic exercise with stretching but this time included more severely symptomatic participants from hospital-based concussion clinics. They replicated the prior finding that early controlled aerobic exercise sped recovery. More importantly, perhaps, early exercise treatment significantly reduced the incidence of PPCS in adolescents after SRC.

Kurowski et al²⁶ performed an exploratory RCT comparing subsymptom threshold aerobic exercise with a stretching program in children and adolescents with PPCS. They demonstrated that aerobic exercise improved recovery in

Table 2 Selected literature and model classification

Author	Year	Participant Demographics	Intervention Described	Main Outcome	Study Design
Generalist-based services					
Arbogast et al ¹⁹	2017	0-17 y old with concussion	Educational lectures and practice sessions for providers.	The development of clinical decision support tools may provide clinical guidance to a geographically widely network of providers. It may increase systematic implementation and documentation of new recommendations and practices.	Experimental study
Butler et al ²²	2021	5-18 y old with concussion	No intervention was given. This study is retrospective.	Few providers adopted a concussion tool in their practice, but those who did were more likely to incorporate important recommendations in documentation.	Retrospective chart review
Cools et al ²¹	2021	7-18 y old with sports-related concussion	No intervention was given. This is a retrospective chart review.	PCPs often did not document important aspects of concussion history or physical examination.	Retrospective chart review
Daughery et al ²³	2021	Rural health care providers	No intervention was completed.	Health care providers found CDC guideline recommendations to be helpful and feasible. They reported barriers to implementation, such as lack of access to specialists.	Qualitative study
Feyissa et al ^{17,*}	2015	PCPs who manage pediatric concussions	PCP comanagement tool kit was developed and follow-up visit templates were provided.	Comanagement can enhance PCPs' capacity to independently manage the care of patients with concussion.	Prospective data collection and retrospective chart review
Kinnaman et al ¹⁸	2013	Medical PCPs and pediatricians, patients with concussions	A 17-item questionnaire was distributed to 1305 PCPs.	Pediatricians routinely use medications when managing patients with concussions. Most pediatricians use guidelines in concussion management.	Questionnaire
Taylor et al ²⁰	2018	Providers who see concussed patients	Education (learning communities) and support materials.	A multimodal educational intervention may help PCPs align their management practices with consensus-based guidelines.	Experimental study with pre-post chart reviews
Specialized care					
Bailey et al ²⁷	2019	14-18 y old with persistent concussive symptoms	Subthreshold exercise program for 6 wk vs control group.	Exercise intervention is effective at reducing symptoms in adolescents with persisting symptoms.	Pilot RCT
Dobney et al ²⁸	2017	Concussed high school and college athletes	Aerobic exercise, coordination activities, visualization activities, and education.	Active rehabilitation improves postconcussion symptoms scores in young athletes.	Prospective cohort
Eagle et al ³⁴	2020	Children and adolescents with acute and persistent concussions	No intervention given. This article is retrospective.	Early, specialized medical care and intervention is beneficial for children and adolescents with concussion.	Retrospective cross-sectional
Ellis et al ²⁹	2017	7-19 y old with concussion/ mTBI	No intervention given. This article is a review	Comprehensive care of pediatric patients with	Retrospective chart review

(continued)

Table 2 (Continued)

Author	Year	Participant Demographics	Intervention Described	Main Outcome	Study Design
			of a multidisciplinary program.	concussion requires access to appropriate diagnostic resources and the multidisciplinary collaboration of experts.	
Feyissa et al ^{17,*}	2015	PCPs who manage pediatric concussions	PCP comanagement tool kit was developed and follow-up visit templates were provided.	Comanagement can enhance PCPs' capacity to independently manage the care of patients with concussion.	Prospective data collection and retrospective chart review
Kurowski et al ²⁶	2017	12-17 y old with persistent mTBI symptoms	Active exercise program vs stretching program.	Subsymptom threshold aerobic exercise is potentially beneficial for adolescents with persistent symptoms after mTBI.	Pilot RCT
Leddy et al ²⁴	2021	Adolescent athletes presenting within 10 d of sport-related concussion	Active exercise program vs stretching program.	Early treatment with subsymptom threshold aerobic exercise safely speeds recovery from sport-related concussion and reduces the risk for persistent postconcussive symptoms.	RCT
Leddy et al ²⁵	2019	13-18 y, acutely concussed, athletes	Active exercise program vs stretching program.	Individualized subsymptom threshold aerobic exercise treatment speeds recovery and may reduce the incidence of delayed recovery.	RCT
McCarty et al ³⁰	2016	11-17 y old with persistent or sports-related concussion	Collaborative care model (with cognitive behavioral therapy).	Systematic implementation of collaborative care treatment approaches may reduce concussive and psychological symptoms in adolescents.	RCT
Schneider et al ³³	2019	Pediatric population with sports-related concussion	No intervention given. This article describes current assessment and management models.	Rehabilitation after concussion should be a multifaceted, interdisciplinary assessment designed to identify underlying sources of ongoing symptoms.	Clinical commentary
Scratch et al ³¹	2019	4-18 y old with persistent concussion	No intervention given. This study follows patients within the Persistent Concussion Clinic at Holland Bloorview Kids Rehabilitation Hospital.	This article outlines the practices of a large, hospital-based interdisciplinary clinic whose model can inform clinical care pathways and practices for this underserved population.	Cohort study
Wilkins et al ³²	2014	0-18 y, acute sports-related concussions	No intervention provided. Chart review was done.	Establishment of a multidisciplinary clinic with standardized protocol decreased resource utilization and more consistent concussion care in this patient population.	Retrospective cohort study
Telemedicine/web models					
Alberts et al ³⁵	2019	15-18 y old with acute or persistent concussions, athletes	C3 app care path was implemented.	Standard care coupled with the C3 app functions to facilitate communication among the interdisciplinary team to create efficient and effective clinical management.	Descriptive study

(continued)

Table 2 (Continued)

Author	Year	Participant Demographics	Intervention Described	Main Outcome	Study Design
Babcock et al ³⁶	2017	Adolescents and their parents, patients with mTBI and persistent symptoms	SMART web-based self-management tool for adolescents and parents.	The SMART program, a novel web-based intervention, may serve as a self-management tool for adolescents and their parents to assist with the recovery after a recent mTBI.	Prospective, open-label, pilot study
Ellis et al ³⁸	2019	Pediatric patients with acute concussion	Telemedicine, subspecialty-based care delivery program.	Telemedicine may be useful to assist pediatric concussion programs with delivering timely, safe and cost-effective care.	Pilot retrospective chart review
Hunt et al ³⁷	2016	5-18 y old with acute concussion	Concussion & You program: return-to-school/play, sleep, nutrition, relaxation, and energy conservation education.	Concussion & You is a feasible program that is acceptable to youth and their families.	Pilot study
Kurowski et al ⁵²	2016	11-18 y old with acute concussion	SMART program: guidance and psychoeducation.	SMART is feasible and reported to be helpful and enjoyable by participants.	Prospective pilot study
McCarty et al ³⁹	2021	11-18 y old with persistent concussion	Collaborative care model (with cognitive behavioral therapy).	Adolescents who received collaborative care had improvements in health behavior inventory scores compared with usual care at 3 and 12 mo.	RCT
Cost of care studies					
Agnihotri et al ⁴³	2021	3-18 years old with persistent concussions	No intervention given. This study assesses health care cost/ utilization.	Interdisciplinary concussion care is an accessible, comprehensive and cost-saving health care model from the client and societal perspectives.	Retrospective chart review
Corwin et al ⁴⁰	2019	5-18 y old with persistent concussion	No intervention given. This study is an assessment of all rehabilitative costs.	Given the high economic costs of postconcussion care, therapies shorten recovery time may have the potential to be cost-effective and even cost-saving.	Retrospective cohort study
Graves et al ⁴¹	2019	Younger than 18 y, rural and urban populations, persistent mTBI	No intervention given. This study is a care cost comparison of rural vs urban children.	Total health care costs were higher for rural children than urban children despite lower utilization of some services. Differences in health service utilization may exacerbate geographic disparities in adverse outcomes associated with mTBI.	Retrospective cohort study
Taylor et al ⁴²	2015	6-21 y old with a minor head injury or concussion	No intervention. This article discusses health care costs associated with concussion care.	Health care encounters for children diagnosed with concussion or minor head injury increased. Care for these injuries increasingly shifted from the ED to primary care and specialty providers.	Retrospective cohort analysis

Abbreviations: CDC, Center for Disease Control and Prevention; RCT, randomized controlled trial.

* Feyissa et al fit the classification for multiple categories.

adolescents even when they were experiencing prolonged symptoms after SRC. In a study that combined aerobic exercise with education on concussion, Bailey et al²⁷ reported a 60% improvement in symptoms in participants with PPCS. They also reported patients with depression took longer to recover, suggesting that some patients may benefit from adjunctive mental health services. Finally, Dobney et al²⁸ also demonstrated that pediatric participants with PPCS experienced fewer postconcussion symptoms after engaging in active (exercise-based) rehabilitation.

The use of a multidisciplinary approach in addition to exercise treatment is another theme common to specialist-based services. Dobney,²⁸ for example, highlighted the benefit of physical therapy for cervical and vestibular signs. Ellis et al²⁹ assessed the effectiveness of a multidisciplinary concussion management program for pediatric patients seen both acutely after injury and those with PPCS, including sport and non-sport-related mechanisms. This program comprised a multitude of specialists, including but not limited to neurologists, physiotherapists, psychiatrists, surgeons, sports medicine physicians, and exercise scientists so that specific forms of care were delivered by appropriate health care providers. One-third of patients received care from more than 1 member of the multidisciplinary team.

McCarty et al³⁰ assessed the effectiveness of mental health interventions as an added element of concussion care. This program compared combined cognitive behavioral therapy, psychiatry, and medication (as needed) with treatment as usual. At the end of the 6-month intervention period, patients in the novel intervention group reported significantly less postconcussive symptoms than treatment-as-usual patients. Scratch et al³¹ provided a comprehensive description of specific interventions and tools used within a pediatric concussion specialty clinic to emphasize the importance of interdisciplinary care. They discuss clinic flow for patients with PPCS, from referral to multidisciplinary concussion treatment. Wilkins et al³² described the effect of concussion care standardization in a large tertiary children's hospital by retrospectively reviewing charts before and after standardization. They found that a standardized clinical evaluation reduced the number of ED visits, increased use of the Sports Concussion Assessment Tool, and increased the number of times physicians documented return-to-play and return-to-learn guidelines.

The remaining articles discuss models of care as well as the timing of care. Feyissa et al¹⁷ discussed the feasibility and utility of a comanagement model including generalists and specialists. Similar to the conclusions of the previously described articles, it suggests that collaborative care may be beneficial for patients and practitioners. Schneider et al³³ describe a dynamic, recursive model of concussion etiology, assessment, and management. They advocate for awareness of risk factors through multifaceted clinical examination, multidisciplinary treatment programs, and adherence to gradual return-to-school/play/work guidelines to facilitate improved outcomes and subsequent injury prevention. Finally, Eagle et al³⁴ discussed the utility of early specialized medical care for pediatric patients with concussion. They found that the strongest predictor of delayed recovery was the number of days from injury to first clinic visit.

Web/telemedicine services

We defined web/telemedicine services as care provided by clinicians (specialists or generalists) using any web-based program or telecommunication as the main intervention or assessment tool. While articles assigned to this category describe approaches within generalized or specialized models, they were separated because of differences between electronic and in-person service delivery. Six of the 28 articles met the description of this category. Four articles discussed web-based interventions, 1 of which was a smartphone app. Two articles presented telemedicine models. It is apparent that telecommunication and internet-based management tools are becoming increasingly common because of their potential for cost and time savings as well as their ability to eliminate geographic barriers.

Alberts et al³⁵ assessed the utility of the Cleveland Concussion Clinic (C3) smartphone app. This app includes electronic incidence reporting, assessment, and RTP modules. The purpose of the app is to guide clinical decision making and to standardize treatment. Multiple modules within the app differentiated those with typical vs prolonged concussion recovery, indicating C3's potential to identify patients early on who may take longer to recover.

The articles by Babcock³⁶ and Kurowski⁵² and colleagues assessed a web-based program, Self-management Activity Restriction and Relaxation Training (SMART). The program consists of modules for symptom management, activity monitoring, and education. Babcock³⁶ assessed the effectiveness of the SMART program, while Kurowski⁵² assessed its feasibility. Babcock³⁶ found that adolescents who used this program reported significantly improved symptom burden, functional disability, and executive functioning. Additionally, the data indicate quicker recovery, but this trend did not reach statistical significance. Kurowski⁵² reported that the majority of participants' symptoms resolved in 2 weeks and all recovered within 4 weeks. These studies suggest that the SMART program may be of use to self-guided care for adolescents.

Hunt et al³⁷ analyzed an intervention similar to the SMART program, Concussion & You, a comprehensive web-based program for pediatric patients with concussion that teaches management strategies for returning to school and play, sleep, nutrition, relaxation, and energy conservation. The program was conducted for 4 weeks or more and included parents, and although located in a hospital-based clinic, the authors advocated for its use in the general public as well. Fifty-two percent of participants reported never having received previous education on concussions. Overall, 99% of participants reported that they enjoyed the program and would recommend it to others, while 94% of participants reported an intention to use their knowledge from the program. The study concluded that Concussion & You is a feasible method of educating youth and their families about concussion.

Ellis et al³⁸ compared in-person specialty clinic concussion care with telemedicine-based care. The authors describe the use of the Concussion in North Education, Consultation, and Telemedicine Program, which serves patients in remote communities with limited access to specialized care. Concussion in North Education, Consultation, and Telemedicine includes a multidisciplinary team of concussion specialists who provide services both in person and remotely

using video conferencing. Eighteen of 20 patients (90%) in this pilot study preferred telemedicine services over in-person assessments. By the end of the study period, 90% of patients had met the definition of clinical recovery. Cost of the telemedicine assessments was reported to be roughly half the cost for in-person assessments. This study suggests that telemedicine is a useful and cost-effective tool, particularly for patients who live in rural and medically underserved communities.

McCarty et al³⁹ compared a collaborative care model vs usual care in adolescents with PPCS. The mental health intervention portion of the program was delivered by video conference to a group of community clinics. The collaborative care group experienced a greater reduction in concussion-related cognitive symptoms and a significant improvement in quality of life when compared with usual care.

Cost of care studies

Four studies focused on the economics of adolescent/pediatric concussion management. Corwin et al⁴⁰ examined the cost of delivering services in a subspecialty concussion clinic for pediatric patients with PPCS. The average per patient cost of concussion management was about \$3500 (US dollars). Not including management costs, \$1575 was spent on sports medicine visits, \$985 for visual-vestibular therapy, \$55 for homebound tutoring, \$22 for prescription medications, and \$120 for subspecialist referral per patient. The authors concluded that PPCS care is costly and that treatments to reduce PPCS incidence is likely cost-saving.

A retrospective observational study by Graves et al⁴¹ aimed at estimating the cost of concussion care for rural vs urban youth. Cost analysis was based on a data set of insurance claims that included diagnostic codes for concussion. The analysis determined that rural children used physical therapy and occupational therapy services more than children in urban populations. However, children in rural populations visited speech language pathologists and mental health professionals less often than children in urban populations. The authors concluded that patients in rural areas had reduced access to mental health services and found that the cost of concussion care was 11% higher for children in rural areas than children in urban areas. The study included only commercially insured patients, so the results are not generalizable to the uninsured population, those on government-subsidized programs, or countries that have universal health insurance.

Taylor et al⁴² examined insurance claims for concussion management in Massachusetts from 2007-2013. The cohort did not include privately paid costs or uninsured persons. They reported a significant increase in the number of concussion diagnoses and in the number of visits per patient over time. Population costs increased by 34% during the study period, yet the cost per patient decreased by 31%. Although population cost on ED and neuroimaging decreased, population cost for PCP and specialist care increased over time likely because of the rising number of patients. The overall cost per individual patient decreased from a mean of \$790 to \$543.

Agnihotri et al⁴³ studied costs of an interdisciplinary concussion clinic in Canada based on 4 dimensions of health

care utilization: accessibility, continuity, comprehensiveness, and productivity. They found that the overall cost was lower for pediatric concussion care than for adults. Moreover, concussion care cost less than other chronic health conditions, including but not limited to mental health disorders, diabetes, and asthma. They concluded that an interdisciplinary model of concussion care management can be accessible, comprehensive, and cost-effective.

Discussion

The purpose of this systematic review was to present the spectrum of currently available concussion services with the secondary goal of developing a classification system for the various SDMs. Our search revealed a variety of concussion management strategies that, when combined with variation in the degree to which each SDM was described, made creating an evidence-based classification system challenging. The proposed classification system is, therefore, relatively broad. Few articles thoroughly described concussion SDMs, and even fewer evaluated their effectiveness. The lack of critical appraisal of SDMs suggests the need for a formal classification system to create common descriptors for these complicated systems and allow for systematic comparison of SDMs.

Generalist-based services include primary care providers, such as family physicians, pediatricians, and other general practitioners, who are often the initial and sole care provider for a patient after concussion but whose duties are not focused primarily on treating concussion.^{15,16} A common finding was that PCPs are not consistently using standardized tools for concussion assessment nor are they generally aware of return-to-sport and return-to-learn guidelines. The studies on generalists focused on the use of provider education to increase adoption of concussion management tools, with most showing a significant increase in awareness and use of tools after concussion-specific education. Effecting change in provider attitudes and practices can be challenging, which is addressed in other literature.⁴⁴ Unfortunately, none of the included articles directly addressed patient outcomes. Based on these articles, it is evident that accessible information and checklists may improve concussion management in generalist-based settings. Given that general practice physicians care for the majority of youth and children with concussion, PCPs should have access to additional supports from specialists.

There is more literature on specialist-based services, perhaps because specialists were more likely to be associated with universities with publication expectations. We found substantial heterogeneity in specialist services, ranging from single provider community-based offices to hospital-based multidisciplinary clinics. We were unable to create further subclassifications within specialist services because crucial information about the exact nature of the clinical environment was often absent. The majority of articles that described specialist-based services focused on specific interventions rather than evaluation of an SDM.

There were several overarching themes in the descriptions of specialist services. First, it appears that early intervention is critical to avoiding delayed recovery.^{24,34} Second, active interventions, including aerobic exercise, are more

effective for speeding recovery vs passive interventions such as rest and stress avoidance.²⁴⁻²⁸ Third, there is the recognition of the heterogeneity of concussion signs and symptoms and the value of a multidisciplinary approach to managing the various phenotypes of concussion.^{17,27,30} Fourth, mental health supports, if delivered in person, appear to reduce symptom burden and length of PPCS.³⁹ Research regarding other interventions for concussion, especially in children and adolescents, is limited.⁴ However, we recognize that there may be other interventions used within specialist-based SDMs that were not included in this review, such as vestibular rehabilitation⁴⁵ and cognitive behavioral therapy.⁴ Therefore, it is prudent that clinicians take a multidisciplinary and individualized approach to concussion management.

Web and telemedicine-based care may offer a potential solution to the increased cost of specialized care, particularly for families. As noted by Ellis et al,³⁸ telemedicine was more cost-effective for concussion management and increased accessibility for patients in remote communities. The main drawback of this SDM category is that in-person neurologic examinations cannot be performed. Recent literature has attempted to assess the reliability and validity of telecommunication vs in-person assessments; however, this research is in the early stages.^{46,47} Web-based interventions offer a potential cost-effective approach to concussion care^{35,36,38,52} by providing self-management strategies for concussion, which have been shown to be useful for symptom management³⁷ and are a useful adjunct to professional diagnosis and management of concussion. Limitations of web and telemedicine care models include access to technology, technology proficiency, language proficiency, and increased attention demands.⁴⁸ In addition, screen-based activities can trigger headaches or nausea for many patients after a concussion.⁴⁹ Further research is needed to determine how best to deliver and incorporate this approach into concussion SDMs. There is some indication that in-person care for psychological and cognitive symptom management may improve outcomes.^{30,39}

It is clear that concussion care cost varies greatly depending on factors such as geographic location and services needed.⁴¹ Many of the articles use projected costs and estimates rather than actual costs associated with care. Included studies did not discuss indirect costs such as travel costs, time off work for parents, and so on. Telemedicine and self-managed care may help to reduce cost for patients and their families, especially those in rural communities.^{22,38} Uninsured patients were not included in the selected studies. Although it was not an eligibility criterion, 3 of the studies describing costs were conducted in the United States and 1 was in Canada and therefore may not be generalizable outside North America. There is a clear need for prospective data collection of direct and indirect costs associated with SDMs.

There were common themes within the included articles. Multiple articles advocated for standardization of concussion assessment and documentation of findings. A few of these articles included using web-based tools to assist in standardizing clinical assessments.^{35-37,52} Articles describing both generalist- and specialist-based services highlighted the need for knowledge translation to

patients and their families. Many of the studies also suggested the use of collaborative care within multi- and interdisciplinary models. Collaborative care can be an effective tool for improving patient care and potentially for reducing cost of care.⁵⁰

The articles emphasized that concussion care needs to be standardized, individualized, collaborative, and evidence-based to provide optimal patient care and reduce costs and barriers to treatment. We recommend that authors provide more detail about the setting for their research for others to determine if the treatment model is a good fit with their own practice setting. We suggest that authors describe location (eg, urban, suburban, rural), setting (hospital-based, community clinic, sole practitioner, etc) patient groups (adults, adolescents, children), and services (interdisciplinary in-house, interdisciplinary by referral). It would be a major step forward if the International Committee of Medical Journal Editors added a requirement for all research studies on patients to describe the setting within which the study took place.

Study limitations

We developed a list of search terms that we believed would cover the topic of interest; however, it is possible that 1 or more search terms could have been added to capture additional articles. It is also possible articles may have been excluded because of a lack of data but may have provided details of SDMs that we did not find within included articles. We also recognize that our cost analysis article selection was limited because included articles had to discuss SDMs of pediatric concussion, which may have excluded articles with further detail on the cost of concussion care. The primary limitation is the absence of substantial research on SDMs. While this was beyond our control, it speaks to the need for research that describes how services are delivered and the environment of the clinic or service delivery program. We urge researchers and clinicians to describe the setting of their research in greater detail so that others who attempt to replicate successful management models have a more complete understanding of the setting within which the treatment model was used.

Conclusions

Although there have been great advances in the development of assessment tools and guidelines for concussion management in the last 20 years, the modus of care delivery has not been systematically studied. Thus, the classification system we developed is simplistic, providing only a starting point for classifying SDMs. By suggesting an initial framework for concussion SDM classification, we hope to provide a common language for reporting and categorizing approaches so that clinicians and researchers can assess strengths and limitations of all concussion SDMs in an attempt to optimize patient management. The Centers for Disease Control and Prevention have produced very useful guidelines for diagnosis and management of mild traumatic brain injury, and perhaps subsequent revisions could also include a classification system for SDMs.⁵¹ We strongly encourage international and multidisciplinary collaboration to gain a deeper understanding of pediatric concussion SDMs.

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