Pediatric Concussion

- Prognostic Utility of Immediate Memory and Delayed Recall Assessments for Adolescent Concussion
- Loss to Follow-Up at Pediatric Concussion Clinic, an Important Area of Study
- Nightly Sleep Duration and Symptom Burden Over 1 Month Following Pediatric Concussion
- Online concussion resources for young children and caregivers: a systematic search
- Understanding Beliefs and Perceptions of Parents, Coaches, and Organizational Leaders toward Non-concussive Head Impact Exposure in Youth American Football
- Altered autonomic cardiovascular function in adults with persisting post-concussive symptoms and exercise intolerance
- Neurocognitive evaluation of adolescents recovering from sports-related concussion: A prospective cohort pilot study utilizing the National Institutes of Health Toolbox cognition Battery
- Shockwaves of War: Neurobehavioral Symptom Analysis Post-Al Asad Missile Strike, 2020

A **pediatric concussion** is a mild traumatic brain injury (mTBI) that occurs in children and adolescents due to a direct or indirect force to the head. Unlike adult concussions, pediatric cases pose unique challenges due to the ongoing brain development, difficulty in symptom assessment, and potential long-term consequences on cognitive and emotional well-being.

The aim is to develop an age-appropriate definition of sport and exercise in children and adolescents for use in concussion management and concussion research.

A modified Delphi methodology, with three rounds and consensus, defined a priori as ≥ 80% agreement.

Thirty-one participants (13 male, 18 female) from 13 countries, including clinical psychologists, epidemiologists, implementation scientists, neurologists, neuropsychologists, neurosurgeons, pediatric emergency physicians, pediatricians, physiotherapists, rehabilitation physicians, speech-language pathologists, and sports medicine physicians came to a consensus that sport-related pediatric concussion extends beyond the sporting arena, and includes the school yard, playground, park, street, recreational site, and home; excludes non-accidental violence, assault, and passenger vehicle road trauma; may include falls; and age-group terminology includes Toddlers and Young Children (1-4 years), Children (5-12 years), and Adolescents (13 to < 18 years). Sport and exercise categories and individual examples are provided.

This consensus definition of sport and exercise in pediatrics for concussion research and management will enable researchers and guideline development groups to expand pediatric concussion research and management guidelines to encompass the broad range of activities commonly associated with sport– and exercise-related concussion in children and adolescents and thus limit the exclusion of relevant studies from systematic reviews and guideline development [1)].

The study provides a much-needed standardized definition of sport and exercise in pediatric concussion research, ensuring that relevant activities are included in future guidelines—however, the lack of empirical validation and potential overgeneralization warrant further investigation. Future

research should focus on testing this definition in real-world concussion management and surveillance programs. Additionally, addressing socioeconomic and cultural variations in how children engage in exercise and play could enhance the definition's applicability across diverse populations

Pathophysiology

- Concussions result from **biomechanical forces** causing **axonal stretching, metabolic dysregulation, and transient neural dysfunction**. - Unlike adults, children have **higher brain plasticity but increased vulnerability** due to thinner skulls, incomplete myelination, and greater head-to-body ratio. - The **neurometabolic cascade** following concussion includes:

1. Ionic shifts (potassium efflux, calcium influx)
2. Increased glucose demand and decreased cerebral blood flow
3. Neuroinflammatory response

Clinical Features

Pediatric concussions present with a **wide range of symptoms**, often categorized into four domains:

Domain	**Symptoms**
———————–	———--
Physical	Headache, dizziness, nausea, light/sound sensitivity, balance issues
Cognitive	Attention deficits, memory problems, brain fog, slowed reaction time
Emotional	Irritability, mood swings, anxiety, depression
Sleep-related	Insomnia, excessive sleep, fragmented sleep

- **Toddlers and younger children** may show non-specific signs such as excessive crying, behavioral changes, or sleep disturbances, making diagnosis challenging.

Diagnosis

1. **Clinical Interview & History**

1. Mechanism of injury, symptoms, and red flags (e.g., vomiting, worsening headache, altered consciousness).
2. Prior concussion history and risk factors (e.g., ADHD, migraine history, learning disabilities).

2. **Sideline/Initial Assessment Tools**

1. **SCAT5 (Sport Concussion Assessment Tool)** – not validated for children < 5 years.
2. **Child SCAT5** for ages 5-12, **SAC (Standardized Assessment of Concussion)** for adolescents.
3. **King-Devick Test** (oculomotor screening) and **Vestibular/Ocular Motor Screening (VOMS)**.

3. **Imaging (if indicated)**

1. **CT Scan**: Only in cases of severe symptoms (e.g., suspected skull fracture, prolonged LOC).
2. **MRI**: Useful for prolonged symptoms (>4 weeks) to rule out structural pathology.

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Management & Return-to-Play/School Protocols

Initial Management - **Cognitive & Physical Rest** (24-48 hours) - **Symptom-limited Activity**: Gradual reintroduction of cognitive tasks and low-intensity activities. - **Multidisciplinary Approach**: Involves pediatricians, neuropsychologists, physiotherapists, and educators.

Return-to-Play (RTP) & Return-to-Learn (RTL) Protocols - **Gradual, stepwise approach**, ensuring symptom resolution before progression. - **School modifications**: Reduced screen time, shortened school days, extra breaks. - **Physical reconditioning**: Light aerobic exercise before contact sports.

Stage	Activity	Goal
———-	————	———-
1	Symptom-limited rest	Recovery
2	Light aerobic exercise	Increase HR
3	Sport-specific drills (non-contact)	Coordination
4	Non-contact training	Cognitive load
5	Full-contact practice	Readiness for competition
6	Return to play	Normal gameplay

- **Post-Concussion Syndrome (PCS)**: Persistent symptoms > 4 weeks, requiring specialized intervention.

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Challenges in Pediatric Concussion Management

1. **Underreporting & Misdiagnosis**

1. Children often fail to recognize or report symptoms.
2. Overlapping symptoms with ADHD, migraines, and anxiety.

2. **Long-Term Neurodevelopmental Impact**

1. Increased risk of learning difficulties, emotional dysregulation, and behavioral changes.
2. Potential links to **CTE (Chronic Traumatic Encephalopathy)** with repetitive injuries.

3. **Limited Evidence on Pediatric-Specific Treatments**

1. Most concussion protocols are adapted from adult guidelines.
2. Need for pediatric-specific neuroimaging markers and biomarkers.

Future Directions in Research

- **Biomarkers for Objective Diagnosis** (e.g., GFAP, UCH-L1 in blood tests) - **Advanced Neuroimaging**: fMRI, DTI for subtle brain injury detection. - **AI & Machine Learning in Concussion Management** - **Concussion Prevention Strategies**: Rule changes in youth sports, helmet technology improvements.

Pediatric concussions require **early recognition, individualized management, and a stepwise return to activity**. Given the **developing brain's vulnerability**, research efforts should focus on **biomarkers, imaging advances, and long-term cognitive outcomes**. Future concussion guidelines must consider **age-appropriate definitions of sport and exercise** to ensure **comprehensive injury prevention and management**.

1)

Davis GA, Anderson N, Babl FE, Ballard DW, Barlow KM, Barrett MJ, Beauchamp MH, Borland ML, Bressan S, Crowe L, Chong SL, Corwin DJ, Dalziel SR, Emery CA, Fauteux-Lamarre E, Gioia GA, Haarbauer-Krupa J, Kirkwood MW, Löllgen RMC, Master CL, McKinlay A, Olver J, Mintegi S, Pavlicich V, Purcell L, Raman R, Rino P, Suskauer SJ, Shavit I, Tavender EJ, van Ierssel J, Yeates KO, Zuckerman SL, Anderson V. International Consensus Definition of 'Sport & Exercise' in Toddlers and Young Children, Children, and Adolescents. Acta Paediatr. 2025 Feb 17. doi: 10.1111/apa.70013. Epub ahead of print. PMID: 39962915.