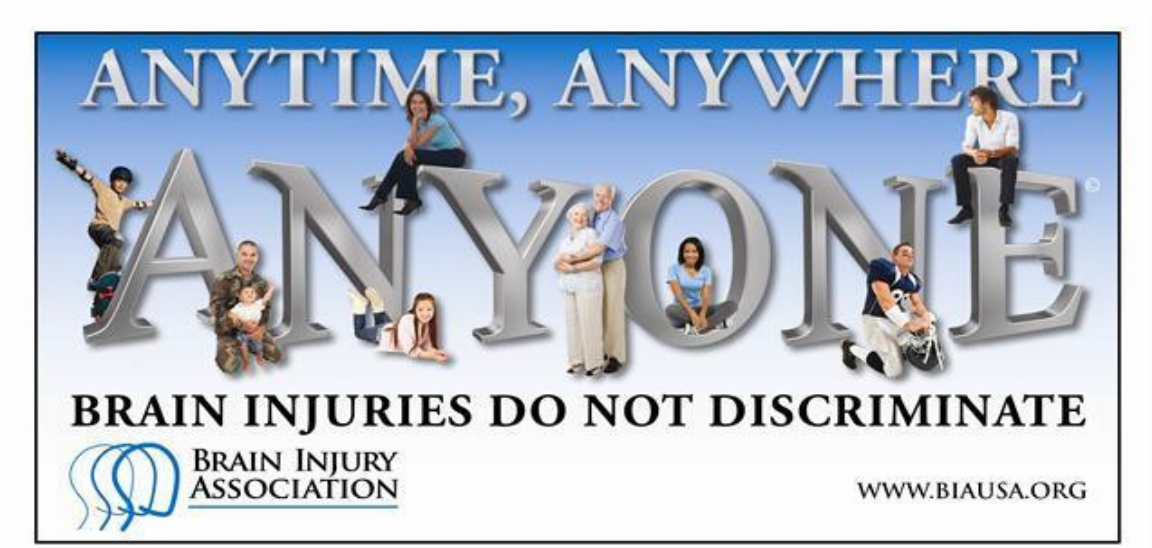
Cognitive and Behavioral Functioning Following Traumatic Brain Injury in Children

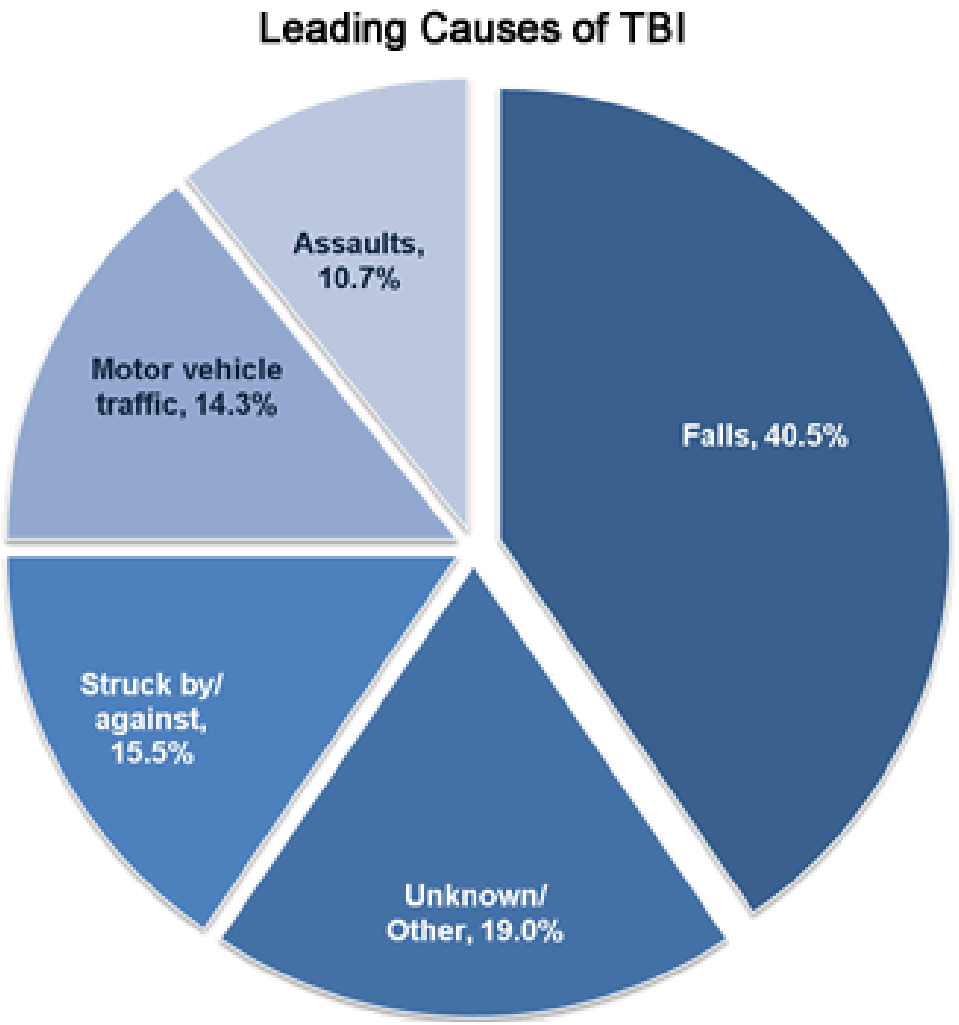


General prevalence

- A leading cause of acquired disability in children and adults
  - 160/ 100,000 in U.S. children under the age of 7
- Rates higher in other counties
  - New Zealand: total incidence rate of 790 per 100,000 persons. Of these cases, approximately 70% were children, adolescents, and young adults
  - Are rates actually higher or does this reflect bias in seeking hospitalization?

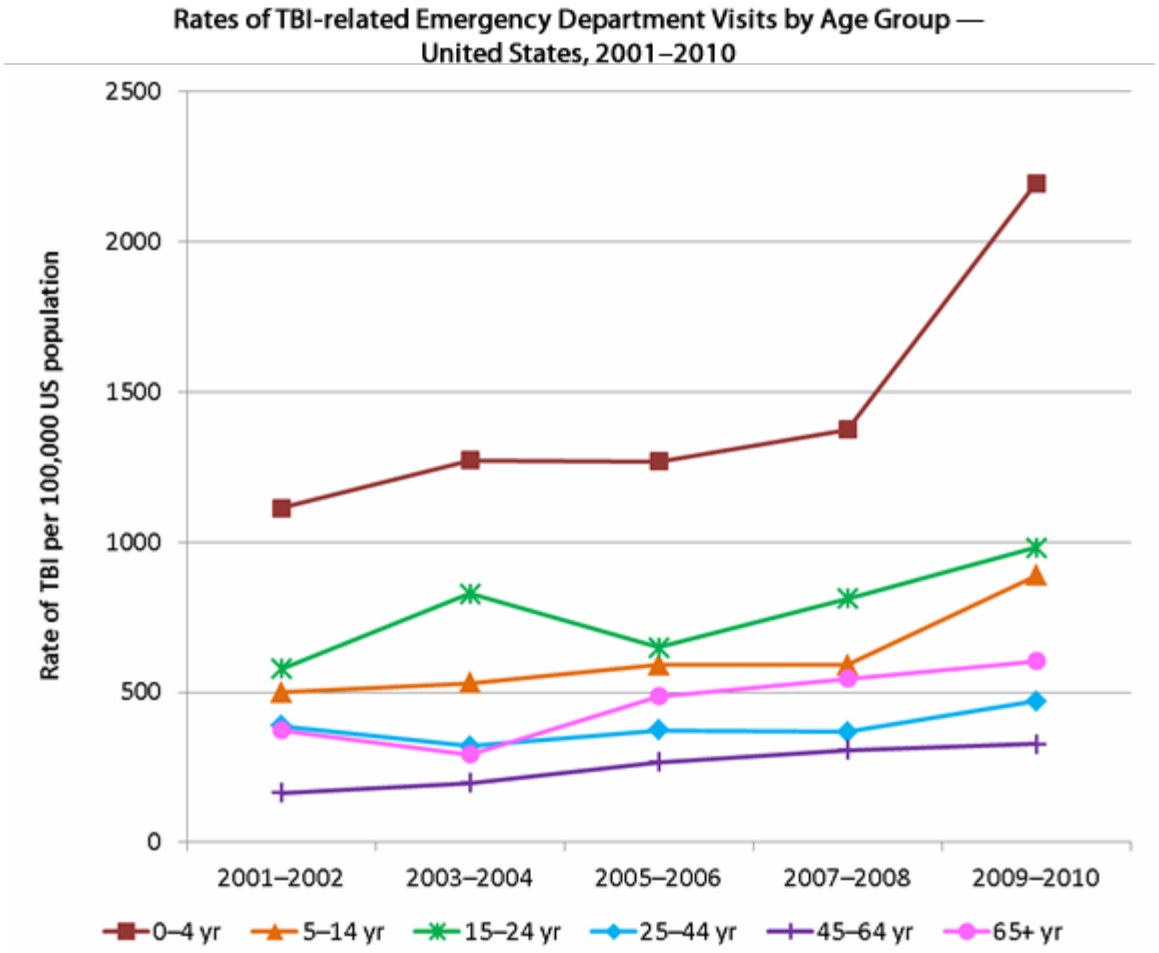
Centers for Disease Control, 2011; Fiegen et al., 2013

Causes of TBI



Centers for Disease Control, 2011

Rates of TBI by age



Centers for Disease Control, 2011

TBI basics

Often diffuse: regardless of the focus of the injury, whole brain often impacted

Symptoms

- Dilated or unequal size of pupils
- Vision changes
- Respiratory failure
- Motor: difficulty moving body parts, motor weakness, poor coordination
- Vomiting
- Headache
- Confusion
- Ringing in the ears or change in hearing
- Trouble with balance
- Cognitive difficulties
- Behavioral problems
- Risk for post-traumatic seizures

Centers for Disease Control, 2013; Torbic et al., 2013

Glasgow Coma Scale (GCS)

Best Eye Response	Best Verbal Response	Best Motor Response
1. No eye opening 2. Eye opening to pain 3. Eye opening to verbal command 4. Eye opening spontaneously	1. No verbal response 2. Incomprehensible sounds 3. Inappropriate words 4. Confused words 5. Appropriate verbal responses	1. No motor response 2. Extension to pain 3. Flexion to pain 4. Withdrawal from pain 5. Localizing to pain 6. Obeys commands

Teasdale & Jennett, 1979

Glasgow Coma Scale (GCS)

- GCS Levels of severity:
  - Mild, sometimes also called concussion
    - GCS > 13
    - Complicated mild: GCS consistent with mild with abnormalities on neuroimaging
  - Moderate: GCS 9-13
  - Severe: GCS < 8

Teasdale & Jennett, 1979

Other assessments of severity

- Post-traumatic amnesia (PTA): time elapsed from injury to when patient demonstrates continuous memory
- Duration of loss of consciousness (Greenwald et al, 2003)

Severity of TBI	Finding
Mild	Mental status change or LOC < 30 min
Moderate	Mental status change or LOC 30 min to 6 h
Severe	Mental status change or LOC > 6 h

- Injury Severity Score (ISS): overall measure of injury in head, face, chest, abdomen, extremities, and other external areas

Mid TBI

Complaints after mild TBI

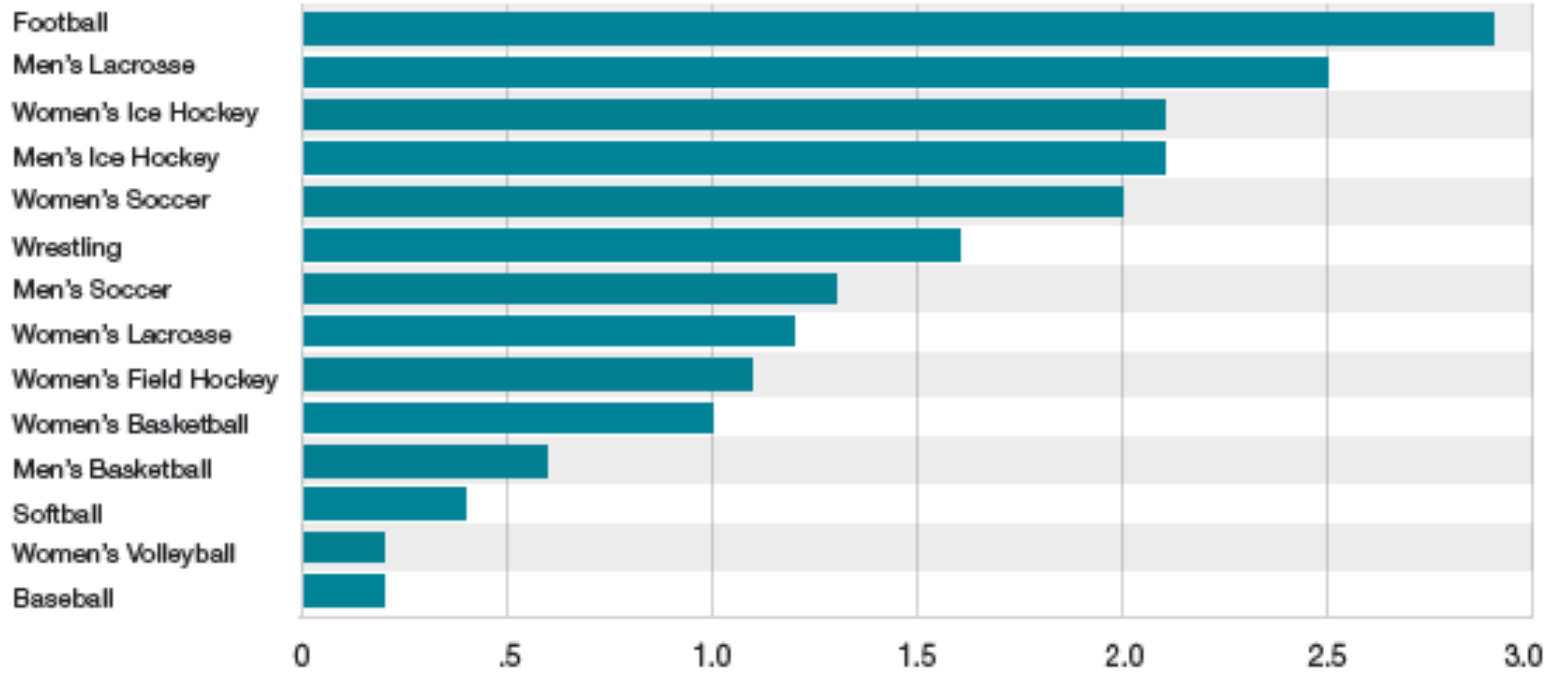
- One week post-injury: headaches, dizziness, and fatigue most reported symptoms; no significant cognitive problems
- Symptoms resolved at 3-months post-injury
- 17% had ongoing complaints; more likely with a history of:
  - Previous head injury
  - Learning difficulties
  - Neurological or psychiatric problems
  - High levels of family stress

Ponsford et al., 1999

Sports-related TBI

- Majority of an estimated 300,000 sports- related TBIs are mild (using GCS criteria)

Figure 1: Rate of competition concussion injury in 14 NCAA sports



Data from 2004-2009. Overall practice and game injury rates for each sport can be found in Appendix C.

NCAA Sports Science Institute, 2013

Cognitive functioning following sports-related TBI

- Compared injured to non-injured college athletes
- Significant post-concussive symptoms 2 hours following the injury
  - Resolved by 48 hours post-injury
- 2 hours and 48 hours: deficits in verbal memory, inhibition, cognitive set shifting, attention, and verbal fluency
- Group differences non-significant at one week and one month

Echemendia, Putukian, Mackin, Julian, & Shoss, 2001

Multiple head injuries

- Chronic Traumatic Encephalopathy (CTE): Additive effects of multiple head injuries
  - Long-term symptoms after repetitive TBIs
- Common manifestations
  - Memory, attention, behavioral, and personality changes
  - Heightened risk for mood disorders: collegiate football players with 3+ concussions had three-fold risk for depression
  - Fatigue and headache

http://content.time.com/time/video/player/0,32068,64253995001_1957921,00.html

McKee et al., 2010

Complicated Mild to Severe TBI

Cognitive problems

- Worse with greater injury severity
- Typically improve with time, but can persist long-term (especially in severe TBI)
- Deficits across multiple domains:
  - Executive functions and attention (DeJong & Donders, 2005; Mottram & Donders, 2005)
  - Short- term memory: learning efficiency, delayed recall, and accuracy (DeJong & Donders, 2005; Mottram & Donders, 2005)
  - Processing speed (Donders & Janke, 2008)
  - Verbal intelligence: unaffected (Schmand, Smit, Geerlings, & Lindeboom, 1997; Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2000) or affected (Ewing-Cobbs et al., 1997; Verger et al., 2001)?

Behavioral problems

- Worse with greater injury severity
- Behavioral problems across multiple domains
  - Internalizing
  - Externalizing
  - Symptoms of ADHD
  - Symptoms of ODD
  - Anxiety disorders
  - Behavioral manifestations of executive dysfunction (e.g., difficulty regulating emotions, planning and organizing behavior)
  - Social competence

Behavioral problems

- Younger children may be at more risk for persistent behavioral problems
  - In children who were pre-school age at the time of injury, younger age at injury was associated with more ADHD and anxiety symptoms that persisted two years post-injury
  - In the absence of intervention, younger children are at greater risk for development and persistence of long-term behavioral problems

Karver et al., 2012

Anxiety

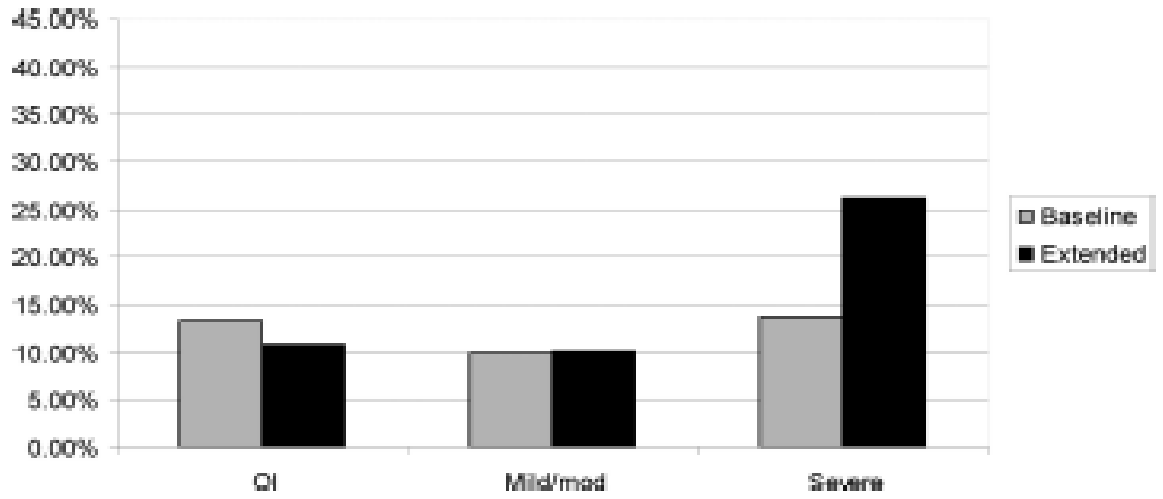
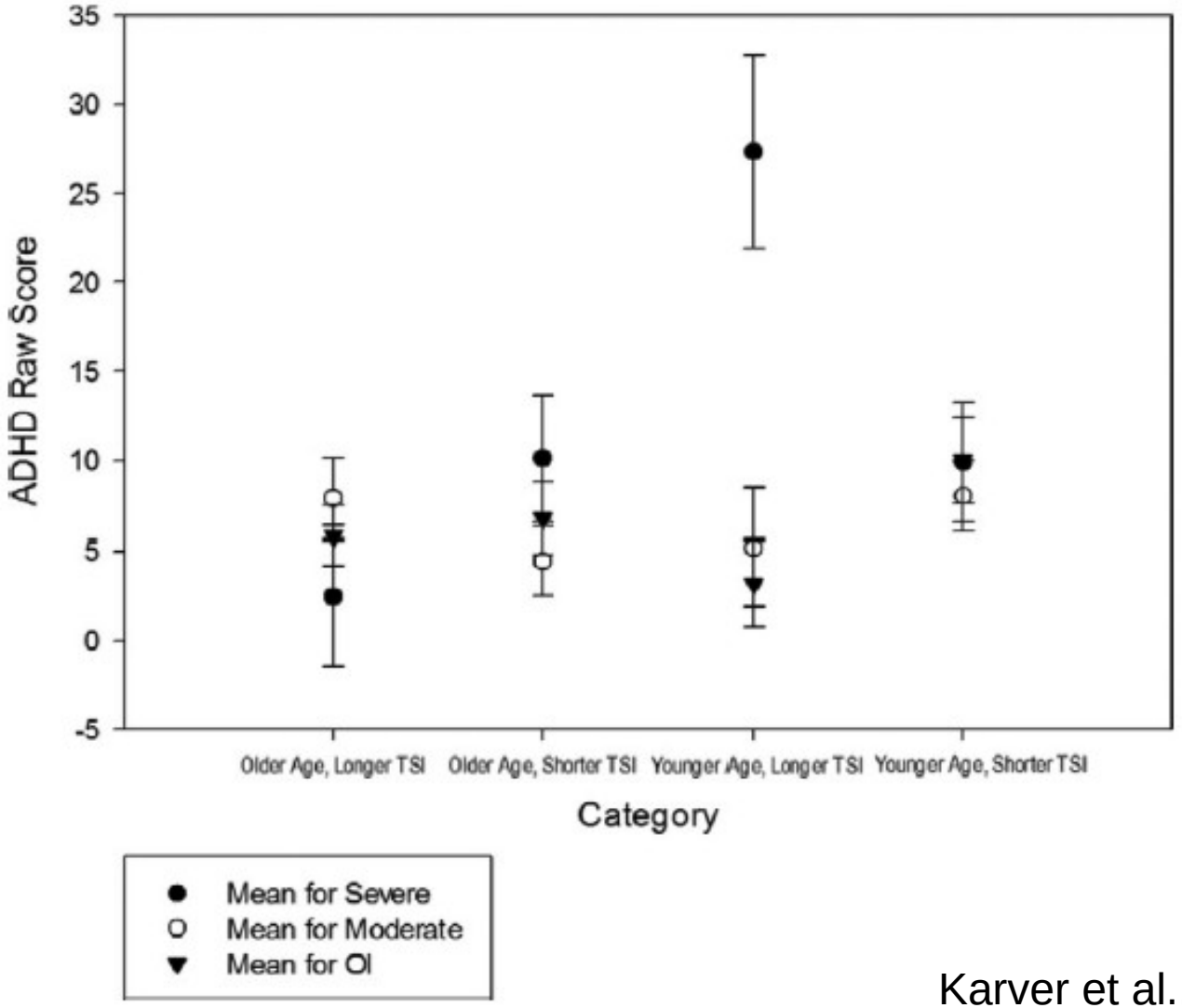


Figure 3. Proportion of participants in each group meeting criteria for clinically significant behavior problems on the CBCL Anxiety subscale at baseline and extended follow-up. Clinical significance defined as *t* score ≥ 63.

Karver et al., 2012

ADHD



Karver et al., 2012

Influence of cognitive deficits on behavior

- Cognitive deficits thought to be a primary contributor to long-term behavioral and social problems
- Working memory, processing speed, and attention reduce ability to efficiently process incoming social information (Willcutt, 2010; Schwartz et al., 2003)
- Executive functions: regulate attention and inhibit emotional reactions, be flexible and adaptive across contexts, plan and organize behavior (Gangesalingam et al., 2006; Gangesalingam et al., 2007)

Recovery

Recovery after TBI

- Complicated and multi-faceted
  - Social support
  - Personal coping style
  - Pre-morbid cognitive ability
  - Mechanism and circumstances of the injury
  - Recent interest in investigating genetic influences

Cognitive reserve

- Higher pre-morbid neurocognitive functioning preserves functional capacity after brain insult
- Greater ability to efficiently use existing brain networks or elicit alternative networks
  - "allows some people to cope with brain damage better than others" (Stern, 2003, pg. 2016)
- Someone who with lower pre-morbid cognitive abilities may be expected to have more post- TBI problems than someone with higher pre-morbid abilities cognitive abilities

Stern, 2003; Karver et al., 2014

Socio-demographic factors and recovery

- Poor family environment (i.e., lower SES, higher family dysfunction) associated with more behavioral and cognitive deficits and less recovery
  - social skills
  - academic functioning
  - behavioral functioning

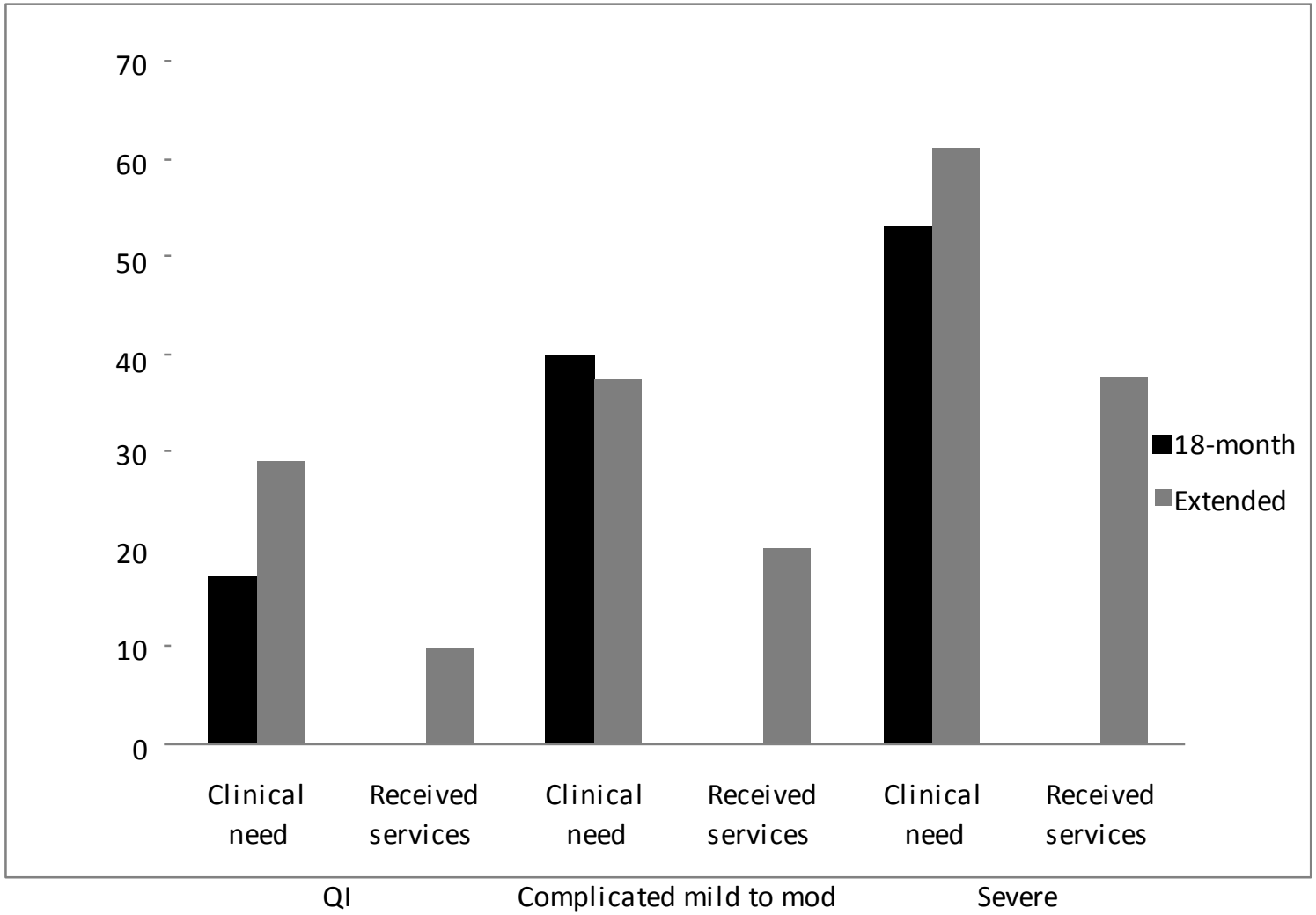
Taylor et al., 2002

Socio-demographic factors and recovery

- Advantaged environments mediate neural reorganization and more efficient recovery
- More opportunities for behavioral adjustment and acquisition of compensatory skills
- Disadvantaged families:
  - Stressors beyond injury-related that may be less common or less disruptive in advantaged families
  - Fewer resources to invest in recovery

Taylor et al., 2002

Utilization of mental health services



Karver et al., 2014

Current post-injury interventions for children

- Exercise
- Stimulant medication
- Re-learn attentional control skills to implement self-regulatory behaviors
- Problem-solving therapy
- Family-based interventions: improving communication to increases social competence
  - Organize external environment and reinforce desirable behaviors
  - Ongoing environmental structure to encourage behavioral control
  - May be particularly efficacious for lower SES families

Wade et al., 2014; Petranovich et al., in press

Take away points

- Cognitive concerns typically resolve within 3 months or less following a single mild TBI
- Increasing awareness of the negative effects of repeated head trauma
- Complicated mild to severe TBI often results in more long-lasting problems with attention, processing speed, behavior, and social competence
  - Problems worse with greater injury severity
- Recovery is complex and influenced by a variety of individual, family, and environmental factors