The Neck’s Role in Sport Related Concussion

James T. Eckner M.D., M.S.
University of Utah 27th Annual Update in PM&R
February 1, 2013
Introduction

- University of Michigan
  - Assistant professor of Physical Medicine & Rehabilitation
  - Research Director, Michigan NeuroSport

- Clinical and Research Focus
  - mTBI in athletes
Disclosures

• Relationships with commercial interests
  – Investigator on research grant funded by ElMindA, Ltd.

• Additional non-commercial research support:
  – Rehabilitation Medicine Scientist Training Program (NIH K12)
  – National Collegiate Athletic Association
  – UM Sport Health and Activity Research and Policy Center for Women and Girls

• Co-Inventor on US Patent application # 12/815,619 filed by the University of Michigan (no financial relationships)
Lecture Overview

• Part 1
  – The neck’s role in concussion susceptibility
Lecture Overview

• Part 2
  – The neck’s role in concussion symptomatology
Part 1: The Neck’s Role in Concussion Susceptibility

• We think it’s good to have a strong neck...

Who would fare better after similar impacts to the head?

And Why?
A little physics

- Newton’s Second Law:

  Force = mass × acceleration

  \[ F = ma \]
A Newtonian Thought Experiment
Applying Newton’s Second Law

\[ \text{Force} = \text{mass} \times \text{acceleration} \]
Concussion Susceptibility

• Applying Newton’s second law to athlete necks and concussion susceptibility
Concussion Susceptibility

• Bring on the forces...

OUCH!
Makes sense—what is the evidence?

- 7 relevant studies will be discussed:
  - 1 impact reconstruction study
  - 3 lab-based controlled force application studies
  - 1 lab-based soccer headgear study
  - 1 in-vivo study involving youth ice hockey players
  - 1 resistance training intervention study

- Will also briefly discuss my own research related to this topic
Video reconstruction of concussive impacts

- 25 NFL helmet-to-helmet collisions resulting in concussion were reconstructed with Hybrid III ATD’s
- Modeling was used to determine the effect of varying neck stiffness on the head’s response

Video reconstruction of concussive impacts

- Increased neck stiffness was found to reduce peak head acceleration and $\Delta V$.
- Noted a large effect on HIC, which is proportional to $\Delta V^4$.
- Suggested further investigation into neck strengthening interventions, exp. in the z-axis (rotation)

Neck muscle resistance to simulated frontal impact

• Backward tugs were applied to the heads of 8 adult subjects under varying conditions

• Modeling was used to compare varying values of elasticity (stiffness) and damping on resultant head kinematics

Reid et al. (1981) Aviation, Space, and Environmental Medicine 52(2): 78-84
Neck muscle resistance to simulated frontal impact

- Primary study objective was to develop a biomechanical model of simulated impact
- However, results were illustrative:
  - Neck stiffness increased with neck girth
  - Neck stiffness was the primary predictor of head response

Reid et al. (1981) Aviation, Space, and Environmental Medicine 52(2): 78-84
Gender differences in head-neck dynamic stabilization

- Applied external forces to induce head-neck flexion and extension (pictured) while recording the kinematic response in 40 healthy, active adult males and females
- Compared anthropometrics, neck strength, and head kinematics between groups

Gender differences in head-neck dynamic stabilization

• Results:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Males</th>
<th>Females</th>
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</thead>
<tbody>
<tr>
<td>Neck Girth</td>
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<td></td>
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<tr>
<td>Maximum Isometric Flexion Strength</td>
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<tr>
<td>Maximum Isometric Extension Strength</td>
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<tr>
<td>Flexion Angular Displacement</td>
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<td>Flexion Angular Acceleration</td>
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<td>Extension Angular Displacement</td>
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<td>Extension Angular Acceleration</td>
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<tr>
<td>Head-Neck Segment Stiffness (Flex &amp; Ext)</td>
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• Concluded that observed gender differences may account for greater concussion risk in females.

Role of loading on head stability

- Used a similar apparatus to apply flexion and extension loads to the head under varying degrees of pre-loading in 7 adult subjects
- Compared kinematic response and neck stiffness between pre-loading conditions

Role of loading on head stability

• Found that pre-loading the neck increased stiffness and decreased angular velocity


• Speculated that pre-loading may modulate the vestibulo-collic reflex
Sex differences in soccer heading

- Male and female collegiate soccer players performed standardized headers wearing various types of soccer headgear.
- Compared isometric neck strength and kinematic head responses under each headgear condition between the genders.

Sex differences in soccer heading

- Results:
  - Greater neck girth and isometric flexion/extension strength in males
  - Greater head linear accelerations and HIC for females under every headgear condition
  - Surprisingly also found that while headgear attenuated head acceleration and HIC in males, it increased these values in females

Cervical muscle strength effect on in vivo head impact biomechanics

- Measured neck strength and recorded a season’s worth of head impacts using the HIT System in bantam ice hockey players
- Compared biomechanical impact profiles between the top, middle, and bottom tertiles of neck muscle strength

Found no differences in linear acceleration, rotational acceleration, or HITsp between the 3 neck strength groups.

Noted limitations in neck strength testing methodology, inability to determine impact anticipation, sample characteristics, and lack of assessment of other relevant variables.

Effect of a neck strengthening intervention on head dynamic response

- Assigned 36 collegiate soccer players to an 8 week flexion/extension neck strengthening program or control
- Compared neck girth, strength, stiffness, and head-neck kinematic responses pre and post intervention

Effect of a neck strengthening intervention on head dynamic response

• Results:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Intervention</th>
<th>Control</th>
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<tbody>
<tr>
<td>Neck Girth</td>
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<td>Head-Neck Displacement</td>
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<td>Head-Neck Acceleration</td>
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• Concluded that the isotonic neck muscle training program utilized may not have been the most appropriate for reducing concussion risk

So, what’s the final verdict?

- Thicker necks are stronger and stiffer
- A thick, strong, stiff neck probably does reduce the magnitude of the head’s kinematic response to external forces (i.e., is good)
- These relationships are not fully understood and may be more complex than initially thought
  - Complicated by limitations in biomechanical injury metrics
- Additional research is needed, including investigation in the coronal and transverse planes
- Optimal neck strengthening interventions for concussion risk mitigation are not known
Overview of my own related research

- Conceptual model
Overview of my own related research

• Conceptual model

- Incoming Threat
- Impact
- Impact Avoidance Response
- Neck Muscle Factors
- Helmet Factors
- Head & Brain Response
- Awareness Reaction Time
- Biomechanical Characteristics of Response
- Individualized Factors Determining “Concussion Threshold”

No Injury → Impact Avoidance Response → Impact → Incoming Threat

Concussion
Overview of my own related research

• Investigating the relationships between
  – Neck size, neck strength, rate of force generation
  – Sonographic SCM cross sectional area
    • Expanding to include additional cervical muscles and muscle stiffness (elastography)
  – Cervical muscle co-contraction
  – Reaction time
  – Dynamic head responses
    • Peak linear and angular displacements, velocities, accelerations
    • Expanding to include directionality of response
• Studying relationships in all 3 planes
Our testing apparatus

Extension Load

Headgear (red) with offset bar (grey) and optoelectronic Marker triad (yellow)

Pulley

In-line force transducer

1 kg mass

Adjustable drop height

Safety landing pad

Stopper

Spring

Spring
Part 2: The Neck’s Role in Concussion Symptomatology

A challenging topic
Vertigo/Dizziness  
Headache  
Whiplash (Neck)  
Concussion (Brain)  
Psychological Factors  
Vertigo/Dizziness
Cervicogenic Headache: Evidence That the Neck is a Pain Generator
Werner J. Becker, MD

Cervicogenic Headache: The Neck Is a Generator: Con
Maurice B. Vincent, MD, PhD

The Literature

• Only one single study investigating these associations specifically in an athlete population
  – Prospective observational cohort study of 187 ice hockey players over one season (ages 15-35)
  – Trainers completed immediate and 7-10 day follow up assessments in 13 athletes diagnosed with either a concussion (7) or whiplash injury (6)
    • Quebec task force whiplash questionnaire
    • Post concussion symptom scale
    • Neck range of motion and strength

• Found both concussion and whiplash-associated symptoms in both groups
  – No athlete with exclusive symptoms
  – No association of symptom severity between diagnoses
  – No association between initial symptom severity and rate of recovery for either diagnosis

• Concluded that athletes with either injury should be assessed and medically cleared for both injuries before returning to play

A Step Back

• Post-traumatic headache
  – Post-traumatic migraine
  – Tension-type PTH
  – Cluster-like PTH
  – TMJ Syndrome
  – Occipital neuralgia
  – Cervicogenic headache

• Post-traumatic vertigo/dizziness
  – Central post-traumatic vertigo
  – Perilymphatic fistula
  – Post-traumatic endolymphatic hydrops (Meniere’s disease)
  – Labyrinthine concussion
  – BPPV
  – Cervicogenic dizziness
Relevant Anatomy: Cervicogenic Headache

- Multiple potential pain generators in the neck
  - Bone, muscle, ligament, disk, facet joints, AO & AA joints
- Role of the trigeminocervical nucleus
  - C1, C2, C3, and CN V nociceptive afferents
  - Explains referral patterns in spinal and trigeminal distributions
Referral Patterns

- Occipit-C1 through C5-C6 interspinous muscles
Referral Patterns

- Upper cervical joints and disks

C2-C3 Facet joint implicated as most common source of cervicogenic HA (up to 70% of cases)
Diagnostic criteria for Cervicogenic Headache

- International Headache Society

**Diagnostic criteria**

A. Pain referred from a source in the neck and felt in one or more regions of the head and/or face, fulfilling criteria C and D

B. Clinical, laboratory, and/or imaging evidence of a disorder or lesion within the cervical spine or soft tissues of the neck known to be, or generally accepted as, a valid cause of headache

C. Evidence that the pain can be attributed to the neck disorder or lesion based on at least one of the following: 1) evidence of clinical signs that implicate a source of pain in the neck; or 2) abolition of headache after diagnostic blockade of a cervical structure or its nerve supply with placebo or other adequate controls

D. Pain resolves within 3 months after successful treatment of the causative disorder or lesion
Cervicogenic Headache: Clinical Features

- Typically unilateral without shift
- May be variable in duration, or continuous
- Moderate intensity, typically non-throbbing
- More commonly affect females
- Pain originates in neck, refers to frontal/orbital/occipital areas
- May have ipsilateral shoulder/upper arm pain
- Uncommonly association with nausea/vomiting, photophobiaphonophobia
Cervicogenic Headache: Objective Findings

- Physical examination
  - Head forward posture
  - Decreased/asymmetrical cervical range of motion
  - Decreased cervical muscle endurance
  - Tenderness on palpation over triggering structure
  - Increased muscle tension on manual examination
  - Segmental restriction on manual examination

- No reliable imaging findings or biomarkers
Cervicogenic Headache: Conservative Treatment

- Medication
  - often ineffective; lacks scientific evidence
  - NSAID, TCA/muscle relaxer, topical analgesic patch

- TENS
  - May be effective; supported by uncontrolled studies with generally short-term follow up

- Manual therapy
  - May be effective; supported by several RCT’s of generally moderate quality
  - Postural education, general cervical stretching, and general aerobic exercise
A Role for Diagnostic Blocks

- Relief following diagnostic blockade of the presumed pain generating structure supports the diagnosis

- Likely targets:
  - C2-3 facet joint
  - Lateral A-A joint (C1-C2)
  - C2-C3 intervertebral disk (discography)

- Opponents cite negative RFA studies
- Proponents cite flaws in the negative studies
Cervicogenic Headache:
Interventional Treatment Options

- **Injections**
  - Greater occipital nerve block w/s corticosteroid
    - Supported by evidence from generally low quality studies, but widely recommended by many authors
  - Intra-articular corticosteroid injection (A-A joint, C2-3 facet)
    - Supported by studies of generally low quality

- **Percutaneous radiofrequency ablation**
  - Best evidence for C2-C3 facet denervation by ablating the 3rd occipital nerve
    - Methodologically sound RCT’s demonstrate good long term effectiveness in well-selected patients

- **Surgical intervention**
  - Procedures described include C2-3 fusion, lateral A-A arthrodesis, and neurolysis (Gr Occ N; C2 spinal n)
Cervicogenic Headache: Challenges

• The “Con” argument:
  – Lack of demonstrable cervical lesions
  – Cervical spine disease is very common, so why do the vast majority not experience cervicogenic HA?
  – Symptom overlap with other HA disorders
  – Inconsistency of interventional blocks

• Don’t forget about comorbidities!
  – Disordered sleep
  – Comorbid depression/anxiety/PTSD
  – Secondary gain
Cervicogenic Dizziness

• Not as well characterized as cervicogenic headache
• A non-specific sensation of altered orientation in space and disequilibrium originating from abnormal afferent activity from the neck
  – Must be accompanied by neck pain
  – Generally not a sensation of vertigo
  – Episodic lasting minutes to hours
  – Exacerbated by neck movement/pain
• A diagnosis of exclusion
  – Central and peripheral vestibular must be ruled out
Cervicogenic Dizziness: Anatomical basis

• Deep cervical musculature possess a high density of muscle spindles
  – Cervical afferents known to be involved in cervico-collic, cervico-ocular, and tonic neck reflexes
  – Assumed to play an important role in postural control

• Experimental evidence
  – Upper cervical dorsal root blockade can induce dizziness and nystagmus
  – Electrical stimulation of cervical muscles can induce sensations of tilting/falling
Cervicogenic Dizziness: Proposed mechanism

- Neck Pain
- Altered cervical somatosensory receptor firing patterns
- Sensory mismatch between vestibular and cervical input
- Cervicogenic Dizziness
Cervicogenic Dizziness: Treatment

- General recommendations:
  - Manual therapy
    - Mobilization, traction, modalities, postural re-education, range of motion, massage
  - Vestibular therapy
    - Compensation, adaptation, substitution, postural control exercises
- Moderate level of evidence to support manual and vestibular therapy
- May consider analgesics, muscle relaxers, trigger point injections, although evidence is lacking
Review: The Neck’s Role in Sport Related Concussion
Thank you!

• Questions/Comments?