Is There An Increased Risk Of Subsequent Musculo-skeletal Injury Following A Concussion?

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NIH National Institute of Neurological Disorders and Stroke

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Presentation Objectives

- 1. ~~Define Concussion~~
- **2. Concussion and Subsequent Lower Extremity Musculoskeletal (LEMSK) Injury Risk**
- 3. Predictors/Determinants of Subsequent LEMSK
- 4. Clinical "So What"

Concussion and Subsequent LEMSK

- There is overwhelming evidence supporting an elevated rate of subsequent musculoskeletal (MSK) injury in the 1 – 2 years following a concussion
  - High School
  - College
  - Professional

Concussion and Subsequent LEMSK Professional Sports

Authors	Population	Results	Main Findings
Makdissi et al, 2009	Professional Australian Football	Non-Significant ↑ 2.23x elevated risk	Only investigated the next football match, elevated non-significant rate
Nordstrom et al, 2014	Professional Soccer Union of European Football Associations	<3 Months: ↑ 1.56x, 3 – 6 Months: ↑ 2.78x 6 – 12 Months: ↑ 4.07x	Concussion was risk factor for sustaining subsequent MSK in following year. MSK rate also elevated in prior year
Cross et al, 2016	Professional Rugby (England)	2 year cohort: ↑ 1.6x	60% greater risk of time-loss injury than players without concussion
Pietrosimone et al, 2015	Retired NFL FB Players. Self report of "serious" injuries	1 Concussion: ↑ 1.59x 2 Concussions: ↑ 2.29x ≥3 Concussions: ↑ 2.86x	Dose response elevated risk of serious injury. Time sequence is unknown (chicken & egg)
Nyberg et al, 2015	Swedish Pro hockey over 28 years	No overall elevated risk ↑ risk serious injury	Increased risk of serious injury (>28 days time loss) within 21 days of RTP post-concussion
Browne (unpublished)	3 Seasons of NFL Players on Injury Reports	No elevated risk (p=0.166, OR: 0.519)	No increased chance of appearing on the injury report following a concussion.

Concussion and Subsequent LEMSK College Sports

Authors	Population	Results	Main Findings
Lynall et al, 2015	D1 College Athletes	180 Days: ↑ 2.02x 365 Days: ↑ 1.97x	Greater Risk to sustain subsequent LE MSK after Concussion than before
Brooks et al, 2016	D1 College Athletes	90 Days: ↑ 2.48x	Concussed athletes at increased risk of LE MSK after RTP than non-concussed teammates
Herman et al, 2016	D1 College Athletes	90 Days: ↑ 3.39x	Elevated injury risk, but no difference in time loss if injured.
Gilbert et al, 2016	Collegiate Athletes (D1, D2, D3, NJCAA)	↑ 1.61 – 2.87x ACL Issue	Assessed reported, unreported, unrecognized concussions. Time sequence unknown (Chicken & Egg)
Houston et al, 2018	D1 College Athletes	↑ Ankle Sprain; 1.12x ↑ Knee Injury: 1.09x	Sex and Concussion hx issues Time sequence unknown (Chicken & Egg)
Fino et al, 2017	D1 College Athletes	↑ 1.67x LE MSK	Replication of prior studies Controlled for prior injury.

Concussion and Subsequent LEMSK Other Sports

Authors	Population	Results	Main Findings
Burman et al, 2016	Mixed athletes, 15 – 35 y.o. in Sweden. Hospital EMR Review	Pre-Concussion: ↑1.98x Post-Concussion: ↑ 1.72x No difference Pre vs Post	Elevated Rate both Pre & Post Injury Prone? More Aggressive/Risk Tasking Behavior?
Kardouni et al, 2018	23,044 Soldiers over 2 years	↑ 38% risk of LE MSK	Similar results between college athletes and military soldiers.
Lynall et al, 2017	High School, NATION Surveillance System	For each concussion, 34%↑ risk of time loss LE MSK	Concussion not associated with prior LE MSK. Data mining limitations

- As there are ~8,000,000 high school athletes, clearly more research is needed in this population
- No studies investigating youth sports and their ~21m – 45m athletes

Concussion and Subsequent LEMSK

- **TAKE HOME**: There is overwhelming evidence supporting an elevated rate of subsequent musculoskeletal (MSK) injury in the 1 – 2 years following a concussion

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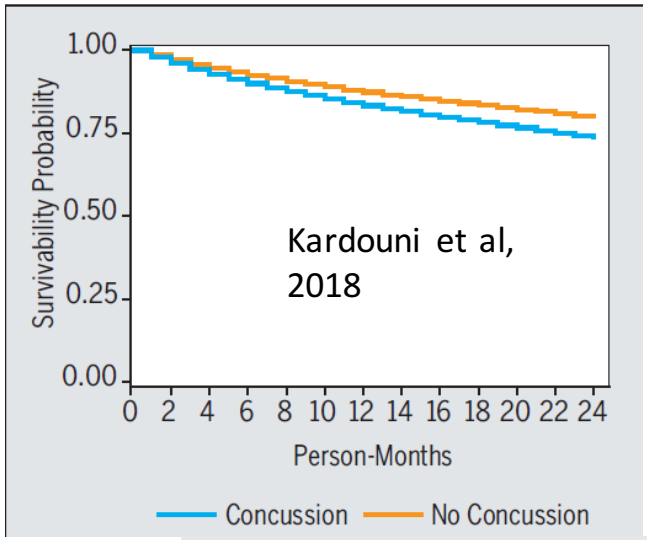
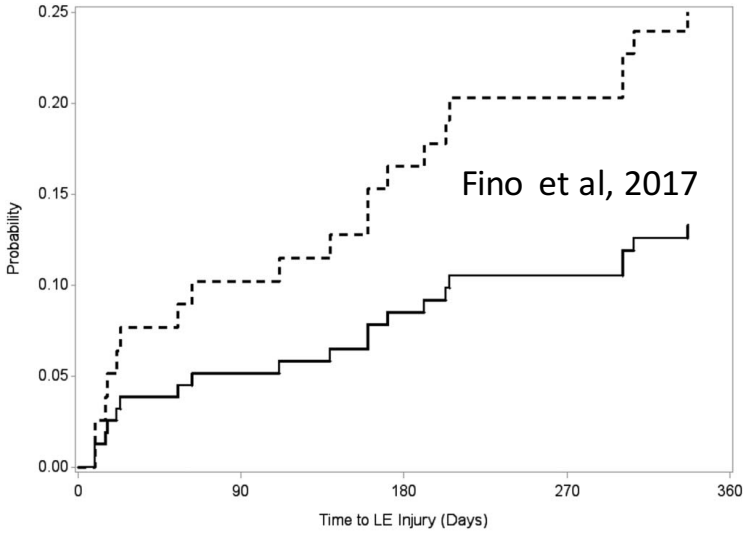
Acutely Post-Concussion: Out of "Game" Shape?



Kardouni et al, 2018



Fino et al, 2017

	At least one injury (n=874)		At least one sudden onset injury (n=709)	
	HR	95% CI	HR	95% CI
0 to <3 months	1.56	1.09 to 2.23	1.76	1.12 to 2.76
3 to <6 months	2.78	1.58 to 4.89	3.00	1.52 to 5.92
6 to 12 months	4.07	2.14 to 7.76	3.69	1.72 to 7.95

Nordstrom et al, 2014

Potential Predictor: Injury Prone

- Mixed Results
  - Lynall et al, 2015 - No

	Group with Concussion					Control Group				
	Injury Incidence					Injury Incidence				
	Before	After	Risk Ratio	95% CI	*P* Value	Before	After	Risk Ratio	95% CI	*P* Value
90 d	2.17	4.55	2.10	0.91–4.81	0.07	3.27	3.10	0.95	0.48–1.90	0.89
180 d	2.05	4.14	2.02	1.08–3.78	0.02	3.08	2.55	0.83	0.48–1.42	0.50
365 d	1.78	3.51	1.97	1.19–3.28	0.01	2.56	2.14	0.83	0.53–1.30	0.42

  - Nordstrom et al, 2014 - Yes

Table 1 Characteristics of players according to the occurrence of concussion during total follow-up time

	Concussion (n=66)	No concussion (n=1599)	p Value
Mean number of injuries during total follow-up period	11.5±8.6	5.0±5.2	<0.001
Mean number of injuries in the year preceding concussion or randomly selected injury	1.8±1.6	0.9±1.4	<0.001

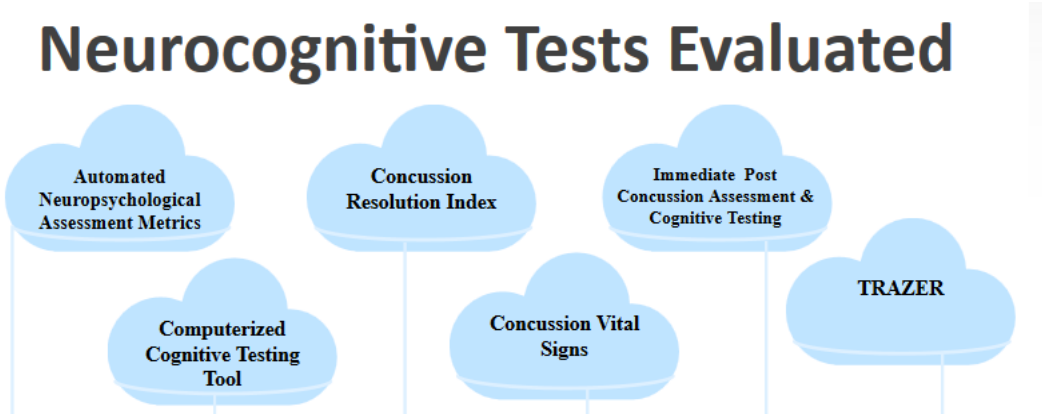
Predictor:
Incomplete Neurophysiological Recovery

What is the physiological time to recovery after concussion? A systematic review

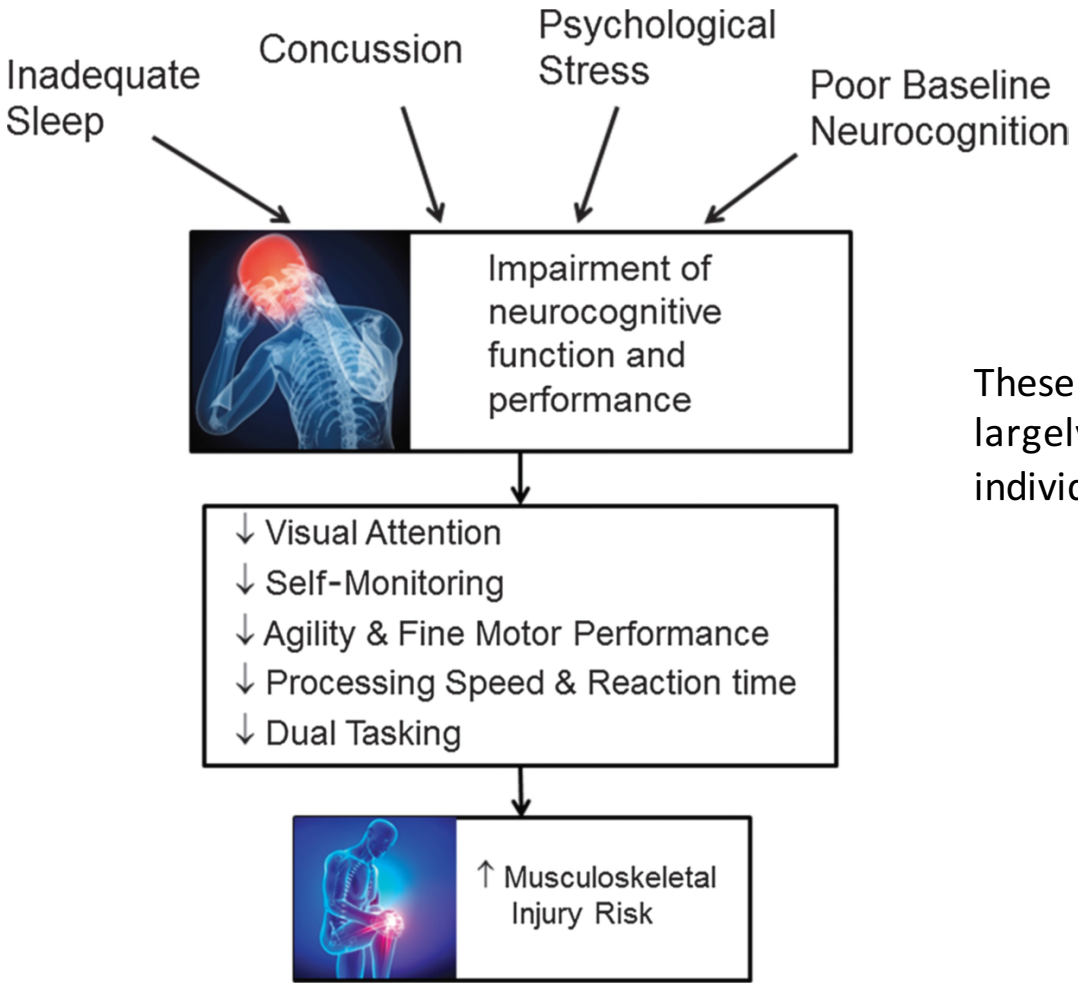
Joshua Kamins,[1,2] Erin Bigler,[3] Tracey Covassin,[4] Luke Henry,[5] Simon Kemp,[6] John J Leddy,[7] Andrew Mayer,[8] Michael McCrea,[9] Mayumi Prins,[10] Kathryn J Schneider,[11] Tamara C Valovich McLeod,[12] Roger Zemek,[13] Christopher C Giza[1,2,14]

Predictor: Neurocognitive Performance

Dimension	Working Definition
Visual attention	The ability to concentrate on visual input to the exclusion of other less essential stimuli
Self-monitoring	The ability to focus on proprioceptive/kinesthetic feedback
Agility/fine motor skill	The ability to make minor adjustments in motor activity
Processing speed/reaction time	The ability to engage in stimulus-response behavior within an intended time frame
Dual tasking	The ability to engage in two activities at the same time to maximize goal attainment



Predictor: Neurocognitive Performance



These variables have largely not been individually evaluated.

Predictor: Neurocognitive Performance

TABLE 3
Neuropsychological Test Score for NCACL and Control Groups (n = 160)[a]

Neurocognitive Test	Mean ± SD	F Test (score)	*P* Value	Effect Size Cohen *d*	95% CI Lower	95% CI Upper
Verbal memory 77, 79						
NCACL	.84 ± .08	4.08	.045[b]	–.47	.83	.86
Control	.88 ± .09				.85	.89
Visual memory 66						
NCACL	.72 ± .12	19.16	.00[c]	–.77	.70	.76
Control	.82 ± 14				.79	.85
Processing speed 33						
NCACL	36.9 ± 6.6	12.04	.001[c]	–.55	35.3	38.6
Control	41.0 ± 8.2				39.4	42.7
Reaction time (ms) .65						
NCACL	.57 ± .07	9.66	.002[c]	.46	.55	.59
Control	.53 ± .10				.51	.55

Am J Sports Med. 2007 Jun;35(6):943-8. Epub 2007 Mar 16.

The relationship between neurocognitive function and noncontact anterior cruciate ligament injuries.

Swanik CB[1], Covassin T, Stearne DJ, Schatz P.

Predictor: Neurocognitive Performance

- Concussion Clinical Assessment Battery (Howard Thesis)
  - No significant differences in baseline performance on the concussion assessment battery between those with and without a post-concussion subsequent LE MSK.
  - No significant differences in acute post-concussion performance on the concussion assessment battery between those with and without a post-concussion subsequent LE MSK.
  - No significant differences at RTP on the concussion assessment battery between those with and without a post-concussion subsequent LE MSK.
  - Does change from baseline to post-concussion predict subsequent LE MSK – still a work in progress…..

Predictor: Dual Task Postural Control

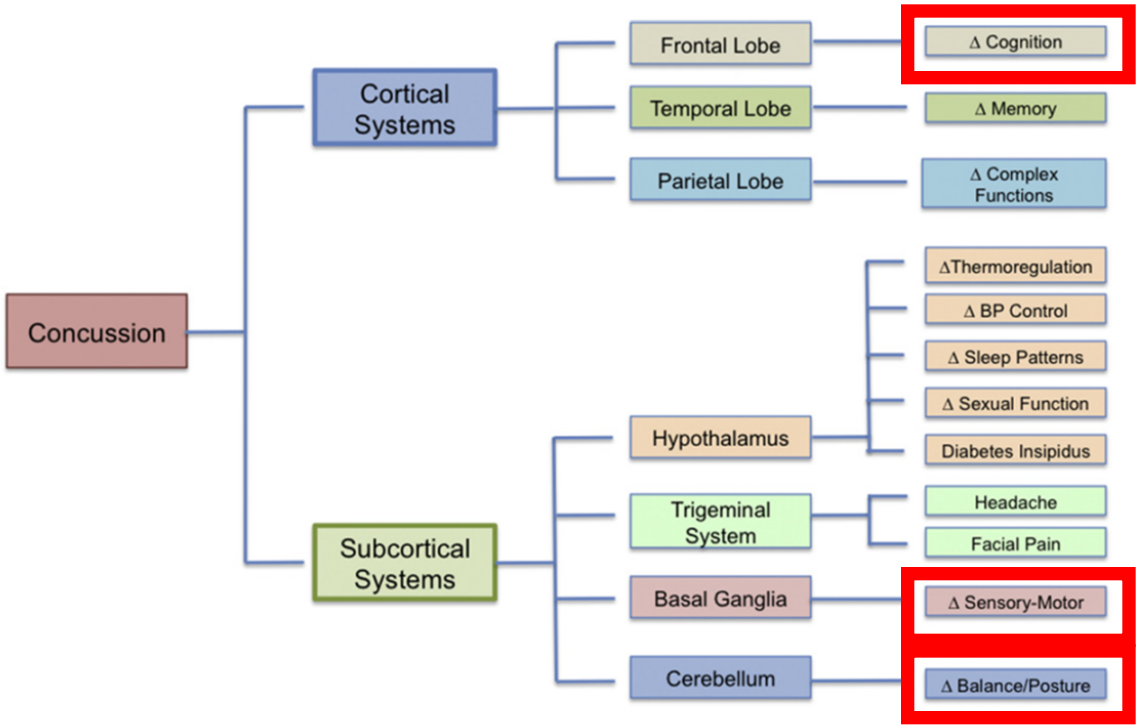


Fig. 4. Brain-related behavioral changes. Conceptualized regional brain involvement and the potential consequences of concussion.

https://www.ncbi.nlm.nih.gov/pubmed/20039582

J Geriatr Phys Ther. 2009;32(2):46-9.

White paper: "walking speed: the sixth vital sign".

Fritz S[1], Lusardi M. PMID: 20039582

- Walking speed is “almost the perfect measure.” A reliable, valid, sensitive and specific measure, self-selected walking speed (WS), also termed gait velocity, correlates with functional ability, and balance confidence.
- It has the potential to predict future health status, and functional decline including hospitalization, discharge location, and mortality.
- WS reflects both functional and physiological changes, is a discriminating factor in determining potential for rehabilitation, and aids in prediction of falls and fear of falling.
- Furthermore, progression of WS has been linked to clinical meaningful changes in quality of life and in home and community walking behavior.
- Clinically significant/meaningful differences range from 0.06 – 0.10m/s change

Predictor: Dual Task Postural Control

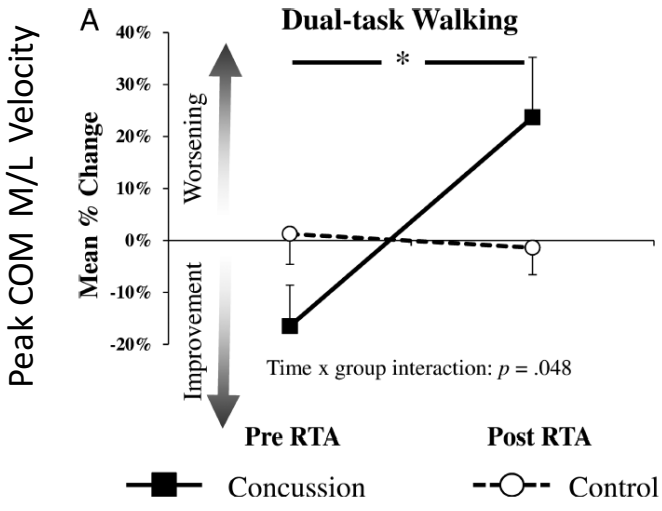
- 2 tests→1 evaluation: simultaneous motor and cognitive function
  - Highly consistent measure across time (Howell et al., *Gait & Posture*, 2016)
- Easy to modulate cognitive perturbations to make the task more or less challenging
- Dual-task costs: the relative change between single-task and dual-task conditions.
  - Individualized measure of how an added cognitive task affects gait

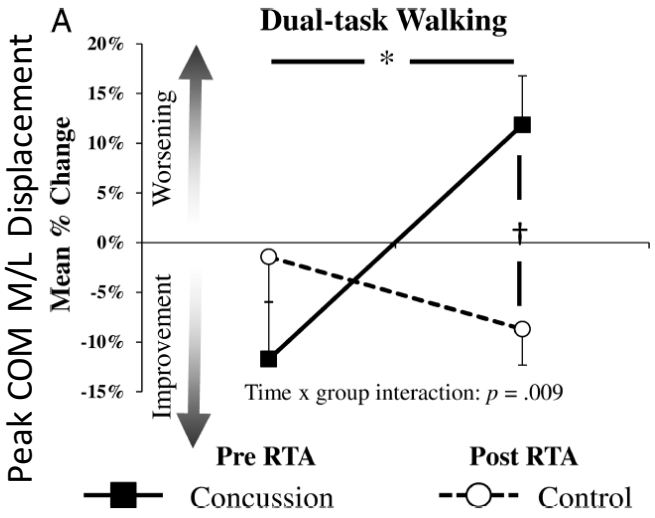
Predictor:
Incomplete Neurophysiological Recovery

Return to Activity after Concussion Affects Dual-Task Gait Balance Control Recovery

DAVID R. HOWELL, LOUIS R. OSTERNIG, and LI-SHAN CHOU

Department of Human Physiology, University of Oregon, Eugene, OR





Predictor: Dual Task Postural Control

JOURNAL OF NEUROTRAUMA 35:1630–1636 (July 15, 2018)

DOI: 10.1089/neu.2017.5570

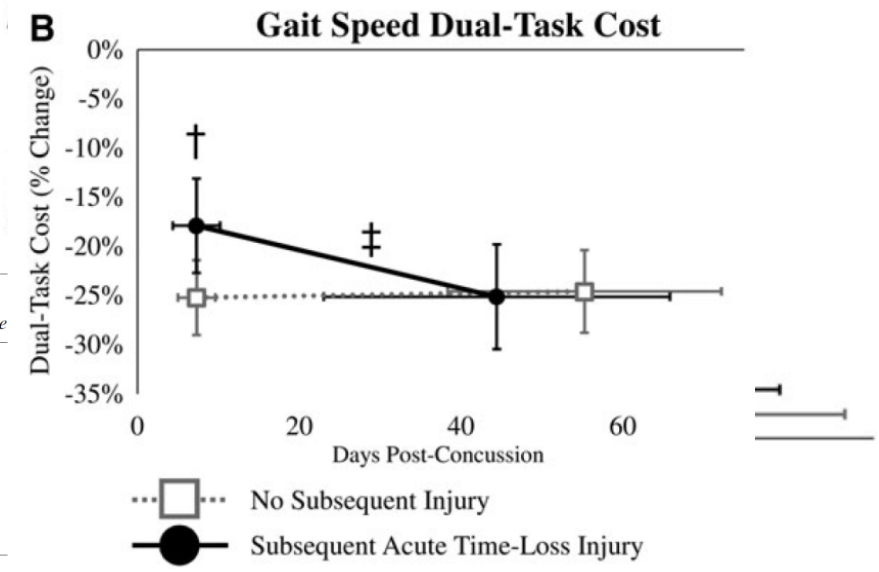
Worsening Dual-Task Gait Costs after Concussion and their Association with Subsequent Sport-Related Injury

David R. Howell,[1–3] Thomas A. Buckley,[4,5] Robert C. Lynall,[6] and William P. Meehan III[3,7,8]

- 42 Adolescents tested acutely post-concussion and then again at RTP clearance on DT Gait.

TABLE 1. MEAN (95% CONFIDENCE INTERVAL) OR *N* (%) DEMOGRAPHIC CHARACTERISTICS OF STUDY PARTICIPANTS

Variable	*No subsequent injury* (n = 27)	*Subsequent Injury* (n = 15)	P *value*
Age (years)	16.1 (14.7–17.6)	17.4 (15.7–19.0)	0.25
Height (cm)	167.6 (161.3–173.8)	171.0 (164.8–177.2)	0.45
Mass (kg)	65.1 (56.0–74.1)	73.8 (58.7–89.0)	0.31
Prior lifetime concussions	1.0 (0.4–1.5)	0.6 (0.2–1.1)	0.45
Female gender	14 (54%)	7 (47%)	0.75
Concussion symptom resolution time (days)	43.1 (24.3–61.8)	33.4 (5.1–61.6)	0.52
Test time (days post-concussion): Test 1	7.5 (5.2–9.8)	7.6 (4.1–11.0)	0.94
Test time (days post-concussion): Test 2	59.1 (41.5–76.)	45.6 (19.0–72.1)	0.37
Subsequent injury question response time (days)	373 (367–379)	375 (369–380)	0.60



Predictor: Dual Task Postural Control

- Stronger evidence, but still in review.
- Collegiate student athletes (N=34) tested at baseline and at clinical RTP (21.9 days)

Basketball: 0/2
Cheerleading: 0/1
Cross Country: 0/1
Field Hockey: 0/1
Lacrosse: 2/2
Soccer: 3/0
Swimming: 0/1
Volleyball: 0/3

Football: 3/0
Lacrosse: 5/2
Rowing: 0/1
Soccer: 2/2
Softball: 0/1
Volleyball: 0/2

In Review, Oldham et al.

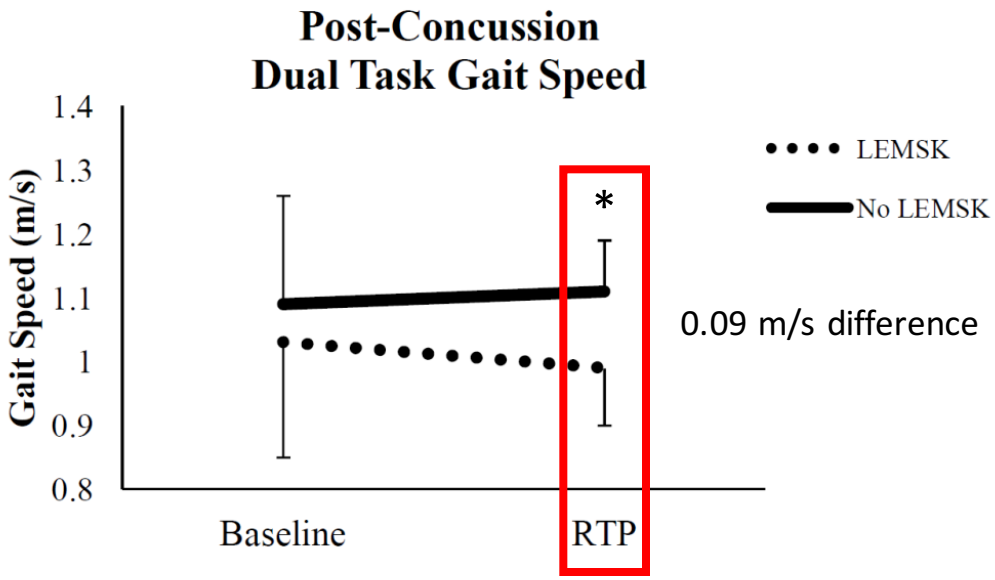
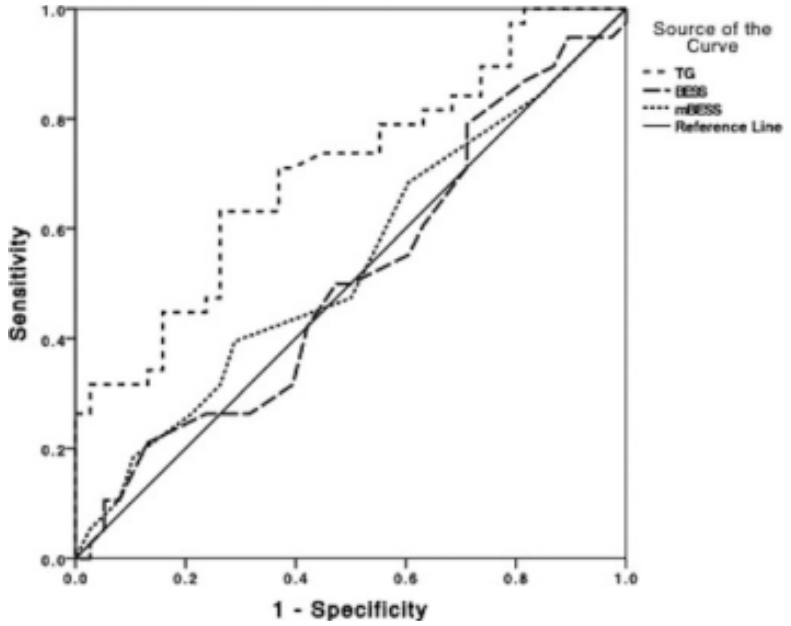


Figure 1B. There was a significant group effect (F= 5.75, p= 0.02) for DT gait speed between those who did and did not sustain a subsequent LEMSK injury following concussion.

Predictors: Best Guess

- Incomplete neurological recovery at clinical “recovery” and across the progressive return to participation protocol.
- Current tests lack sensitivity to identify these differences
- Tests which do identify sensitivity are generally not clinically feasible.
- Dual Task Tandem Gait?
- Smart Phone Gait Assessment?



Med Sci Sports Exerc. 2018 Jun;50(6):1162-1168. doi: 10.1249/MSS.0000000000001540.

Efficacy of Tandem Gait to Identify Impaired Postural Control after Concussion.

Oldham JR[1], Difabio MS[1,2], Kaminski TW[1], Dewolf RM[3], Howell DR[4], Buckley TA[1,2].

Author information

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4 Sports Medicine Center, Colorado Children's Hospital, Department of Orthopedics, University of Colorado School of Medicine, Aurora, CO.

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Clinical "So What"?

- IF there's an elevated risk of injury due to lingering impairments in postural control – what can we can about it?
- Does CARE provide any helpful aspects to address this?
- Prolonged time loss/restriction from play?
  - 2001 NCAA FB Study: Average Time Loss = 6.1 Days
  - CARE Consortium: Average Time Loss = 14.3 Days
    - http://www.ncaa.org/about/resources/media-center/news/researchers-discuss-initial-care-concussion-study-findings
- Same Day RTP
  - 2001 NCAA FB Study: 15.3% (30/196) same day RTP
  - CARE Consortium: 0 Same Day RTP
- Recurrent Concussion
  - 2001 NCAA FB Study: 91.7% same season repeat concussions <10 days
  - CARE Consortium: 0 same season repeat concussions <10 days.

Clinical “So What”?

- IF there’s an elevated risk of injury due to lingering neurological impairments– what can we can about it?
  - Reporting Issues?

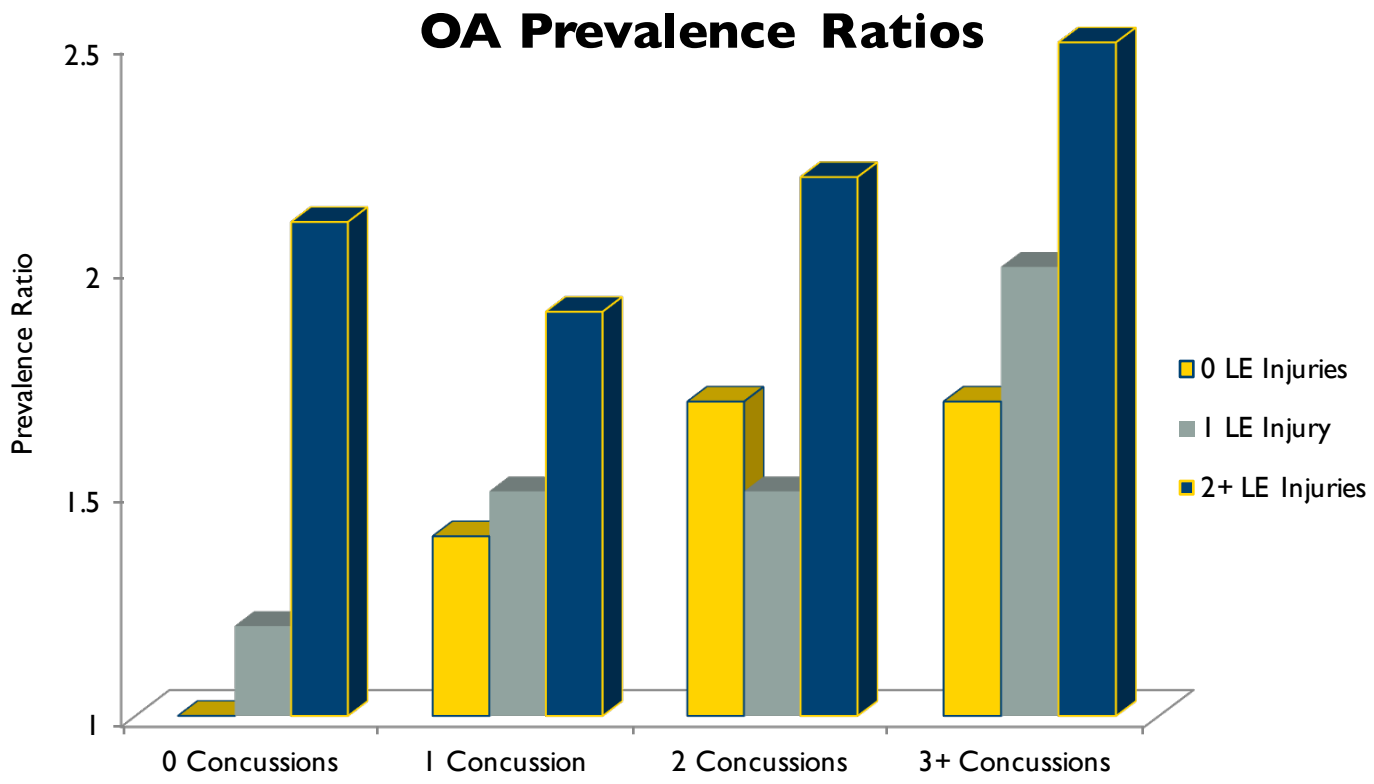
		Days Missed	
Group	No.	Median (Range)	Mean ± SD
Total	97	7 (3–67)	9.6 ± 9.3
Immediate removal from activity	47	6 (3–15)	6.8 ± 2.6
Delayed removal from activity	50	9 (3–67)	12.3 ± 12.2

J Athl Train. 2016 Apr;51(4):329-35. doi: 10.4085/1062-6050-51.5.02. Epub 2016 Apr 25.

"Playing Through It": Delayed Reporting and Removal From Athletic Activity After Concussion Predicts Prolonged Recovery.

Asken BM[1], McCrea MA, Clugston JR[2], Snyder AR[1], Houck ZM[1], Bauer RM[1].

Long-term Consequences?



J Athl Train. 2017 Jun 2;52(6):518-525. doi: 10.4085/1062-6050-52.2.03.

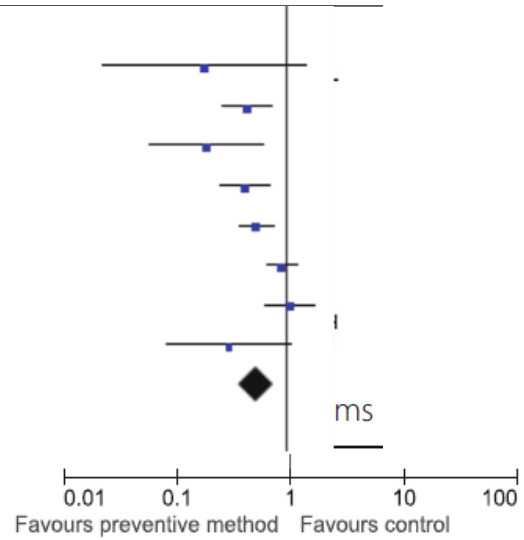
Osteoarthritis Prevalence in Retired National Football League Players With a History of Concussion and Lower Extremity Injury.

Lynall RC[1,2], Pietrosimone B[3,4,2], Kerr ZY[5], Mauntel TC[4,2], Mihalik JP[1,2], Guskiewicz KM[1,2].

What can we do about this?

- Injury prevention programs? (e.g., FIFA 11+)
  - Often unsuccessful because of lack of time, lack of buy-in, and lack of successful execution of the program.

3.1.4 Warm-up programs						
Gilchrist et al. 2008	2	583	10	852	1.0%	0.29 [0.06, 1.33]
LaBella et al. 2011	47	737	83	755	3.8%	0.55 [0.38, 0.80]
Longo et al. 2012	14	80	17	41	2.2%	0.30 [0.13, 0.70]
Olsen et al. 2005	46	958	76	879	3.8%	0.53 [0.37, 0.78]
Soligard et al. 2008	121	1055	143	837	4.2%	0.63 [0.48, 0.82]
Steffen et al. 2008	204	1073	192	947	4.3%	0.92 [0.74, 1.15]
van Beijsterveldt et al.	135	223	139	233	3.8%	1.04 [0.71, 1.51]
Waldén et al. 2012	7	2479	14	2085	2.1%	0.42 [0.17, 1.04]
Subtotal (95% CI)		**7188**		**6629**	**25.3%**	**0.64 [0.49, 0.83]**
Total events	576		674			



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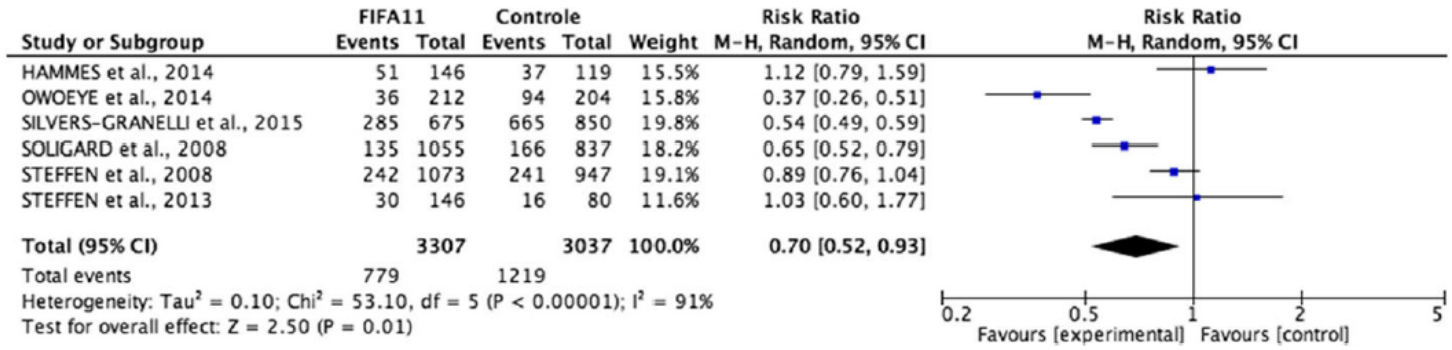

Study or Subgroup	FIFA11 Events	Total	Controle Events	Total	Weight	Risk Ratio M-H, Random, 95% CI
HAMMES et al., 2014	51	146	37	119	15.5%	1.12 [0.79, 1.59]
OWOEYE et al., 2014	36	212	94	204	15.8%	0.37 [0.26, 0.51]
SILVERS-GRANELLI et al., 2015	285	675	665	850	19.8%	0.54 [0.49, 0.59]
SOLIGARD et al., 2008	135	1055	166	837	18.2%	0.65 [0.52, 0.79]
STEFFEN et al., 2008	242	1073	241	947	19.1%	0.89 [0.76, 1.04]
STEFFEN et al., 2013	30	146	16	80	11.6%	1.03 [0.60, 1.77]
Total (95% CI)		**3307**		**3037**	**100.0%**	**0.70 [0.52, 0.93]**
Total events	779		1219			

Heterogeneity: $Tau^2 = 0.10$; $Chi^2 = 53.10$, df = 5 ($P < 0.00001$); $I^2 = 91\%$
Test for overall effect: Z = 2.50 (P = 0.01)

Fig. 2 Analysis of the six independent samples, relating to the risk of injury in patients with different injury prevention programs

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QUESTIONS

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