

Development of Data-Driven, Individual-Specific Interventions for WMSD Prevention

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SPINE BIOMECHANICS

UNIVERSITY OF
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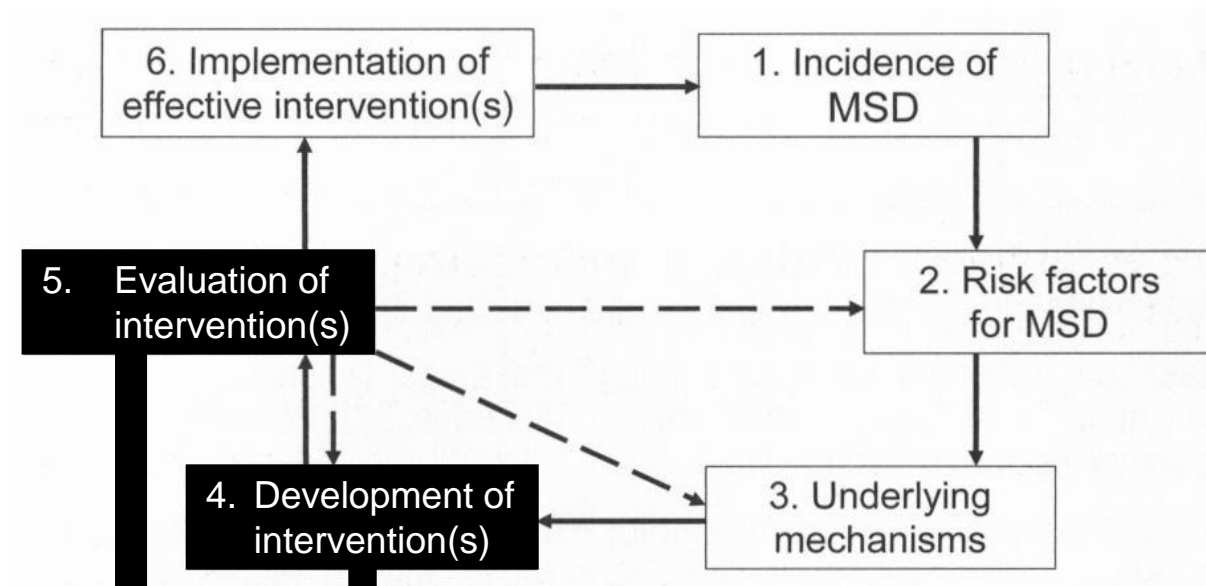
Work-related Musculoskeletal Disorders (WMSD)



Oranye & Bennett, Ergonomic, 2018; Sarkar et al., Int. J. Occup. Environ. Health, 2016



Primary WMSD Prevention



- Identifying effective approaches for interventions
- Evaluating intervention efficacy

van der Beek et al., Scand J Work Environ Health, 2017



Engineering Controls



Powered Ambulance Cot
Stryker



**Automated Medication
Crusher**
Powder Crush



Patient Transfer Board
SafetySure

Armstrong et al., Appl Ergon, 2017; Lavender et al., Appl Ergon, 2003

Movement Training





Training Methods Elicit Spine-Sparing Movement



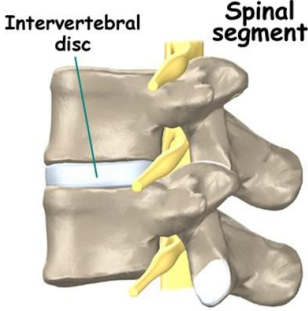
Visual Aids for Safe Lifting

From StateFoodSafety

Education

INTERVERTEBRAL DISCS

- ❖ Separates vertebrae and acts as a shock absorber
- ❖ Degeneration can occur with chronic compressive forces or a single acute injury
- ❖ Becomes less elastic with degeneration and can rupture, bulging outwards towards the spinal cord.



©MMG 2002

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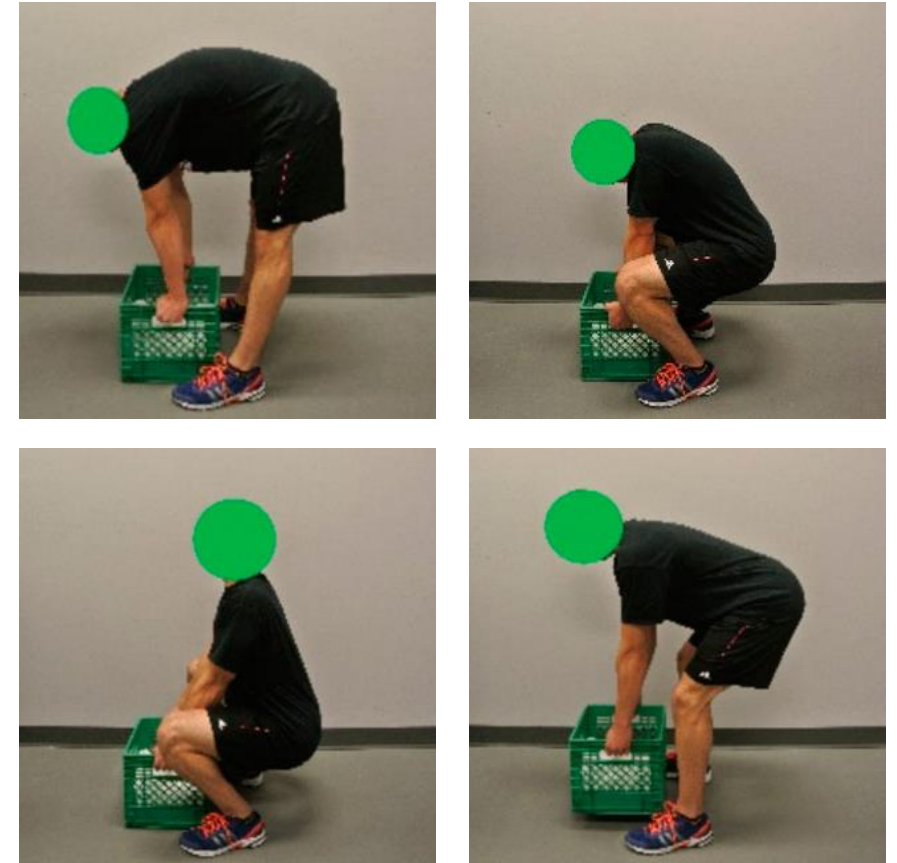


Augmented Feedback



Can visual aids elicit changes in spine motion during lifting?

- Asked to replicate postures in lifting images
 - Displaying different amounts of knee & spine flexion
- Significant differences in spine kinematics between image conditions
- Greatest reduction in peak spine angles & velocities *did not correspond* to image with “best” spine position



Chan et al., *Int J Occup Saf Ergon*, 2019

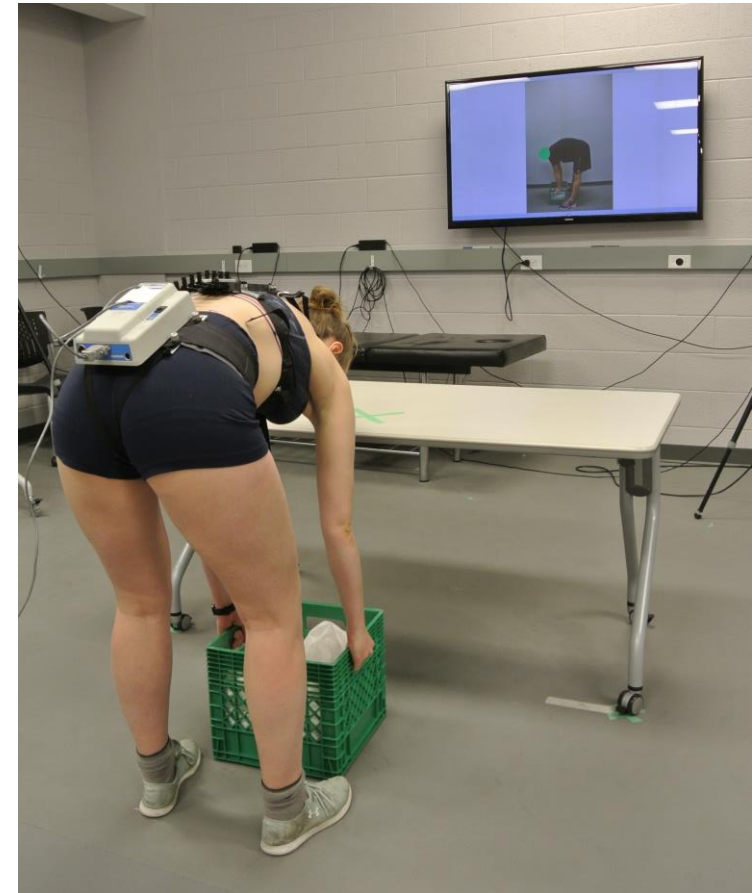


Can visual aids elicit changes in spine motion during lifting?

Yes, but images may not elicit the desired effect on their own.

Perhaps due to limitations in:

- Awareness
- Strength
- Mobility
- Coordination



Chan et al., Int J Occup Saf Ergon, 2019



Education-based Manual Handling Training

SAFE PRINCIPLES OF LIFTING

- Situation
- Prepare
- Interact
- Neutral spine
- Execute
- Smooth



- ❑ Decreased load on the structures of the spine and its supporting muscles
- ❑ Keep core muscles tight to maintain stable spine

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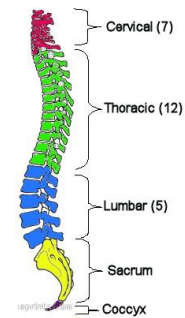
Safe Lifting Principles

Chan et al., in review

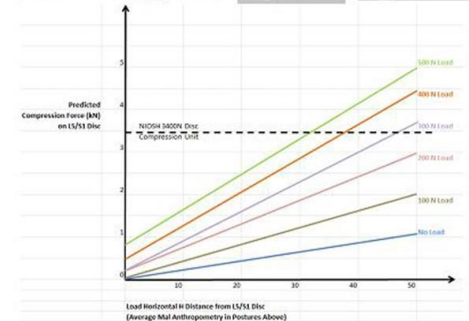
Anatomy

THE SPINE

- ❑ Composed of bones, discs, nerves, muscles and ligaments
- ❑ When an injury occurs, one or more of these structures are damaged and the spine is unable to function properly



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Biomechanics



Feedback-based Manual Handling Training

1 IN LINE
(Knee in line with hip/feet)

What to Look For

1. Body from the front
2. Line from hip to toes
3. Position of knee in relation to line
 - Medial to the line
 - On the line
 - Lateral to the line

Coaching Tips

- Grip the floor with the toes
- Push the knees out
- Point knees in direction of toes

2 MID-FOOT
(Bodyweight over mid-foot)

What to Look For

1. Body from the side
2. Line through middle of foot
3. Position of weight in relation to line
 - In front of the line (toes)
 - On the line (arch)
 - Behind the line (heel)

Coaching Tips

- Push through the floor
- Grip the floor with the toes
- Hinge at hips, lean forward.

3/4 STRAIGHT
(Normal low back curve)

What to Look For

1. Body from the front, back or side
2. Two lines through hips/upper back
3. Distance between the two lines
 - Closer than standing
 - Same as standing
 - Farther apart than standing

Coaching Tips

- Stiffen trunk
- Let trunk move with hips
- Dowel touches head, back, hips

5 ALIGNED
(Hips and shoulders aligned)

What to Look For

1. Body from the front, back or side
2. Two lines through hips/upper back
3. Alignment of the two lines
 - Shoulders rotate more than hips
 - Shoulders in line with hips
 - Hips rotate more than shoulders

Coaching Tips

- Use upper/lower body together
- Rotate with hips
- Practice with one hand

6 DOWN
(Shoulders away from ears)

What to Look For

1. Body from the front, back or side
2. Two lines through ears/shoulders
3. Distance between the two lines
 - Closer than standing
 - Same as standing
 - Farther apart than standing

Coaching Tips

- Elbows down/close to body
- Treat elbows as push and pull
- Hold shoulders back

7 BACK
(Elbow and shoulder together)

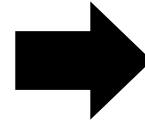
What to Look For

1. Body from the front, back or side
2. Line from shoulder to elbow
3. Movement at both ends of the line
 - Move in opposite direction
 - Move in same direction
 - Only one end moves

Coaching Tips

- Rotate thumbs out when pulling
- Pull shoulder blades together
- Limit how far elbows pulled back

PERFORMANCE REDEFINED.



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(Normal low back curve)

What to Look For

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Coaching Tips

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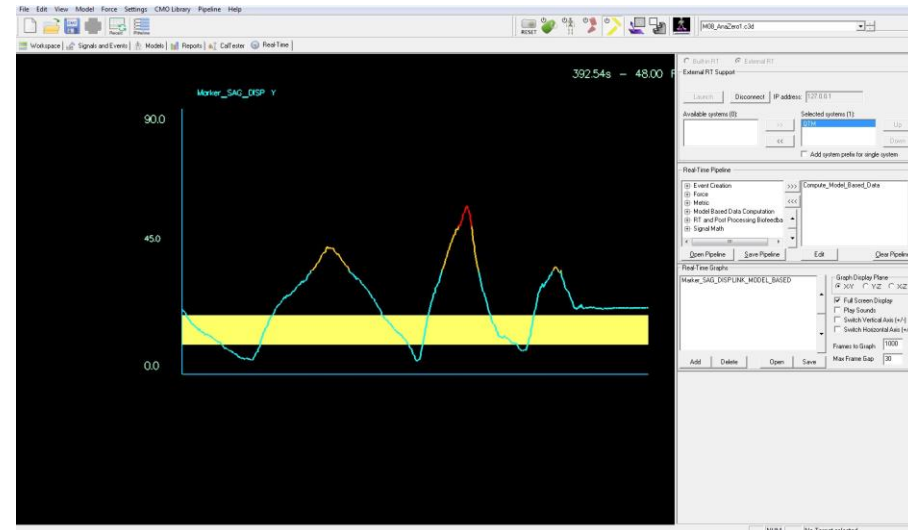
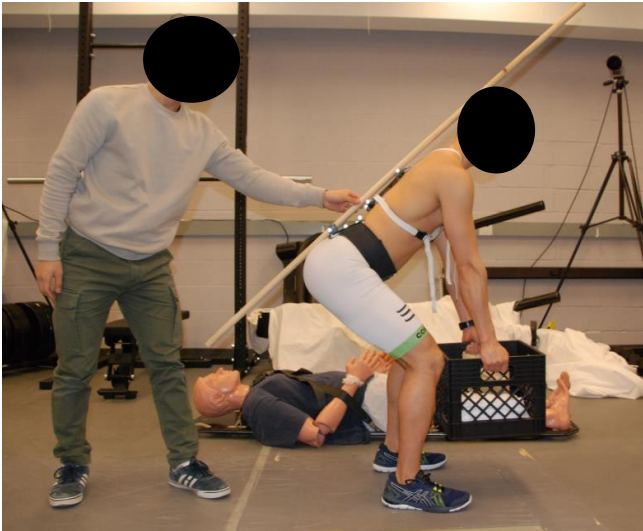
Neutral Spine

The 7 'Key' Features
From Performance Redefined



Comparison of Approaches to Movement Training

- Didactic (DID) compared to augmented feedback (AUG) interventions
- Both interventions had 5 sets of 10 practice lifts



Chan et al., in review

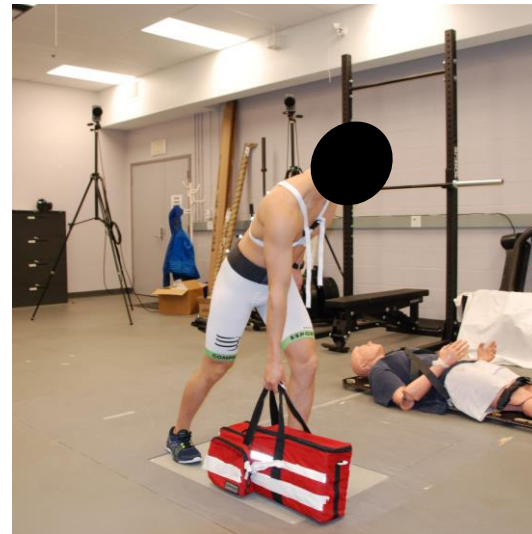


Comparison of Approaches to Movement Training

- Tested immediately after and one-week after interventions



6kg



8.7kg



82.5kg shared

Chan et al., in review



Both interventions elicited reductions in spine motion after one-week

Number of significantly reduced LBD risk factors with after 1-week

Lifting Task	DID	AUG
Box	2 of 4	4 of 4
Medication Bag	4 of 4	4 of 4
Backboard	0 of 4	1 of 4

Chan et al., in review



AUG elicited equal or greater reductions in spine motion compared to DID

Lifting Task	Absolute peak spine flexion angle	Relative peak spine flexion angle	Peak spine flexion velocity	Peak spine extension velocity
Box	AUG	×	AUG	AUG
Medication Bag	×	×	×	×
Backboard	×	×	AUG	AUG*

**Difference found immediately post-intervention only*

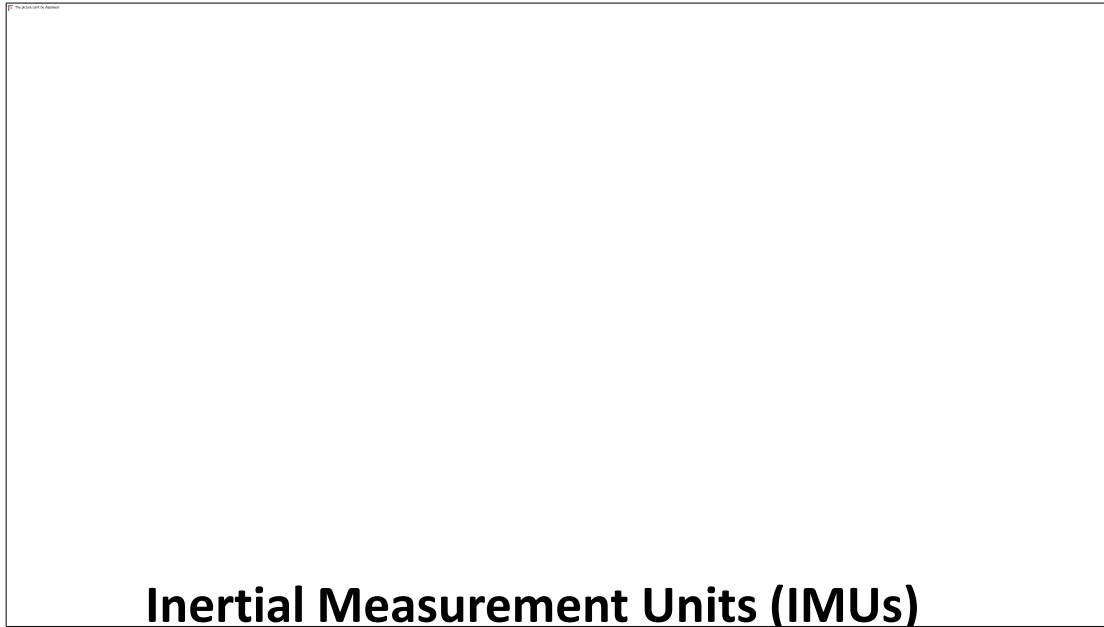
× = no difference between DID and AUG

AUG = AUG elicited significantly larger reduction compared to DID

Chan et al., in review



Real-time WMSD Risk Monitoring



Inertial Measurement Units (IMUs)

Xsens DOT

Chan et al., in review



Insole Plantar Pressure Monitoring System

Tekscan F-Scan System

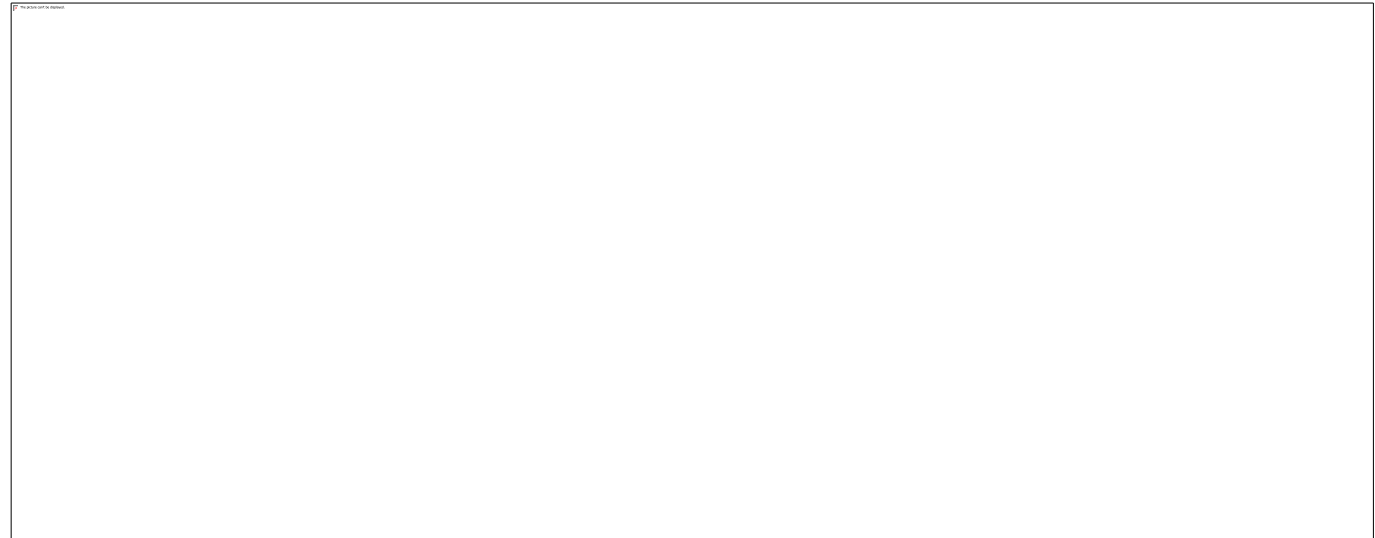


Lee et al., Automat Constr, 2020



Individual-specific method to recognize atypical spine motion using wearable sensors

- Asked to perform 50 spine flexion-extensions
 - 11 sets or until fatigued
 - Assessed using visual analogue scale & maximal lift strength
- 2× IMUs: Pelvis & T8 vertebrae

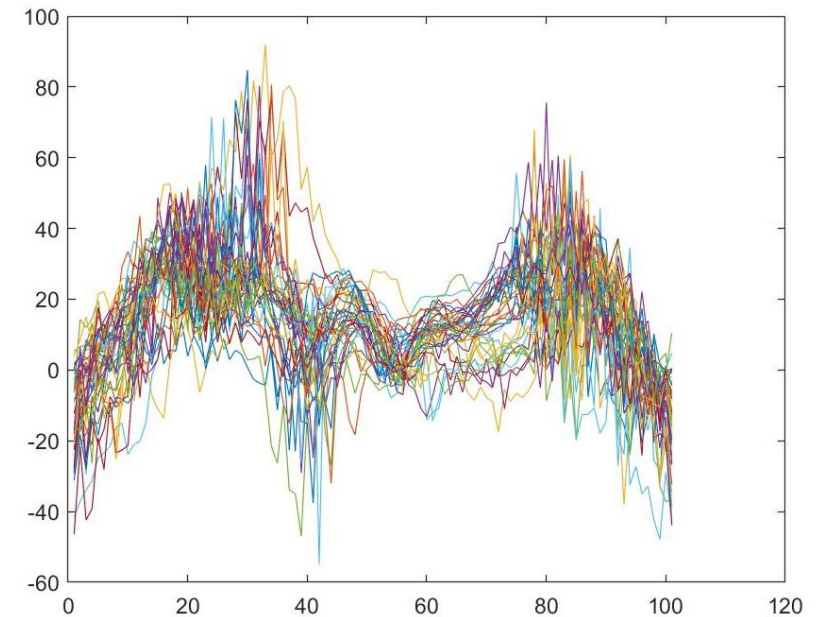


Chan et al., Sensors, 2020



10-feature spine motion composite index (SMCI)

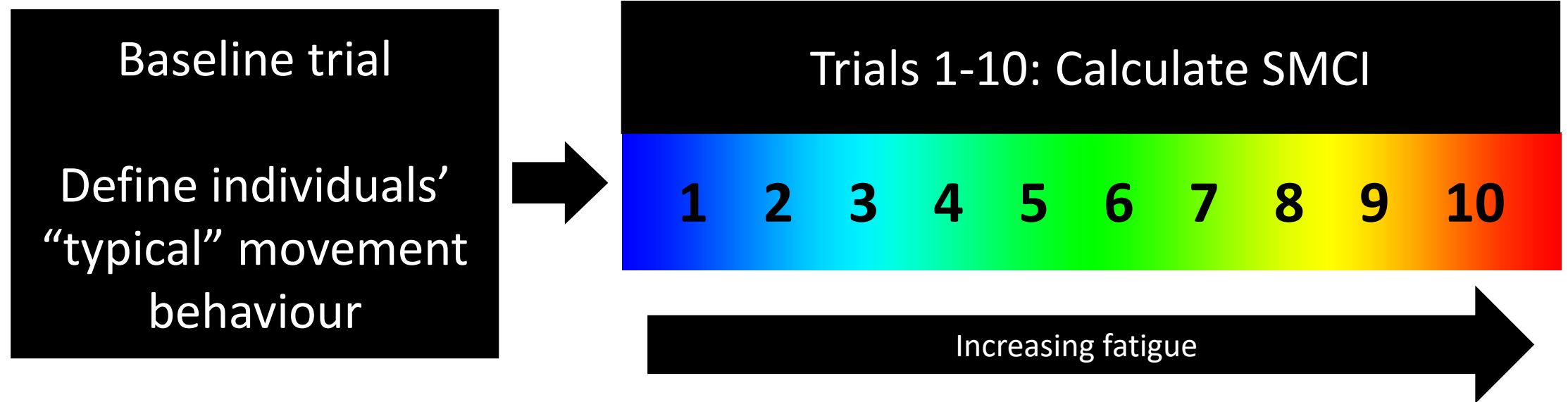
- Peak thoraco-pelvic continuous relative phase (CRP)
- Repetition time
- Pelvis & T8 vertebrae:
 - Orientation range
 - Peak orientation
 - Peak angular velocity
 - Peak angular acceleration



Thoraco-pelvic CRP



10-feature spine motion composite index (SMCI)





SMCI correlated with increases in fatigue



SMCI & Fatigue visual analogue scale



SMCI & Maximal lift strength

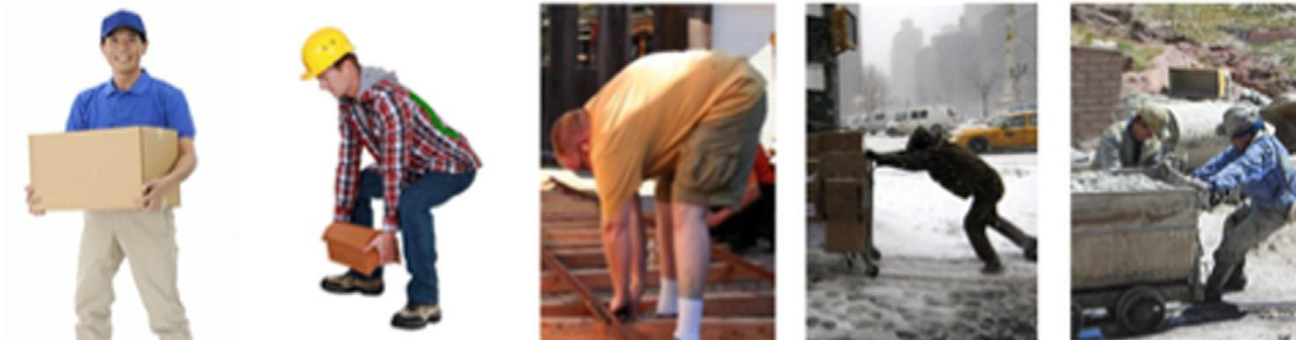
- Strong correlations when averaged
- Moderate repeated measures correlations

Chan et al., Sensors, 2020



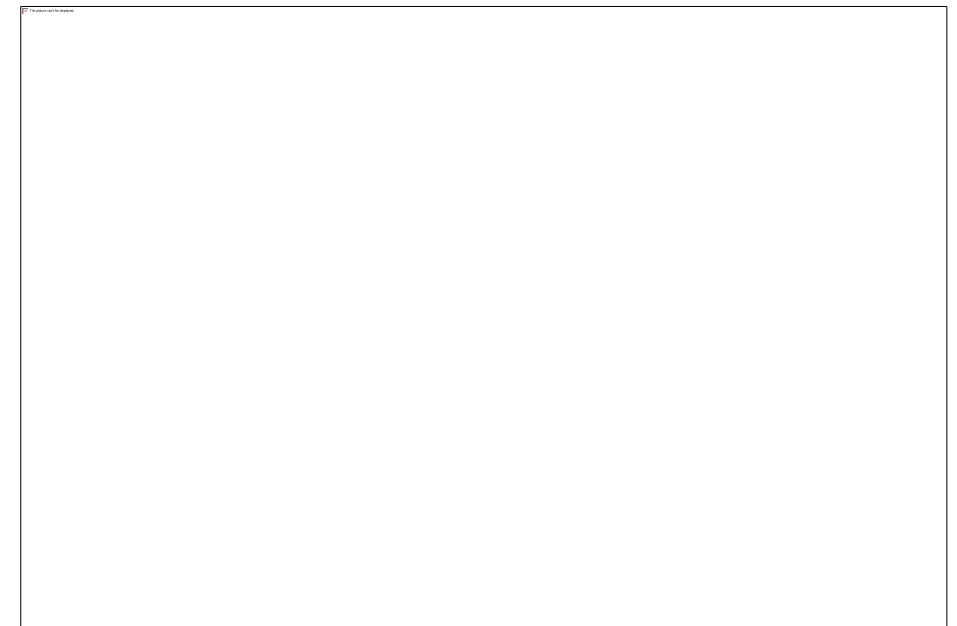
Practical Significance

- Wearable sensors can detect atypical movement associated with fatigue
- Feedback or cues can be automated & individual-specific
- Widely applicable for repetitive tasks



Chen et al., Smart Health, 2018

Chan et al., Sensors, 2020



Beange et al., 2017

Thank you for attending!

PhD, Human Kinetics (2019 - present)

- Supervisor: Dr. Ryan Graham
- Spine and Movement Biomechanics Laboratory
- University of Ottawa

MSc, Exercise Sciences (2016 - 2018)

- Supervisor: Dr. Tyson Beach
- Musculoskeletal Biomechanics and Injury Prevention Laboratory
- University of Toronto



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Association of Canadian Ergonomists
Association Canadienne d'Ergonomie



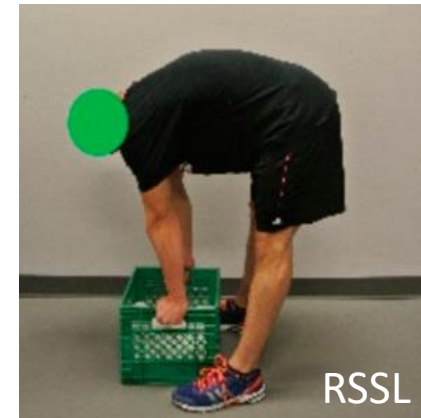
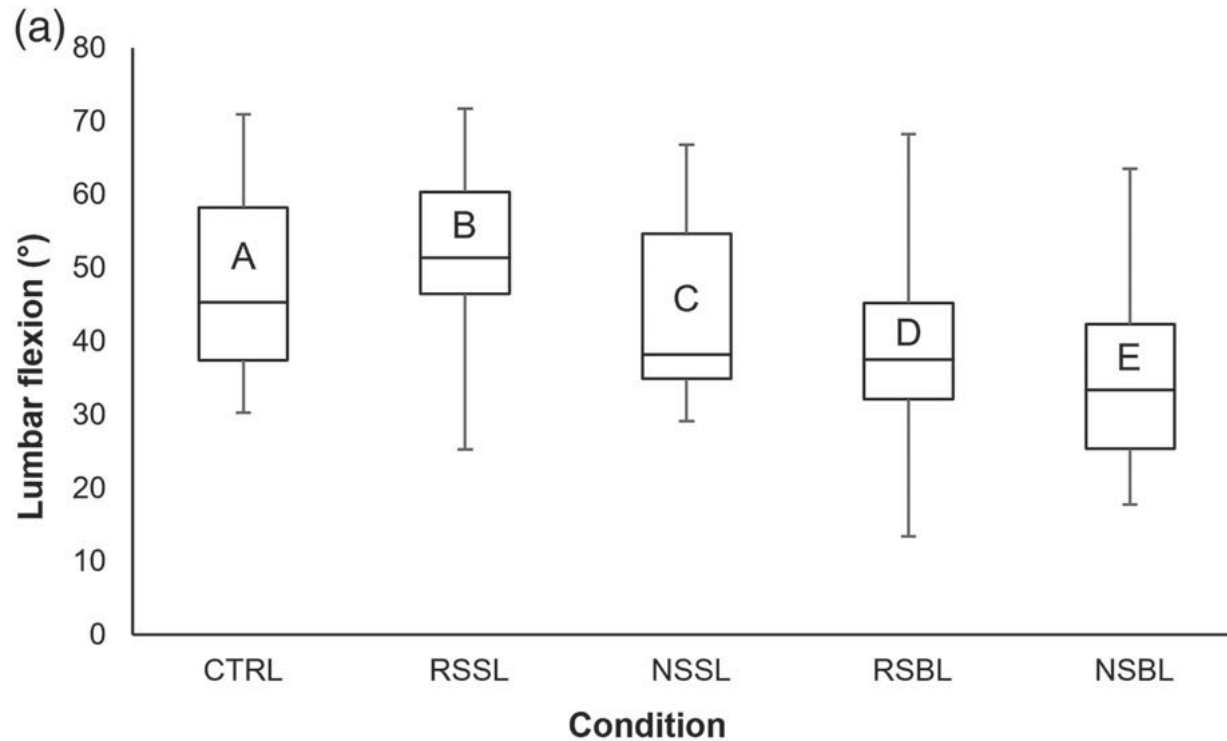
NSERC
CRSNG



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Can visual aids elicit changes in spine motion during lifting?



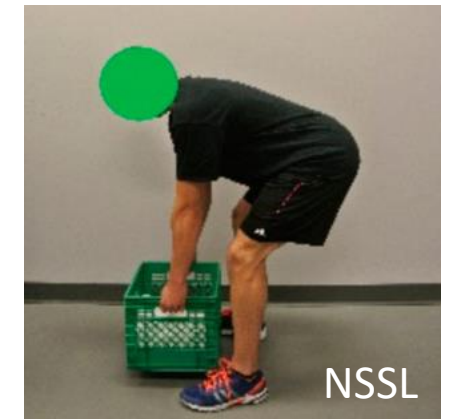
RSSL



RSBL



NSBL

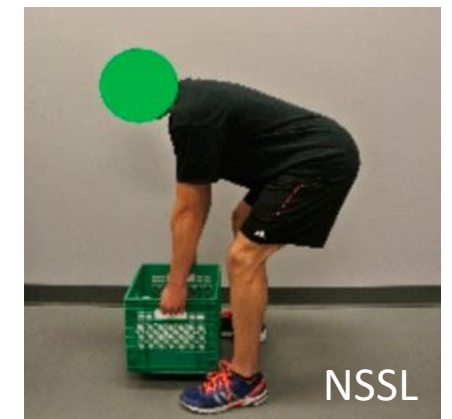
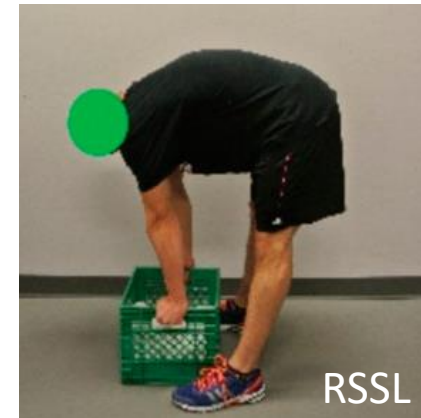
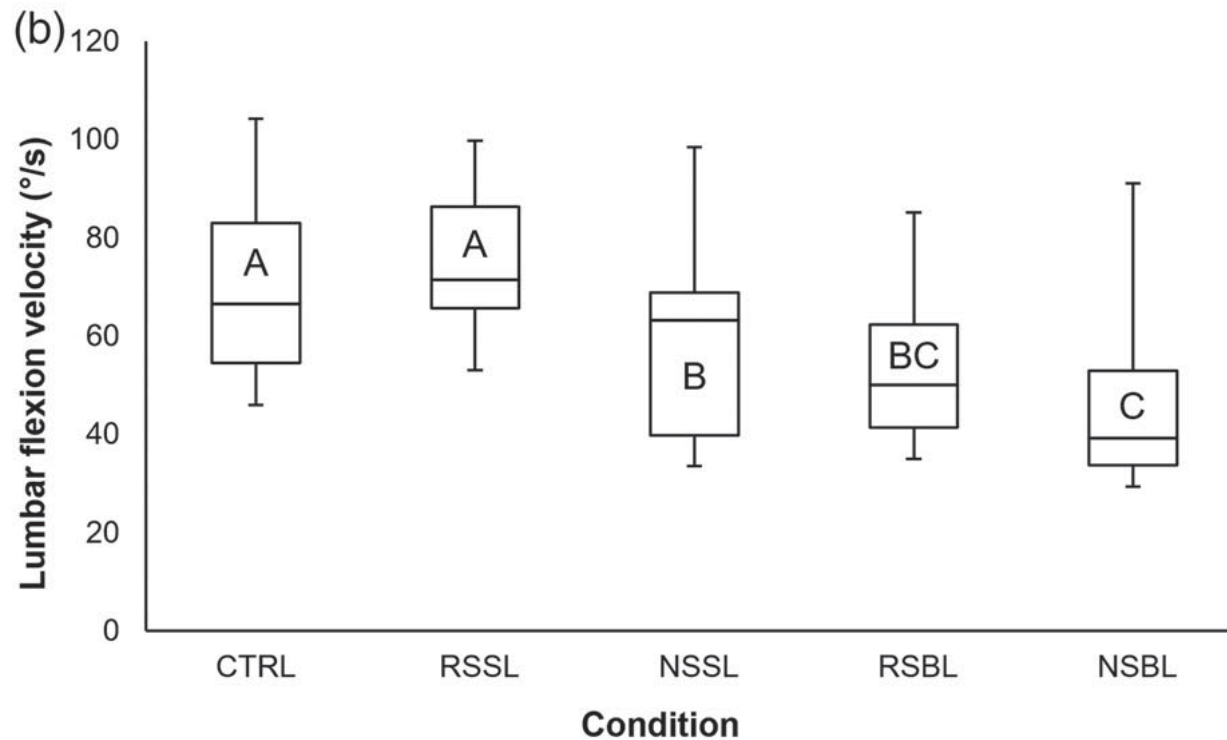


NSSL

Chan et al., *Int J Occup Saf Ergon*, 2019



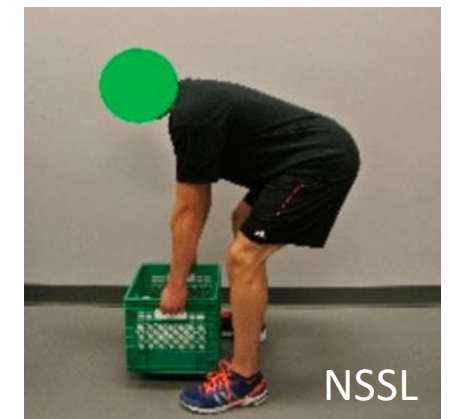
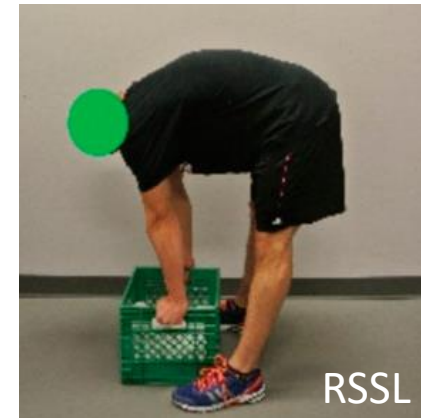
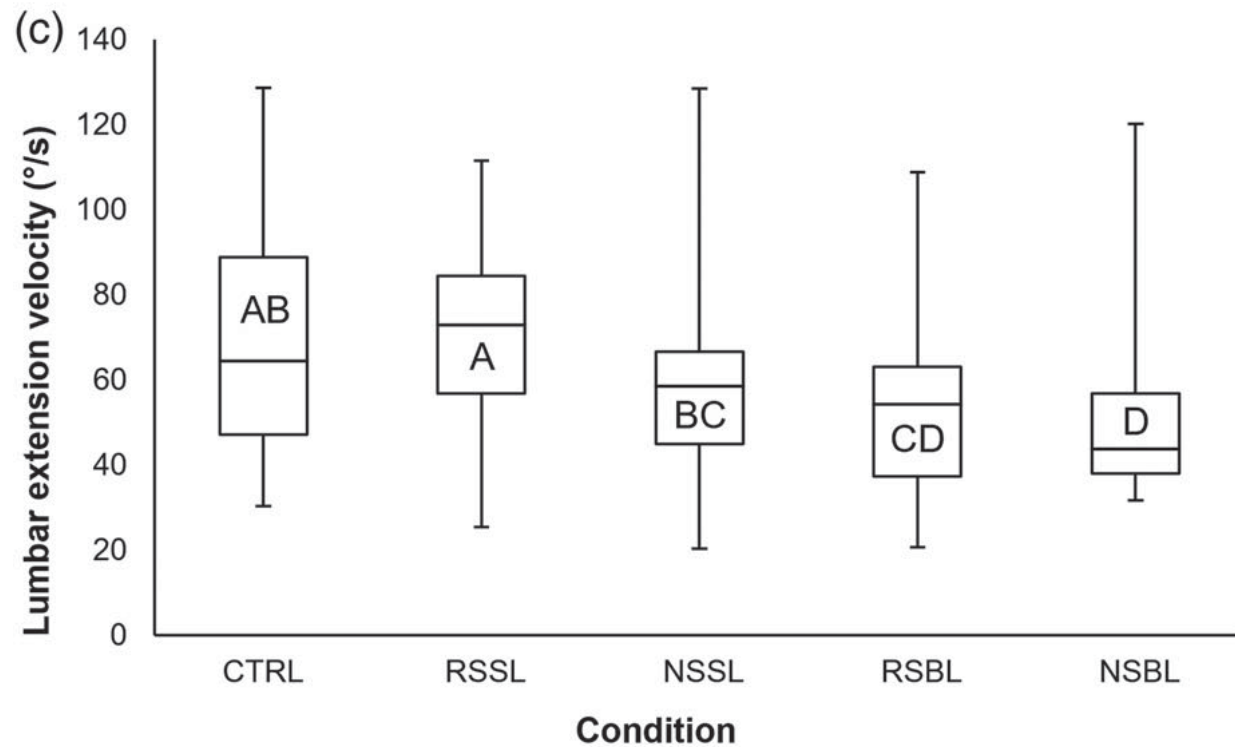
Can visual aids elicit changes in spine motion during lifting?



Chan et al., *Int J Occup Saf Ergon*, 2019



Can visual aids elicit changes in spine motion during lifting?



Chan et al., *Int J Occup Saf Ergon*, 2019



AUG Intervention

Feedback Schedule

Set #	Augmented Feedback Administered
1	All 10 lifts with dowel + individualized coaching cues
2	5x opportunities for KP Feedback
3	4x opportunities for KP Feedback
4	3x opportunities for KP Feedback
5	2x opportunities for KP Feedback

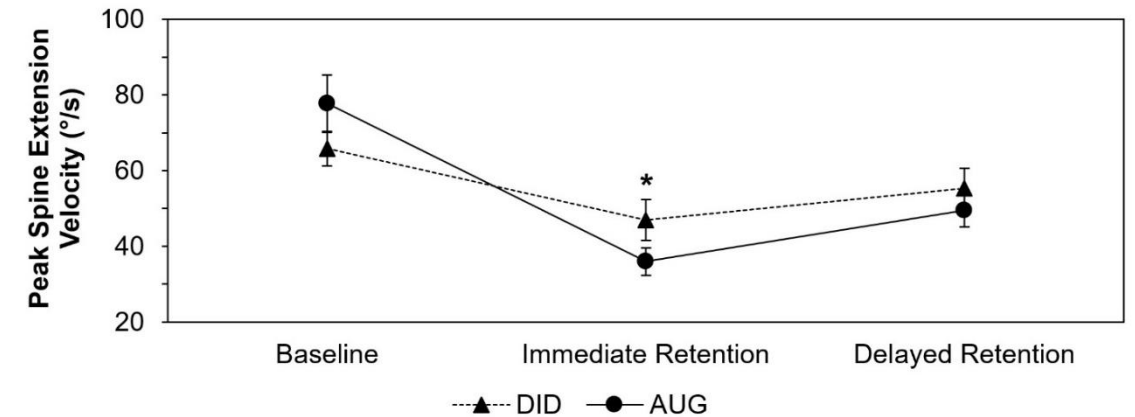
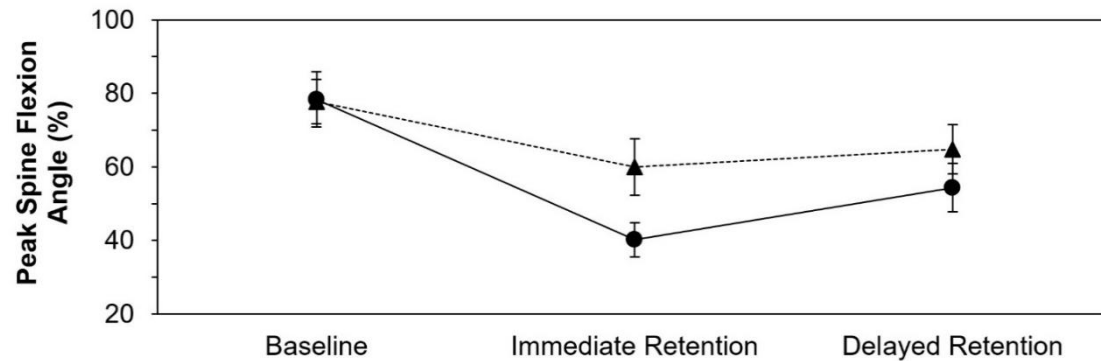
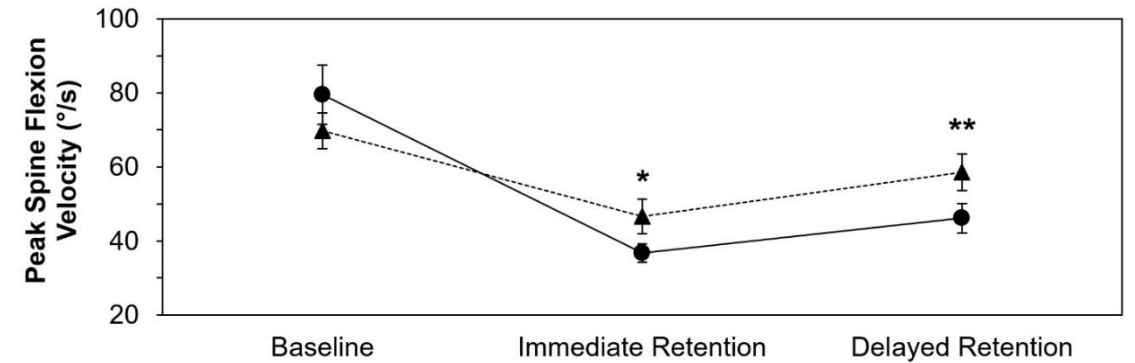
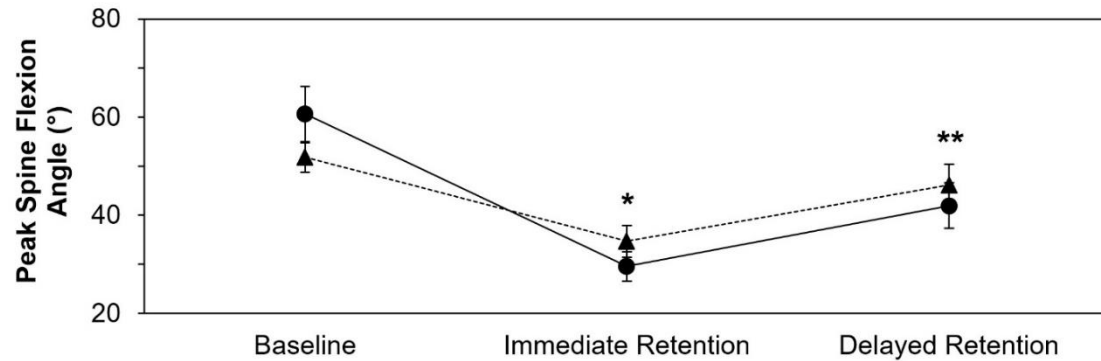
Standardized phrases provided

Spine flexion angle (°)	Qualitative feedback given
< 10	“Excellent. Keep this up!”
10-20	“This was good and there is still room to improve.”
21-35	“Not bad but keep trying to resist flexion even more.”
36-50	“Your spine was flexed during that lift.”
> 50	“There was a lot of spine flexion during that lift.”

Chan et al., in review



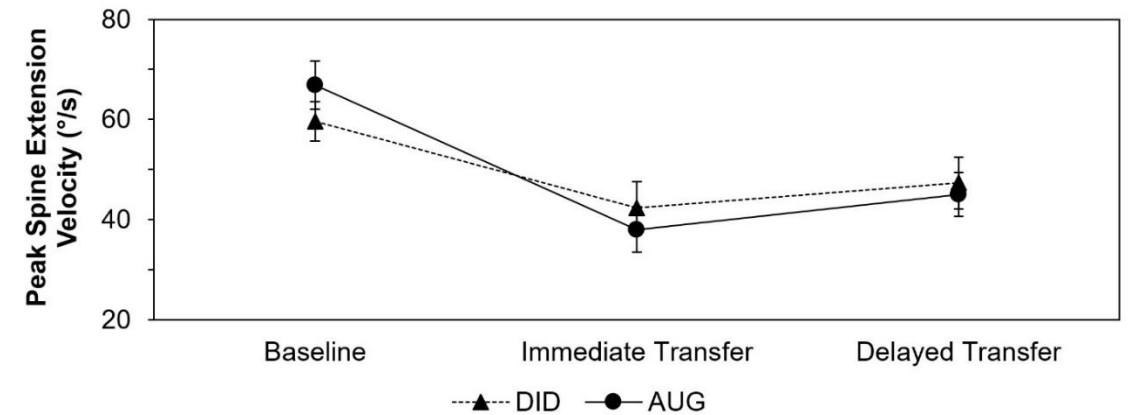
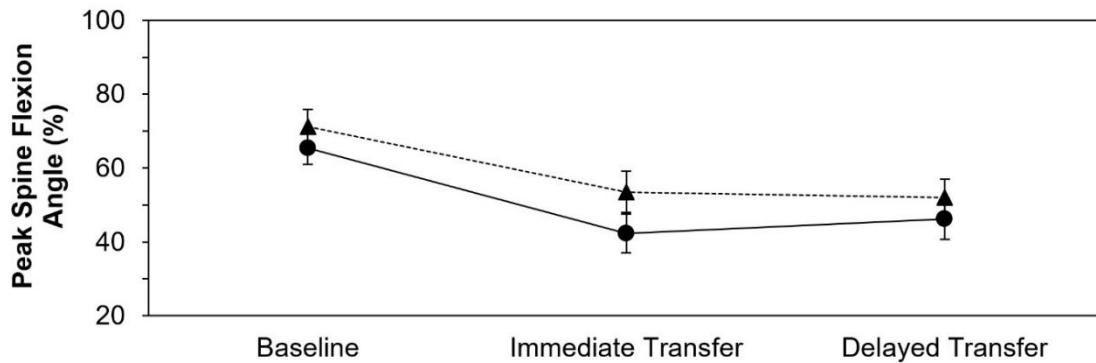
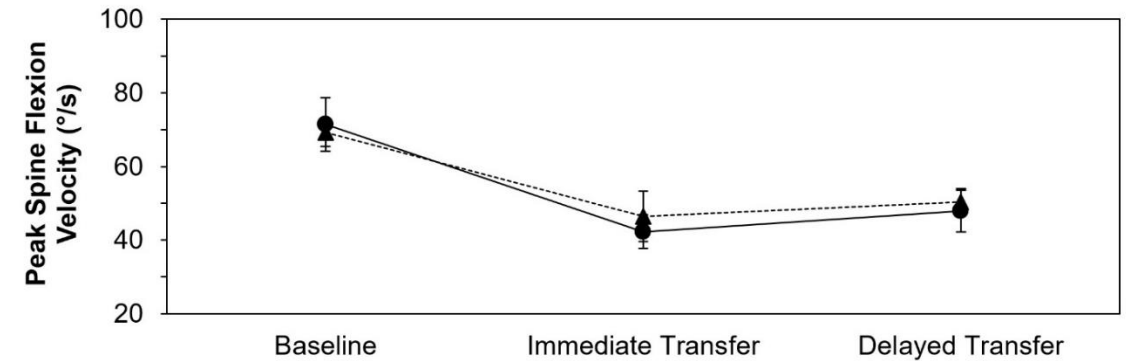
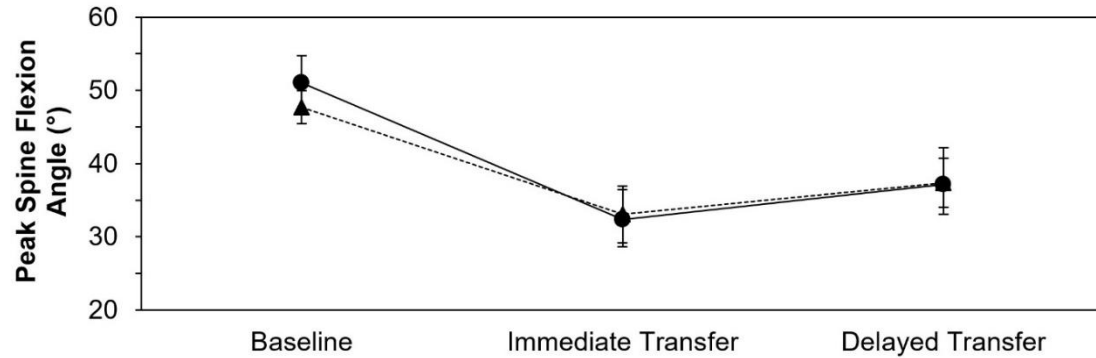
Retention: Box Lifting Task



Chan et al., in review



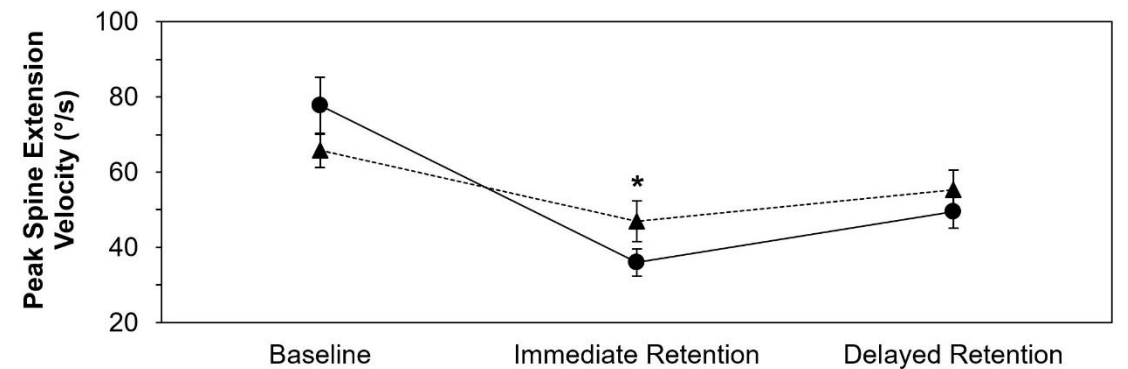
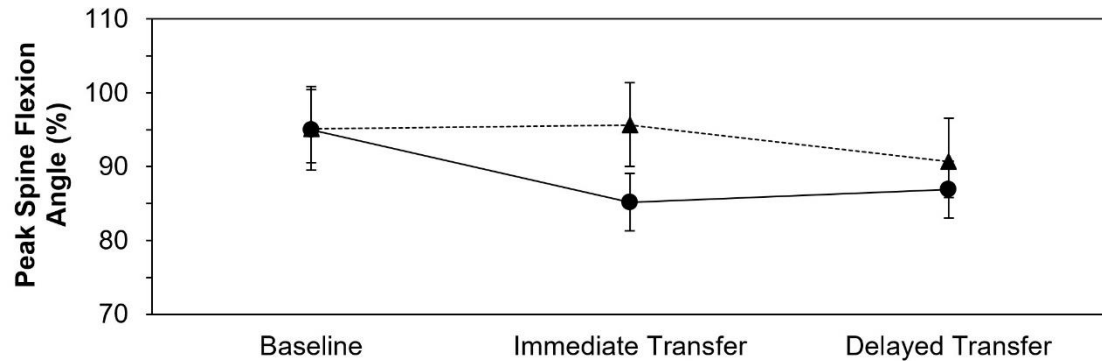
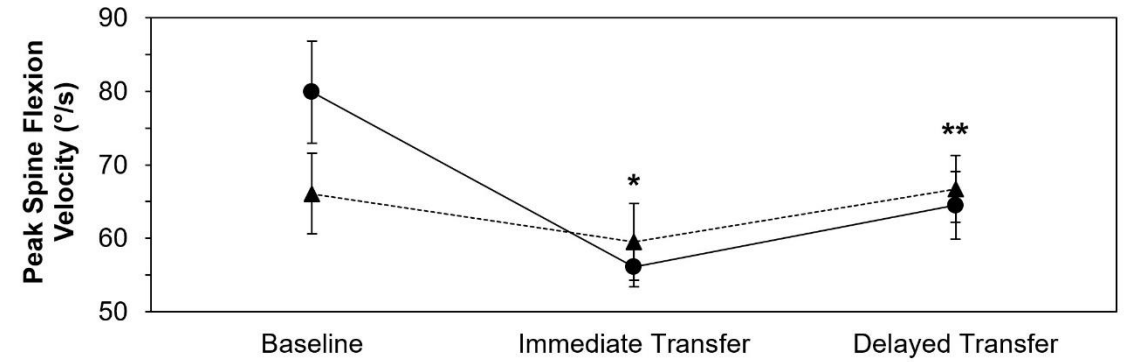
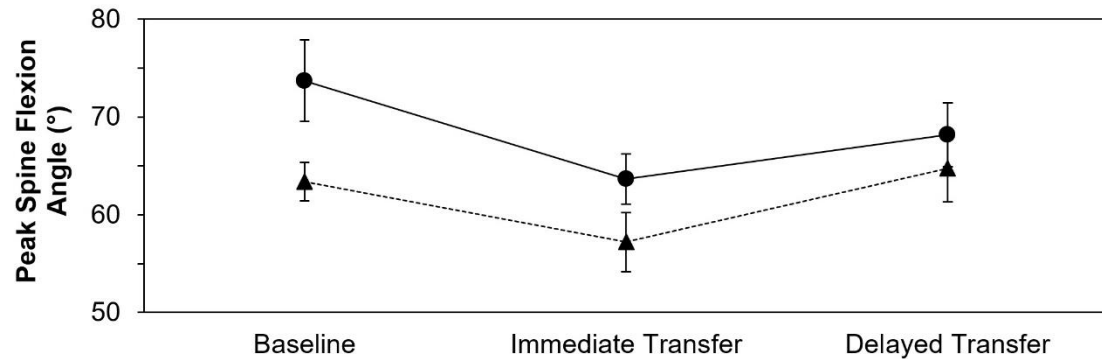
Transfer: Medication bag lifting task



Chan et al., in review



Transfer: Paramedic backboard lifting task

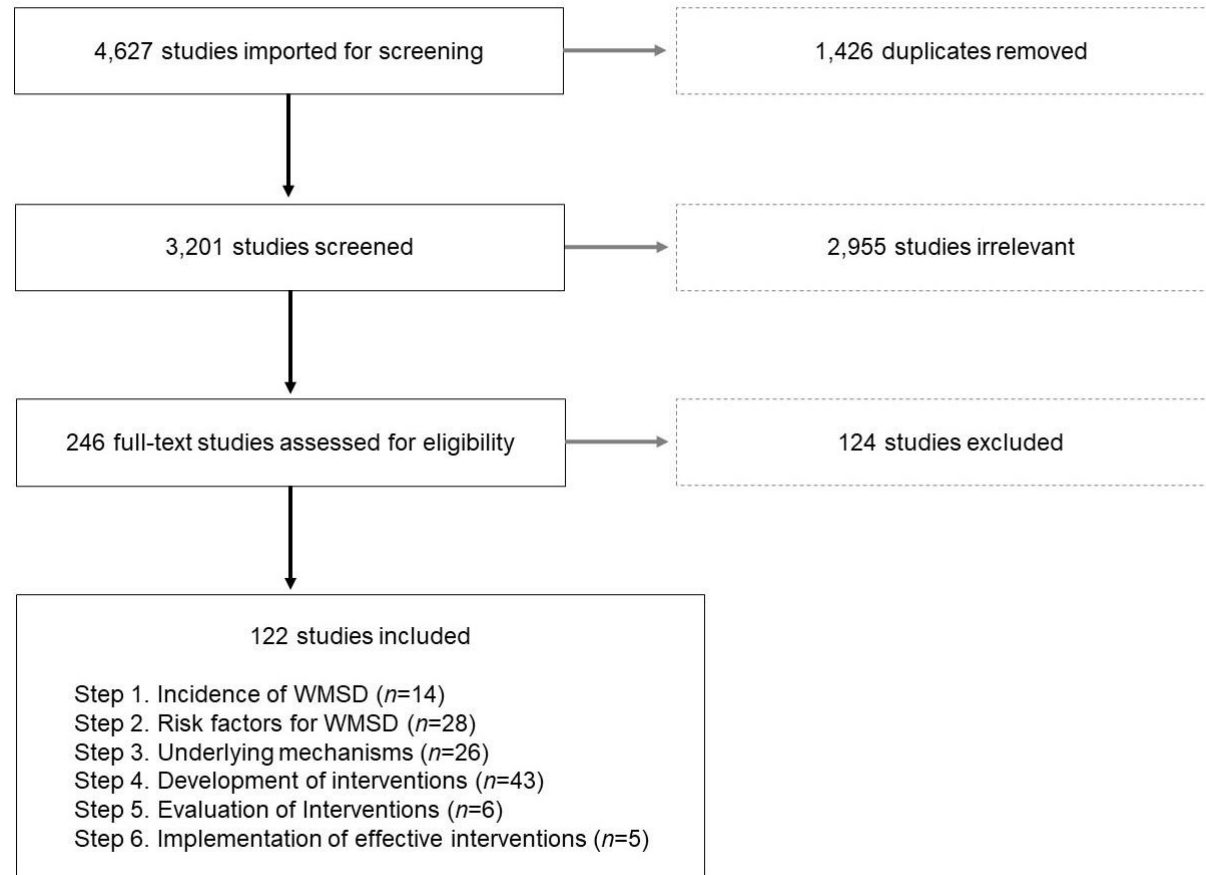


---▲--- DID —●— AUG

Chan et al., in review



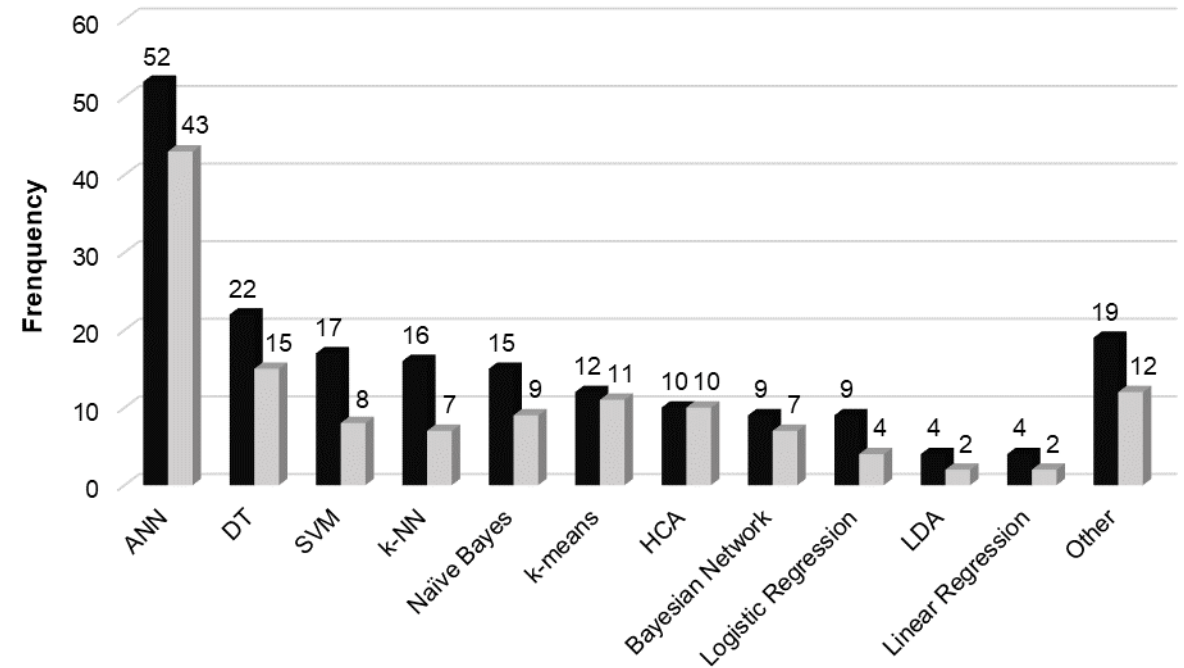
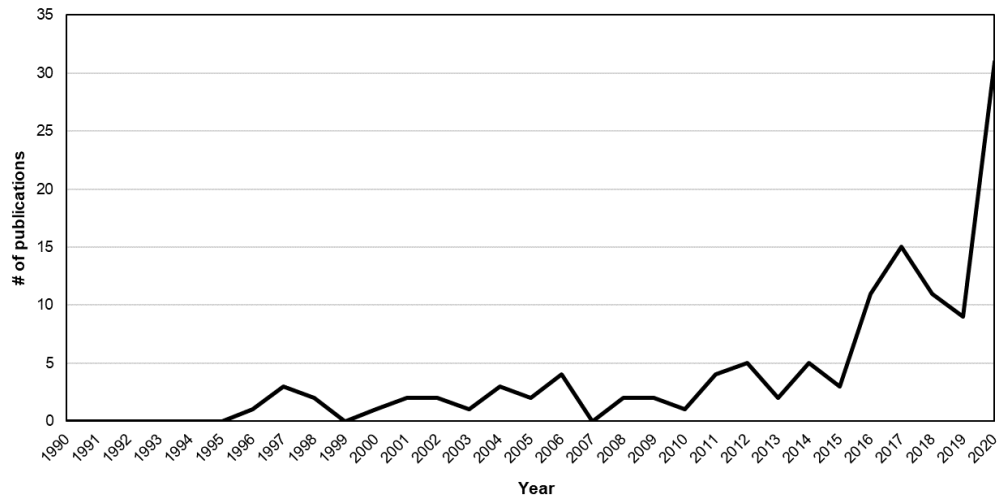
ML Scoping Review



Chan et al., in review



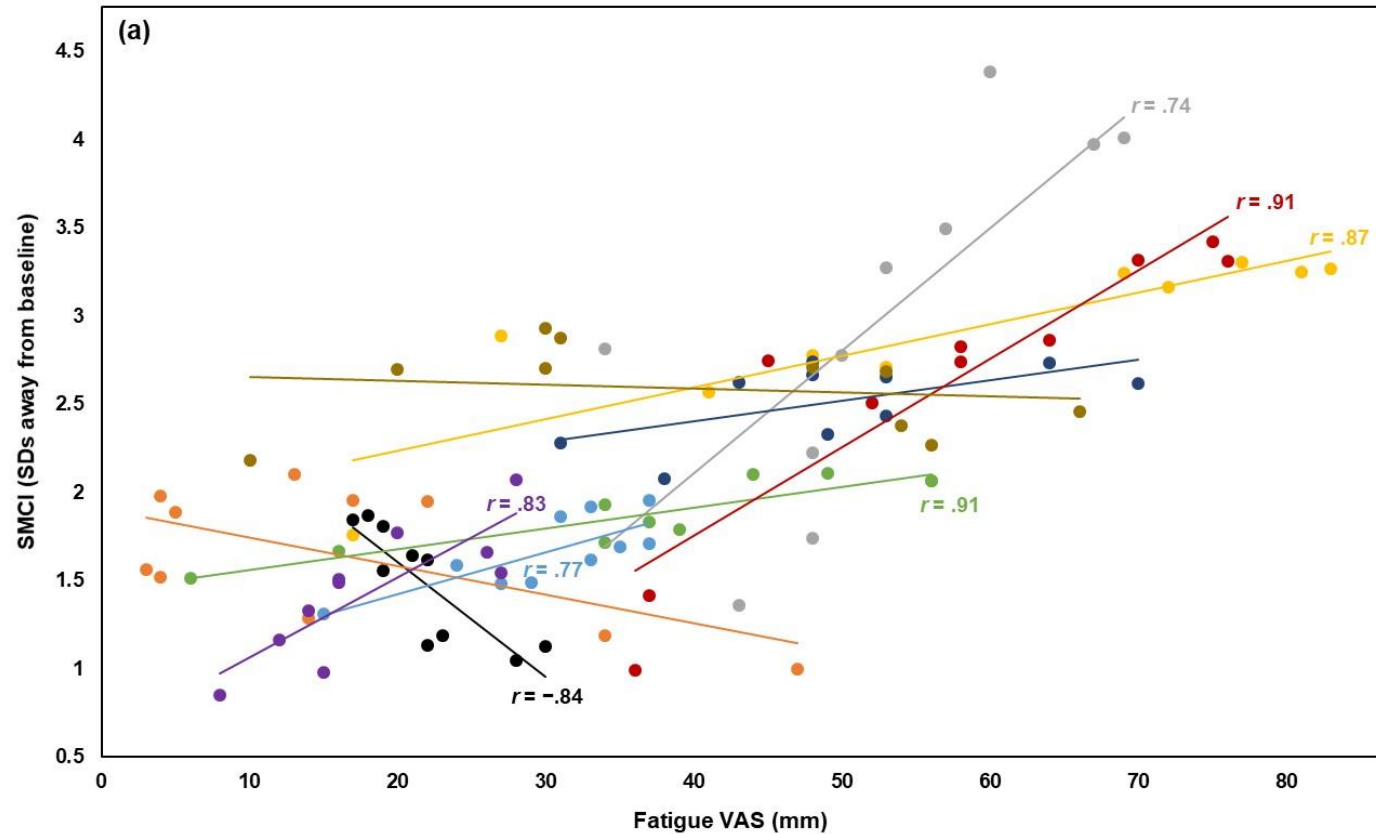
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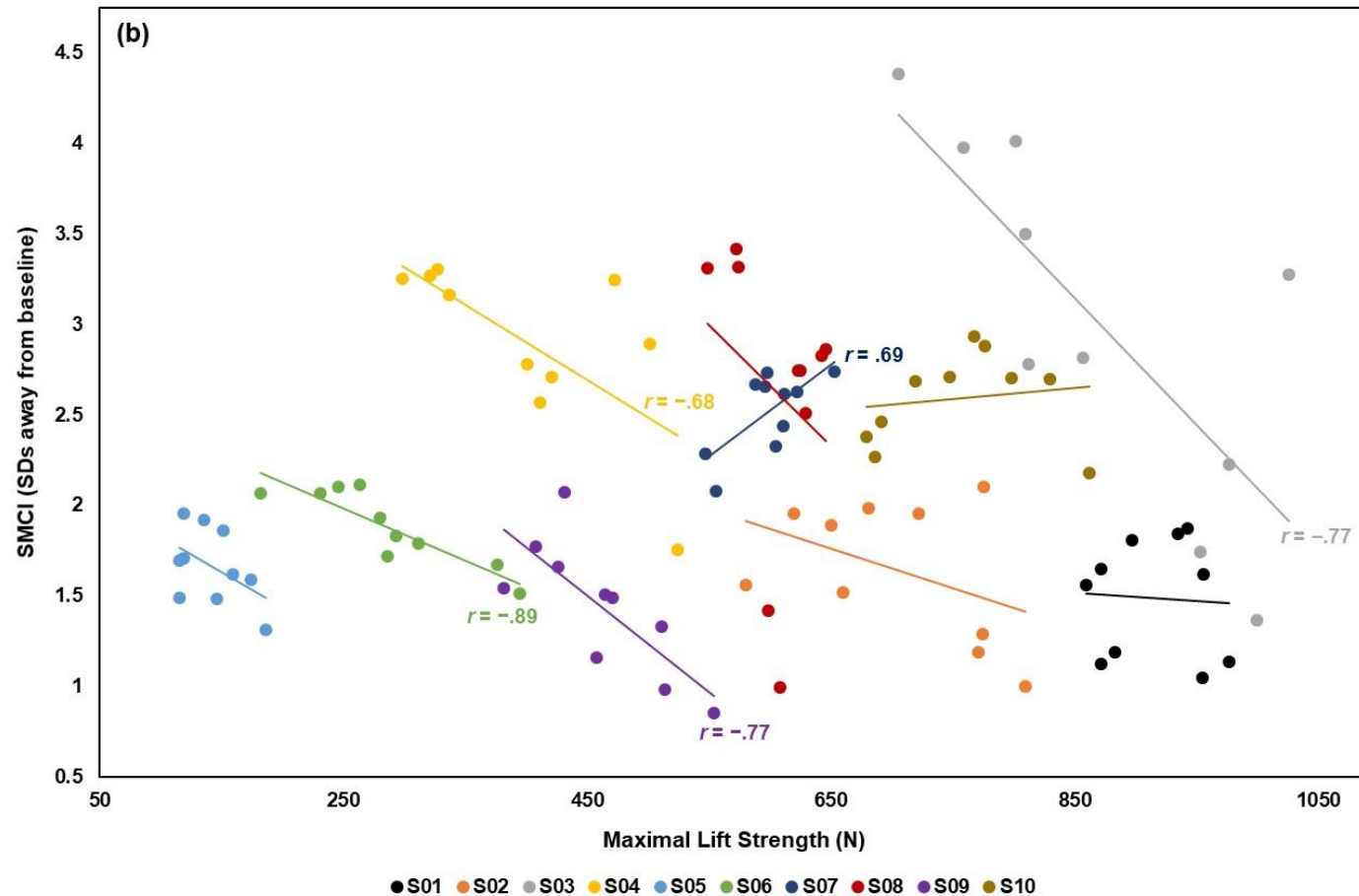
Individual Correlations for SMCI & Fatigue



Chan et al., Sensors, 2020



Individual Correlations for SMCI & Fatigue



Chan et al., Sensors, 2020