Effects of Working Memory and Muscle Fatigue on Dynamic Gait Balance Control in Older Worker

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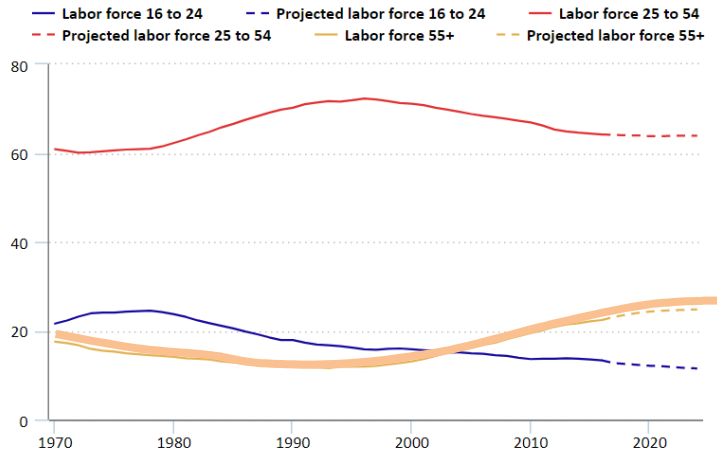
Background- older worker

- The percent of older Americans in the labor force has been increasing. [1]
  - employment-to-population ratios for workers age 55+ in the state of Montana, Wyoming, Idaho, Oregon and Washington are 41.5%, 45.5%, 37.6 &, 38.1 % and 28.7%, respectively



- For workers age 55 and older, the incident rate for fall was much higher than all other age groups. [1]
- Older workers who suffer a workplace injury may experience as twice as long recovery periods than their younger counterparts. [2]

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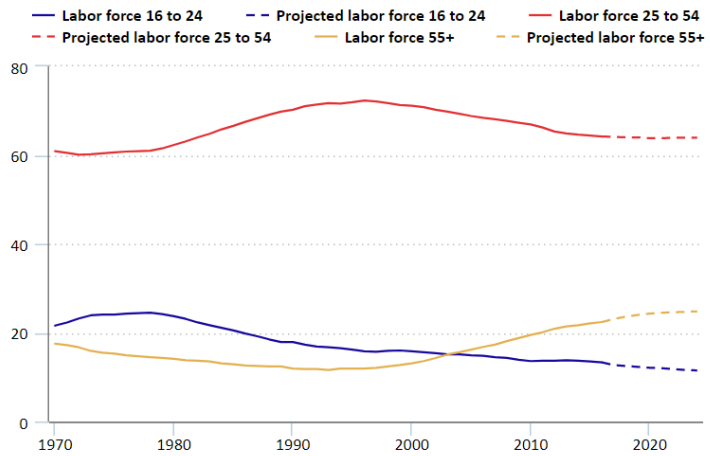

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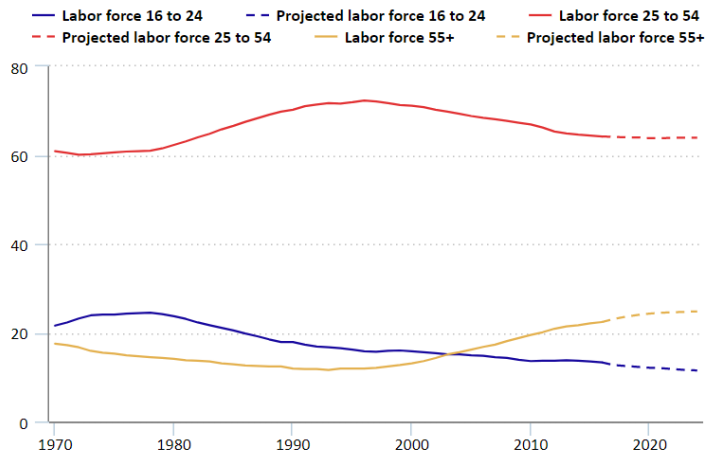

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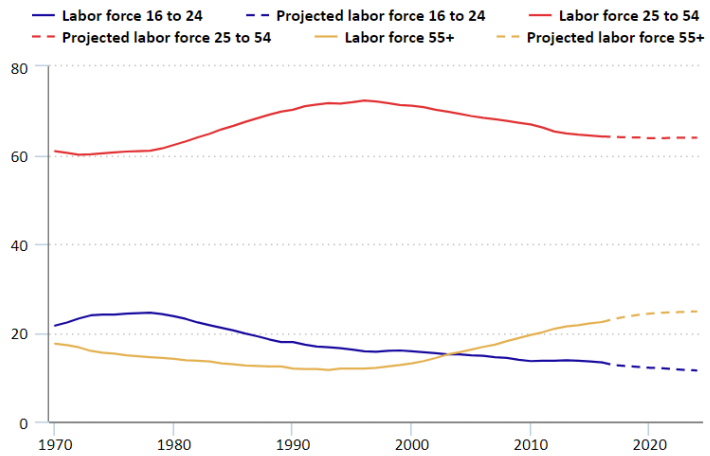

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- Muscle fatigue
  - is a symptom often found among older population
  - has been found to cause motor adjustments in daily activities
  - has been linked to falls. [1]
- Work requires both physical and cognitive demands, such as working memory. [2,3]
- Working memory
  - a mental process that stores information in a temporarily accessible state and manipulates the information when necessary
  - deficits in working memory compromise their ability to perform job-related tasks and daily activities efficiently and accurately

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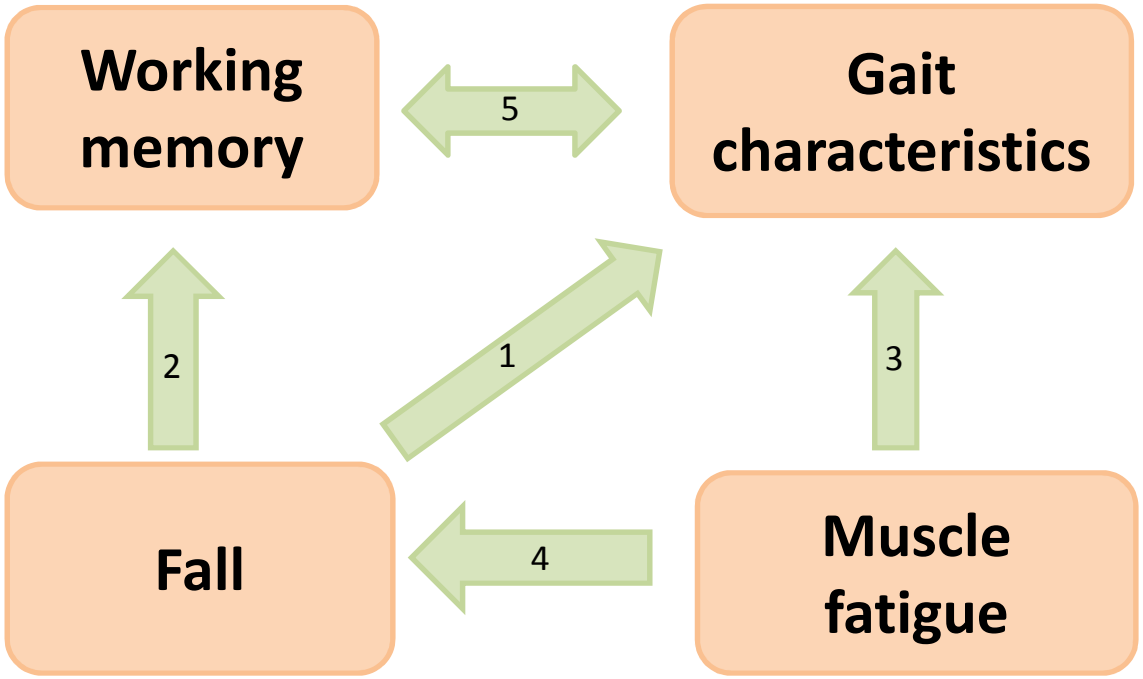
What we have learned from literature



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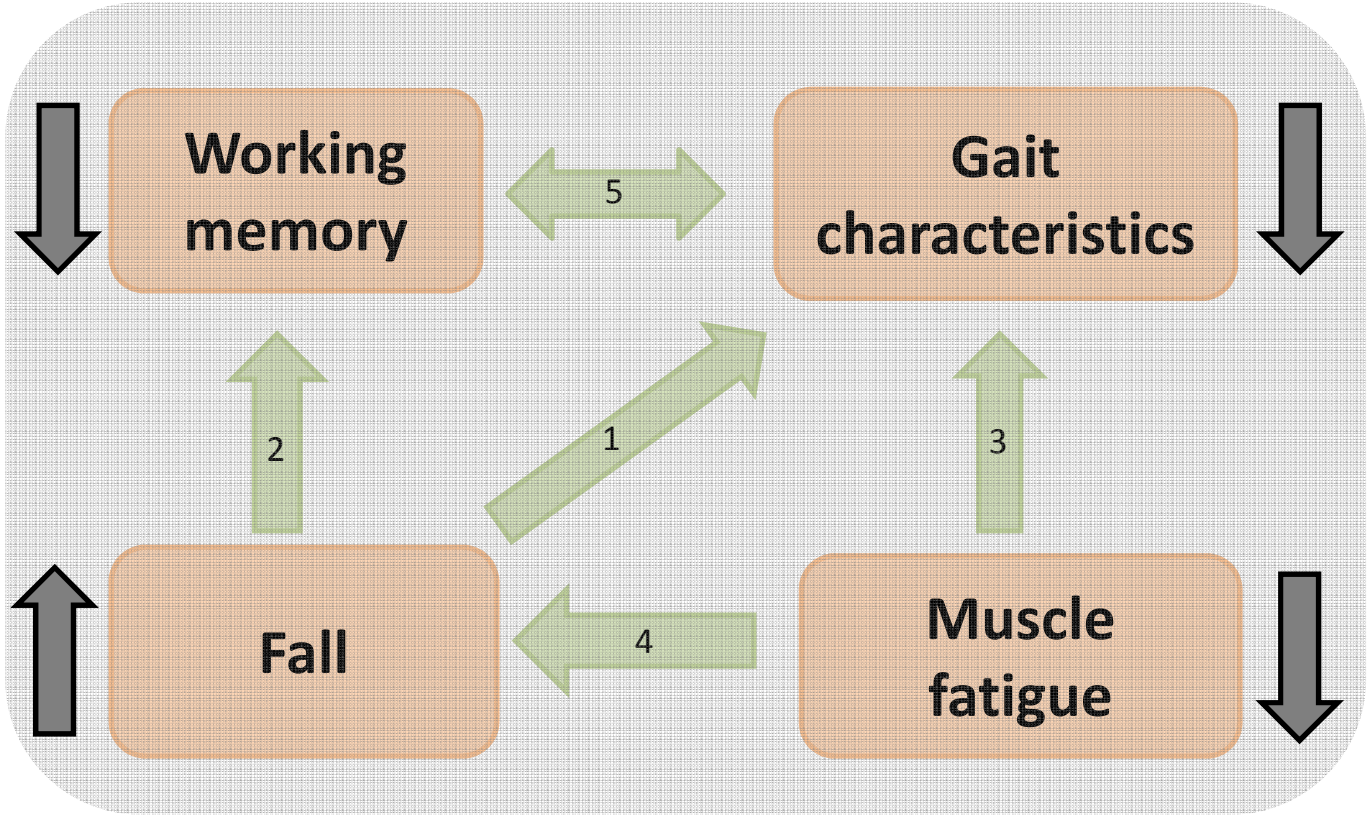
Additionally…



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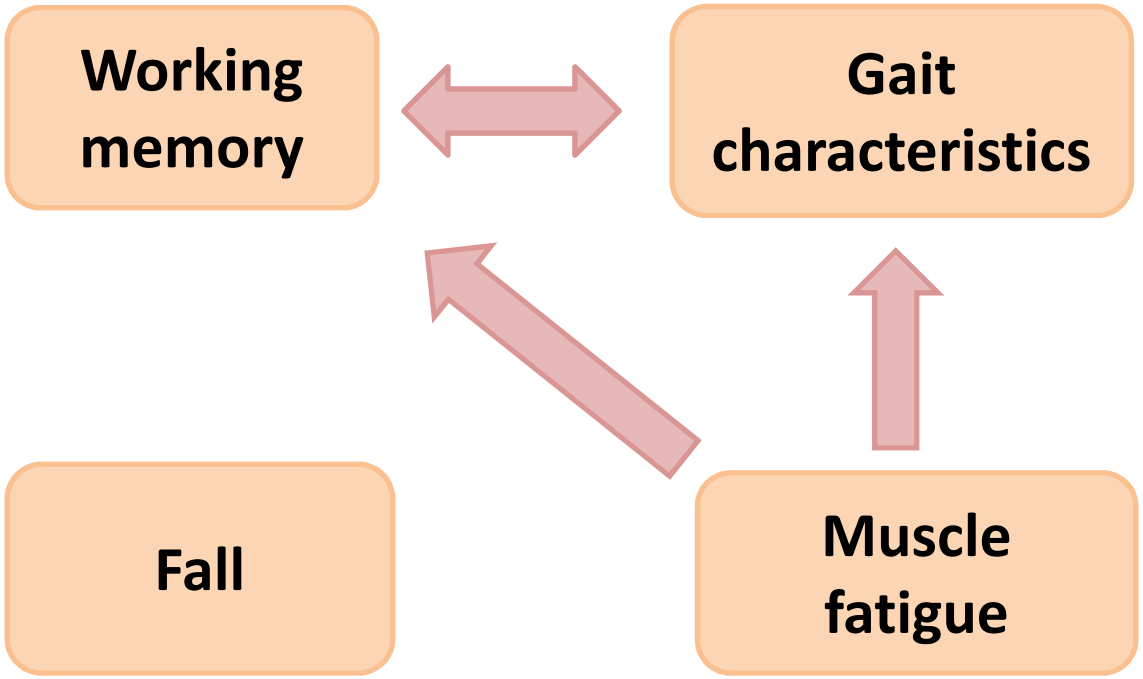
Knowledge Gap



U. Granacher et al, 2010

Study Purpose

- To examine changes in gait balance and working memory performance using dual-task paradigm in older workers compared to young controls after lower extremity muscle fatigue
  - What are the relative contributions of the following mechanisms in response to muscle fatigue in older workers: (1) reduced working memory capacity; (2) balance deficits after muscle fatigue or (3) inability to adequately allocate attentional resources to balance control?
  - What are the differential effects of age on gait balance control during dual-task performance with working memory engaged in fatigued subjects?

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Participants

- Inclusion criteria
  - ages of 18-40 or 55-70 years old
  - involved in occupational activities with moderate-to-heavy physical demands *
  - able to walk over ground and cross over an obstacle without an assistive device
  - normal hearing

- Exclusion criteria
  - a history of neurological disease or head trauma
  - impairments involving bones, muscles, or joints in the past six months
  - persistent symptoms of dizziness, lightheadedness, unsteadiness, or any other medical condition that may affect walking ability or ability to step over an obstacle
  - any extreme strenuous activity in the past 24 hours before the test

* Older adult group

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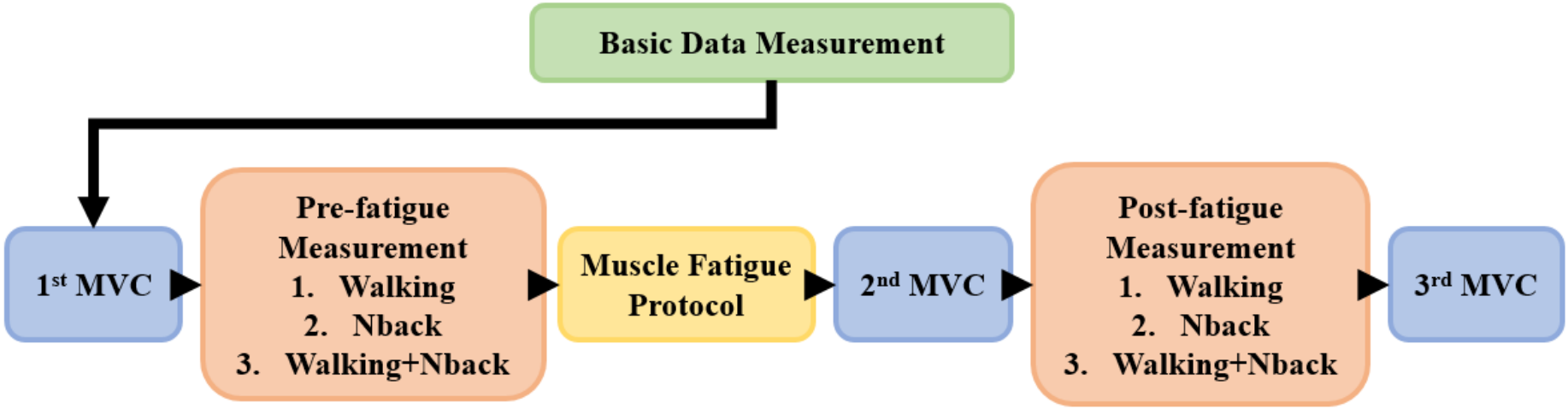
Participants

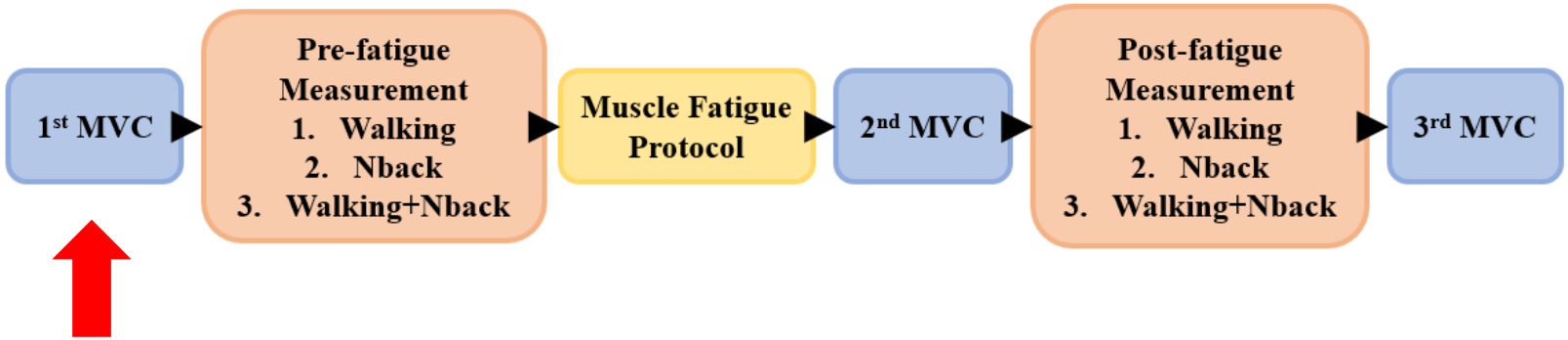
	Young adult (N = 22; F = 11)	Older adult (N = 5; F = 4)
Age (ys)	20.7 ± 1.3	59.6 ± 4.0 (55-65)
Height (cm)	171.6 ± 6.6	159.5 ± 12.5
Weight (kg)	69.3 ± 9.0	59.2 ± 14.7

Motion Analysis Lab

- 12-camera motion analysis system (Motion Analysis Corp)

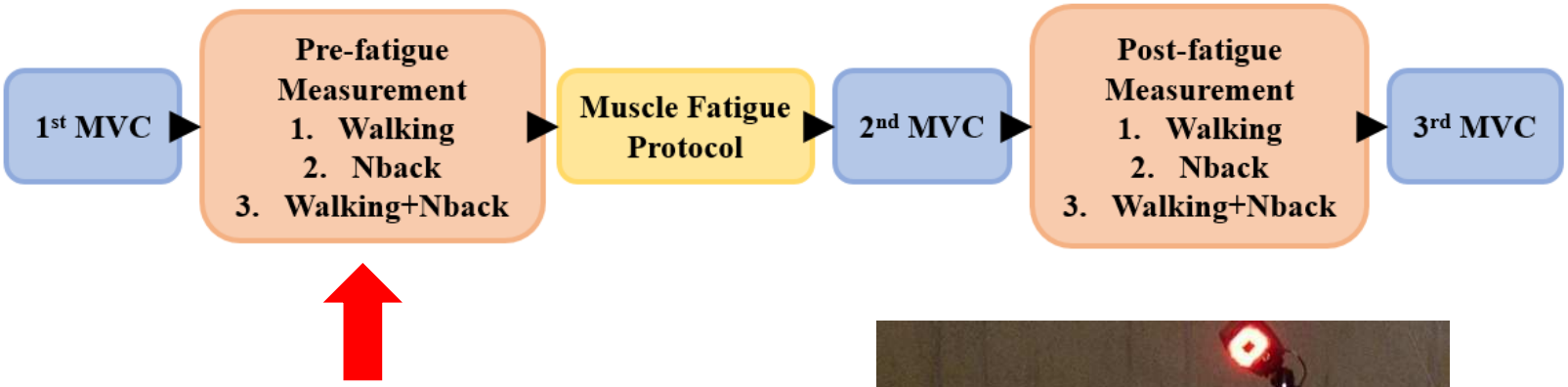
Study Protocol



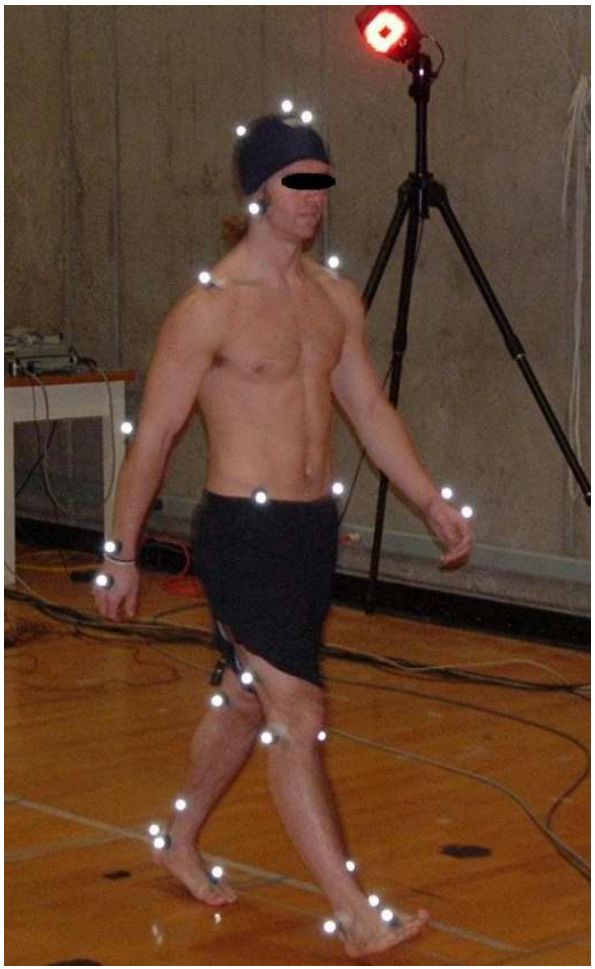


- MVC-maximal voluntary contraction
- Isometric dynamometer of right leg

- MVC of knee extension for 5 seconds
- Total of 3 Sets in one sitting with 1 minute in between
- Recorded highest value



- 29 reflective markers placed on bony landmarks



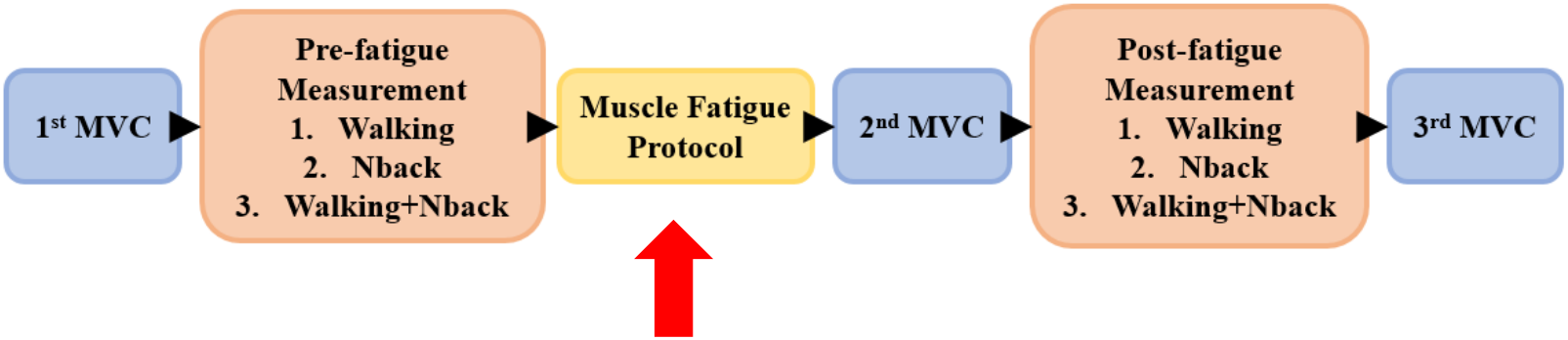
Walking

- 2 min at self-selected speed

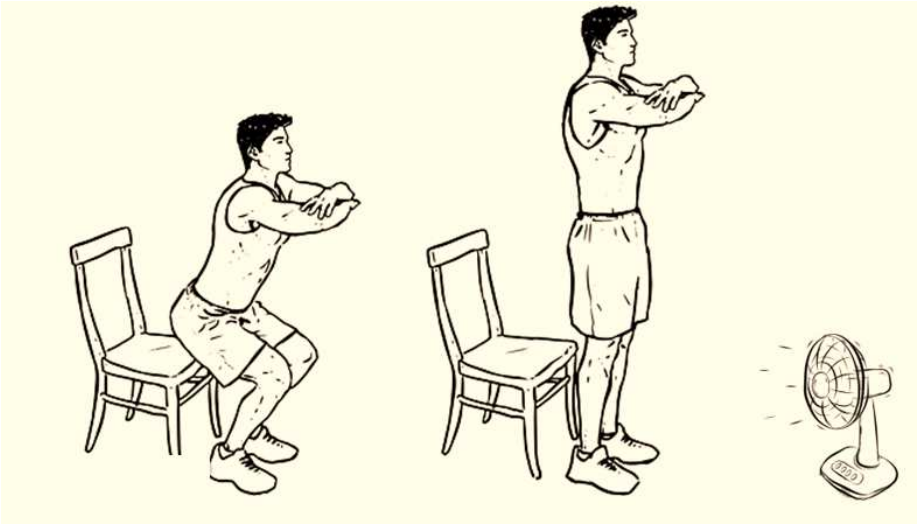
N-back test

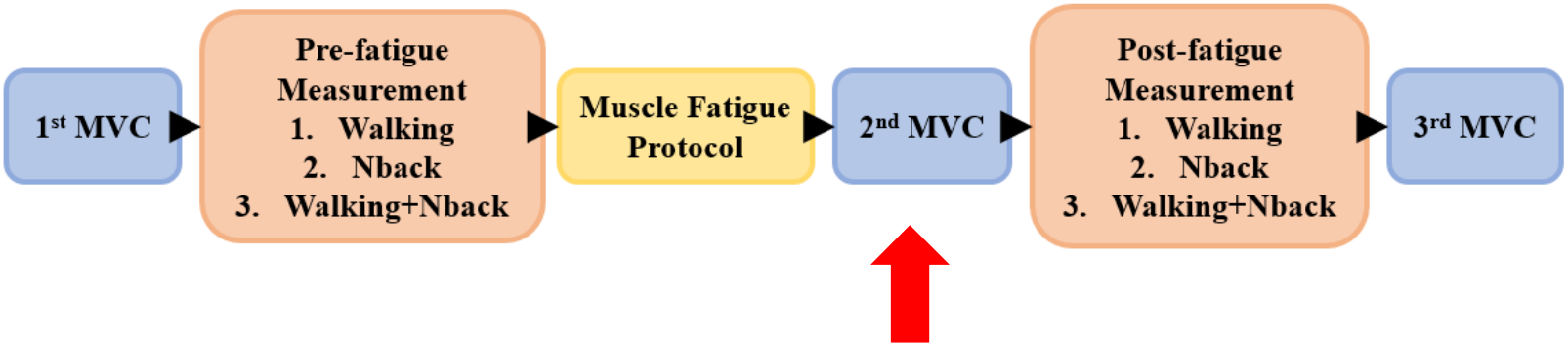
- 2 minutes
- N = 3 digits

Dual task: Walking + N-back



- Repeated sit-to-stand task at pace of 1 Hz or below until
  - Exhausted
  - Unable to keep up the beep
  - 30 minutes




1st MVC
Pre-fatigue Measurement
1. Walking
2. Nback
3. Walking+Nback
Muscle Fatigue Protocol
2nd MVC
Post-fatigue Measurement
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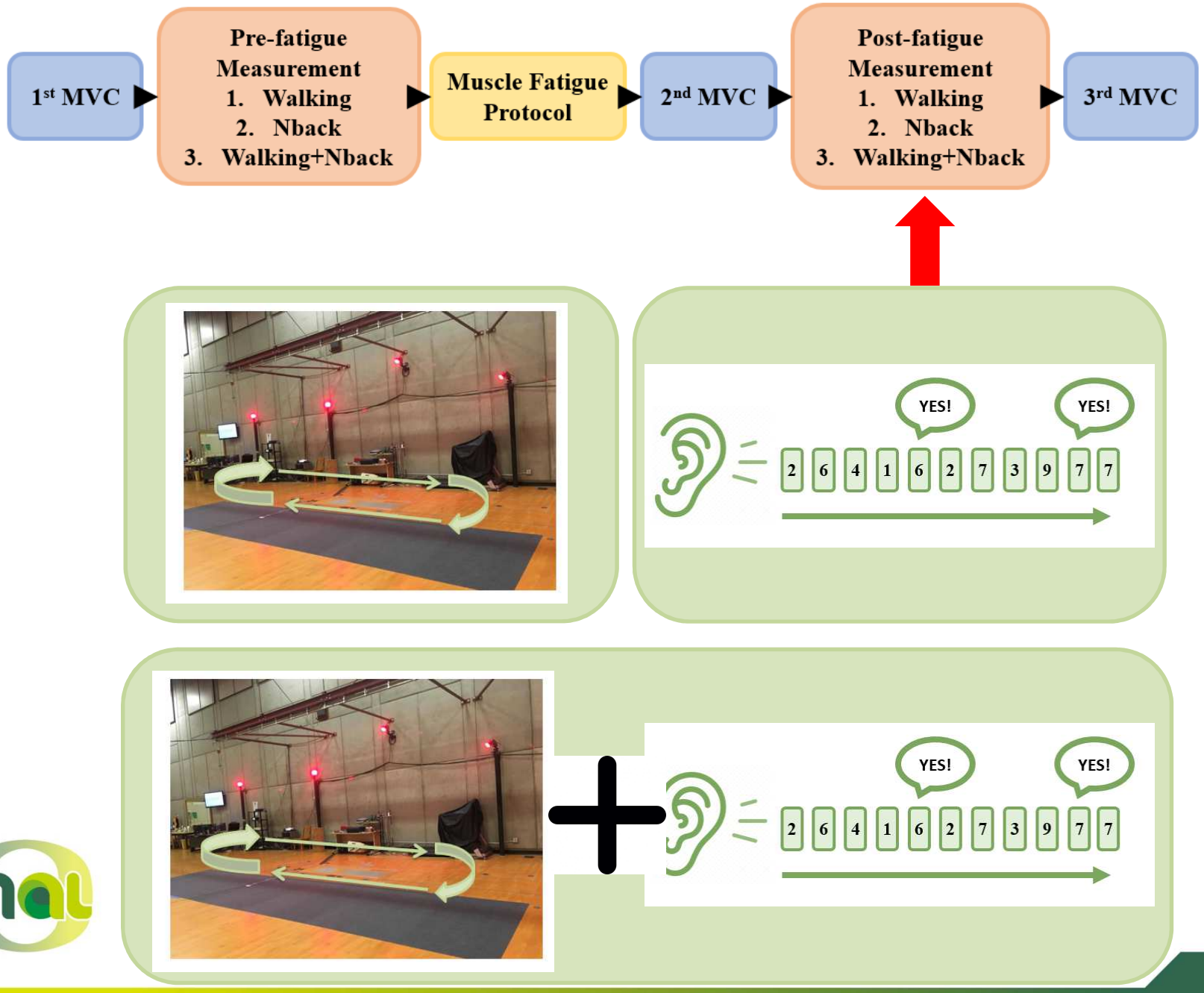
3rd MVC


BIODEX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YES!
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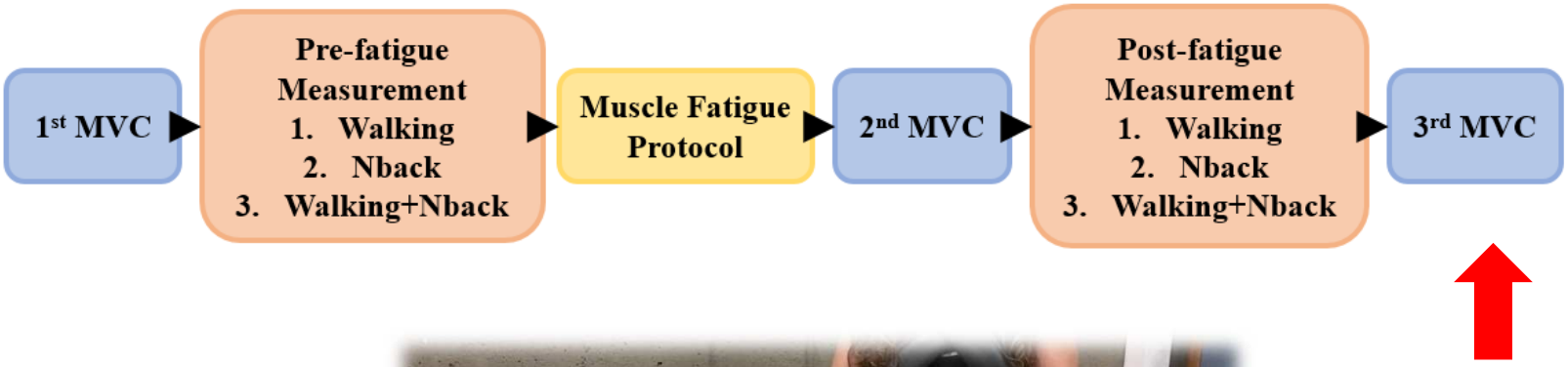
2 6 4 1 6 2 7 3 9 7 7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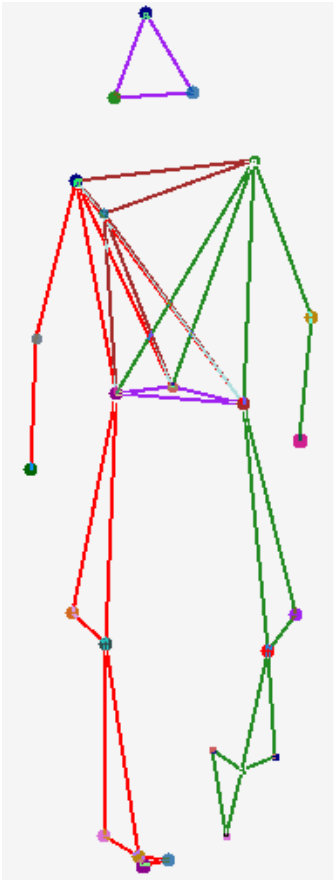

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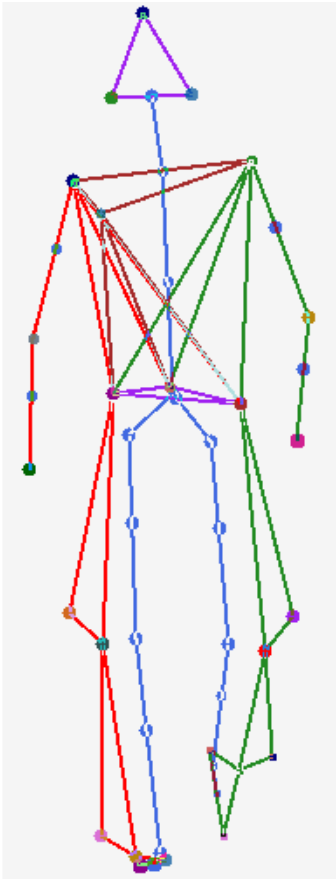
  - CoMs of 13 segments



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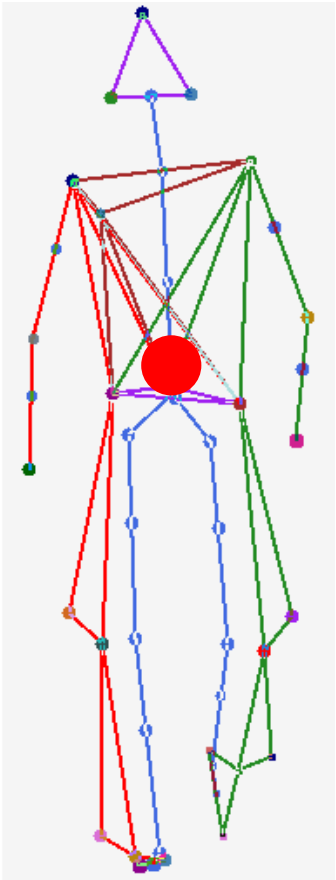

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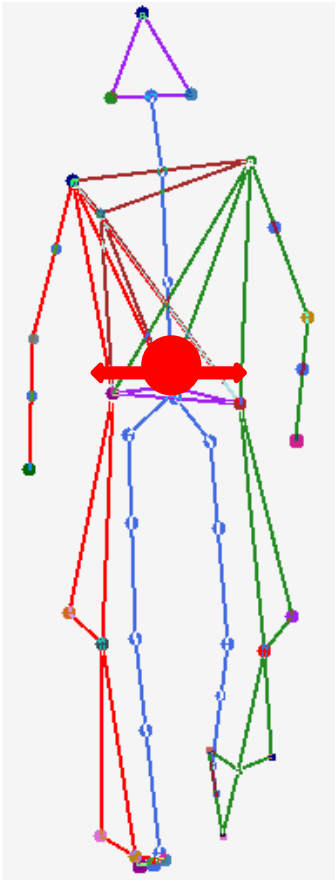
  - Mediolateral sway during a gait cycle



Variable 2: working memory

- Accuracy of N-back test (%)
  - 1-(number of missed digits/number of total digits)*100

Statistical Analysis

- Young controls
  - 2X2 ANOVA with repeated measures using condition and fatigue
    - Condition: single- task vs dual-task
    - Fatigue: pre-fatigue vs post-fatigue
  - $\alpha = 0.05$
- Older adults
  - Descriptive analysis

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Results: degree of fatigue

	Young adult (N = 22; F = 11)	Older adult (N = 5; F = 4)
Time to fatigue (min)	24.5	23.8
strength drop (%)	23.8	16.6
strength drop after testing (%)	13.1	9.8
Hz during sit to stand	1	0.84
Rate of perceived exertion (6-20)	14.4	13.0

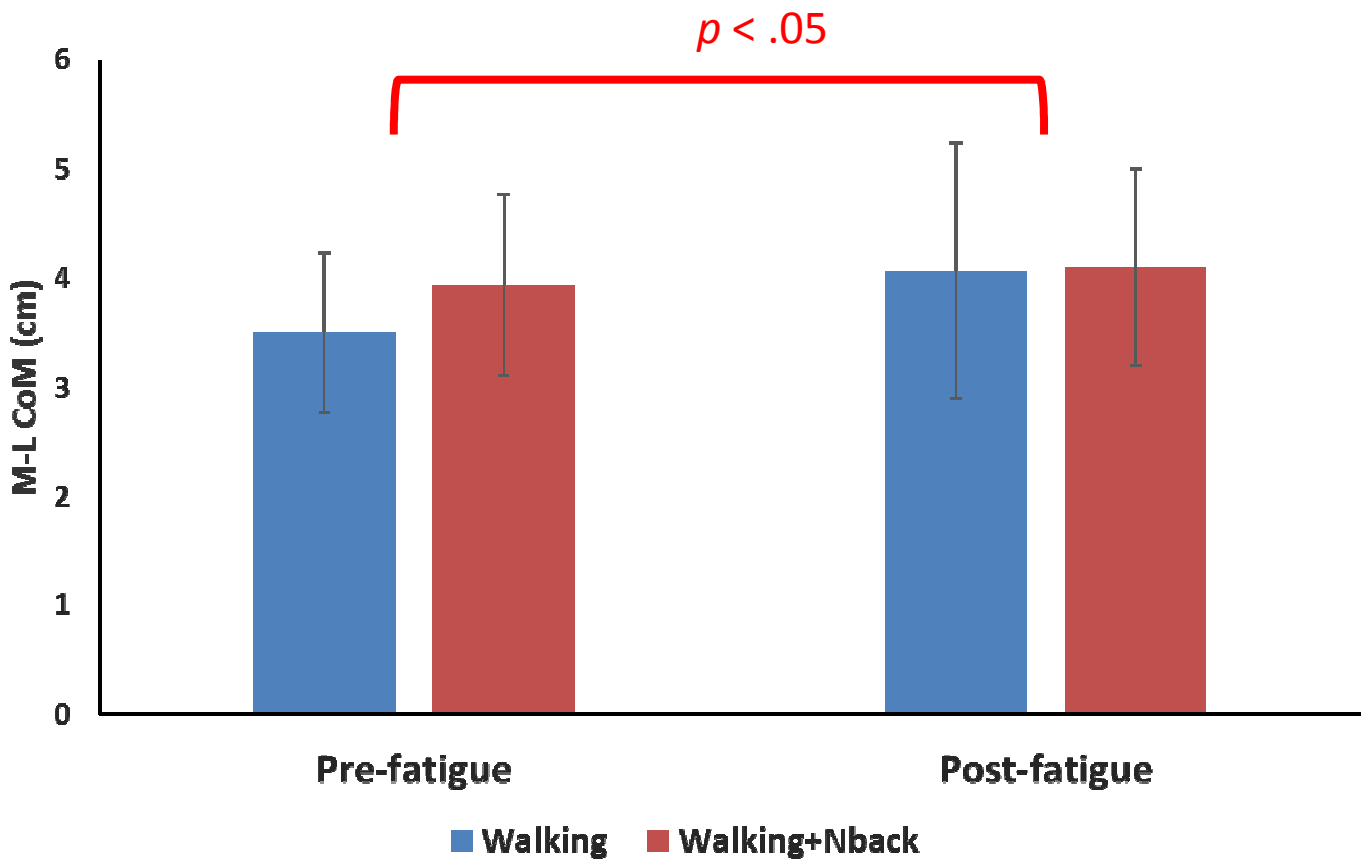
Results: Young

		Pre-fatigue	Post-fatigue
Gait velocity (m) [a,b]	Single	1.21 ± 0.12	1.22 ± 0.13
	Dual	1.14 ± 0.13	1.19 ± 0.11
Stride length (m) [a,b]	Single	1.21 ± 0.12	1.23 ± 0.13
	Dual	1.14 ± 0.13	1.19 ± 0.11
Step width (cm) [a]	Single	7.67 ± 2.11	8.41 ± 2.23
	Dual	7.78 ± 2.45	9.01 ± 2.35

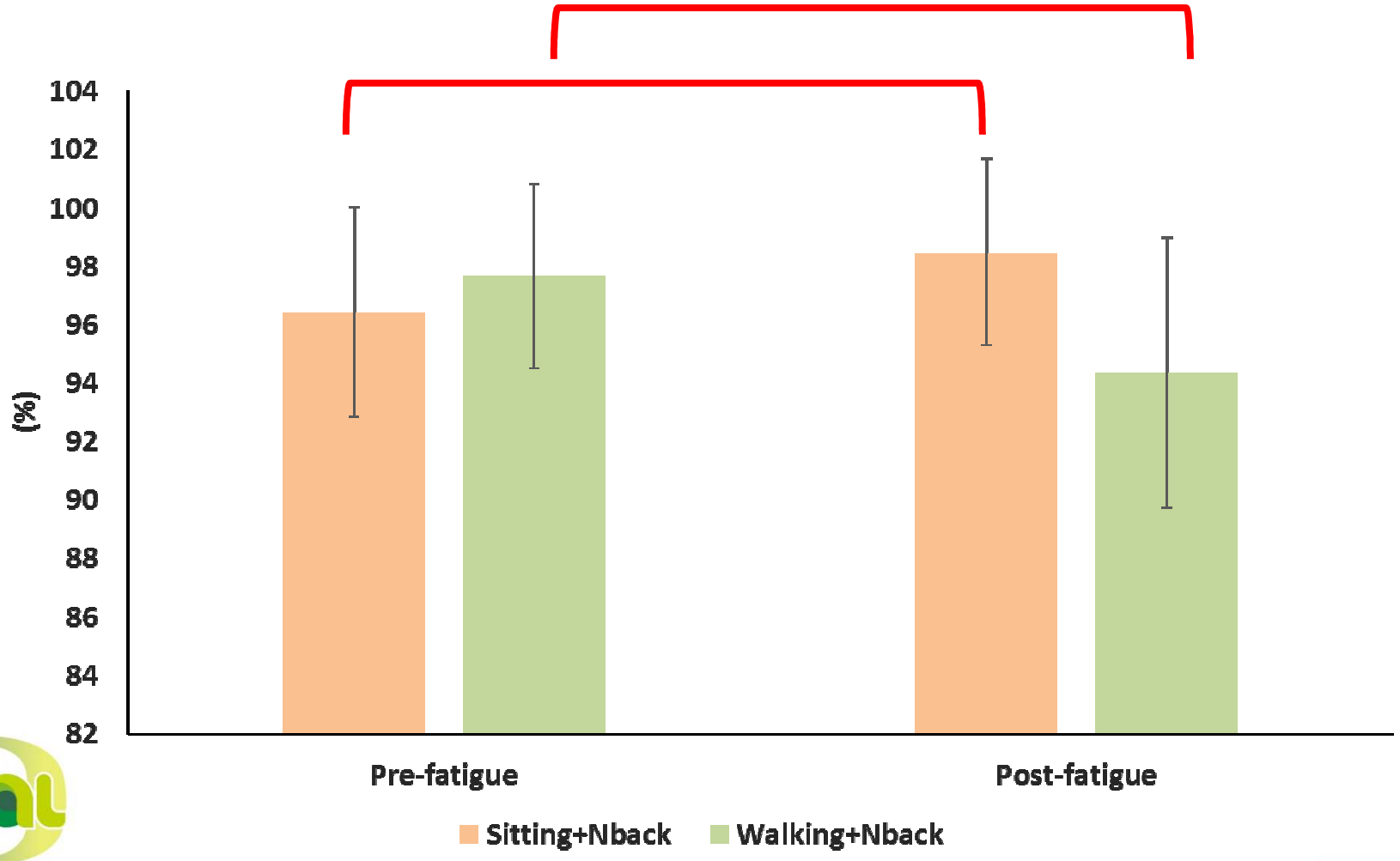
a. fatigue main effect; b. condition main effect; c. interaction effect

M-L CoM (cm) [a]	**Single**	**3.50 ± 0.73**	**4.07 ± 1.17**
	Dual	3.94 ± 0.83	4.10 ± 0.90
Working memory (%) [c]	Single	96.43 ± 3.59	98.48 ± 3.22
	Dual	97.67 ± 3.17	94.34 ± 4.64

Results: gait balance control (Y)



Results: working memory performance (Y)



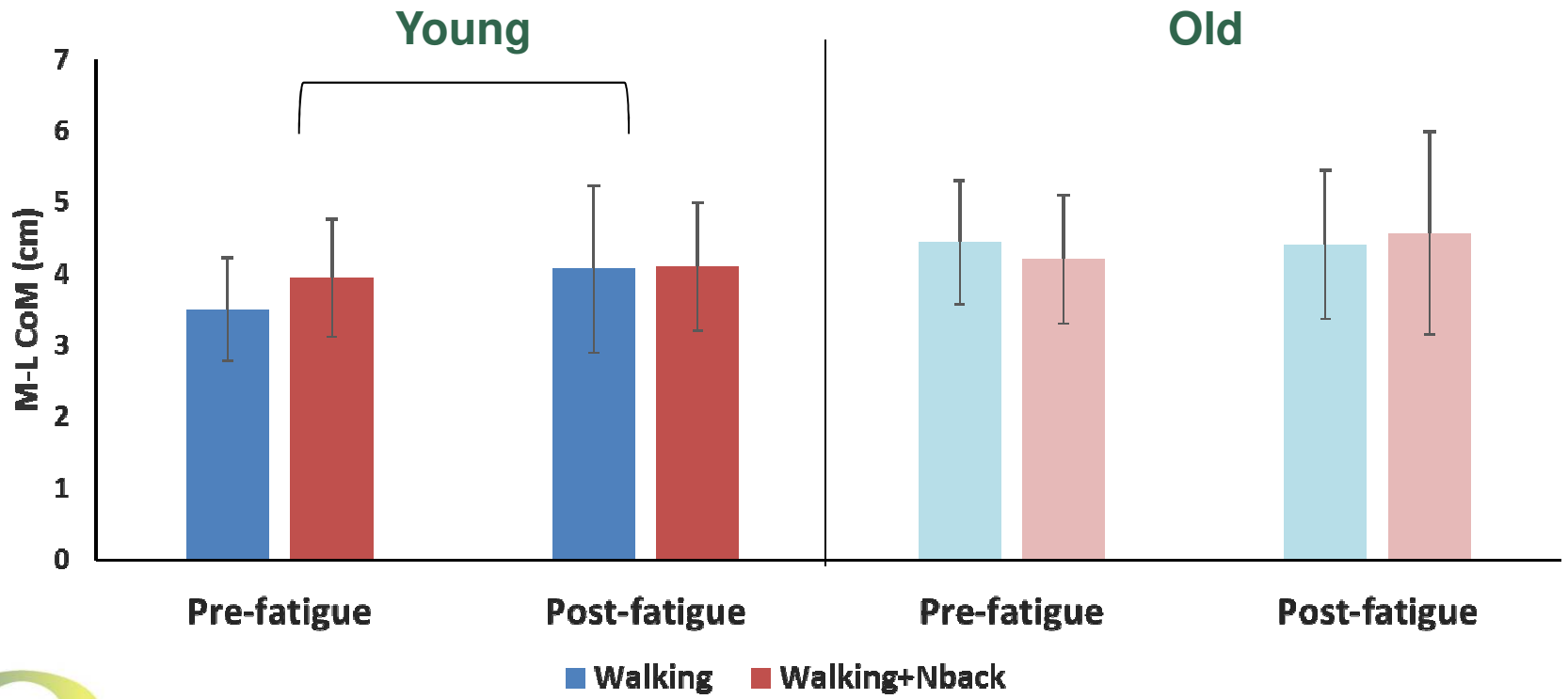
Results: Older

Do older adults have similar response to muscle fatigue?

		Pre fatigue	Post fatigue
M-L CoM (cm)	Single	4.44 ± 0.87	4.41 ± 1.05
⇧	Dual	4.20 ± 0.90	4.57 ± 1.43
Working memory (%) ⇧	Single	90.77 ± 4.39	92.31 ± 7.20
⇩	Dual	90.77 ± 7.98	86.92 ± 4.39

		Pre fatigue	Post fatigue
Gait velocity (m)	Single	1.37 ± 0.20	1.36 ± 0.20
	Dual	1.21 ± 0.21	1.26 ± 0.18
Stride length (m)	Single	1.29 ± 0.13	1.28 ± 0.13
	Dual	1.21 ± 0.14	1.23 ± 0.11
Step width (cm)	Single	7.11 ± 4.01	7.53 ± 3.90
	Dual	6.53 ± 3.24	7.44 ± 4.09

Results: gait balance control



Discussion

- Our preliminary findings indicated that
  - young and older might have different strategies to compensate for fatigue
  - working memory was more negatively affected by the acute muscle fatigue during a dual-task gait task, as compared to the single-task condition.
    - Reduced working memory (X)
    - Inability to adequately allocate attentional resources (O)
- Increased CoM sway in frontal plane was reported:
  - in young adults during walking while texting, older adults with complaint of imbalance and individuals with concussion compared to healthy age-matched groups [1]
  - Implying reduced ability in dynamic control of gait

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  - in young adults during walking while texting, older adults with complaint of imbalance and individuals with concussion compared to healthy age-matched groups [1]
  - Implying reduced ability in dynamic control of gait

1 L.-S. Chou et al, 2003; T.M. Parker et al., 2006; S.H. Chen et al., (submitted)

Future Study

- Walking and simultaneously performing an attention demanding task (e.g. talking to customer, looking at order lists etc.) may take place concurrently with muscle fatigue toward the end of a shift in a variety of jobs

- Present study
  - Identify the effect of muscle fatigue on dual-task gait characteristics which could be potential risk factors for falling accidents.
  - Provide a baseline database for further research on fatigue-prone population.

1 N. Nenonen. 2013

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  - to recruit more subject (older worker & young matched control)
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- Northwest Center for Occupational Health and Safety/ Professional Training Opportunities Program

Thank You

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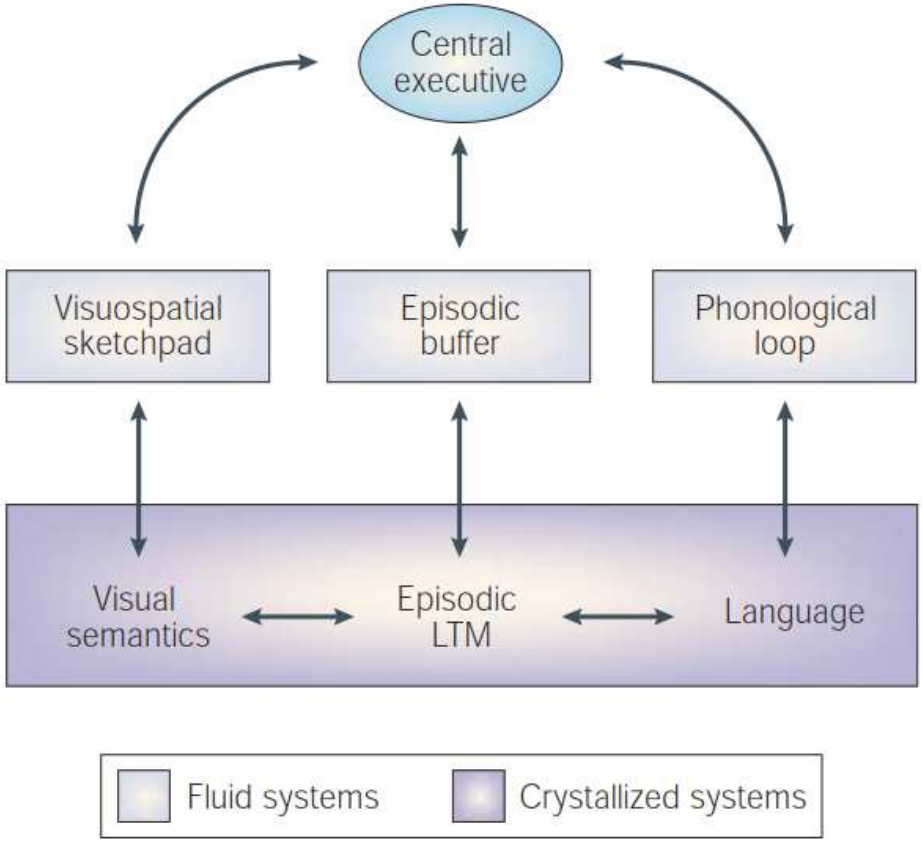
Working Memory



A. Baddeley, 2003