Neuromuscular Changes in Aging: Advanced Concepts

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Goals and Objectives:

- Discuss the newest findings on aging and the neuromuscular system
- Integrate research on assessment of the neuromuscular system for screening, diagnosis and evaluation to determine best practice for assessment of the aging neuromuscular system
- Integrate research on interventions to improve neuromuscular function in the aging individual and those with degenerative disease to determine best practice for improving health across the International Classification of Function categories.

Neuromuscular System

- Normal and pathological age related changes in the neurologic system
- Assess and Interventions for:
  - Cognitive Impairment
  - Risk Reduction for loss of balance and falling
  - Stroke
  - Parkinson disease
  - Peripheral neuropathies
  - Spinal Cord Injury

Normal v. Pathological

- The nervous system experiences declines at a rate of 1% per year, starting at age 30.
- It is important for therapists to have an understanding of normal age-related changes versus pathologies,
- as behaviors that fall outside of what is considered to be the range of normal function should be assessed and treated.

Areas of Decline Functional Impact

<table>
<thead>
<tr>
<th>Areas of Decline</th>
<th>Functional Impact</th>
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<tbody>
<tr>
<td>Gray Matter</td>
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<tr>
<td>Cortical mantle</td>
<td>Deficits in memory, attention, perceptual awareness, thought, language, and consciousness</td>
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<tr>
<td>Prefrontal cortex</td>
<td>Disrupted learning, memory, problem solving, and planning</td>
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<tr>
<td>Orbital frontal cortex</td>
<td>Decreased taste and smell, reward value of taste and smell; impaired learning and reversal of stimulus-reinforcement associations</td>
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<tr>
<td>Parietal cortex</td>
<td>Poorer body scheme, attention and perception</td>
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<tr>
<td>Hippocampus</td>
<td>Declining memory, especially for recent memory</td>
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<tr>
<td>Thalamus</td>
<td>Impaired sensory perception and regulation of motor functions</td>
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<tr>
<td>Basal Ganglia</td>
<td>Disrupted motor planning, limb movement, and skills acquisition</td>
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<tr>
<td>Cerebellum</td>
<td>Poorer coordination and movement timing</td>
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<tr>
<td>White Matter</td>
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<tr>
<td>Myelin</td>
<td>Slower or impaired stimulus conduction</td>
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<tr>
<td>Corpus Callosum</td>
<td>Disrupted interhemispheric communication and decline in bimanual skills</td>
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Brain volume declines

- Greatest age-related differences in the prefrontal and orbital frontal cortices, areas critical for executive function and memory. (Salat)
- The parietal cortex also shows more age differences in gray matter volume than either the temporal or occipital regions.
- Motor control is not only dependent on these areas but is also more dependent on these areas in the elderly than in young adults.
- Subcortical structures, including the cerebellum and basal ganglia, also exhibit reduced volume with aging.
- The cerebellum is important for movement timing and coordination, while the caudate nucleus of the basal ganglia is involved in skill acquisition, specifically motor planning.

Brain volume changes
- Declines in white matter volume begin later but continue at a more accelerated rate than gray matter changes.
- Changes in the corpus callosum, the largest white matter bundle, significantly impact interhemispheric communication that is critical for bimanual coordination.
- There is a decrease in myelin in the gracilis fasciculus and an associated decrement in vibration threshold, indicating that fibers conveying proprioception are most affected by aging.
- Which may contribute to balance deficits due to the loss of long latency postural reactions.
- Fortunately, some brain areas do not exhibit age-related changes, including the cingulate gyrus (influential in linking behavioral outcomes to motivation) and the occipital cortex (vision).

Acetylcholine declines are noted in the hippocampus and associated with changes in memory function. Dopamine are associated with declines in frontal lobe function, including executive function and working memory. Loss of dopamine is closely linked to impairments in gait, balance, and fine motor control.

Alterations in serotonin with age correlate with declines in activity level and diminished balance in mice.

Norepinephrine levels decrease in the cerebellum and are related to diminished motor learning with age.

Peripheral Nervous system
- There is axonal degeneration and greater internodal length variability with shorter internodes more prevalent, suggesting a process of denervation and then regeneration.
- The capacity for axonal regeneration and reinnervation is maintained throughout life but tends to be slower and less effective with aging.
- This pattern of degeneration and re-innervation also leads to changes in the muscle.
Muscle innervation
- Interestingly, there is also a decrease in the number of neurons per muscle fiber,
- leading to fiber grouping, a consequence of denervation and subsequent re-innervation.
- The result of this pattern of changes is likely an increased recruitment of motor units for a given task in older adults.
- It takes more work to do any given task.

Normal age-related changes in the nervous system
- lead to small declines in the sensory and motor systems, including all three systems related to balance:
  - the visual
  - vestibular
  - somatosensory systems.
- These age-related declines result in slowing of movement and difficulty in situations that require faster responses or a higher level of sensory-motor integration.
- Overall, individuals experiencing healthy aging remain able to engage in typical daily activities.
- In the old-old we would expect to see slowing of function and an inability to engage in high-level motor activities such as:
  - balancing on a moving surface or
  - negotiating an unfamiliar area in low light.
- Any loss of function beyond this would potentially be beyond normal age-related changes and may be due to a treatable pathology.

Neurosensory System
- Elderly often cannot maintain balance when vision and somatosensory are removed due to normal degeneration of the vestibular system.

TOUCH
Many studies have shown that with aging, there is reduced or changed sensations of:
- pain
- vibration
- temperature
- pressure
- touch.
It is hard to tell whether these changes are related to aging itself or to the disorders that occur more often in the elderly such as diabetic neuropathy.

VISION
- Pupil reacts more slowly to light
- Ability to change focus quickly from far to near declines - presbyopia - lens becomes more dense and inelastic - reduced accommodation
- Far vision is easier because it is achieved by muscle relaxation
- Poor contrast sensitivity
- Decreased ability to adapt to glare and declines in acuity in glare
- Visual attention impairment

Vision in Gait:
- We use vision to find obstacles and avoid them.
- Obstacle location and motor planning to avoid them happens long before the obstacle is "underfoot".
- Slowing of visual processing and declines in visual attention are related to mobility problems (Owsley C. 2004)
- So, when vision is poor the person won't be able to locate the object until it is much closer (underfoot).
- Knowing this they adapt by:
  - Walking slower,
  - Walking with their head down.

Low Vision’s affect on gait

In a study by Heasley K et al. 2005 they found that elderly subjects with blurred vision increased time in double stance. This allows them to spend more time organizing the postural adjustments necessary to initiate movement. They also did NOT increase step height to clear the step as younger subjects did. This means they didn’t allow greater room for error as younger subjects did.

BUT if they lift the foot higher they have to spend more time in single limb stance and increase medial lateral instability. They are trying to improve medial lateral stability. They improve M-L stability at the expense of risking a trip, in general people’s response to an A-P trip is better than to a loss of M-L stability as people can take a couple of steps forward or backward to recover from a trip in the A-P plane.

Blurred vision and change in surface

There is preliminary data suggesting that blurred vision and compliant surface significantly increases TUG time. Blurred vision on a hard surface and normal vision and compliant surface did not significantly alter TUG time.

So, individuals can compensate for declines in one of the systems but when both vision and somatosensation are impaired mobility skills decline.

Situations that are particularly difficult:

- Bright light and glare
- Poor contrast
- Poor lighting
- Areas with lots of obstacles or a lot of movement in the environment
- Changes in grade or level of the surface (slopes, hills, ramps)

Falls and Low vision clients

Fear of falling and falls are more common than thought in those with low vision (macular degeneration, diabetic retinopathy...)

VISION PATHOLOGY

Glaucoma - increase in intraocular pressure - loss of peripheral vision
Macular degeneration - loss of central vision
Cataract - increased density of the lens. Blurring
Diabetic retinopathy - leaking blood and increased vasculature lead to vision loss
Role of Glare and Color:

- Greater sensitivity to glare can lead to a restriction of the visual field, which in turn leads to an inability to see objects in one's pathway.
- Common sources of glare include:
  - Sunlight shining through windows and reflecting off waxed floors or glossy tabletops,
  - And bright light from unshielded light bulbs.

Contrast Sensitivity

- A loss of ability to see objects that are in poor contrast to the background makes the perception of objects in the environment more difficult.
- The detection of low-contrast objects can lead to unsafe walking.
- If not seen clearly, objects such as door thresholds and carpet edges can cause trips.
- Furnishing surfaces (e.g., chairs and toilet seats) that are not visually distinguishable also can interfere with safe transfers from one surface to another.
- More evident under conditions of dim illumination.

Depth Perception

- A decline in depth perception can cause the visual detection of certain floor surfaces (patterned carpet designs, for example) to appear as elevations or depressions on the ground -- surfaces that older adults prefer to step around or avoid walking on entirely.
- A loss of depth perception makes it difficult to perceive objects in areas of shadows, low illumination or excessive brightness.

Hearing

- Presbycusis - a sensorineural hearing loss. Changes in the inner ear or auditory nerve prevent transmission to the brain.
- Lose the higher and lower frequency levels.
- Speak slowly and allow to visualize your face.

Intelligence and Aging

- If information is presented in a way to compensate for age-related changes in vision and hearing (slower) short term memory is improved. There does appear to be some decline in STM.
- Overall intelligence is not affected by normal aging.

Cognitive Impairment

- Nearly 30% of those over the age of 80 develop severe cognitive impairment - Dementia (pathological).
- Cognitive disorders of all types account for 2/3 of nursing home admissions.
- Cognitive problems can be reversible if result from metabolic, toxic derangements or psychiatric illness.
Dementia
- Slow gradual onset of
  - Diminished ability to reason and make sound judgments.
  - Loss of social skills and development of regressed or antisocial behavior.
- Alzheimers and multi-infarct dementia are the two most common.

Screening for Cognitive Impairment
- Mini-Mental Status Exam - has been in use for a very long time. < 24 indicates possible dementia
- Many add the clock drawing test - ask to draw a clock showing 10 after 11. Normal is correct number hand placement with only minor spacing problems. The test can provide huge amounts of information about general cognitive and adaptive functioning such as memory, how people are able to process information and vision. A normal clock drawing almost always predicts that a person’s cognitive abilities are within normal limits.

Montreal Cognitive Assessment (MoCA)
- Assesses attention, concentration, executive function, memory, language and visual constructional skills, conceptual thinking, calculations and orientation.
- Time to administer is 10 minutes.

Other Cognitive Screening Tests
- Dementia Quick Screen - 3 simple tests (three word recall, animal name generation, clock drawing)
- Mini Cog Assessment - 3 item recall and clock drawing
- Trail Making Test - circles on paper have numbers (part A) or letters (part B) and the person must draw lines connecting them in order

Some types of reversible dementia:
- Depression
- Multi infarct can be stopped if can treat blood pressure
- Vitamin B12 deficiency
- Normal pressure hydrocephalus
- Hypothyroid

Normal Pressure Hydrocephalus
- Presents with dementia, slow shuffling gait and urinary incontinence
- Recommended treatment is to test for response to CSF drainage and if positive do a shunt to improve cognition, gait and incontinence
Assessment and Interventions for the aging Neuromuscular System

Risk Reduction: Cognition

- Previous view – functional decline in cognition unavoidable due to wearing down of the machinery
- Brain plasticity can go in the positive and negative direction.
- New view is that processes with negative consequences begin to dominate brain functioning.
  - Negative Plasticity

4 core factors

- Disuse: not use brain to learn
- Noisy processing
- Ears and eyes give degraded input
- Changes in temporal and spatial integration
- Weakened neuromodulatory control
- The metabolism, connectivity, and eventually, structure of neuromodulatory control systems, which regulate learning and plasticity in adults, become degraded.
- This weakens the brain’s control over its own plasticity, lowering learning rates and trapping the brain in potentially inappropriate or unhelpful patterns of activation.
- Maladaptive compensatory behaviors, ie. look down when walk
- Maladaptive physical behaviors, ie. Walk slower
- These interact to create a self-reinforcing downward spiral of degraded brain function in older adults

Aging changes can be Remediated

- This all suggests that there is the possibility of remediation
- An Effective program would consist of:
  - Adaptive – difficulty level always changing
  - Novel stimuli
  - Attention demanding

Exercise and Cognition

- Studies support that physical activity is related to cognitive function with increased physical activity leading to better cognitive function and less dementia.
- Physical activity in middle age can impact later cognitive function
- Things that can influence or moderate this effect:
  - Executive function most likely to be influenced
  - Combination of aerobic with strength and flexibility worked better
  - Women respond better in the presence of estrogen

DOSE (new slide)

- We need to determine dosage just as physicians do for medications:
  - What exercise do we prescribe?
  - How much should the person “take”?
  - When should they “take” it?
  - How often should they “take” it?
  - How will it interact with other treatments?
Dual task neurologic disorders
- Deficits in motor-cognitive dual tasks (e.g., walking while talking) are common in individuals with neurologic disorders.
- A systematic review shows that dual-task training improves single-task gait velocity and stride length in subjects with PD, CVA and AD, dual-task gait velocity and stride length in subjects with PD, AD, CVA and brain injury.
- And may improve balance and cognition in those with PD and AD.
- While available studies are limited motor-cognitive dual-task deficits in individuals with neurologic disorders appear to be amenable to training.
- Improvement of dual-task ability in individuals with neurologic disorders holds potential for improving gait, balance, and cognition.

Risk Reduction for balance, mobility and falling
OLDER PERSONS LIVING IN THE COMMUNITY
- The components most commonly included in effective interventions were:
  - Exercise, particularly balance, strength, and gait training [A]
  - Adaptation or modification of home environment [A]
  - Withdrawal or reevaluation of psychoactive medications [B]
  - Management of postural hypotension [C]
  - Management of foot problems and footwear [C]
  - Management of medication side effects [C]

- The multifactorial fall risk assessment should be followed by direct interventions tailored to the identified risk factors, coupled with an appropriate exercise program [A]
- All older adults who are at risk of falling should be offered an exercise program to support balance, gait, and strength training. Flexibility and endurance training should also be offered, but not as sole components of the program [A]
- Multifactorial/multicomponent interventions should include an education component (implementing a fall prevention education program, tailored to individual cognitive function and language) [C]
**Circuit Training Study**

- Both groups reduced falls significantly and improved scores in TUG and TUG cognitive
- Balance Circuit group improved more in functional activities of:
  - Roll to left
  - Ambulation velocity
- Total Clinical Outcomes Variable Scale
  - Lateral reach
  - Step test
  - TUG manual
- Neither group improved in functional reach or laboratory balance measures

**Life Study**

- The Lifestyle-integrated Functional Exercise (LiFE) program is a way of reducing the risk of falls by integrating balance and strength activities into regular daily tasks. Unloading
  - the dishwasher becomes an opportunity to improve strength.
  - Squats for leg strengthening
  - Lifting objects for UE strengthening
- Brushing your teeth becomes an opportunity to improve balance.
  - Single limb stance for balance

**Stroke**

- CVA
  - Forced use or Constraint Induced Training
  - Bilateral Training
  - Balance and agility training
  - Treadmill
  - Orthotics
  - Medications/botulinum toxin

**Constraint Induced Movement Therapy**

- Involves demanding that the individual use the involved UE for all activities by restraining use of the uninvolved extremity.
- Works to improve function
- Can lead to some other problems:
  - Anxiety
  - Overson of some joints leading to pain and overuse syndromes

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**Table 1**

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<thead>
<tr>
<th>Exercise Category</th>
<th>Response</th>
<th>Exercise Details</th>
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<tbody>
<tr>
<td>Balance Circuit</td>
<td>Response</td>
<td>Exercise Details</td>
</tr>
<tr>
<td>TUG</td>
<td>Improvement</td>
<td>Improvement</td>
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Nitz et al. Age & Aging 2004
Why does CIT work?

- Involves task-oriented therapy
- Involves thousands of repetitions
- Results continue to support previous findings for specificity of training.
- Subjects improved in the areas that were trained and not in those that weren’t as evidenced by the Stroke Impact Scale findings.
- When might it not be ideal or should be modified if the involved UE is not the dominant extremity these activities may not be appropriate.

fMRI evidence for mCIMT

- Study of 4 subjects showed fMRI evidence for cortical reorganization after mCIMT training.
- mCIMT - 30 minutes, 3 times a week for 10 weeks. Restrained unaffected hand 5 hours a day during this 10 weeks.
- 3 subjects improved in measures of affected arm use, impairment and function. These 3 subjects fMRI showed cortical reorganization.
- The 4th subject showed little change on any impairment, use or functional measure and also showed little evidence of cortical reorganization.

What does this tell us?

- Changes that we see in impairment, function and amount of use correlate with cortical reorganization seen on fMRI.
- The subject who reported using the involved UE the least had no real change on any measure.
- Perhaps there are individuals who cannot respond to CIT training due to inability to effectively cortically reorganize.
- Perhaps future studies will help us to determine who these individuals may be. Is it lesion location? Size? Both?

Bilateral Training

- Studies to date have been small but with positive findings.
- Carraugh has looked at combination of bilateral training and FES.
- Subjects were divided into 3 groups: NMES only, NMES and bilateral movement and control.
- Subjects in the coupled treatment improved significantly more in box and block test and speed tests. The unilateral group also improved.

BATRAC

- McCombe, Whitall and Luft have looked at BATRAC (bilateral arm training with rhythmic auditory cueing) as a means of doing bilateral training.
- They correlated the improvement in arm use, impairment and function with fMRI findings.
- Those who used the arm more improved in function and impairment measures and demonstrated cortical reorganization.
Mudie and Matyas

- Fascinating study with a single subject design across 12 subjects.
- Looked at 3 paradigms:
  - Equivalent tasks bilateral such as lift a block, put a peg in a hole and simulate drinking
  - Tried doing opposing tasks and had interference with learning under this paradigm
  - Also compared bilateral isokinematic training - use of the uninvolved arm to assist the involved.

Bilateral Training Summary

- Studies have had positive results demonstrating that interlimb coordination can be used in rehabilitation of the hemiparetic UE
- Appears that bilateral training with both extremities doing the same, symmetrical task is more effective
- For very weak individuals combining with sensory feedback appears to facilitate the effects, two types studied:
  - NMES – functional electrical stimulation
  - BATRAC – auditory cueing

Video-Games

- Video-game use is popular and has potential to be of benefit.
- If it is fun the person is more likely to be compliant and to exercise more.
- Needs to be functional and to train the appropriate motions.
- No game yet shown to do the job. So far conventional therapy and gaming equally effective.
- Some studies using commercially available games.

Dosage is the key

- All studies of CMT and bilateral training use a very high dosage – thousands of repetitions daily
- When dosage is matched conventional treatment focused on exercise and functional training of the UE can be equally effective (van Delden, 2013)
- Patterns of fMRI changes are different based on the intervention.
- Bilateral and dCMT both lead to increases in bilateral hemisphere activation
- Bilateral leads to increased cerebellar activation and dCMT leads to decreased cerebellar activation (Wu, 2000)

Lower Extremity and Mobility

- Task-specific gait training improves gait post-stroke.
- Virtual reality devices may enhance gait performance.
- Balance training, using specific devices or exercises, post stroke is beneficial.
- Rhythmic sensory auditory stimulation improves gait post-stroke.
- The use of canes is associated with improved mobility post-stroke.
- Electric stimulation combined with gait training improves hemiplegic gait. EMG/Biofeedback treatment improves gait control.
- Ankle foot orthoses appear to improve gait, particularly in association with popliteal tibial nerve deinnervation.
- Strength training is beneficial for hemiparetic stroke patients. Cardiovascular training improves physical fitness post-stroke.
Lower Extremity and Mobility

- A tilt table or night splint can prevent ankle contracture early post stroke.
- Electrical stimulation and therapeutic ultrasound can reduce ankle plantarflexion spasticity.
- Robotic devices may not offer additional benefit compared with conventional therapy.
- It is uncertain whether partial body weight support and treadmill training result in improved gait training.
- Encouraging self-propelling a wheelchair by hemiplegic stroke patients does not have an impact on functional outcomes.
- Treatment with Botulinum toxin reduces lower-limb spasticity, but has not convincingly been shown to improve function.

Agility training v. Stretching and weight shifting

- Looked at agility training v. stretching and weight shifting in chronic stroke survivors.
- Agility group significantly better in:
  - Step reaction time
  - Reflex onset latency rectus femoris
  - Balancing (no or fewer falls) during platform translation
- Both groups showed significant improvement in the rest of the outcome measures.
- Other measures were:
  - Berg
  - TUG
  - ABC Scale
  - Nottingham health profile
  - Reflex onset latency of tibialis posterior, medial gastroc, biceps femoris non and paretic.

Sensation and Recovery of Function

- Sensory function is essential to recovery of function.
- Studies to date demonstrate the sensory system is an integral part of motor output.
- We use the hand to both manipulate objects and to explore the object’s properties.
- Studies support the use of sensory training to improve dexterity and function in the hand.
- No studies yet in lower extremity.
- Much more work is needed in this area, we know sensation plays a role but it is usually ignored in the rehabilitation program for survivors of CVA.

Parkinson Disease

- Studies show that exercise improves function and appears to perhaps delay disease progression.
- Effective interventions:
  - Treadmill training (Herman T, review)
  - Auditory cueing (Kadivar Z)
  - LST/BIG (Farley B)
  - Dance (tango and ballroom) (Hachney)
  - Eccentric strength training (Dibble LE)

Parkinson Disease: Auditory cues
- Several studies utilized music or metronome to set the pace during walking
- They improved stride length and gait speed.

Lift Stride, a new gait-tracking technology in the palm of your hand.

Parkinson Disease: LSVT BIG
- Exercise program that emphasizes BIG movements
- The protocol had subjects exercise one hour per day - 4 days per week.
- There is a program to train people how to do “LSVT BIG.”

Parkinson Disease: Dancing and Eccentric training
- Several studies have used dancing - including tango – to help improve mobility and balance (Hackney)
- Eccentric training improved strength, 6 minute walk test and stair climbing. (Dibble LE)

Parkinson Disease: Dancing

Neuropathy:
Polyneuropathy
- Diffuse distal symmetric polyneuropathies are the most common of the neuropathic syndromes in diabetes.
- Studies showed that an ankle brace improved gait on irregular surfaces in those with peripheral neuropathy though it did not improve proprioception. (Son)
- Focus on training balance and practicing walking with soft and uneven surfaces


SCI
In a study by Pickett et al. it was found (age adjusted incident rate):
- Motor Vehicle Collisions were the most frequent causes of SCI in young and middle-aged persons

Pickett, G Spine, 31(7), 2006, p. 769-805
Older Individuals with SCI

- Older individuals experienced greater functional deficit (FIM scores) than younger individuals, despite experiencing similar rates of sensorimotor recovery.
- Older individuals have a substantially increased mortality rate during the first year following SCI in comparison with younger patients.
- The potential of older patients with SCI to neurologically improve within the first year post-injury does not appear to translate into similar functional recovery compared to that seen in younger individuals.
- Given this fact, rehabilitation protocols that are more focused on functional recovery may reduce disability among older people with acute traumatic SCI.


Rehabilitation of the Older Client with SCI

- We need to be prepared to rehabilitate these individuals and train the professionals working with them to recognize the unique challenges facing an aged individual with SCI as compared to younger SCI patients.
- Greater levels of weakness on entering rehabilitation
- More comorbidities - including arthritis
- Caregiver is also likely to be elderly and have medical issues

Thank You

- Many thanks to the support of my co-PI’s Anne Kloos and Sandra Kostyk and the many students who constantly challenge me.