technology for injury prevention in seniors
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INJURY PREVENTION AND MOBILITY LABORATORY

Falls Detection and Description: How We Monitor and What Can We Learn?

Part 1: Video capture technology

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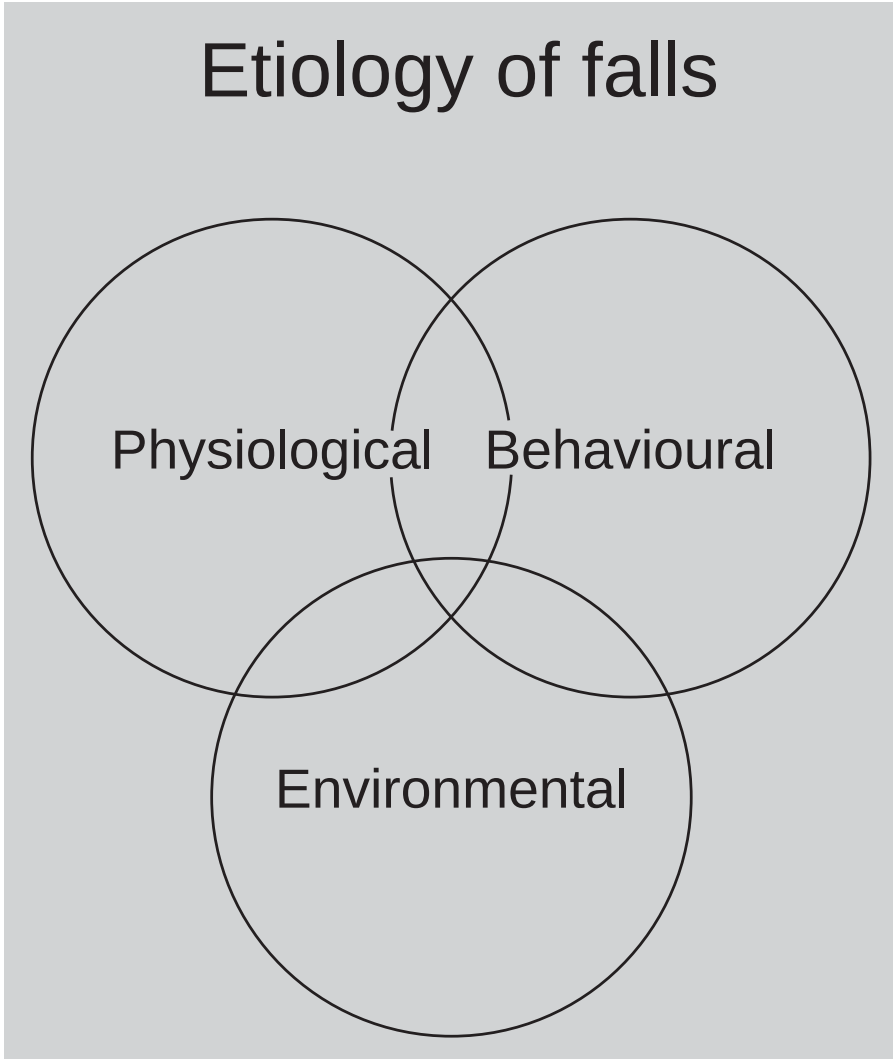
Falls result from complex interactions between intrinsic and extrinsic factors



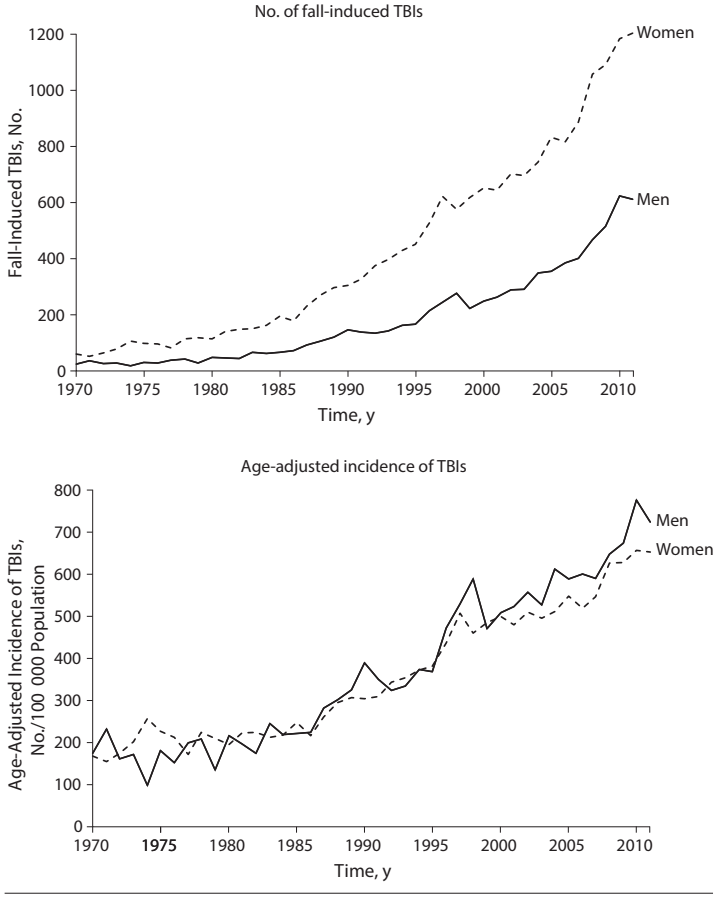
Fall mechanics at least as important as bone density in predicting hip fracture

Risk factors for hip fracture during a fall:	
1 SD decrease in BMD*:	2-3x increase
falling sideways:	6x increase
impact to hip:	30x increase
lower limb weakness:	5x increase
impact to hand or knee:	3x decrease
upper limb weakness:	2x increase

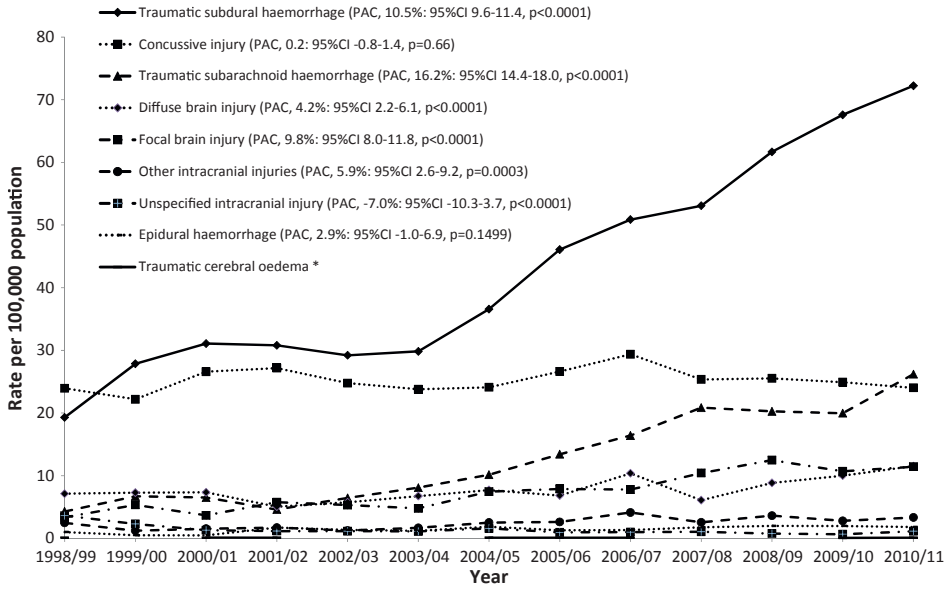
Sources: Greenspan et al., 1994; Schwartz et al., 1998; Nevitt and Cummings, 1993

Rates of fall-related head injuries in seniors are increasing

Fall-Induced Traumatic Brain Injuries (TBIs) in Finnish Women and Men Aged 80 Years or Older Between 1970 and 2011



Source: Kornhonen et al., 2013



Age standardised TBI admission rates by type of injury and year, persons aged 65 years and older, NSW 1998/99 to 2010/11.

Source: Harvey and Close, 2012

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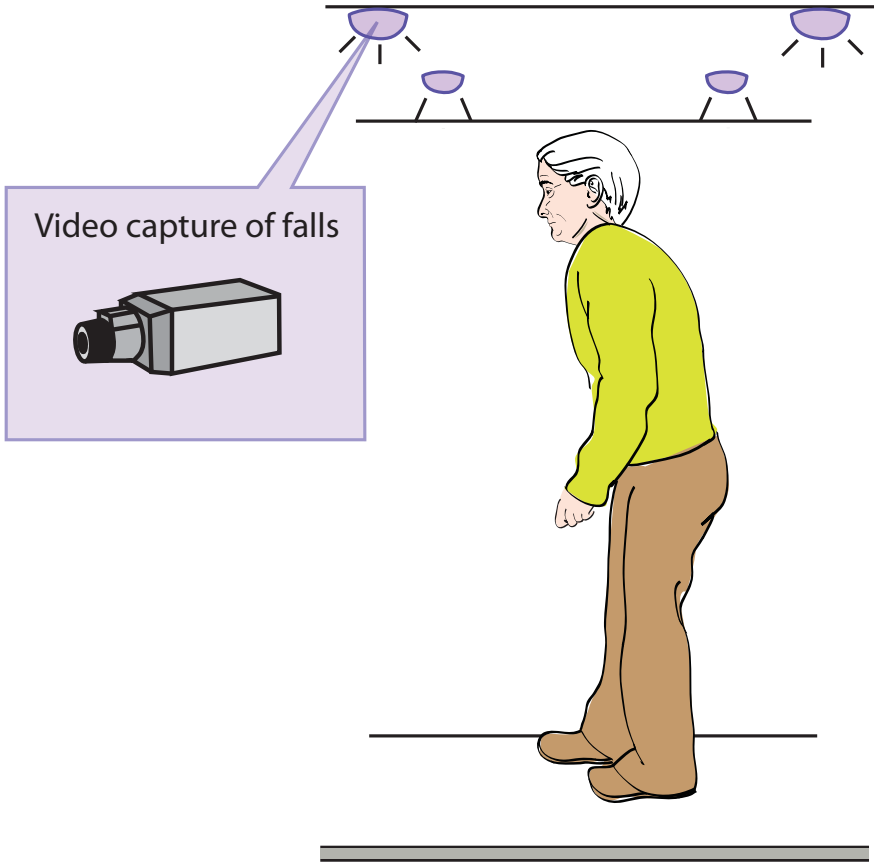
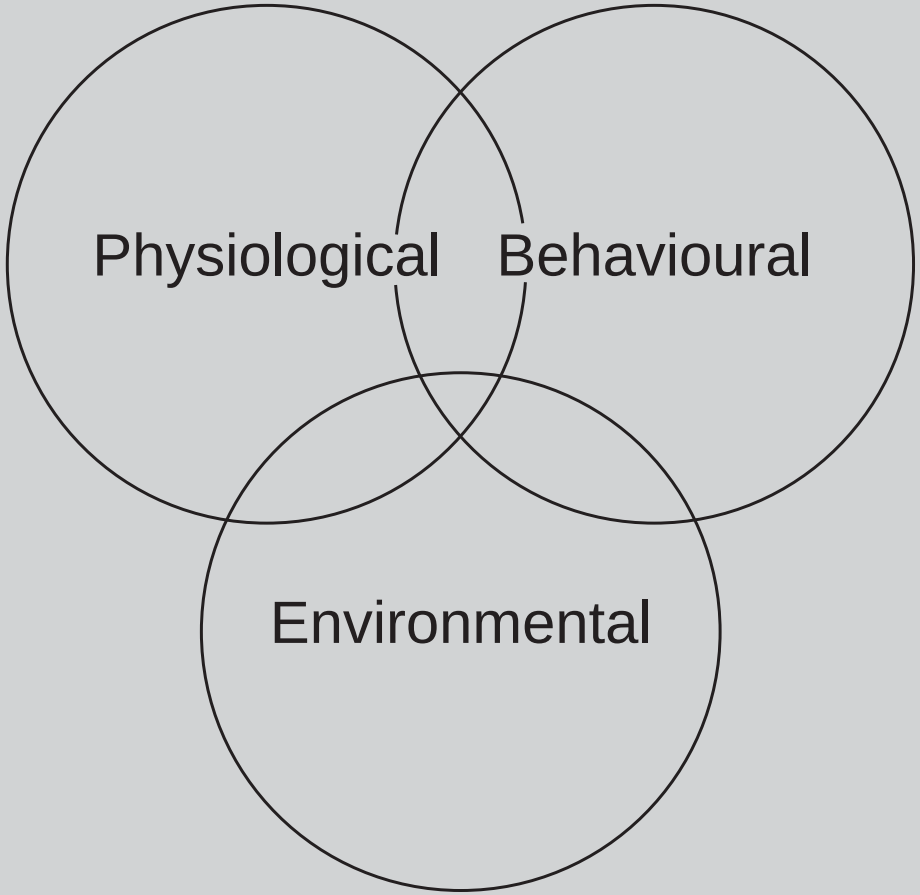
AAST 2013 Plenary Paper

Mortality after ground-level fall in the elderly patient taking oral anticoagulation for atrial fibrillation/flutter: A long-term analysis of risk versus benefit

Tazo Stowe Inui, MD, Ralitza Parina, MPH, David C. Chang, MBA, MPH, PhD, Thomas S. Inui, MD, MSc, and Raul Coimbra, MD, PhD, San Diego, California



Etiology of falls



Consent for use of video and images

- all individuals shown in videos and images have provided us with consent for use of those materials for educational purposes

Video capture of real-life falls in LTC

- 270 digital video cameras in common areas of 2 long-term care (LTC) facilities (with 522 collective residents)
- fall incidence report triggers video collection
- between 2007-2015, analyzed 1376 falls in 426 residents
- access to medical records: 826 falls in 211 fallers
- consent to share for education: 800 falls in 183 fallers

Characteristics from Minimal Data Set (MDS) for n = 160 fallers captured on video

Characteristics of 160 participants captured on video providing consent to access medical records.

Demographics and health condition	
Age (mean, (SD))	81.7 yrs (SD = 9.5)
Female (n, (%))	100 (62.5%)
Dependent ADL performance (n, (%))	101 (63.1%)
Moderate to severe cognitive impairment (n, (%))	119 (74.4%)
Impaired vision (n, (%))	63 (39.4%)
Disease Diagnoses (n, (%))	
Alzheimer's Disease	47 (29.4%)
Diabetes	34(21.3%)
Cardiac arrhythmia	8 (5.0%)
Hypertension	64 (40.0%)
Hypotension	2 (1.2%)
Stroke	18 (11.3%)
Parkinson's Disease	4 (2.5%)
COPD	19 (11.9%)
Use of Medications (n, (%))	
Antipsychotic	72 (45.0%)
Antianxiety	30 (18.8%)
Antidepressant	73 (45.6%)
Hypnotic	23 (14.4%)
Diuretic	36 (22.5%)
Analgesic	82 (51.2%)

SD = standard deviation; n = number of residents.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Video analytics

how should I word the questions and responses?

what questions can I answer from video footage of falls?

should individuals or teams conduct the analysis?

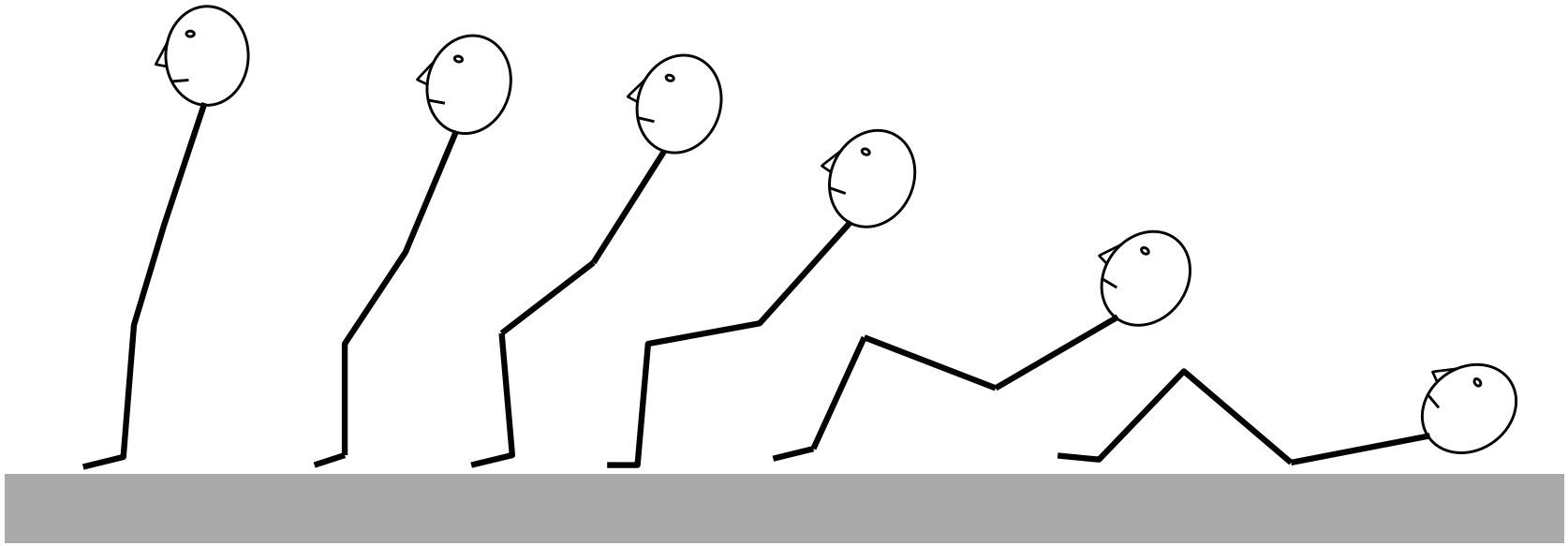
what questions are important to my stakeholders?

how can I best translate the results of my research?

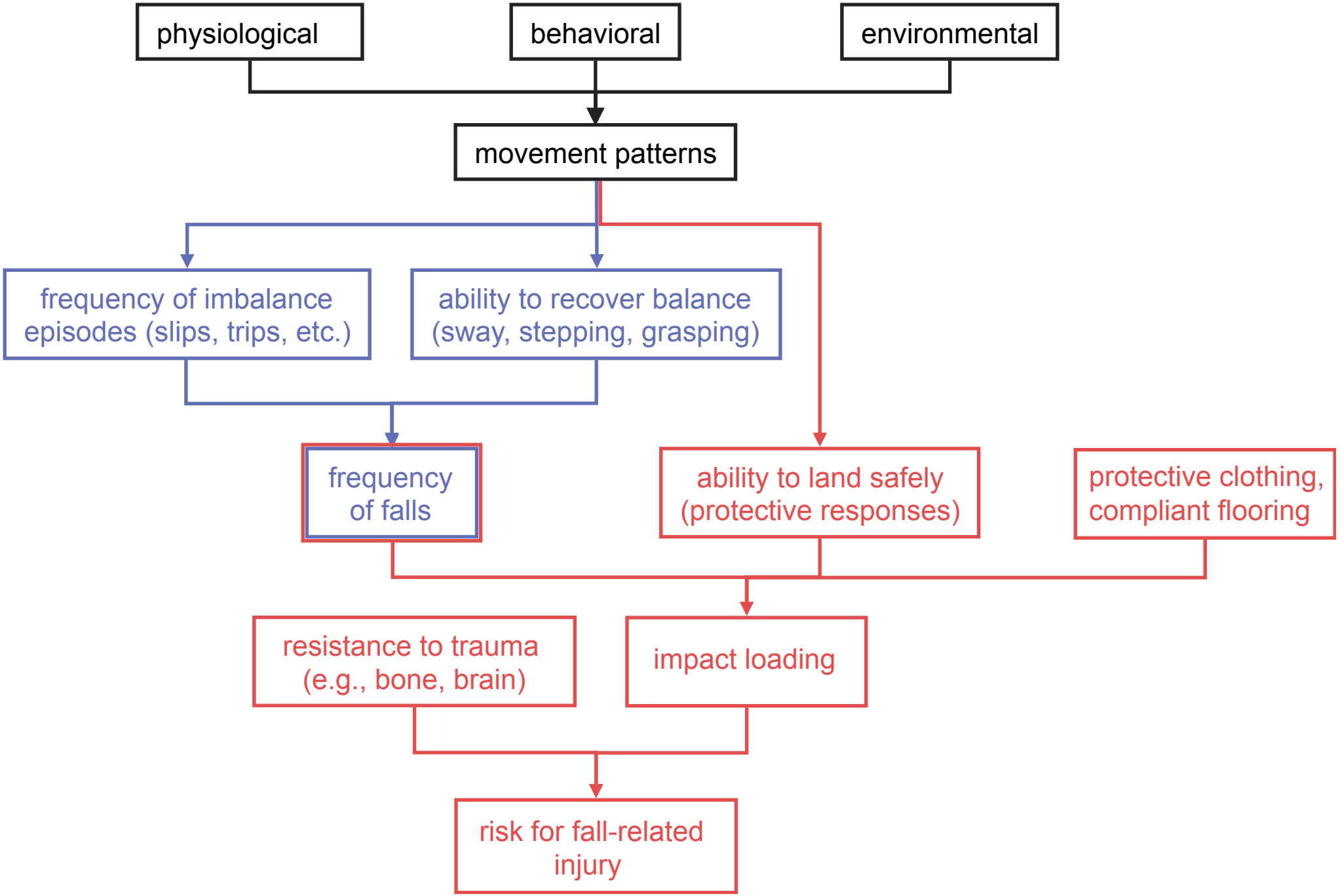
Strengths and weaknesses to our approach

- standard resolution video (640x480 resolution)
- focus on long-term care
- observational and not interventional
- falls in common areas (not bedrooms or bathrooms)

Stages of falling



initiation descent impact


physiological
behavioral
environmental
movement patterns
frequency of imbalance episodes (slips, trips, etc.)
ability to recover balance (sway, stepping, grasping)
frequency of falls
ability to land safely (protective responses)
protective clothing, compliant flooring
resistance to trauma (e.g., bone, brain)
impact loading
risk for fall-related injury

Conceptual basis for Fall Video Analysis Questionnaire

Initiation stage (A, B)	Descent stage (C, D)	Impact stage (E, F)
Cause of fall	Initial fall direction	Landing configuration
Activity at time of fall	Stepping responses	Floor material
Height of fall	Reach-to-grasp responses	Head impact
Mobility aids		Pelvis/ hip impact
Held objects		Hand/ wrist impact
Footwear		Elbow/ forearm impact
Floor conditions - Wet/Dry		Knee impact
Floor conditions - Transition		Shoulder impact
Lighting		Torso impact
Contribution of clutter		Site of greatest energy absorption
		Site of injury risk/ impact severity

Reference: Yang, Y., *et al*., BMC Geriatrics, 2013 (internal validation and downloadable questionnaire) http://www.biomedcentral.com/1471-2318/13/40

Sample question - FVAQ

Question 2. Cause of fall.

Describe the primary biomechanical cause of imbalance. Select the best answer among those listed. Estimate the percent probability (1-100%) of your answer being correct at the bottom.

i. Slip
ii. Trip/stumble
iii. Hit/bump
iv. Fell asleep/legs collapsed/loss of consciousness
v. Incorrect transfer/shift of body weight
vi. Loss of support with external object

Probability: _____

Question 2. Cause of fall.

Select the answer that best describes how, from a biomechanical perspective, the resident lost balance and fell. Estimate the percent probability (1-100%) of your answer being correct. Consider the following definitions in selecting your response:

- SLIP: Loss of balance due to an apparent sliding of the foot along the floor.
- TRIP/STUMBLE: Loss of balance due to the foot or shin apparently colliding with, or becoming caught, on an object. The object may be moving or stationary, and may include, for example, another person, or the individual's other foot.
- HIT/BUMP: Loss of balance due to a body part above the knee apparently colliding with an object. The object may be moving or stationary, and may include, for example, another person.
- FELL ASLEEP/ LEGS COLLAPSED/ SUDDEN LOSS OF CONSCIOUSNESS: This is a class of falls related to loss in muscle tone, control of balance, or consciousness.
    - Select "fell asleep" when it appears most likely that the individual lost balance after dozing off.
    - Select "legs collapsed" when there is no apparent loss of consciousness, but sudden loss in muscle tone and collapsing of one or more lower extremity joints, leading to a fall.
    - Select "sudden loss of consciousness" for events that involve fainting (syncope) or seizure. Fainting is usually accompanied by loss of muscle tone (and slinking of the body to the ground). Some types of seizures also lead to loss of muscle tone, while others produce muscle rigidity.
- INCORRECT TRANSFER/ SHIFT OF BODY WEIGHT: Loss of balance due to self-induced movement of the body's centre-of-gravity beyond the base of support. Different from slip, trip/stumble, and hit/bump in the sense that the cause of imbalance is an "internal" rather than an "external" perturbation.
- LOSS OF SUPPORT WITH EXTERNAL OBJECT: Imbalance due to a sudden decrease in the supporting force from an external object (e.g., handheld object, chair, wheelchair)

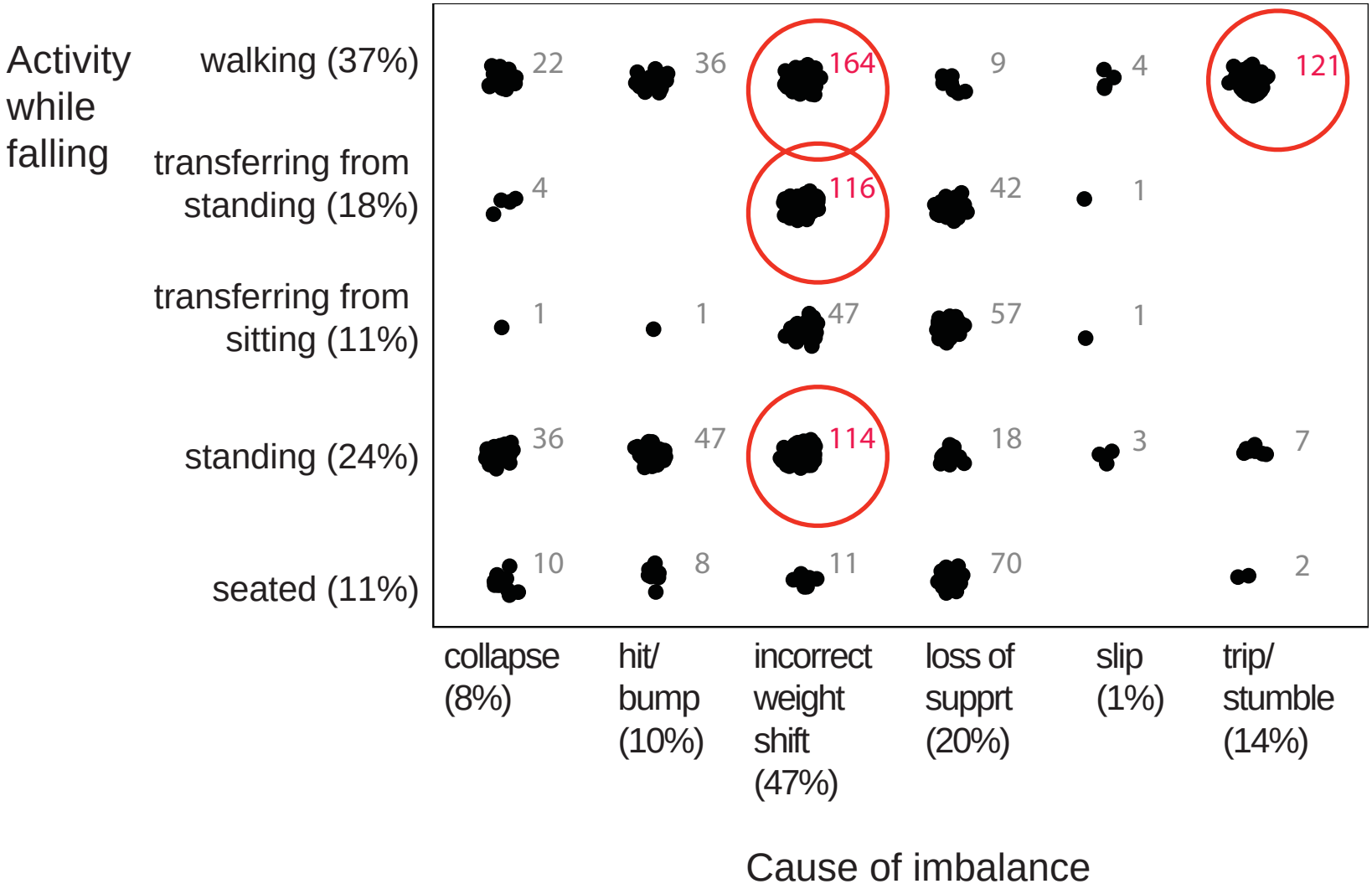
Source: Yang, Y., *et al*., BMC Geriatrics, 2013
http://www.biomedcentral.com/1471-2318/13/40

20% of falls resulted in injury; 47% to the head

Characteristics of 176 primary injuries associated with 863 falls (in 309 individuals) analyzed between April 2007 - May 2013

Site of injury	**Type of injury**							**Total cases**
	Pain	Tenderness	Cut/Scrape/ Abrasion	Bruise	Redness/ Swelling	Sprain/Strain/ Dislocation	Bone Fracture	
Head/Face	4	1	**50**	6	**22**	0	0	83 (**47.2%**)
Elbow	1	0	**23**	3	4	0	0	31 (17.6%)
Knee/Shin	3	1	8	2	3	0	0	17 (9.7%)
Spine/Back	4	1	6	1	1	0	0	13 (7.4%)
Hip/Thigh	2	0	2	0	0	1	**6**	11 (6.3%)
Hand/Wrist	0	1	8	0	2	0	**0**	11 (6.2%)
Shoulder/Arm	1	0	7	0	0	0	0	8 (4.5%)
Pelvis/Tailbone	1	0	0	0	0	0	0	1 (0.9%)
Chest/Abdomen	0	0	0	0	1	0	0	1 (0.9%)
Total cases	16 (9.1%)	4 (2.3%)	104 (59.1%)	12 (6.8%)	33 (18.8%)	1 (0.6%)	6 (3.4%)	176 (100%)

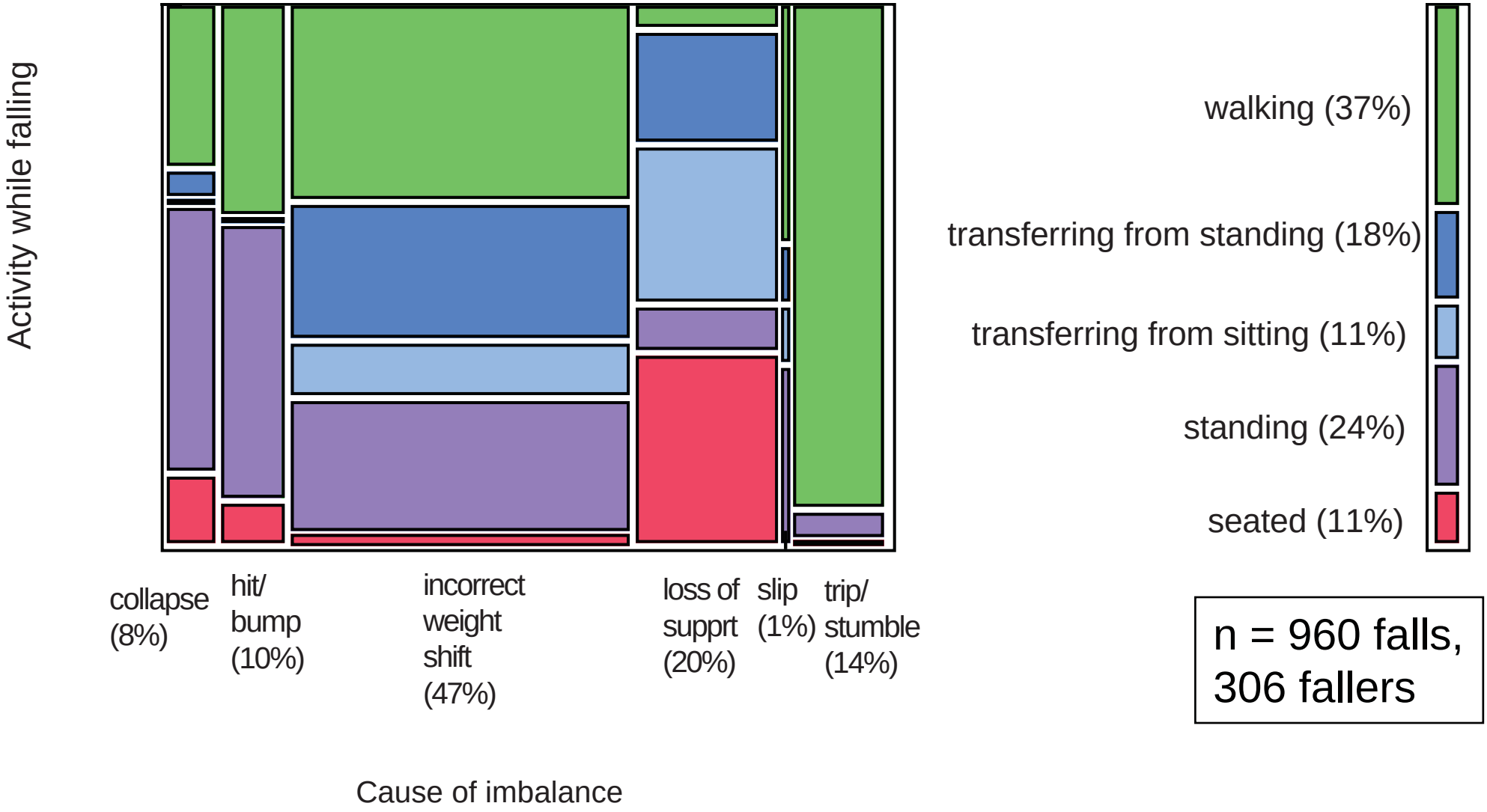
Combinations of cause of imbalance and activity when falling



n = 960 falls, 306 fallers

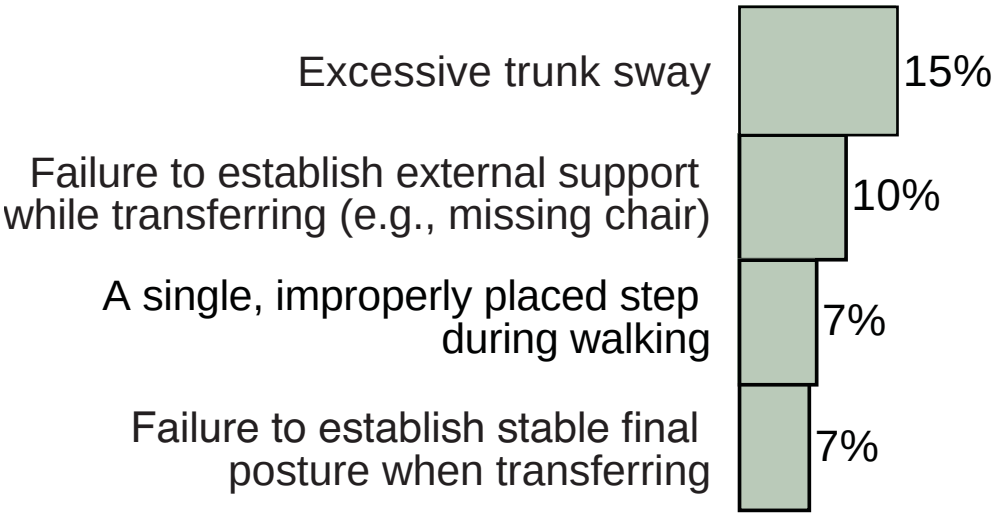
Source: Robinovitch et al., Lancet, 2013

Combinations of cause of imbalance and activity when falling

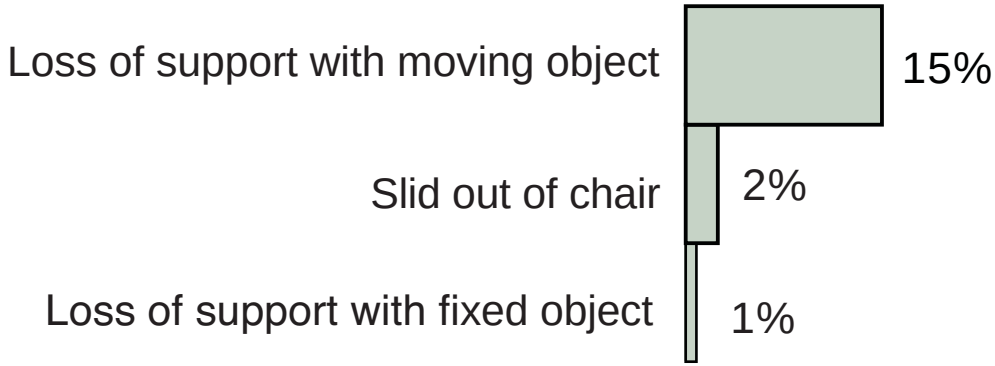


n = 960 falls, 306 fallers

Sub-categories: incorrect weight shift

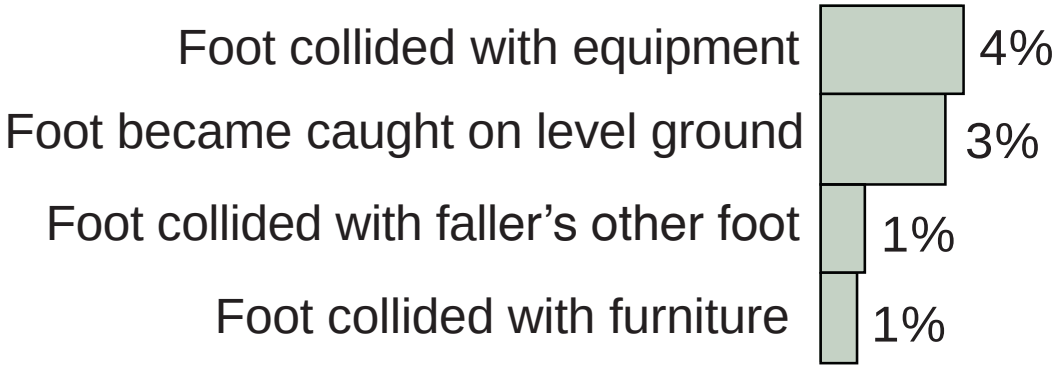


Sub-categories: loss of support



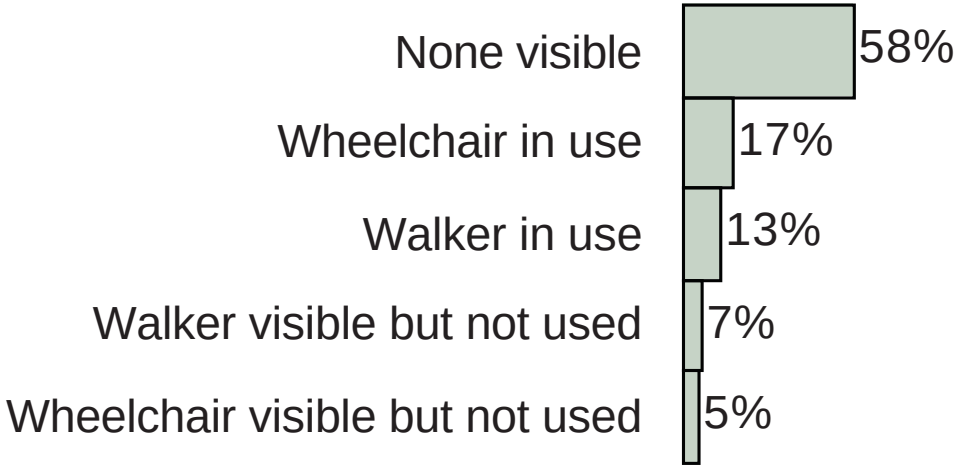
n = 960 falls,
306 fallers

Sub-categories: tripping



n = 960 falls,
306 fallers

Mobility aids



Agreement between incident reports and video analysis on fall circumstances

Fall characteristic	Cases (n)	Percentage of agreement	Cohen's Kappa (95% CI)
Cause of imbalance	331/ 119	45.3%/ 52.8%	0.25 (0.18-0.32)
Activity at time of fall	420/ 151	45.1%/ 48.4%	0.22 (0.21-0.23)
Use of mobility aids	731/ 190	79.5%/ 81.0%	0.59 (0.53-0.65)

Source: Yang et al., JAMDA, 2015

Cause of imbalance

		Incident report (n = 334 falls)						
		Incorrect weight transfer	Trip/ stumble	Loss-of-support	Hit/ bump	Collapse	Slip	Total
Video Analysis (n = 334 falls)	Incorrect weight transfer	92	17	10	2	9	27	157
	Trip/stumble	19	20	3	1	6	4	53
	Loss-of-support	20	2	10	3	2	15	52
	Hit/bump	14	4	3	20	2	1	44
	Collapse	13	1	2	0	9	1	26
	Slip	1	0	0	0	0	1	2
	Total	159	44	28	26	28	49	334

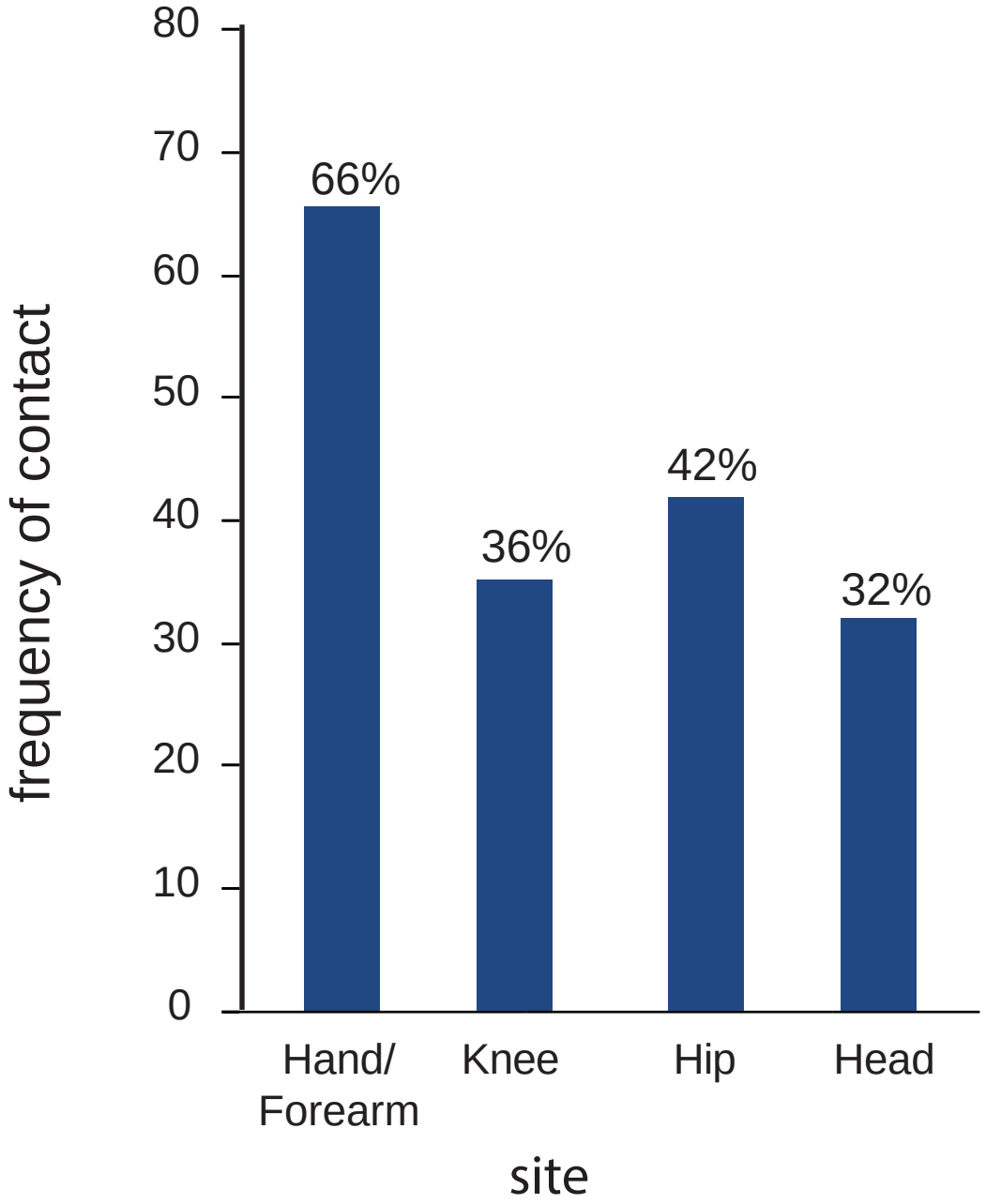
Activity at the time of falling

		Incident report (n = 421 falls)					
		Walking	Standing	Sitting down/ lowering	Getting up/ rising	Seated/ wheeling in wheelchair	Total
Video analysis (n = 421 falls)	Walking	132	8	6	32	7	185
	Standing	58	19	4	23	3	107
	Sitting down/lowering	24	5	16	12	4	61
	Getting up/rising	8	1	7	15	12	43
	Seated/ wheeling in wheelchair	3	2	3	9	8	25
	Total	225	35	36	91	34	421

Use of mobility aids

		Incident report (n = 731 falls)				
		No mobility aid being used	Wheelchair in use	Walker in use	Cane in use	Total
Video analysis (n = 731 falls)	No mobility aid being used	420	35	43	3	501
	Wheelchair in use	50	75	1	0	126
	Walker in use	7	9	82	0	98
	Cane in use	1	1	0	4	6
	Total	478	120	126	7	731

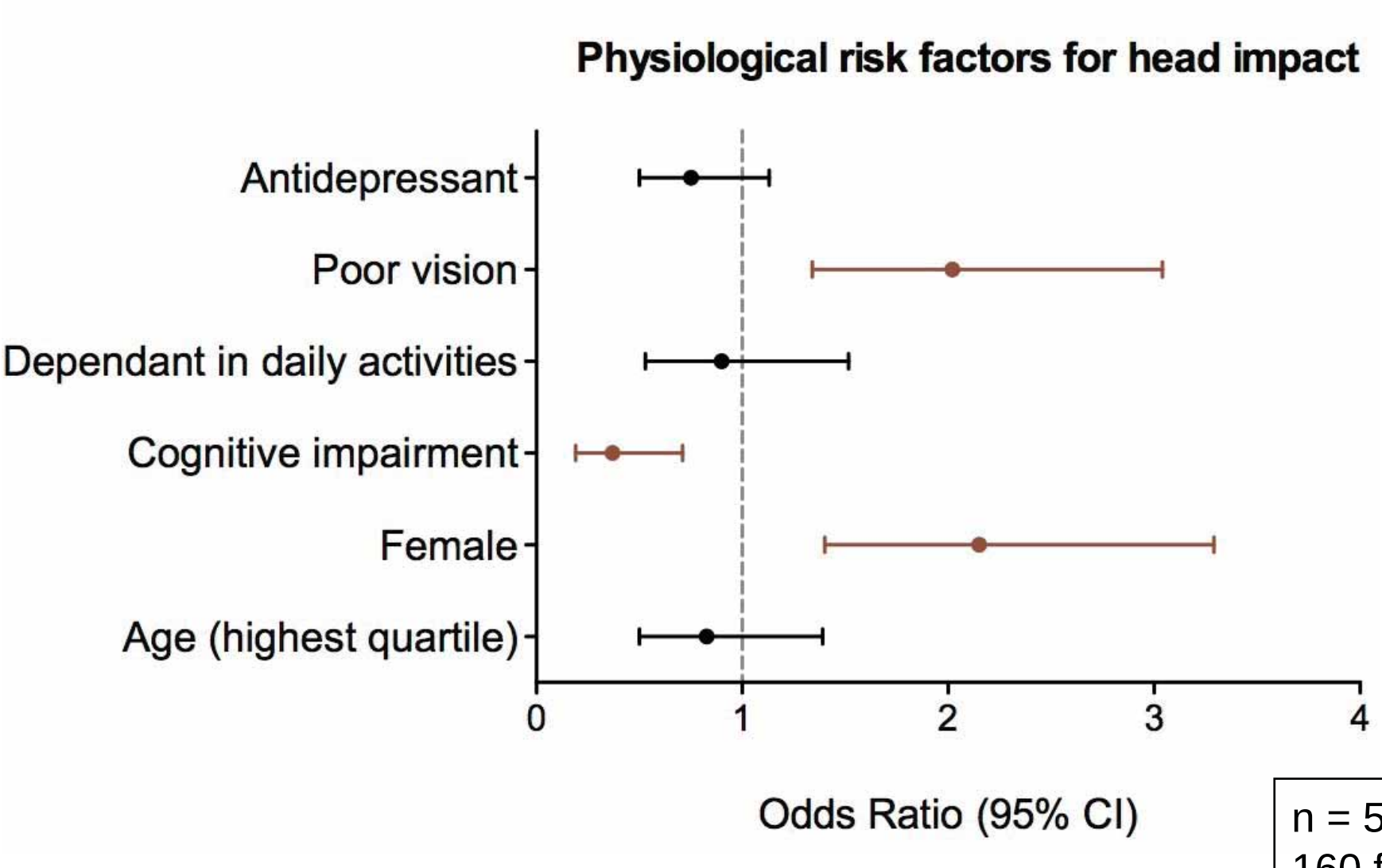
32% of falls resulted in head impact



n = 960 falls,
306 fallers


Unsuccessful arm arrest

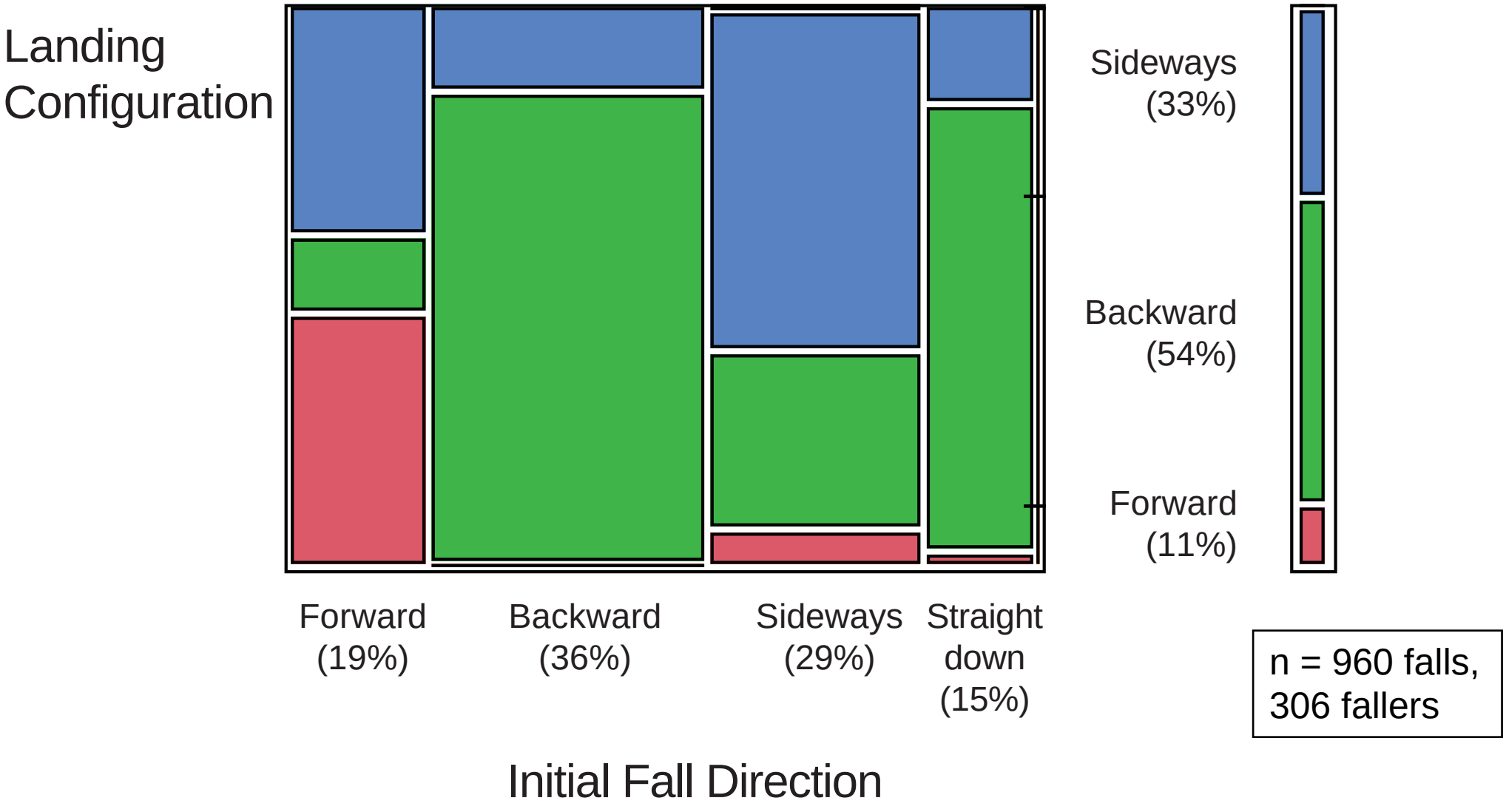
Probability for head impact associated with vision and gender



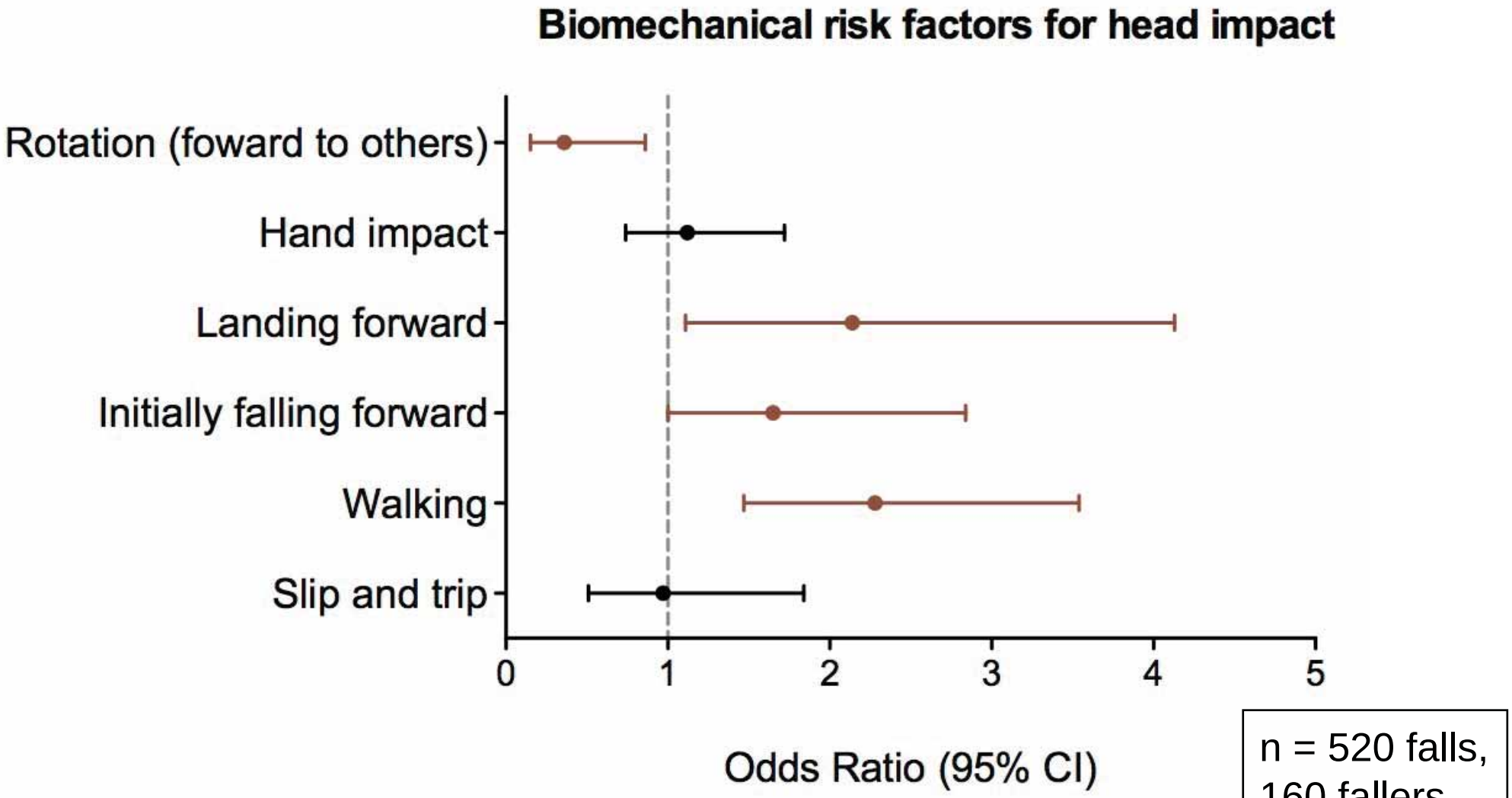
n = 520 falls,
160 fallers

Reference: Yijian Yang, PhD thesis, 2015

Direction of falls: tendency for backward rotation during descent



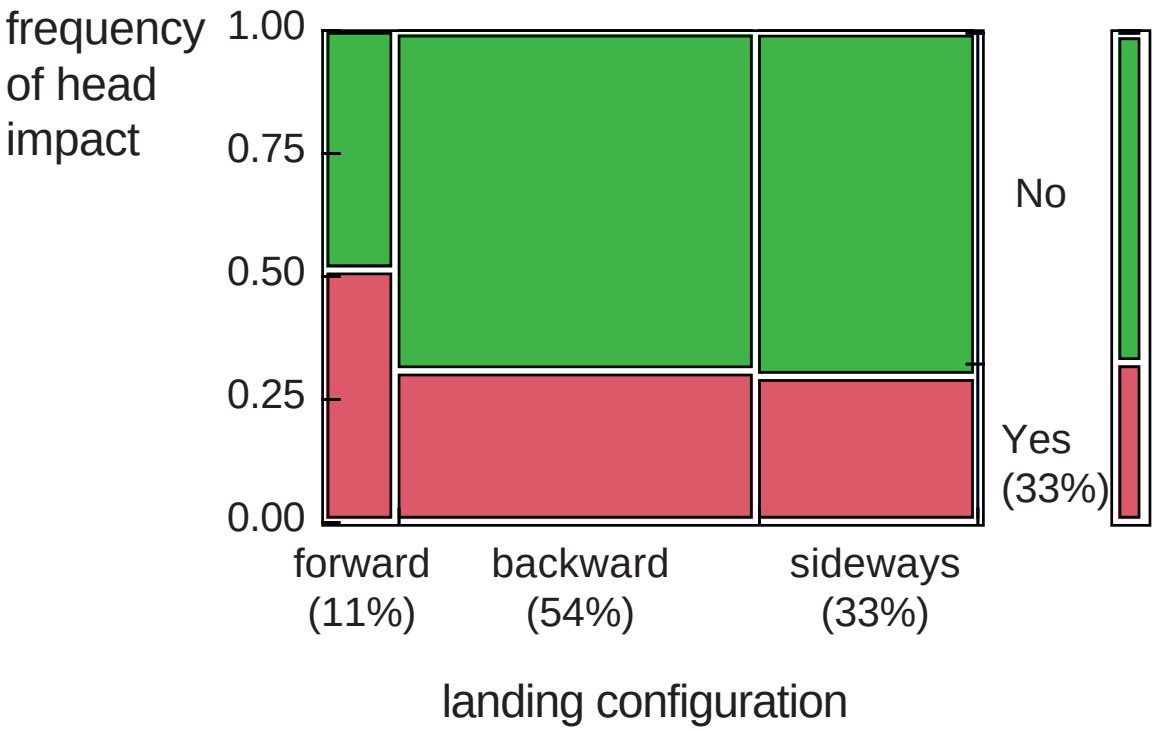
Head impact most likely in forward falls, no effect of hand impact

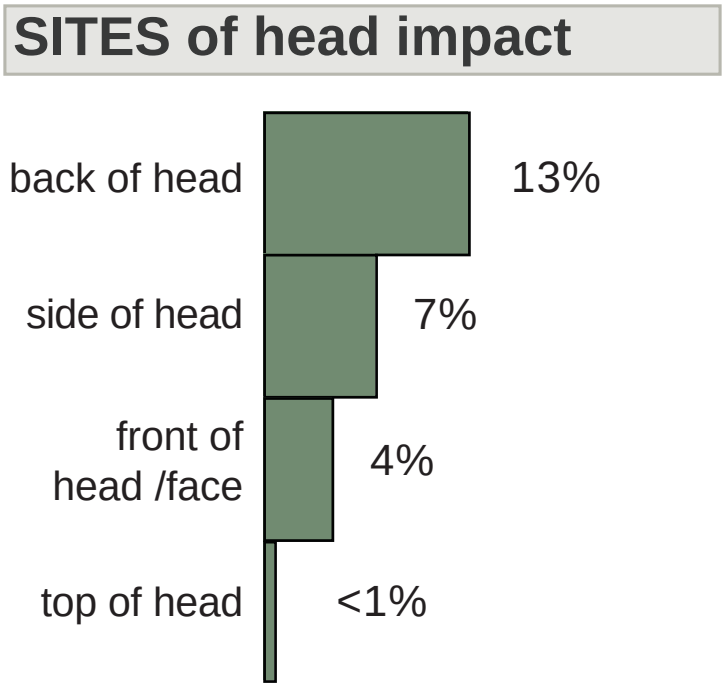


n = 520 falls,
160 fallers

Reference: Yijian Yang, PhD thesis, 2015

While forward falls created higher risk, most head impacts were due to backward falls





n = 960 falls, 306 fallers

Associations between physiological factors and fall mechanisms.

	Odds Ratio (95% CI)					
	Cause of imbalance	**Activity at time of fall**	**Initial fall direction**	**Landing configuration**	**Body rotation during descent**	**Hand impact**
	Slip and trip vs. Other causes	Walking vs. Other activities	Forward vs. Other direction	Forward vs. Other configuration	Forward to others vs. No rotation	Yes vs. No
Age						
Q3 (>87) vs. Q2 (77 - 87)	0.88 (0.45 – 1.72)	0.90 (0.57 – 1.43)	1.01 (0.58 – 1.75)	0.80 (0.38 – 1.64)	1.05 (0.34 – 3.27)	1.00 (0.48 – 1.12)
Q3 (>87) vs. Q1 (<77)	1.13 (0.58 – 2.21)	1.10 (0.70 – 1.76)	0.60 (0.35 – 1.02)	1.26 (0.61 – 2.60)	1.48 (0.52 – 4.25)	1.00 (0.63 – 1.59)
Sex						
Female vs. Male	1.47 (0.83 – 2.61)	1.91 (1.28 – 2.85) *	1.25 (0.78 – 2.00)	1.04 (0.58 – 1.89)	0.71 (0.29 – 1.69)	0.82 (0.56 – 1.21)
Vision						
Adequate vs. Impaired	0.59 (0.33 – 1.06)	0.87 (0.60 – 1.27)	1.23 (0.79 – 1.93)	1.27 (0.72 – 2.24)	0.66 (0.28 – 1.52)	0.90 (0.63 – 1.31)
ADL performance						
Independent vs. Dependent	1.71 (0.96 – 3.05)	2.15 (1.41 – 3.26) *	1.75 (1.07 – 2.84) *	2.14 (1.18 – 3.88) *	0.57 (0.24 – 1.40)	1.40 (0.90 – 2.17)
Cognitive impairment						
Intact to mild vs. Moderate to severe	1.87 (0.95 – 3.66)	1.84 (1.11 – 3.07) *	2.62 (1.51 – 4.56) *	1.98 (1.00 – 3.98) *	0.70 (0.27 – 1.79)	1.08 (0.64 – 1.84)

Q1 lowest quartile, Q2 two middle quartiles, Q3 highest quartile; * indicates statistical significance from the comparison ($p \leq 0.05$).

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