


Aging, Mobility and the Health Care Team

June 2018
Maine Geriatrics Society
Stephanie Studenski MD MPH

Agenda

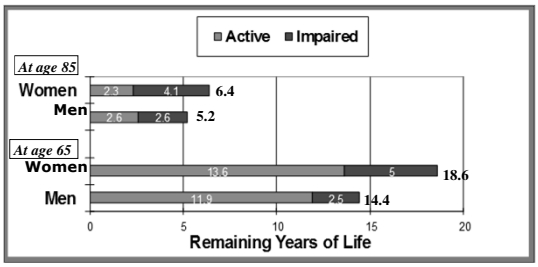
- Why is mobility important for clinicians?
- Aging and speed of movement
- Gait Speed: Clinical applications
- Assessment and management
- New developments

Mobility

- Mobility is fundamental to virtually all animal species and is intimately linked to health, function and survival
- Despite extensive evidence, mobility status is not yet routinely incorporated into clinical care

Active Life Expectancy

The ability to get around is key to functional independence
a goal of aging research and care is "More good time"

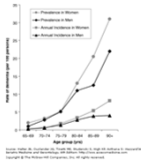


Population Impact

The ability to think and to move are essential for independent living. Loss of either or both lead to disability and dependence. Disorders of cognition and movement are common and often coexist in older people

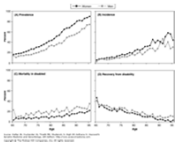
Cognitive Impairment

- Prevalence age 75: 5% M and F
- Prevalence age 85: 12% M 20% F
- Major contributor to disability, need for caregiver, long term care



Mobility Impairment

- Prevalence age 75 20% M 30% F
- Prevalence age 85 40% M 60% F
- Major contributor to disability, need for caregiver, long term care



Guralnik and Ferrucci Epidemiology of Aging in Hazzard text 6th Ed

An Unrecognized Clinical Reality

An 86 year old man is brought to clinic by his son for a several year history of decline. He has withdrawn from life and spends all his time sitting in a chair dozing. He has had several recent falls.

PMH diabetes on oral agent, HBP

Meds HCTZ, glipizide

Exam shows deficits in cognition specifically construction, sequencing, recall and language. He has a slow shuffling gait and increased tone. His affect is flat and he states that life is not worth living.

He is diagnosed with dementia and depression and given a cane.

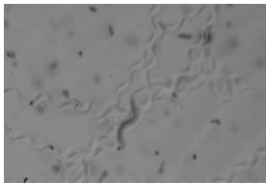
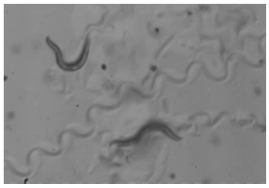
Brain-related gait abnormalities in older people are often ignored or attributed to "normal aging".

"senile gait"

If you saw this person clinically, what would you think about her gait?

Aging doesn't have to mean slow walking

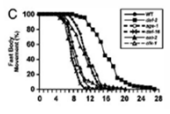
Movement slows with age

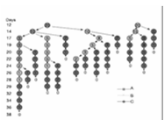
Speed of Movement and Survival

Speed of movement declines with age in all species
Among similar aged animals, slower die sooner
Even among genetically identical, same age organisms in a supportive environment, slower die sooner

C. elegans

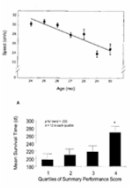


Huang et al PNAS 2007



Herndon Nature 2002

rodents

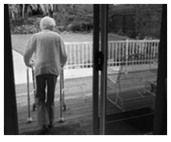


Carter et al JGMS 2002

Why does mobility slow with aging?

- Movement requires integration of multiple systems: energy sources, timing/coordination, force production
- Optimal movement speed requires all systems to be operating together efficiently
- Aging increases likelihood of damage and degeneration of systems
- **Movement is a sensitive final common pathway that reflects damage and loss of integration across systems**
- Slow movement is sensitive to system deficits but not specific to causes

Walking is Fundamental



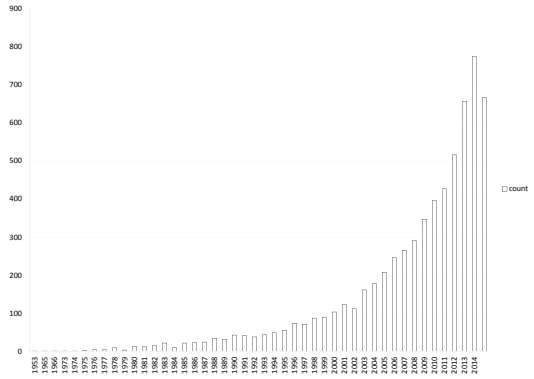
How to Measure Gait Speed?

Distance
Standing start vs constant velocity
Instructions
Timing

Figure 1 – Gait speed measurement setup.

For clinical use, consider 4 meter standing start, usual pace, recorded to the closest 0.1 sec

Articles about Gait Speed by Year



What do the numbers mean?
Gait velocity reflects function and fitness

	Dependent in self-care	Not dependent in self-care
<1.0 m/sec	2	138
>1.0 m/sec	45	287

LR=0.096

People who walk > 1.0 m /sec are rarely dependent in self care: likely to be **healthy**

Walking speed		METS	function
m/sec (standing start)	mph		
.67	1.5	< 2	self care
.89	2.0	2.5	household activities
1.11	2.5	3.0	Carry groceries, light yard work
1.33	3.0	3.5	Climb several flights of stairs

	Independent in IADL and IADL	Not independent in all functions
<0.6 m/sec	0	63
>0.6 m/sec	127	302

LR<.01

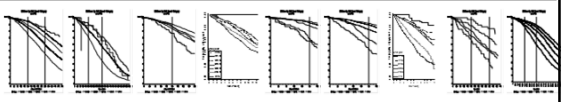
People who walk <0.6 m/sec are virtually never independent in all functions: they have **disability**

Baseline data on 492 elders Studenski et al JAGS 2003

What do the numbers mean?
Gait Speed and Survival:

Consortium analysis of over 34,000 older adults followed for up to 21 years

	CHS	EPESE	Health ABC	HEPESE	In Chianti	MrOS	NHANES	PEP	SOF
n	5801	2128	3048	1905	972	5833	3958	491	10350
Yrs	16	21	10	12	8	8	12	12	21



JAMA Jan 5, 2011

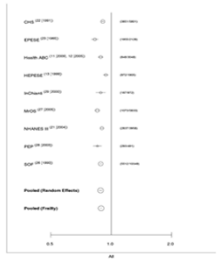
Gait Speed and Survival: Forest Plot and Pooled Survival Nomograms

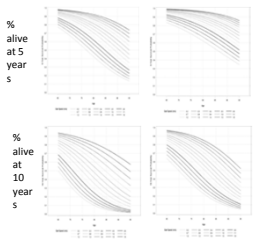
Consortium analysis of over 34,000 older adults followed for up to 21 years

Median survival for age and gender at about 0.8 m/sec

men women

Speeds of 1.0 m/sec or higher suggest healthy aging





JAMA Jan 5, 2011

ROC Curve analysis

accuracy comparable to more complex models that include common diseases and function

Outcome and Predictors	C statistic
Five year survival	
Age, Gender	0.690
Age, Gender, Diseases	0.698
Age, Gender, Diseases, smoking, BMI, Systolic BP, Prior Hospitalization	0.719[a]
Age, Gender, Functional Status, mobility aids (4 studies)	(0.751)
Age, Gender, Gait Speed	0.717[a] (0.741)†
Ten Year Survival	
Age, Gender	0.712
Age, Gender, Diseases	0.724
Age, Gender, Diseases, smoking, BMI, Systolic BP, Prior Hospitalization	0.739[a]
Age, Gender, Functional Status. Mobility aids (3 studies)	(0.733)
Age, Gender, Gait Speed	0.737[a] (0.734)†

JAMA Jan 5, 2011

Diseases: heart, diabetes, cancer, arthritis

What is the potential role of slowed mobility in clinical care and research?

- Predictor of health, function, survival and utilization
- Marker of disease severity
- Summary indicator of co-morbid burden of illness
- Detect change
- Presenting problem for diagnosis and management
- Framework for inquiry into novel problems of aging

JAGS 2003

Physical Performance Measures in the Clinical Setting

Stephanie Studenski, MD, MPH,† Subashan Perera, PhD,*‡ Dennis Wallace, PhD,‡§ Julie M. Chandler, PhD, PT,§ Pamela W. Duncan, PhD, PT,*† Earl Rooney, MD, MHA,‖¶†† Michael Fox, ScD,*† and Jack M. Guralnik, MD, PhD***

Outpatient clinics in Kansas City Missouri
n=487
gait speed predicts probability of one year
hospitalization
decline in function
decline in self-reported health

Gait Speed in Hospitalized Older People

Inability to walk or slow walking on hospital admission predicts increased LOS and decreased probability of discharge to home. These effects are independent of functional status .

Table 2. Length of Stay and Home Discharge by Gait Speed Category

Gait Speed	No. of Patients	Length of Stay, Mean (SD), d	Home Discharge, %
Unable to complete gait speed test	116	4.8 (4.7)	66.4
Gait speed, m/s			
<0.40	69	4.1 (3.9)	82.6
0.40-0.59	65	3.6 (3.2)	92.3
≥0.60	72	3.1 (2.6)	98.6
Overall	**322**	4.1 (3.9)	82.5

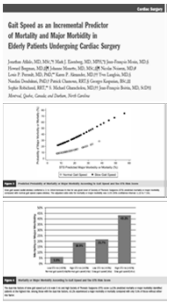
Ostir et al Arch Int Med 2012

Table 4. Multivariable Logistic Regression Models Predicting Home Discharge by Gait Speed and ADL Disability

Predictor	Odds Ratio (95% CI) of Home Discharge: Gait Speed Model	ADL Disability Model	Combined Gait Speed and ADL Disability Model
Adjustment for Age and Sex			
Gait speed[a]			
Unable to complete gait speed test	0.03 (0.04-0.22)	…	0.08 (0.01-0.50)
<0.40 m/s	0.08 (0.04-0.19)	…	0.10 (0.01-0.78)
0.40-0.59 m/s	0.19 (0.02-1.68)	…	0.22 (0.10-1.96)
ADL disability[b]			
1-2	…	0.87 (0.24-1.85)	1.02 (0.26-3.98)
3-4	…	0.26 (0.11-0.58)	0.32 (0.22-1.39)
>5	…	0.10 (0.04-0.21)	0.22 (0.10-0.54)
Additional Adjustment[c]			
Gait speed[a]			
Unable to complete gait speed test	0.03 (0.003-0.21)	…	0.06 (0.01-0.46)
<0.40 m/s	0.07 (0.01-0.63)	…	0.10 (0.01-0.86)
0.40-0.59 m/s	0.24 (0.03-2.29)	…	0.28 (0.03-2.79)
ADL disability[b]			
1-2	…	0.64 (0.21-1.91)	0.96 (0.31-2.99)
3-4	…	0.23 (0.09-0.55)	0.32 (0.10-1.39)
>5	…	0.10 (0.04-0.24)	0.25 (0.10-0.63)

Abbreviations: ADL, activities of daily living; ellipsis, not applicable.
[a]Compared with those having gait speed of at least 0.60 m/s.
[b]Compared with those having no ADL disability.
[c]Age, sex, race/ethnicity, marital status, education, Charlson Comorbidity Index, and body mass index.

Gait Speed and risk of cardiac surgery



J Am Coll Cardiol. 2010 Nov 9;56(20):1668-76.

Surgical risk score with > 30 factors

5 meter walking speed dichotomized at 6 sec= about 0.83 m/sec

PostOP Morbidity= stroke, renal failure, prolonged ventilation, deep infections or need for reoperation

Gait speed alone did as well as 30+ factor risk score
Both together were better than either alone

Original Investigation

Gait Speed and Operative Mortality in Older Adults Following Cardiac Surgery

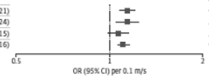
Jonathan Afilalo, MD, MSc; Sunghee Kim, PhD; Sean O'Brien, PhD; J. Matthew Brennan, MD, MPH; Fred H. Edwards, MD; Michael J. Mack, MD; James B. McClurken, MD; Joseph C. Cleveland Jr, MD; Peter K. Smith, MD; David M. Shahian, MD; Karen P. Alexander, MD

JAMA cardiology 2016

Over 15,000 heart surgery patients
30 day mortality
Post-op morbidity and mortality during the index hospitalization

Figure 3. Effect of Gait Speed After Adjusting for Society of Thoracic Surgeons (STS) Predicted Risk

Surgery	No.	OR (95% CI) per 0.1 m/s	P Value
CABG	9005	1.14 (1.08-1.21)	<.001
Valve	3765	1.14 (1.05-1.24)	.002
CABG plus valve	2401	1.07 (0.99-1.15)	.07
All posted	15 171	1.11 (1.07-1.16)	<.001



A logistic regression model was stratified for the 3 cardiac surgical procedures, and adjusted for the STS predicted risk of mortality as a fixed offset term (from the surgery-specific STS model). The pooled odds ratio (OR) for gait speed to predict operative mortality was 1.11 (95% CI, 1.07-1.16) per 0.1-m/s decrease in gait speed. CABG indicates coronary artery bypass graft.

New Utility for an Old Tool

Can a Simple Gait Speed Test Predict Ambulatory Surgical Discharge Outcomes?

ABSTRACT

Odonkor CA, Schonberger RB, Dai F, Shelley KH, Silverman DG, Barash PG: New utility for an old tool: can a simple gait speed test predict ambulatory surgical discharge outcomes? Am J Phys Med Rehabil 2013;92:849–863.

602 patients undergoing elective ambulatory surgery
Outcomes: ready for home discharge within 90 minutes after surgery and admission

TABLE 2 Predicting the likelihood of early home discharge readiness (≤90 mins)

Variable	Crude OR (95% CI)	Adjusted OR (95% CI)*
Age	1.007 (0.99–1.02)	1.01 (0.99–1.03)
Preoperative heart rate	1.007 (0.99–1.02)	1.02 (1.008–1.04)
Preoperative gait speed	1.92 (0.80–4.72)	3.70 (1.21–11.26)
Postoperative pain	1.02 (0.97–1.07)	1.01 (0.96–1.08)

Area under the curve for the model = 0.78 (95% CI, 0.74–0.82).
For a 0.1 unit change in gait speed, the OR of early discharge was 1.14 (1.02–1.27).
Surgical risk was categorized as major intervention vs. minor intervention. Minor intervention was defined as all of the following: surgery duration of less than 1 hr, expected blood loss of less than 500 mL and no opening of visceral cavity (except in case of diagnostic laparoscopic procedures). Major intervention was defined as any of the following: duration of procedure of 1 hr or longer, expected blood loss of 500 ml or more, opening of visceral cavity, and potential massive respiratory or hemodynamic effects as a result of surgery.
*Model was adjusted for sex ($P = 0.07$), anesthesia technique ($P = 0.14$), surgical risk ($P = 0.8$), preoperative mean arterial pressure ($P = 0.001$), and comorbidity status ($P = 0.02$).
OR indicates odds ratio.

TABLE 4 Likelihood of unplanned admissions based on gait speed cut-off of 1 m/sec.[a]

Gait Speed, m/sec	n (%)	OR (95% CI)
<1	422 (70)	Reference
≥1	180 (30)	0.35 (0.16–0.76)[b]

[a]Results of 2 analyses.
[b]$P = 0.008$; positive predictive value = 85.9 (95% CI, 74.2–93.7); negative predictive value = 31.6 (95% CI, 27.7–35.7).

COPD

Gait speed and readmission following hospitalisation for acute exacerbations of COPD: a prospective study

Samantha S C Kon,[1,2] Sarah E Jones,[1] Susie J Schofield,[3] Winston Banya,[1] Mandy J Dickson,[2] Jane L Canavan,[1] Claire M Nolan,[1] Brigitte M Haselden,[2] Michael I Polkey,[1] Paul Cullinan,[3] William D-C Man[1]

Thorax (online August 2015)

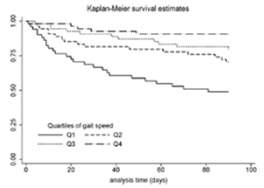


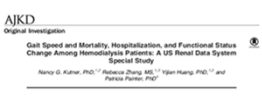
Figure 2 Kaplan–Meier curve demonstrating time to 90-day all-cause non-elective readmission according to 4MGS quartile (Q1≤0.40 m/s; Q2=0.40–0.59 m/s; Q3=0.60–0.79 m/s; Q4≥0.80 m/s). 4MGS, 4 m gait speed.

The 90 day hospital admission rate was 11.5% in those walking > 0.8 m/sec vs 48.5 % in those walking < 0.4 m/sec

Gait speed remained an independent predictor after accounting for demographics, comorbidities, prior hospitalization and FEV1

Gait Speed and Hemodialysis

One and two year mortality lowest in faster walkers
Hospitalization and disability lowest in faster walkers


AJKD
Original Investigation

Gait Speed and Mortality, Hospitalization, and Functional Status Change Among Hemodialysis Patients: A US Renal Data System Special Study

Nancy G. Kutner, PhD,[1,2] Rebecca Zhang, MS,[1,2] Yijian Huang, PhD,[1,2] and Patricia Painter, PhD[3]

Am J Kidney Disease 2015
> 750 hemodialysis patients from the US Renal Data System.

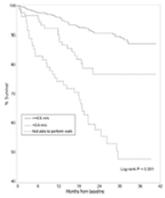


Figure 1. Kaplan-Meier estimate of cumulative survival by study participants' baseline gait speed category. For the ≥0.6 m/s, <0.6 m/s, and not able to perform walk test groups, the number of deaths/number at risk at 12 months were 21/526, 8/82, and 22/59, respectively. At 24 months, these values were 47/256, 19/38, and 34/24, respectively.

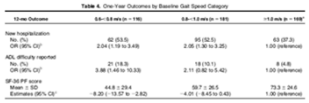


Table 4. One-Year Outcomes by Baseline Gait Speed Category

12-mo Outcome	0.6–0.8 m/s (n = 116)	0.8–1.0 m/s (n = 181)	>1.0 m/s (n = 169)*
New hospitalization No. (%) OR (95% CI)†	62 (53.5) 2.04 (1.19 to 3.49)	95 (52.5) 2.05 (1.30 to 3.25)	63 (37.3) 1.00 (reference)
ADL difficulty reported No. (%) OR (95% CI)†	21 (18.3) 3.86 (1.46 to 10.33)	18 (10.1) 2.11 (0.82 to 5.42)	8 (4.8) 1.00 (reference)
SF-36 PF score Mean ± SD Estimates (95% CI)†	44.8 ± 29.4 −8.20 (−15.07 to −2.62)	50.7 ± 26.5 −4.01 (−8.45 to 0.43)	70.3 ± 24.6 1.00 (reference)

Do we need the long walks?


[Original Research COPD] CHEST

Determinants of Gait Speed in COPD

Craig Kerpman, MD; Zachary S. Delhaas, MD; Nathan K. LeBrasseur, PhD; Paul J. Novotny, BS; and Roberto P. Benzo, MD

2014

Gait speed < 0.9 predicts 6MWT < 350 meters
<0.8 predicts 6MWT < 200 meters

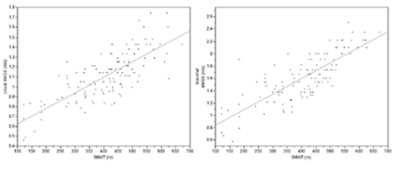


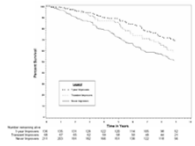
Figure 2 – Correlation between 6MWT and usual and maximal 4MGS. 4MGS = 4-m gait speed; 6MWT = 6-min walk test.

The meaning of change

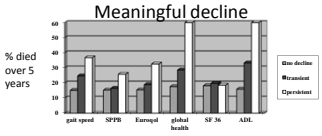
Hardy, Perera, Studenski 2008,2009

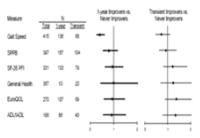
Magnitude of change	Effect Size	SEM	Anchor-Based Estimate	Recommended Criterion
Gait Speed (m/sec)				0.05
small	0.04-0.06	0.04-0.06	0.02-0.04	
substantial	0.10-0.17	-----	0.05-0.09	0.10
6MWD (m)				
small	16-21	----	----	20
substantial	39-64	21-35	39-64	40
SPPB score (points):				
small	0.54	-----	0.27-0.55	½
substantial	1.34-1.61	1.42	0.60-1.88	1

Meaningful improvement



Meaningful decline





Mobility measures in routine primary care

- 14 Primary care offices: space available, staff can perform during routine care
- Gait speed measure takes < 2 minutes during intake as part of "vital signs".
- Reliability comparable to slightly worse than BP

coefficient of variation

interobserver		test-retest
4.5% gait	3.0% DBP	15% gait, 10% DBP

AHRQ R03 Woolley

507 70+ in 14 primary care offices in Kansas

Woolley, D. C. 1; **Studenski**, S. 3; Perera, S. 2; Rogers, N. 1 **FEASIBILITY AND REPRODUCIBILITY OF WALKING SPEED AS A GERIATRIC VITALSIGN INCOMMUNITY PRACTICE**...*Journal of the American Geriatrics Society. 52 Supplement 1:S195, April 2004.*

Diagnosis of dismobility for gait speed < 0.6

VIEWPOINT

A Diagnosis of Dismobility—Giving Mobility Clinical Visibility
A Mobility Working Group Recommendation

Cummings Studenski Ferrucci JAMA 2014

Increase clinical awareness
Begin to allow for coding in inpatient and outpatient records
Allow for evaluation of utility in care planning
Evaluate intervention effects

Differential Diagnosis of Abnormal Walking Speed

Three main systems:

- Cardiopulmonary

- Neurologic

- Musculoskeletal

Studenski "Mobility" in Hazzard Textbook of Geriatrics and Gerontology 7th ed 2017
Ferrucci Subsystems of the ability to walk J Am Ger Soc 2000

Differential Diagnosis of Abnormal Walking Speed:

Symptoms

System	Symptoms limiting walking
cardiopulmonary	Dyspnea, fatigue
neurological	Unsteady, hesitant
musculoskeletal	Pain, stiffness

Many older adults have multiple contributing factors

Differential Diagnosis of Abnormal Walking Speed:

key clinical findings

System	Clinical Findings
Cardiopulmonary: lung, heart, blood	FEV_1, O_2 sat with activity, Hg, EF, ?rate-pressure product?
Neurologic: frontal, primary motor, extrapyramidal, peripheral	tone, timed tapping, executive cognitive function, peripheral sensation
Musculoskeletal: Weight bearing structures, muscle	Knee, hip, low back range of motion, pain Manual muscle tests, chair rise

Many older adults have multiple contributing factors

Nursing

- Current and recent change in mobility function: bed mobility, transfers, walking, wheelchair mobility, stairs, community mobility
- Symptoms
- Assessment of bed mobility, transfers, walking, stairs
- Depends on setting: nursing home, home, hospital

Physical Therapy

- Current and recent history
- Strength, ROM, balance, endurance, coordination, cognition
- Specific gait abnormalities
- Use of aids

Pharmacist

- Current and recent change
- Review medication list for agents that affect attention (especially CNS active drugs), endurance, orthostasis, muscle problems (steroids, lipid lowering agents)

Interventions for slow gait speed

- Medical care: CHF, COPD, anemia, arthritis, pain, extrapyramidal conditions…
- Medication adjustments for side effects (dizzy, slow, stiff…)
- Vision services
- Exercise: rehab referral if very slow, community programs if mild
- Many novel interventions in development

Therapeutic exercise to improve gait efficiency

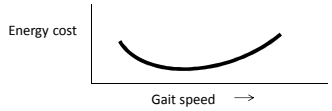
Jessie VanSwearingen, PhD, PT
Subashan Perera, PhD
Jennifer Brach, PhD PT
Rakie Cham PhD
Caterina Rosano, MD, MPH
Stephanie Studenski, MD MPH

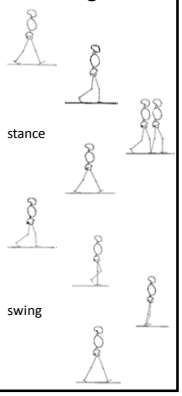
Departments of Physical Therapy, Division of Geriatric Medicine, Bioengineering, and Epidemiology, University of Pittsburgh; Pittsburgh Pepper Center NIA P30 AG024827.
J G MS 2009

JGMS 2009

Gait Efficiency and the Energy Cost of Walking (Wert, VanSwearingen)

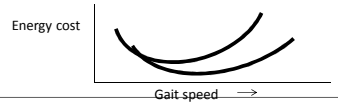
- Efficiency depends on optimal use of momentum and stored energy from the passive elements (pendulum effects) of movement cycles: pendulum base is foot during stance and hip during swing
- Changes in pace and stride length decrease energy efficiency
- There is a U shaped curve relating gait speed to energy use with an optimal nadir for gait efficiency. Slowing beyond optimal pace increases energy cost





Age, Gait Disorders and Gait Efficiency

- Age and gait disorders decrease gait efficiency
- With Age, energy cost is higher at any gait speed
- Nadir for optimal efficiency moves to the left
- Can examine effect of biomechanical and physiological abnormalities on energy cost and efficiency
- Variability and loss of smoothness of movement are contributors to loss of efficiency



Therapeutic exercise to improve gait efficiency

TC: timing & coordination in walking

Stepping and walking patterns
Step across forward & backw

Walking ovals, spirals, serpentine paths

Adapting to conditions: Speed, direction & amplitude

Treadmill paced-walking

VanSwearingen et al J Gerontol A Biol Sci Med Sci 2009; 64A: 1190-1198

WEBS: walking endurance, balance & strength

Lower limb strengthening
Lower limb flexibility

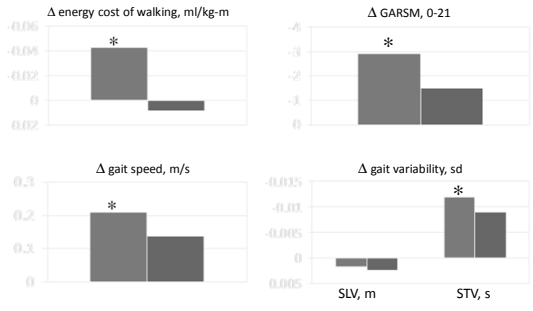
Gait training
Heel-toe; increase step length & speed

Balance training
narrow stand & reach

Endurance exercise

TC improves efficiency, variability, gait speed and clinical gait alterations

TC n=23 WEBS, n=24; ∗TC better than WEBS, p<.05



VanSwearingen et al J Gerontol A Biol Sci Med Sci 2009; 64A: 1190-1198

Effectiveness of a Timing and Coordination Group Exercise Program to Improve Mobility in Community-Dwelling Older Adults

A Randomized Clinical Trial

Brach, JS et al JAMA Intern Med. 2017 Oct; 177(10): 1437–1444

Baseline to Follow-up Change in Primary Outcome Measures and Between-Intervention Differences

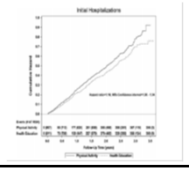
Measure	Baseline to Follow-up Change Estimate (SE)		Adjusted Difference (SE)[a]	*P* Value
	On the Move	Usual Care		
LLFDI overall function	0.4 (5.7)	−0.6 (5.8)	0.8 (0.7)	.27
LLFDI disability frequency	0.4 (4.1)	0.7 (5.0)	0.3 (0.6)	.61
Six-minute walk distance, m	20.6 (57.1)	4.1 (55.6)	16.7 (7.4)	.03
Instrumented walkway gait speed, m/s	0.05 (0.13)	−0.01 (0.11)	0.05 (0.02)	.002

Cluster-randomized, single-blind intervention trial. Thirty-two independent living facilities, senior apartment buildings, and senior community centers were randomized to On the Move (16 sites; 152 participants) or usual care (16 sites; 146 participants).

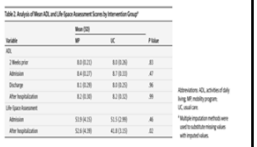
Interventions to reduce health care complications via mobilization

Marsh et al JAGS 2016

LIFE study- no effect of exercise
on risk of hospitalization



Clinical Trial of a Hospital Mobilization Program
Brown et al JAMA Int Med 2016



BMC Geriatrics 2017

Eat Walk Engage

CHERISH (collaboration for hospitalised elders reducing the impact of stays in hospital): protocol for a multi-site improvement program to reduce geriatric syndromes in older inpatients

Future Directions

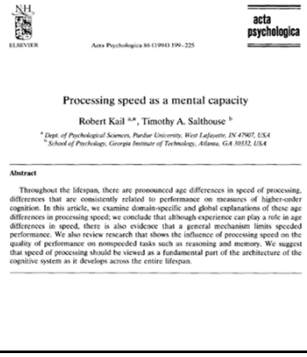
Nervous System Aging and Movement

"My legs don't move when my brain tells them to. It's very frustrating"
GHW Bush

Thinking and Moving must be studied together

- Extensive epidemiological evidence supports interrelationships between cognition and movement
- Brain networks for movement overlap with networks for cognition
- Thinking and Moving share behavioral and etiological factors that can drive new insights into prevention and treatment

PSYCHOMOTOR SLOWING



ELSEVIER

Acta Psychologica 86 (1994) 199–225

acta psychologica

Processing speed as a mental capacity

Robert Kail [a,*], Timothy A. Salthouse [b]

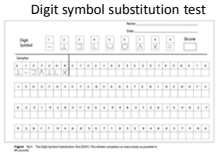
[a] Dept. of Psychological Sciences, Purdue University, West Lafayette, IN 47907, USA
[b] School of Psychology, Georgia Institute of Technology, Atlanta, GA 30332, USA

Abstract

Throughout the lifespan, there are pronounced age differences in speed of processing, differences that are consistently related to performance on measures of higher-order cognition. In this article, we examine domain-specific and global explanations of these age differences in processing speed; we conclude that although experience can play a role in age differences in speed, there is also evidence that a general mechanism limits speeded performance. We also review research that shows the influence of processing speed on the quality of performance on nonspeeded tasks such as reasoning and memory. We suggest that speed of processing should be viewed as a fundamental part of the architecture of the cognitive system as it develops across the entire lifespan.

- Controversial concept
- Is processing speed an indicator of fundamental brain function?
- What is actually being measured: perception, retrieval, movement initiation….?

Digit symbol substitution test



Psychomotor slowing and incident overt and subclinical problems with cognition, movement and mood

Table XXX: Longitudinal association between year 5 DSST and year 6-11 cumulative incident thinking, moving and feeling outcomes: odds ratio or *regression coefficient* and significance

Nature of Analysis, Outcome Tune and Year 5 DSST	Thinking Outcome 3MSE				Moving Outcome Gait Speed (m/s)				Feeling Outcome CES-D			
	Continuous	Full Syndrm (<80)	Subsyn (80-85)	Unclssfd	Continuous	Full Syndrm (<0.6)	Subsyn (0.6-1.0)	Unclssfd	Continuous	Full Syndrm (11+)	Subsyn (5-10)	Unclssfd
Unadjusted Year 6-11												
DSST (raw)	NA	0.89***	0.91***	0.96***	NA	0.94***	0.96***	0.94***	NA	0.95***	0.97***	0.96***
DSST ≤29	NA	40.8***	29.0***	6.07***	NA	23.1***	10.1***	25.5***	NA	16.4***	7.89***	10.8***
30-39	NA	5.97***	6.91***	2.33***	NA	2.54***	1.98**	3.36***	NA	2.13**	1.59	1.89**
40-48	NA	1.97***	3.22***	1.61***	NA	1.50	1.53*	2.26***	NA	1.76*	1.33	1.31
>48	NA	1.0 (ref)	1.0 (ref)	1.0 (ref)	NA	1.0 (ref)	1.0 (ref)	1.0 (ref)	NA	1.0 (ref)	1.0 (ref)	1.0 (ref)
Adjusted for Covariate Set 1 Year 6-11												
DSST (raw)	NA	0.92***	0.94***	0.97***	NA	0.95***	0.97***	0.94***	NA	0.98	0.99	0.98
DSST ≤29	NA	13.9***	9.48***	4.27***	NA	15.5**	7.91**	19.8***	NA	4.25**	3.15**	4.32***
30-39	NA	3.15***	3.46***	1.87***	NA	2.38**	1.89*	2.87**	NA	1.16	1.04	1.30*
40-48	NA	1.40	2.01***	1.45***	NA	1.47	1.52	2.18**	NA	1.31	1.09	1.10
>48	NA	1.0 (ref)	1.0 (ref)	1.0 (ref)	NA	1.0 (ref)	1.0 (ref)	1.0 (ref)	NA	1.0 (ref)	1.0 (ref)	1.0 (ref)
Adjusted for Covariate Set 1+2 Year 6-11												
DSST (raw)	NA	0.93***	0.95***	0.97***	NA	0.96**	0.97**	0.94***	NA	0.98	0.99	0.99
DSST ≤29	NA	9.95***	6.69***	3.38***	NA	9.09**	7.55*	18.1**	NA	3.27**	3.80*	4.98*
30-39	NA	2.43***	2.65***	1.69***	NA	1.75	1.83	2.66**	NA	1.10	1.02	1.23
40-48	NA	1.20	1.81***	1.35***	NA	1.32	1.67*	2.17**	NA	1.34	1.15	1.13
>48	NA	1.0 (ref)	1.0 (ref)	1.0 (ref)	NA	1.0 (ref)	1.0 (ref)	1.0 (ref)	NA	1.0 (ref)	1.0 (ref)	1.0 (ref)

Covariate set 1=3MSE, gait speed and year 6-11 [illegible]; Set 2=Age, gender, race, [illegible], APOE, AAI and education; *p<0.10, **p<0.05, ***p<0.01

Age and Aging 2016

Motor Skill

a link between gait and cognition

What is Motor Skill?

Smooth efficient learned movement created through motor maps

Characteristics of Novice and Skilled Motor Actions	
Novice movement	**Skilled movement**
Behavioral and Peripheral factors	
○ **guided, discontinuous movement, irregular velocity profile** ○ **task-oriented practice necessary for acquisition of motor sequence learning** ○ **multiple muscles often activated in a cocontraction pattern** ○ **movement sequence variable** ○ **submovements, with stops and starts redirecting path to movement target**	○ non-guided, continuous movement, smooth velocity profile ○ practice necessary to achieve and maintain motor expertise (automaticity) ○ multiple muscles activated sequentially in brief bursts ○ preplanned motor sequence ○ movement acceleration and deceleration programmed together
Central factors	
○ **brain activity in fronto-parietal [cortico-cortico] pattern of connections** ○ **sustained, generalized pattern of brain activity** ○ **cingulate motor area activity high**	○ brain activity in cortico-basal ganglia, cortico-cerebellar circuits ○ brief, specific 'efficient' pattern of brain activity ○ reduced cingulate motor area activity

Vanswearingen and Studenski JGMS 2014

Signs of Loss of Motor Skill

OVERT
- **Generalized Slowing**
  - motor function
  - psychomotor function

SUBCLINICAL
- **Inefficient**
  - Increased energy cost
  - Variable
- **Reduced reserve**
  - Dual task cost
- **Reduced plasticity**
  - Slow and incomplete motor learning

Aspects of Gait Variability and Aging Brach et al

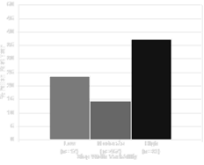
Stance Time Variability Predicts Decline in Mobility

Model	HR (CI)	P
1	1.26 (1.15, 1.37)	<.0001
2	1.15 (1.04, 1.27)	.007
3	1.13 (1.02, 1.25)	.02
4	1.13 (1.01, 1.27)	.03

Model 1: Stance time variability
Model 2: Model 1 + gait speed
Model 3: Model 2+ age, gender, and race
Model 4: Model 3 + chronic conditions, medications, health status, physical activity

Brach et al, 2007

Step Width Variability and Fall History



Contributors to Variable Gait
(linear regressions adjusted for age, gender, and race)

	Stance Time Variability	Step Length Variability	Step Width Variability
CNS			
3MS			
Finger Tap			
Trails A			
Trails B			
DSST			
Sensory			
Vibration			
Vision			
Strength			
Grip			
Chair stand			
LE pain			
Depression			

BLSA: Does amyloid burden affect age-related slowing independent of cognitive change?

Q. Tian

S Resnick

- Slowing precedes cognitive decline and dementia often by a decade or more
- Amyloid buildup in the brain also precedes dementia by a decade or more
- Early amyloid deposition areas are often not related to memory areas (hippocampus) but rather to associative and planning areas.

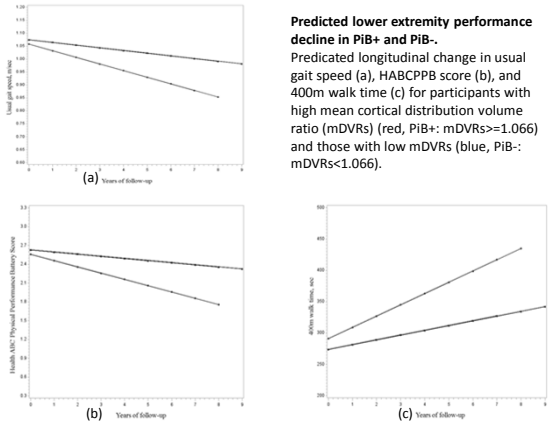
Tian et al JGMS 2017

Greater β-amyloid burden is associated with steeper subsequent decline in mobility

Associations of mean cortical DVR^ with longitudinal change in lower extremity motor function (n=59)

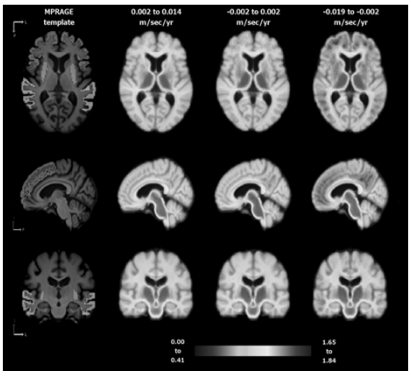
		Usual gait speed, m/sec		400-m walk time, sec		HABCPPB score		Total standing balance time, sec	
Covariates		Cross-sectional	Longitudinal	Cross-sectional	Longitudinal	Cross-sectional	Longitudinal	Cross-sectional	Longitudinal
Model 1: unadjusted	β	-0.004	-0.009	2.851	3.638	**-0.094**	-0.028	**-4.705**	-0.552
	(SE)	(0.018)	(0.003)	(6.607)	(1.011)	**(0.045)**	(0.012)	**(1.630)**	(0.373)
	p-value	0.84	0.006	0.67	<0.001	**0.04**	0.03	**0.006**	0.15
Model 2: age, sex, BMI	β	0.024	-0.009	-5.586	3.566	-0.024	-0.028	-2.434	-0.571
	(SE)	(0.017)	(0.003)	(5.587)	(0.997)	(0.042)	(0.012)	(1.564)	(0.372)
	p-value	0.15	0.004	0.32	<0.001	0.56	0.03	0.13	0.13
Model 3: model 2 + cardiovascular risk score	β	0.023	-0.009	-4.640	3.176	-0.031	-0.023	-3.138	-0.356
	(SE)	(0.017)	(0.004)	(5.724)	(1.054)	(0.043)	(0.013)	(1.544)	(0.398)
	p-value	0.17	0.02	0.42	0.003	0.47	0.08	0.05	0.37
Model 4: model 2+ *ApoE*ε4 status (n=53)	β	0.031	-0.010	-5.380	4.109	-0.055	-0.030	-2.689	-0.458
	(SE)	(0.019)	(0.004)	(6.935)	(1.034)	(0.060)	(0.011)	(1.968)	(0.380)
	p-value	0.11	0.008	0.44	<0.001	0.37	0.009	0.18	0.23
Model 5: model 2+ change in CVLT	β	0.018	-0.011	-4.713	3.212	0.003	-0.034	-1.103	**-0.840**
	(SE)	(0.017)	(0.004)	(5.595)	(1.072)	(0.045)	(0.012)	(1.510)	**(0.395)**
	p-value	0.28	0.003	0.40	0.003	0.95	0.008	0.47	**0.03**
Model 6: model 3 excluding CDR of 0.5 at baseline (n=54)	β	0.035	-0.008	-6.569	3.392	-0.010	-0.012	-2.660	-0.068
	(SE)	(0.017)	(0.004)	(6.715)	(1.222)	(0.046)	(0.015)	(1.673)	(0.434)
	p-value	0.05	0.04	0.33	0.007	0.83	0.41	0.12	0.87

Note: DVR=distribution volume ratio; HABCPPB=Health ABC Physical Performance Battery; CDR=Clinical Dementia Rating; CVLT=California Verbal Learning Test. Mean cortical DVR^ was first centered to the mean and multiplied by 10 for interpretation purposes. Baseline age was centered to the mean age. Bold numbers reflect statistically significant associations.



Predicted lower extremity performance decline in PiB+ and PiB-.
Predicated longitudinal change in usual gait speed (a), HABCPPB score (b), and 400m walk time (c) for participants with high mean cortical distribution volume ratio (mDVRs) (red, PiB+: mDVRs>=1.066) and those with low mDVRs (blue, PiB-: mDVRs<1.066).

Figure 2. Mean cortical distribution volume ratio images by tertile of gait decline.



Top to bottom: Axial, sagittal, coronal slice.

Left to right: MPRAGE template
orange: putamen
purple: dorsolateral prefrontal cortex
green: lateral temporal lobe

Other recent papers:
Wennberg JAGS 2017
Nadkarni JAMA Neurology 2017
Nadkarni JGMS 2016
Del Campo Neurology 2016

Summary

Measures of mobility are useful in clinical settings
The CNS is a major contributor to abnormal gait

- Gait speed is a generic indicator of function, health status, prognosis, utilization.
- Change in gait speed is clinically meaningful and affects future status.
- Gait speed may help busy clinicians attend to mobility assessment. It is quick and easy to measure in clinical settings.
- Slow walking could be a billable diagnosis "**bradypedia**" , "**dismobility**"
- Cognition and gait are both affected by age-related changes in the nervous system

- **For optimal and efficient care, objective measures of function like gait speed should be incorporated into clinical care and medical record systems**