Balance Exercises and Fitness to Prevent Injuries and Cognitive Decline

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School of Anthropology
University of Arizona
95% of hip fractures come from falls.

Falls are most common cause of TBI.

We spend ~$30 Billion/year on fall-related injuries.
Increased Fall Risk Is NOT Inevitable

Why?
Nothing in Biology Makes Sense Except in the Light of Evolution

- Theodosius Dobzhansky

Road map:
1) Evolutionary history of aging and exercise
2) Exercise and fall risk: predictors and prevention
3) What can you do to reduce fall risk?
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Road map:
1) Evolutionary history of aging and exercise
2) Exercise and fall risk: predictors and prevention
3) What can you do to reduce fall risk?
We evolved to get old, but not frail
This lifestyle requires long, physically active days away from camp. Grandparents care for offspring when parents foraging.
Why long life?

Grandmother Hypothesis

Must be healthy and active in old age (Falls should be rare!)

Physically active lifestyle was the key to successful aging in our ancestors
Exercise: key to living longer?

8 year study of over 400,000 Taiwanese men and women

Wen et al., 2011
Staying Healthy Longer Too

![Graph showing disability score by age for runners and non-runners](Fries, 1996)
Why long life?

Grandmother Hypothesis

Physically active lifestyle the key to successful aging (falls are rare)

We live in a mismatch environment:
Our bodies evolved to be active
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What Causes Falls?

Most falls occur during walking

Berg et al 1997; Robinovitch et al. 2013
Fall Predictors

Traditional View:

1) Muscle weakness (Moreland et al., 2004)

Instability, poor balance, and lack strength to recover from a trip.
Muscle Strength and Fall Risk

Meta-analysis (study of studies):
Compiled data from 13 studies

Total n = 6146 older adults

Odds of falling in future if subject displays muscle weakness

Moreland et al. 2004
Muscle Strength and Fall Risk

Odds Ratio (OR): Odds that an outcome (fall) will occur given a particular condition (muscle weakness)

Moreland et al. 2004
Fall Predictors

Traditional View:
1) Muscle weakness

Novel View:
2) Cognitive decline
   May be responsible for trips and stumbles
Cognition and Walking

Walking is a complex task that requires coordination between brain and body.

Executive function: Management of cognitive processes

1) Planning and execution
2) Response inhibition
3) Task flexibility/multi-task

Frontal Lobe
Cognition and Walking

Executive function: Management of cognitive processes

1) Planning and execution
2) Response inhibition
3) Task flexibility/multi-task

Walking is a complex task that requires coordination between brain and body

Making decisions in a complex environment
Cognition and Walking

Executive function: Management of cognitive processes

1) Planning and execution
2) Response inhibition
3) Task flexibility/multi-task

Walking is a complex task that requires coordination between brain and body

Filter out distractions; Focus attention on gait
Cognition and Walking

Executive function: Management of cognitive processes

1) Planning and execution
2) Response inhibition
3) Task flexibility/multi-task

Walking is a complex task that requires coordination between brain and body.

Walk and talk at the same time
Decline in EF affects walking

4-meter course  
Usual pace

7-meter course with obstacles  
Fastpace

Performance on Executive Function Test

Walking speed (m/sec)

Yogev-Seligman et al., 2008
Executive Function Predicts Fall Risk

Herman et al. 2010

% of subjects who fell

Time to first fall (months)

Low Executive Function

High Executive Function
Dual-task paradigm

Serial subtractions
(501-7-7-7...=?)

[Image of a running person with a thought bubble containing the text above.]
Odds of Falling

Odds of falling when gait changes during multi-tasking

Beauchot et al., 2008

Dual-task
n = 2290
Fall Risk Model

Reduced Executive Function

Easily Distracted

Can’t multi-task

Increased trips & stumbles

Fall

Muscle Weakness (can’t recover)
Prevention

Exercise can increase muscle strength

Exercise can improve executive function
Fall Prevention

Traditional View:

1) Muscle weakness
Exercise Improves Muscle Mass

- 40-year-old triathlete
- 70-year-old triathlete
- 74-year-old sedentary man

Adipose tissue
Quadriiceps
Strength Training Improves Muscle Function

Fiatarone et al. 1990

One Rep Maximum Left (kg)

Baseline

2 months

3 x per week; ~5 minutes of lifts
Strength Training Improves Muscle Function

One Rep Maximum Left (kg)

Baseline 2 months

3 x per week; ~5 minutes of lifts

Fiatarone et al. 1990
Fall Prevention

1) Muscle weakness

2) Cognitive decline (e.g., multi-tasking)

Can exercise reduce cognitive decline?
Aerobic Exercise Improves Cognition

Analysis of 18 studies show exercise training benefits for cognition in older adults for multiple cognitive domains, but especially for executive abilities

Hillman et al., 2008
Aerobic exercise increases brain volume

Healthy elderly adults randomly assigned to aerobic exercise for 6-months, 3 hrs/week had increased brain volume in gray matter (GM; blue) and white matter (WM; yellow) compared to a non-exercise group.

Colcombe et al., 2006
Exercise program reduces fall risk without increasing muscle strength (meta-analysis of a standard fall prevention program)  
Robertson et al., 2002
Meta-analysis of Exercise Studies

597 subjects in five RCTs

~55% reduction in falls in individuals in exercise programs (aerobic + strength training) Petridou et al., 2009
Fall Prevention

Traditional View:
1) Muscle weakness

Novel View:
1) Cognitive declines (e.g., multi-tasking)
Fall Risk Model

- Reduced Executive Function
- Easily Distracted
- Can’t multi-task
- Increased trips & stumbles
- Muscle Weakness (can’t recover)

Fall
Fall Risk Model

Reduced Executive Function

Muscle Weakness (can’t recover)
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What Can You Do?

Focus on two main activities:

– Aerobic
– Strength/balance
Aerobic Exercise

Activities that increase your heart rate:
brisk walking, cycling, swimming
Suggestions for daily life changes

Work your way up to moderate intensity

<table>
<thead>
<tr>
<th>Age</th>
<th>Max. HR (220-Age)</th>
<th>Target HRs (60-70%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>155</td>
<td>93-109</td>
</tr>
<tr>
<td>70</td>
<td>150</td>
<td>90-105</td>
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<tr>
<td>75</td>
<td>145</td>
<td>87-102</td>
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<td>80</td>
<td>140</td>
<td>84-98</td>
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<td>85</td>
<td>135</td>
<td>81-95</td>
</tr>
<tr>
<td>90</td>
<td>130</td>
<td>78-91</td>
</tr>
</tbody>
</table>

American Heart Association Guidelines
Suggestions for daily life changes

Work your way up to moderate intensity

Light intensity:
Can talk and sing without problem
No change in breathing patterns

Moderate intensity:
Change in breathing, but not out of breath
Can talk, but not sing
Strength Training
National Institute on Aging at NIH:
http://go4life.nia.nih.gov
National Institute on Aging at NIH: http://go4life.nia.nih.gov

Find Activities and Exercises Here

**STRENGTH EXERCISES**

Upper Body

- Hand Crips
- Wrist Curl
- Overhead Arm Raise
- Front Arm Raise
- Side Arm Raise
- Arm Curl
- Arm Curl with Resistance Band
- Seated Row with Resistance Band

**BALANCE EXERCISES**

- Stand on One Foot
- Heel-to-Toe Walk
- Balance Walk
- Tai Chi

**FLEXIBILITY EXERCISES**

- Neck
- Shoulder
- Shoulder and Upper Arm
- Upper Body
Suggestions for daily life changes

How to start? Small changes can add up to big results

Increasing stair use can improve aerobic fitness by 10%

Park farther away: Lifestyle change comparable to structured program in intervention study

Ross and McGuire et al., 2011; Meyer et al., 2010; Dunn et al., 1999
Suggestions for daily life changes

Make it a priority: Schedule exercise into your calendar like an appointment

Cox et al., 2003

Making exercise social improves adherence: 84% vs. 60% after 6 months
Suggestions for daily life changes

Keep it fun: You will keep doing activities if you enjoy them

Ryan et al., 1997
Wankel, 1993
Start Today
Remember: Activity is in our Genes

Grandmother Hypothesis

Physically active lifestyle allows for successful aging
Thanks!
Thank You Supporters!
Causes of Falls

1. Accident/environment based (~31%)
2. Gait disorders (~17%)
3. Symptoms of underlying diseases account for rest

Rubenstein 2006 Age and Ageing
Lower Body

- Back Leg Raise
- Side Leg Raise
- Knee Curl
- Leg Straightening
- Chair Stand
- Toe Stand
Balance

Stand on One Foot

Heel-to-Toe Walk

Balance Walk

Tai Chi
Three Suggestions

• Start small

• Make a plan (exercise is a priority)

• Keep it fun (you do what you enjoy)
Suggestions for daily life changes

Make a plan: Ask a friend to take a walk or join a group exercise class/activity

Making exercise social improves adherence: 84% vs. 60% after 6 months

Cox et al., *Prev Med*, 2003
Suggestions for daily life changes

Work your way up to moderate intensity

Light intensity:
Can talk and sing without problem
No change in breathing patterns

Moderate intensity:
Change in breathing, but not out of breath
Can talk, but not sing
Strength Training Improves Muscle Function

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean ± SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcutaneous</td>
<td>31.00 ± 17.02</td>
</tr>
<tr>
<td>Intramuscular</td>
<td>8.46 ± 1.14</td>
</tr>
</tbody>
</table>

*Computed tomographic scans could not be digitized in two subjects due to technical problems. All area values are expressed as means ± SEMs.

Fiatarone et al. 1990
Strength Training Improves Muscle Function

Fiatarone et al. 1990
**Dual-Task Performance and Fall Risk**

Odds of falling when gait changes during multi-tasking

<table>
<thead>
<tr>
<th>Study ID</th>
<th>ES (95%CI)</th>
<th>% Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Studies with retrospective data collection of falls</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shumway-Cook et al., 2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faulkner et al., 2007*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faulkner et al., 2007†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtotal (I-squared = 78.4%, p = 0.010)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Studies with prospective data collection of falls</strong></td>
<td></td>
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<tr>
<td>Lundin-Olsson et al., 1997</td>
<td></td>
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<tr>
<td>Bootsma-Van Der Wiel et al., 2003</td>
<td></td>
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<tr>
<td>Hyndman et al., 2004</td>
<td></td>
<td></td>
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<tr>
<td>Andersson et al., 2006*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Andersson et al., 2006†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beauchet et al., 2007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beauchet et al., 2008b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kressig et al., 2008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beauchet et al., 2008a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtotal (I-squared = 86.9%, P = 0.000)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.1 0.25 0.5 1 2 4 10 25 50 100</td>
<td></td>
</tr>
<tr>
<td>Overall (I-squared = 87.9%, P = 0.000)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: Weights are from random effects analysis

*: Simple attention-demanding task
†: Complex attention-demanding task

Beauchot et al., 2008
Muscle Strength and Fall Risk

Odds Ratio (OR): Odds that an outcome (fall) will occur given a particular condition (muscle weakness)

**Lower Extremity Weakness**
- Any Fall

<table>
<thead>
<tr>
<th>OR [95% CI]</th>
<th>STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.95 [1.41 – 2.68]</td>
<td>Campbell</td>
</tr>
<tr>
<td>1.66 [1.12 – 2.46]</td>
<td>Tinetti</td>
</tr>
<tr>
<td>1.76 [0.62 – 4.99]</td>
<td>Lipsitz</td>
</tr>
<tr>
<td>2.09 [1.56 – 2.80]</td>
<td>Northridg</td>
</tr>
<tr>
<td>2.48 [1.58 – 4.38]</td>
<td>Graafman</td>
</tr>
<tr>
<td>1.20 [1.10 – 1.40]</td>
<td>Tromp</td>
</tr>
<tr>
<td><strong>1.76 [1.31 – 2.37]</strong></td>
<td><strong>COMBINE</strong></td>
</tr>
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**Upper Extremity Weakness**
- Any Fall

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<td>2.28 [1.57 – 3.31]</td>
<td>Campbell</td>
</tr>
<tr>
<td>1.46 [0.97 – 2.20]</td>
<td>Tinetti</td>
</tr>
<tr>
<td>1.17 [1.09 – 1.26]</td>
<td>Tromp</td>
</tr>
<tr>
<td>1.53 [1.01 – 2.32]</td>
<td><strong>COMBINED</strong></td>
</tr>
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1 = no difference

Moreland et al. 2004
Strength Training Improves Muscle Function

Fig 3. — Effects of weight training on knee extensor strength. Maximum left knee extensor strength before and after 8 weeks of high-intensity progressive-resistance training in nine subjects aged 87 to 96 years (\(P<.0001\) compared with baseline). Similar strength gains were seen in the right leg (see text). Symbols represent individual subjects.

Fiatarone et al. 1990
Executive Function Predicts Fall Risk

Herman et al. 2010 J. Gerontology
Meta-analysis of Exercise RCTs

~55% reduction in falls in individuals in exercise programs (aerobic + strength training) Petridou et al., 2009
Humans Have Long Lifespans

Finch C E PNAS 2010;107:1718-1724
Odds of Falling

Odds of falling when gait changes during multi-tasking

Retrospective | Prospective
---|---
Odds Ratio | Odds Ratio

1 = no difference
Higher odds

Beauchot et al., 2008
Millions of years ago

2 Ma: Hunting and gathering (Homo)

From ~7-2 Ma: Bipedal fruit eating apes (Australopithecus)
Fall Risk Model

Reduced Cognitive Function

Distraction

Slow decision making

Muscle Weakness (can’t recover)

Increased trips & stumbles
Exercise Training and Dual-Task Performance

Theill et al., 2013
Exercise is Good For Us

We live in a mismatch environment:
Our bodies evolved to be active

Exercise is the “magic pill”
Is exercise the key to reducing fall risk?
Fall risk in more active populations?

Hip fractures in 75 and older (per 100k)
Nigeria: 8.0
Britain: 190.8

Adebajo et al. 1991