

MEASURING AND IMPROVING CARDIOVASCULAR HEALTH IN PEOPLE POST-STROKE

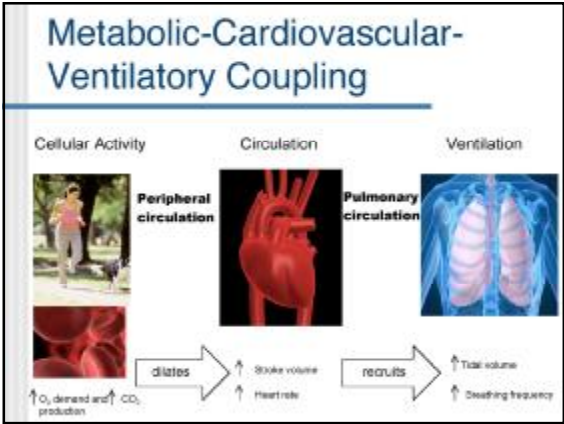
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DISCLOSURES: NONE

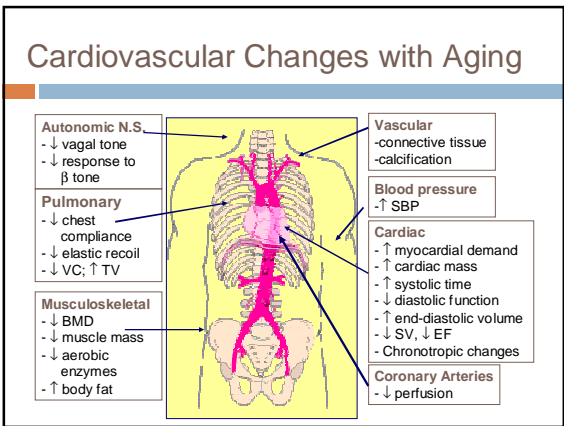


CURRENT ENVIRONMENT

- ∴ Promotes sedentary lifestyles
 - Examples
- ∴ Few opportunities for physical activity during the course of daily living
 - Jobs, school, commuting
- ∴ Almost no **need** to be physically active to survive
- ∴ Abundance of high density foods
 - Easy accessibility
- ∴ Little **need** to expend energy for foods

How Do We Help Our Patients Improve CR Fitness?





Heart

- Organ with 4 chambers:
- 2 chambers work to pump blood to lungs
 - (R atria/ventricle)
- 2 chambers to pump blood to the body
 - (L atria and ventricle)

Innervation of the Heart

- Provided by sympathetic and parasympathetic nerve fibers and by accompanying visceral afferent fibers through cardiac plexuses
- Originates largely in the cervical area, attesting to original location of cardiogenic area at cranial end of embryonic disc
- Sympathetic innervation
 - Derives mostly from cardiac branches of cervical sympathetic ganglia
 - Increases the frequency and strength of cardiac contractions
- Visceral afferent fibers traveling with sympathetic fibers
 - Pass through cervical cardiac nerves and down cervical sympathetic trunk to cell bodies in dorsal root ganglia of upper thoracic spinal nerves
- Provide sensory input for important cardiac reflexes and are sole conductors of pain from heart

CARDIAC REGULATION

- Sinoatrial (SA) node
 - Pacemaker of the heart
 - Highest concentration of intrinsic rhythmicity
 - Location in right atrium
 - Intrinsic rate \approx 72 beats per minute

AUTONOMIC NERVOUS SYSTEM

- PARASYMPATHETIC NERVOUS SYSTEM
- SYMPATHETIC NERVOUS SYSTEM
 - HOMEOSTASIS
 - RESPONDS TO VARIOUS STIMULI

AUTONOMIC NERVOUS SYSTEM

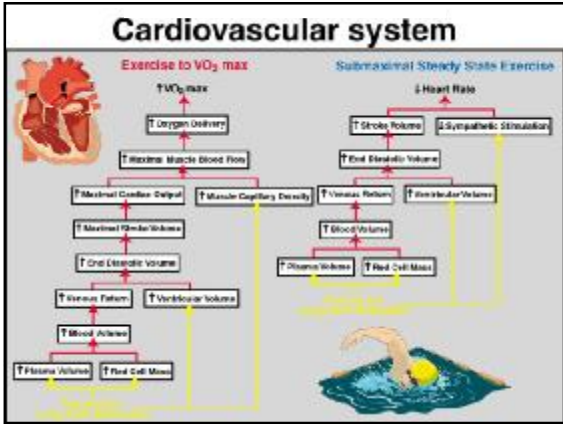
- PARASYMPATHETIC NERVOUS SYSTEM
 - ▣ VAGUS NERVE
 - ▣ SA NODE IN THE RIGHT ATRIA
 - ▣ REST
 - ▣ LIGHT TO MODERATE EXERCISE/ACTIVITY

AUTONOMIC NERVOUS SYSTEM

- SYMPATHETIC NERVOUS SYSTEM
 - ▣ CATECHOLAMINES
 - ▣ EPINEPHRINE
 - ▣ NOREPINEPHRINE
 - ▣ Increased myocardial contractility and blood flow
 - ▣ NEAR MAXIMAL AND MAXIMAL EXERCISE
 - ▣ Maximal stimulation = doubles force of ventricular contraction

Lungs

- Lungs are organs of respiration for the oxygenation of blood and removal of CO₂
 - ▣ Each in their own pleural cavity
- The lungs are light, soft, spongy, elastic organs that change in size with each breath.
- The lung tends to collapse (due to elastic fibers), just as the chest wall tends to retain its normal shape (keeps them inflated).
- The elasticity of the lung is counter balanced by the muscles and structural elements of the thoracic cage and the negative pressure in the pleural space.



BLOOD FLOW REGULATION

NEURAL CONTROL

- Change in position
- Exercise

Influence on vascular tone

- Vascular tone = degree of constriction of a blood vessel (relative to its maximally dilated state)
 - Vessels have some degree of smooth muscle contraction
 - Determines diameter (thus tone) of the vessel.
- Heart, muscle, and skin have ↑ vascular tone vs. cerebral and renal circulation
 - Due to vasodilatory capacity

Influence on vascular tone

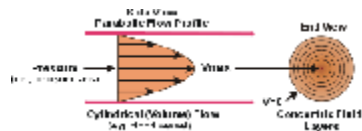
- Balance of competing vasoconstrictor and vasodilator influences
 - Extrinsic factors
 - Neurohumoral = e.g. sympathetic nerves, circulating angiotensin II ↑ vascular tone (i.e., cause vasoconstriction); however, some circulating factors ↓ vascular tone.
 - Intrinsic factors include:
 - Myogenic mechanisms (originating from vascular smooth muscle), which ↑ tone.
 - Endothelial factors (e.g., nitric oxide, endothelin) can either ↑ or ↓ tone.
 - Local hormones/chemical substances (e.g., arachidonic acid metabolites and histamine can either ↑ or ↓ tone)
 - Metabolites (or hypoxia) generally ↓ tone.

Influence on vascular tone

- ↑ metabolic activity = release of adenosine (potent vasodilator)
- Other metabolic influences
 - CO₂
 - [H⁺]
 - [La⁻],
 - K⁺
 - Inorganic phosphate (Pi)

Laminar vs. turbulent blood flow

- Laminar Flow
 - Fluid travels in layers
 - Little energy loss due to viscous interactions between layers and blood vessel wall
 - Disruption of laminar flow results in turbulence

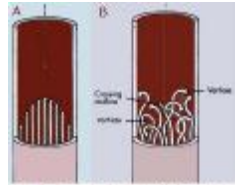


Picture from: <http://www.cvphysiology.com>

Laminar vs. turbulent blood flow

• Turbulent Flow

- ▣ Disrupted laminar flow
 - Following narrowed (stenotic) arterial vessels
 - Vessel branch points
 - Ascending aorta at high cardiac ejection velocities (e.g., during exercise)



Figures from:
<http://mcrcr4.med.nyu.edu/Physio/EvanStuff/cardio/cardio.html>

Now What??

The Conundrum of Starting to Exercise

- How does an individual start to exercise??
- For those sedentary or unfamiliar with exercise and want to start, the answer may not be that easy
 - ▣ Medical evaluation?
 - ▣ Exercise test?
 - ▣ How long, how often, how intense?
 - ▣ Endurance vs resistance exercise vs both?

Medical Clearance/Evaluation

- Consider whether the individual is low, moderate or high risk
 - High risk for medical evaluation and determination of exercise supervision
 - Exercise prescription
 - HR or BP limits, blood sugars, orthopedic issues, neurologic deficits
 - Baseline for comparison
 - Risk factor assessment
 - CAD

Graded Exercise Test

- Maximal effort is given using treadmill (most common), cycle ergometry or other devices
- EKG (ECG)
 - Baseline reading for heart rate and rhythm
 - Monitor changes in cardiac parameters (ischemia)
 - Abnormalities or signs suggestive of cardiovascular, pulmonary or metabolic disease
 - SOBOE (mild exertion), syncope, tachycardia, pain in chest, jaw
 - Blood pressure
 - Normal vs abnormal response

Exercise Test or Not To Test?

- Are they necessary? Should we perform tests?
- Specificity and Sensitivity of GXT
- Most individuals can perform low to moderate exercise safely
 - ACSM guidelines for beginning an exercise program
 - Low vs high risk
 - Exercise intensity
 - Clinic vs research

Patient Case #1

- 77 y/o female
 - Sudden onset of chest pain with SOB
 - Anterior MI w/ atrial fibrillation
 - Ventricular rate at 120 bpm
 - CABG x 3
 - First day post-op
 - Mental status change
 - Right hemiplegia
 - CT scan
 - Acute ischemic stroke (L frontoparietal; R parietal)

Patient Case #1

- PMH
 - Hyperlipidemia
 - HTN
 - Atherosclerotic PVD
 - CAD, positive for congestive heart failure (CHF)
 - Carpal tunnel syndrome w/ surgical release
 - OA; Lumbar and cervical spine surgery
 - Positive for fatigue

Patient Case #1

- Neurologic
 - DTR absent on right, normal left
 - ROM intact with end-range limitations
 - OA
 - Decreased sensation on right, normal left
 - Motor = 4/5 on left; 0/5 right
 - Impaired left finger to nose and rapid alternating movements
 - Language deficits

Patient Case #1

- Physician orders PT for
 - AROM
 - Strengthening
 - Balance
 - Coordination
 - Ambulation, stairs, challenging surfaces
- Estimated LOS = 3-6 weeks for plan to return home

Patient Case #1

- Four weeks of therapy from all disciplines
 - D/C'd to SNF (early fatigue, tolerance with activity)
- Presented with ataxic gait (R. weak glut med, spastic adductors, AFO, weak hip extensors)
 - Used hemicane w/ min/mod A, 75 feet
 - Manual facilitation
 - Motor plan deficits
 - SOB with ambulation, transfers

Patient Case #1

- Family reported, "Mom has had difficulty with activity during therapy and gets tired really fast."
- No information in previous notes regarding structured aerobic exercise training

Should We Focus on Aerobic Exercise after Stroke?

- Why have exercise training?
- Is it necessary when considering all other deficits?
 - "So many other activities to work on."

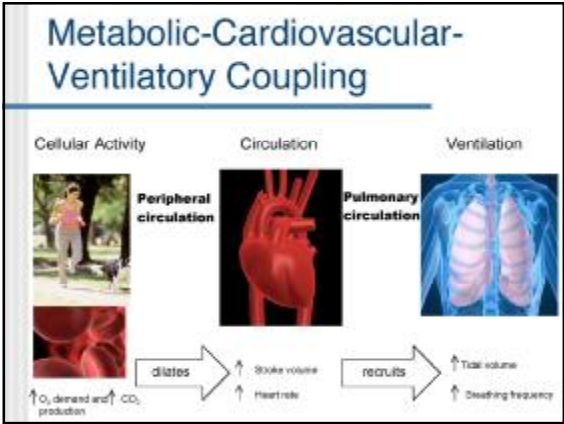


Should We Focus on Aerobic Exercise after Stroke?

- "Impairments in cardiorespiratory (CR) function and neuromotor control are independent, yet can mutually reinforce one another"
 - Tang and colleagues, Neurorehabilitation and Neural Repair, 2009
- Previous cardiac conditions may be more limiting than the stroke (Gresham, et al, Framingham Study)
 - Limits performance in rehabilitation, reduced capacity to perform ADLs, and ambulation

Should We Focus on Aerobic Exercise after Stroke?

- " Professionals who design and conduct stroke rehab programs should consider allocating more time to aerobic exercise training to optimize pt outcomes"
 - AHA, Scientific Statement for Physical Activity and Exercise Recommendations for Stroke Survivors, 2004
- "Stroke is a cardiovascular disease..." (Pam Duncan, PT, PhD)



MAJOR CARDIOVASCULAR FUNCTIONS

Maximal oxygen consumption (VO₂ max)

- Measure of cardiorespiratory fitness
- $VO_2 \text{ max} = SV * HR * \text{arteriovenous oxygen difference}$
- Measured through direct or indirect calorimetry
- Improves with training $\approx 10\% - 30\%$

MAJOR CARDIOVASCULAR FUNCTIONS

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Exercise Testing

- Information obtained

- Cardiorespiratory fitness
- RER, BP, HR, VE and VO_2 max/peak
- Exercise prescription



- 40% less than age-matched sedentary counterparts (Eng, Dawson, and Chu, 2004; Pang, 2006; Macko, et al, 2001)

- Methods to obtain VO_2 peak

- 15% body weight support treadmill (MacKay-Lyons, 2002)
- Cycle ergometer (Potempa, 1995; Yates, 2004; Chen, 2005)
- Submaximal exercise testing (Macko, 1997)

RER = Respiratory Exchange Ratio, BP = Blood Pressure, HR = Heart Rate, VE = Volume of air expired

Peak Oxygen Uptake (VO_2 peak)

- Reductions in VO_2 peak

- Age
- Disease
- Sedentary Lifestyle

- Male sedentary lifestyle

- 70 yr $\approx 26.2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$
- 20 yr $\approx 46.0 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$

Exercise Testing

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- Cardiorespiratory fitness
- RER, BP, HR, VE and VO_2 max/peak
- Exercise prescription



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RER = Respiratory Exchange Ratio, BP = Blood Pressure, HR = Heart Rate, VE = Volume of air expired

Challenges Associated with Exercise Post-Stroke

- n Decreased fitness levels (physical inactivity)
- n Exercise testing protocols/modalities
- n Hemiparesis
- n Balance
- n Muscle incoordination

Challenges Associated with Exercise Post-Stroke

- n Increased energy expenditure (submax)
- n Fatigue
- n Depression
- n Pain
- n Muscle atrophy
- n Blood Flow

Safety in Peak Exercise Testing Post-Stroke

- .. Limited data on safety and exercise testing post-stroke
 - ▣ 100/117 sub-acute stroke survivors completed test
 - n 14 unable to complete, 3 failed for cardiac reasons^(Yates, 2004)
 - ▣ 57 initial sub-acute stroke participants for GXT
 - n 9 unable to complete, 3 failed for cardiac problems^(Tang, 2009)
 - ▣ 168 GXT in chronic stroke ^(Billinger, Taylor, Quaney, in prep)
 - n Retrospective analysis
 - n 1 cardiac event-- d/t ST segment depression
 - n Early test termination

Challenges with Exercise Testing Post-stroke

- Exercise testing protocols
 - Obtaining accurate oxygen uptake
- Neuromuscular system
 - Muscle tone, coordination
- Physiology of cardiovascular system
 - Cardiovascular disease
 - Left ventricular dysfunction
 - Atherosclerosis
 - Type 2 Diabetes

MAP= Mean Arterial Pressure, Q= Cardiac Output, TPR= Total Peripheral Resistance

Limitations During Exercise Post-stroke

- Muscle fiber type
 - Type I vs Type II (De Deyne et al, 2004; Landin, 1977)
- Fatigue
 - Whole body vs hemiparetic limb
- Blood Flow
 - Resting (Landin, 1977; Ivey, 2004; Billinger, 2009); Exercise (Landin, 1977)
 - Increased vasomotor tone
 - Impaired vasodilation responses
 - Disuse/Physical Inactivity

Peak Exercise Testing Post-Stroke

- Neuromuscular Deficits
 - 100/117 sub-acute stroke survivors completed test
 - 14 unable to complete (Yates, 2004)
 - 57 initial sub-acute stroke participants for GXT
 - 9 unable to complete, (Tang, 2009)
 - 168 GXT in chronic stroke (Billerger, Taylor, Quaney, in prep)
 - Retrospective analysis
 - All completed GXT

Use of Total Body Recumbent Stepper Exercise Test (TBRS-XT) to Obtain Maximal Oxygen Consumption

Billinger S, Loudon J and Gajewski B, *Journal of Strength and Conditioning Research*, September, 2008

TBRS-XT

Purpose: Determine the validity and reliability of total body recumbent stepper exercise test (TBRS-XT) for obtaining VO_2 max using TBRS

Methods: Validity and Reliability of TBRS-XT

- Adults n = 22; (Males = 13; 27.0 ± 6.1 years)

- Equipment

Results: VO_2 max

- Pearson Correlation Coefficient; $r = 0.92$

- Linear regression (prediction model), $R^2 = 0.85$

- Reliability (n = 5)

- ICC = 0.98 $p < 0.001$

Modified Total Body Recumbent Stepper Exercise Test (mTBRS-XT) to Obtain $\text{VO}_{2\text{peak}}$ Post-stroke



Billinger SA, Tseng, BY and Kluding, PM, *Physical Therapy Journal*, October, 2008

Manuscript awarded Dorothy Briggs Memorial Scientific Inquiry Award, March 2009

mTBRS-XT

Purpose: Determine if mTBRS-XT is a valid protocol in individuals with stroke

Methods: Eleven adults with chronic stroke; age = 63.0 ± 10.0 years

Equipment: Cycle ergometer and TBRS; metabolic cart for gas analysis

Results: VO_2 peak

Pearson Correlation Coefficient; $r = 0.91$

VO_2 peak for mTBRS-XT significantly higher ($p = 0.04$)

Stroke severity (lower extremity Fugl-Meyer) and modality

Submaximal GXT

- Used to predict VO_2 max
- Accurate assessment of HR is crucial
 - HR monitor, stethoscope or EKG
- Factors affecting testing:
 - Caffeine intake, meds, anxiety, dietary
- Modalities
 - Treadmill, cycle, recumbent stepper, walk tests
 - Mendelsohn, 2008 (frail older adults)
 - Eng, 2004
 - Macko, 1997, 2001

EXERCISE PRESCRIPTION POST-STROKE

AEROBIC EXERCISE

- Duration
 - 20-60 minutes
- Frequency
 - 3-5 days per week
- Intensity
 - 40-70% VO_2 peak
 - Heart rate (Beta Blockers)
- Mode

EXERCISE PRESCRIPTION POST-STROKE

Treadmill, Cycle Egometer, Seated Stepper

Goals

- Ambulation speed/distance
- Increase independence with ADL/IADLs
- Decrease risk of cardiovascular disease
- Physiological response

EXERCISE PRESCRIPTION POST-STROKE

Neuromuscular (Coordination, Balance)

Goals

- Improve levels of safety with mobility
- Improved movements (SLS = gait)
- Decrease risk of falls
- Core strength

EXERCISE PRESCRIPTION POST-STROKE

MUSCLE STRENGTHING

Frequency

- 2-3 days/week

Intensity

- 3 sets 8-12 reps

Mode

- Weight machine
- Free weights, Theraband (Isotonic)
- Isometric

EXERCISE PRESCRIPTION POST-STROKE

- MUSCLE STRENGTHENING GOALS
- Increase # of repetitions/sets/weight
- Increase strength for ADL/IADLs
- Decrease tone
- Improve functional mobility

EXERCISE PRESCRIPTION POST-STROKE

- MUSCLE STRENGTHENING
- Delayed Onset Muscle Soreness (DOMS)
 - Rest in between sessions
- Modifications to exercise
 - Seated vs standing
 - Balance/Posture

Rationale for Exercise Post-Stroke

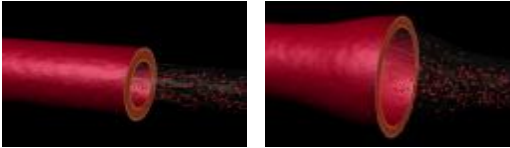
IMPROVE CARDIORESPIRATORY FITNESS

- Physical Deconditioning
 - Increased energy demand (Gait, ADL's)
- Sarcopenia
- Risk for second stroke
- Type 2 diabetes

Blood Flow: Does It Change After Stroke?

Blood Flow Regulation

- Sympathetic nervous system regulates vasomotor tone
- Endothelial response to maintain homeostasis
 - Sheer stress
 - Flow-tension relationship (Ono, 1991; Kamiya, 1988; Langille, 1986)



http://nobelprize.org/nobel_prizes/medicine/laureates/1928/medarim/images.html

Use of Doppler Ultrasound to Assess Femoral Artery Adaptations in the Hemiparetic Limb in Chronic Stroke

Billinger SA and Kluding, PM. *Cerebrovascular Diseases*, 2009

SUBJECTS & METHODS

17 Individuals post-stroke

- 8 males; 10 right hemiparesis
- 69.0 ± 17.0 y/o; 6.0 ± 5.0 years post-stroke

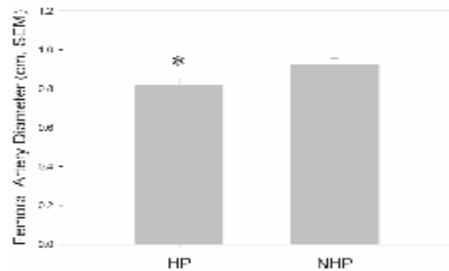
Methods

• Doppler ultrasound femoral artery

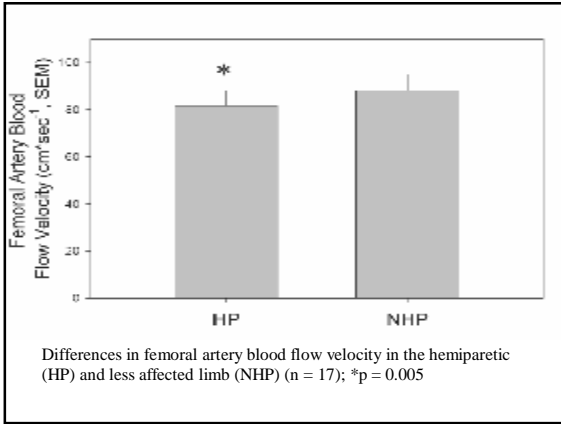
- Supine 30 minutes
- 1 cm proximal to the bifurcation
- Right/Left
 - Arterial diameter
 - Blood flow velocity

RESULTS





Differences in femoral artery diameter in the hemiparetic (HP) and less affected limb (NHP) (n = 17); *p = 0.001



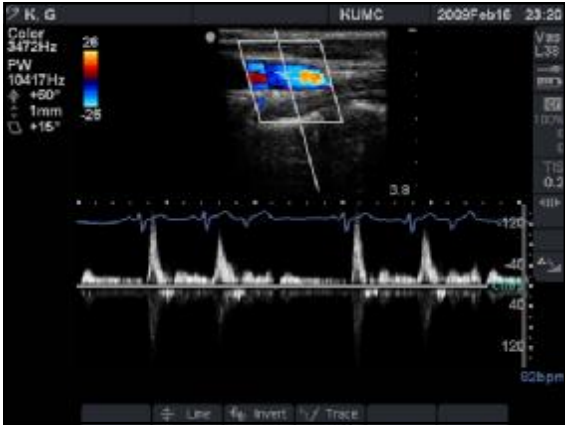
CONCLUSION

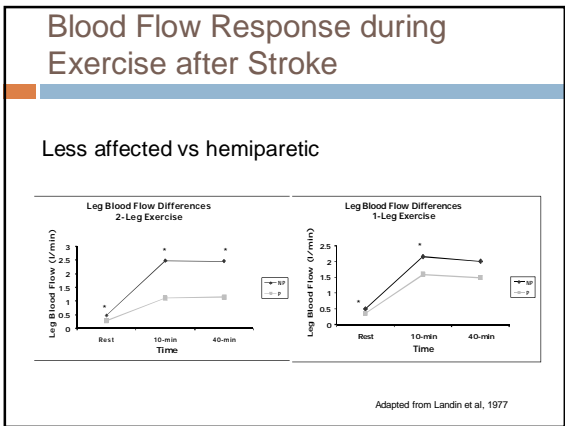
- Femoral artery adaptations in the hemiparetic limb in people with chronic stroke
- Mechanisms driving alterations are unknown
 - Peripheral
 - Central
- Interventions aimed at minimizing these vascular alterations

Background

Blood Flow Post-Stroke

- Limited information about vascular changes post-stroke
 - Time course unknown
- Reductions in blood flow (Landin, 1977; Ivey, 2004; Billinger, 2009 review) and femoral artery diameter (Billinger, 2009)
- **Acute** exercise response and blood flow (Landin, 1977)
 - Metabolic and physiological characteristics





Background

- Single Limb Exercise (SLE)
- Healthy Adults
 - Vascular changes with SLE (Asanoi, 1992; Klausen, 1982)
 - Improvements in VO_2 peak (Saltin, 1976; Davies, 1975; Bell, 2001; Miyachi, 2001)
- Congestive heart failure (LeJemtel, 1986)
- Respiratory dysfunction (Dolmage, 2006)

Background

- SLE in stroke?
 - Bilateral vs unilateral exercise
 - Force production (Landin, 1977; Chen, 2005)
 - Coordination or timing with movements
 - Constraint-induced movement therapy (CIMT, mCIMT) (Taub, 2006; Page, 2004; Ro, 2006)

Background

Cardiorespiratory Fitness

- Decreased peak oxygen uptake (VO_2 peak) (Macko, 1997; Eng, 2004)
- Energy expenditure at submaximal efforts (Macko, 1997, 2001)
- Exercise training
 - VO_2 peak
 - Oxygen uptake (VO_2)
 - Energy expenditure

Cardiovascular Regulation- The Next Step

Statement of the Problem

- Relatively poor understanding of blood flow regulation and response to exercise in the legs following stroke

Project Goal

- Characterize cardiovascular response to a single limb exercise (SLE) training protocol in people post-stroke

SINGLE LIMB EXERCISE
INFLUENCES CARDIOVASCULAR
FUNCTION FOLLOWING STROKE:
“A ONE-SIDED VIEW”

Participants

- ≥ 6 months post-stroke without diabetes
- Provide written informed consent
- Doppler ultrasound
 - > 2% difference between the two limbs for diameter and blood flow velocity
- Ankle-brachial index (ABI)
 - > 0.40 (Andreozzi, 2007)
- Assessment of motor performance
 - Lower extremity Fugl-Meyer (LEFM) 20-33/34

Participants

- Knee extensor strength
 - Biodex
- SLE
- Dual Energy X-ray Absorptiometry (DEXA)
- Maximal and submaximal exercise test

Participants

- 12 participants
 - 5 males
 - 60.6 ± 14.5 years of age
 - 69.1 ± 82.2 months post-stroke
 - Mild to moderate stroke (Daly, 2006)
 - LEFM score
 - 26.7 ± 3.8 (range: 20-32/34)

METHODS

SLE Protocol

- Hemiparetic limb
- 3x * week⁻¹ for 4 weeks
- 40-70% HR max (ACSM, 2003)
 - Maximal effort exercise test
- Isokinetic knee extension/flexion protocol
- 150° * sec⁻¹; 40 repetitions per set
- 30-second rest between sets
- 40 sets



Does SLE influence cardiovascular function?

Aim 1: Characterize the effect of a 4-week SLE training protocol on the femoral artery vasculature in the hemiparetic leg

Aim 2: Determine whether a 4-week SLE intervention can improve cardiovascular fitness

Single Limb Exercise Induces Femoral Artery Remodeling and Improves Blood Flow in the Hemiparetic Leg Post-Stroke

Billinger, SA, Guo, LX, Gajewski, BJ and Kluding, PM. Single Limb Exercise Induces Femoral Artery Remodeling and Improves Blood Flow in the Hemiparetic Leg Post-Stroke, *Stroke*, 2009, 40(9): 3086-90.

Hypotheses

- If repeated bouts of acute exercise increases blood flow and metabolic demand, vascular remodeling should occur. After 4 weeks of SLE using the hemiparetic leg, femoral artery:
 - **Hypothesis:** diameter and blood flow velocity will significantly increase from baseline values
 - **Hypothesis:** blood flow will improve from baseline

Femoral Artery Measures

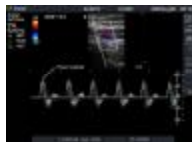
- Doppler Ultrasound
 - Sonosite MicroMaxx system
 - 5-1 MHz transducer (vascular scanning)
- Lie supine 30 minutes prior to assessment
- Measures duplicate
 - Diameter
 - Blood flow velocity
- Repeated measures
 - Baseline, T1, Post-Intervention
- 24-72 hours post-exercise (Anton et al., 2006)

Femoral Artery Measures

- Diameter
 - Systole (R-wave)

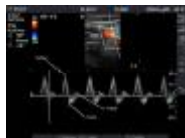


- Blood Flow Velocity
 - Peak systole



Femoral Artery Measures

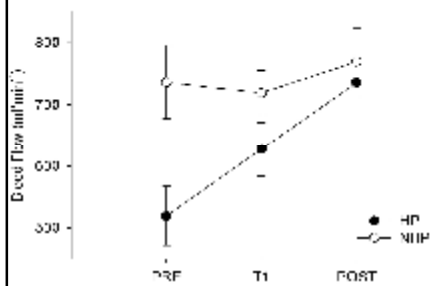
- Blood Flow (BF)
- $BF (ml \cdot min^{-1}) = 3.14 \cdot V_{mean} \cdot r^2 \cdot 60$ (Anton, 2006)
- V_{mean} is the average blood flow velocity of the Doppler waveform for one cardiac cycle (Gerrits et al., 2001)
 - $V_{mean} = ((V_{max} + V_{min} + V_{dias})/3)$
- Average of 6 cycles for data analysis



Data Analysis

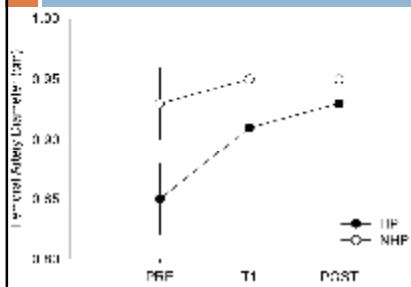
- 2- way ANOVA with repeated measures
 - Time
 - Side (HP, NHP)
 - Variables: Blood Flow, Diameter, Velocity
- Post-hoc
 - Parameter Estimates
 - Diameter and velocity

Results



Side by Time interaction $F_{(2,22)} = 12.12, p < 0.001$

Results



Side by Time interaction $F_{(2,22)} = 24.76, p < 0.001$

Results

- Less Affected Limb
 - No significant differences for blood flow ($p = 0.08$); diameter ($p = 0.65$); peak velocity ($p = 0.30$)
- Parameter estimates
 - NHP diameter, $p = 0.78$
 - NHP peak velocity; $p = 0.15$

Vascular Conductance

- Blood pressure (baseline and post-intervention)
- Femoral artery blood flow values
- Vascular conductance = BF/MAP (Newcomer, 2004; Parker, 2007; Raedgran 2000)
- Results
 - Vascular conductance significantly improved ($p = 0.001$)
 - MAP ($p = 0.08$)
 - Blood flow ($p < 0.001$)

BF = blood flow, MAP = mean arterial pressure; SBP = systolic blood pressure; DBP = diastolic blood pressure

Discussion/Conclusion

- These findings support those reported in healthy adults (Asanoi, 1992) and spinal cord injury (Thijssen, 2006; Hopman, 2002)
- Results suggest SLE training improves cardiovascular function in the femoral artery of the hemiparetic limb
 - Exercise is a robust stimulus
 - Increased metabolic demand

Does SLE influence cardiovascular function?

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Aim 2: Determine whether a 4-week SLE intervention can improve cardiovascular fitness

Single Limb Exercise: A Pilot Study of the Physiological and Functional Responses to Encouraged Use in the Hemiparetic Lower Extremity

Billinger, SA, Guo, LX, Pohl, PS, BJ and Kluding, PM. Single Limb Exercise: Pilot Study of Physiological and Functional Responses to Forced Use of the Hemiparetic Lower Extremity. *Topics in Stroke Rehabilitation* (in press)

Hypotheses

- If exercise intensity, frequency and duration are sufficient, the cardiovascular system will demonstrate a training effect after the exercise intervention.
- **Hypothesis:** After 4 weeks of SLE, peak oxygen uptake (VO_2 peak) will increase during a maximal effort exercise test
- **Hypothesis:** Post-intervention, oxygen uptake (VO_2) will decrease after SLE training

Exercise Testing

Maximal Effort

- Metabolic cart
- ECG
- TBRS and mTBRS-XT (Billinger, 2008)

Variables of interest

- Rating of perceived exertion
- VO₂ peak
- Peak heart rate (HR)
- Respiratory exchange ratio (RER)



Exercise Testing

Submaximal Effort

- Metabolic cart
- Polar heart rate monitor
- Biodex (SLE)

Variables of interest

- VO₂
- Heart rate (HR)
- Respiratory exchange ratio (RER)

Data Analysis

Paired T-tests

Maximal effort exercise test

- VO₂ peak
- HR peak
- RER
- RPE

Submaximal exercise test

- VO₂
- HR
- RER

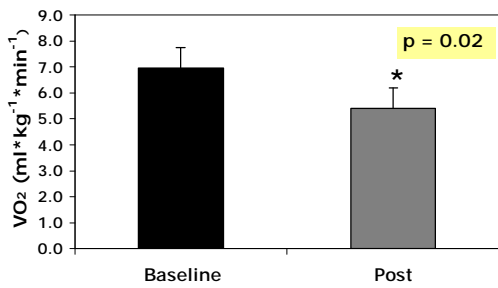
Results

Maximal Effort Exercise Test

- VO₂ peak
 - 19.3 ± 2.0 vs 19.0 ± 2.2 ml*kg⁻¹*min⁻¹; p = 0.41
- HR peak
 - 136.5 ± 6.5 vs 139.2 ± 6.3 bpm; p = 0.74
- RER
 - 1.1 ± 0.03 vs 1.1 ± 0.04; p = 0.89
- RPE
 - 16.0 ± 0.75 vs 17.0 ± 0.82; p = 0.31



Oxygen Uptake (VO₂) during SLE



Results

- Submaximal Exercise
- Effect size (ES) = 0.89 (Thomas, 1997)
- -20.3% in energy expenditure (VO₂)
- HR
 - 85.5 ± 16.6 vs 80.6 ± 13.7 bpm; p = 0.04
- RER
 - 0.99 ± 0.10 vs 0.95 ± 0.12; p = 0.08

Discussion

- SLE did not increase cardiorespiratory fitness at maximal effort
 - Unilateral training vs bilateral exercise test
- Training effect at submaximal effort
 - Economy of movement (Macko, 2001)
- Clinically, would improved economy of movement influence functional outcome?
 - Walking speed

Methods

- 10-Meter Fast Walk Test (n = 7)
 - Baseline and post
 - Walk as fast as possible (AD)
 - 12 meter walkway
 - 3 trials (average taken)
 - Brief rest in between each walk
- Lower Extremity Fugl-Meyer (LEFM)
 - Baseline and post-intervention

Results

- 10-Meter Fast Walk Test (n = 7)
 - 1.18 ± 0.6 vs 1.35 ± 0.6 m*sec⁻¹; p = 0.001
 - ES = 0.37
- LEFM (n = 12)
 - 26.7 ± 3.8 vs 28.7 ± 4.8 ; p = 0.007
 - ES = 0.46

Results

- Percent change 10 meter walk test (n = 7)
 - Percent change LEFM
 - Moderate relationship; $r = 0.50$, $p = 0.26$
 - Cardiovascular function
 - Percent change femoral artery blood flow
 - Strong relationship; $r = 0.80$, $p = 0.03$

Discussion/Conclusion

- Encouraged use beneficial?"
- Cardiovascular mechanisms
 - Cardiac output (Dolmage, 2006)
 - Peripheral response
 - Training effect of exercise
 - VO_2
 - Functional outcomes

Clinical Implications

- Cardiovascular function
 - Daily performance
- Functional measures
 - Gait speed
 - Endurance (6-MWT)
- Application to physical therapy

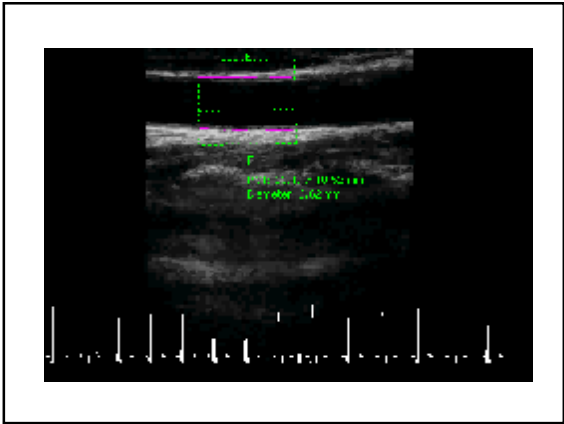
CONCLUSIONS

The “One-Sided View”

- .. SLE
 - ▣ Healthy adults (Bell, 2001; Klausen, 1982; Miyachi, 2001; Shoemaker, 1994)
 - ▣ Chronic obstructive pulmonary disease (Dolmage, 2006)
 - ▣ Congestive heart failure (LeJemtel, 1986)
 - ▣ SLE “interesting mechanism”
 - ▣ Stroke (Landin, 1977)
- .. Unilateral training of upper extremity
 - ▣ Constraint induced therapy (Page, 2004; Taub, 2006)
 - ▣ Penny pinchers

Conclusions

- .. Unique exercise training model
 - ▣ Stroke rehabilitation
- .. Hemiparetic limb
 - ▣ Endothelial response
 - ▣ Repetitive overloading
- .. Central vs peripheral responses to exercise
 - ▣ Training effect
- .. Functional outcome
 - ▣ Cardiovascular vs motor performance
 - ▣ SLE # of repetitions: 120-1,600; mean = 899.4





THANK YOU
