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38TH ANNUAL MEETING

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Serving Challenging Diagnoses in Cardiac Rehabilitation: A Case-Based Approach

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- Grant/Research support: Sleep Number, Inc. – ongoing until 12/2023
- Institutional Relationships with Industry: Mayo Clinic has relationships with industry including companies that provide remote cardiovascular care



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Adult Congenital Heart Disease Case

Congenital Heart Disease

- Population of adults living with CHD has grown rapidly
 - Heterogenous group of conditions
 - Affects ~1% of live births
 - Advances in surgical and medical care
- Minimal evidence to guide physical activity and exercise training
 - Restrictions early in life (unwarranted)
 - Parental and environmental overprotection
 - Recent literature shows concerns are unfounded
- Increased risk of obesity and physical inactivity

Cordina et al., Prog Cardiovasc Dis, 2020; Reybrouck, et al., Eur J Cardiovasc Prev Rehabil, 2005; Pemberton et al., Circ, 2010



Congenital Heart Disease

- Types of CHD

- Atrial and ventricular septal defects
- Bicuspid aortic valve
- Ebstein's anomaly
- Coarctation of the aorta and aortic dilatation
- Tetralogy of fallot
- Transposition of the great arteries
- Fontan circulation

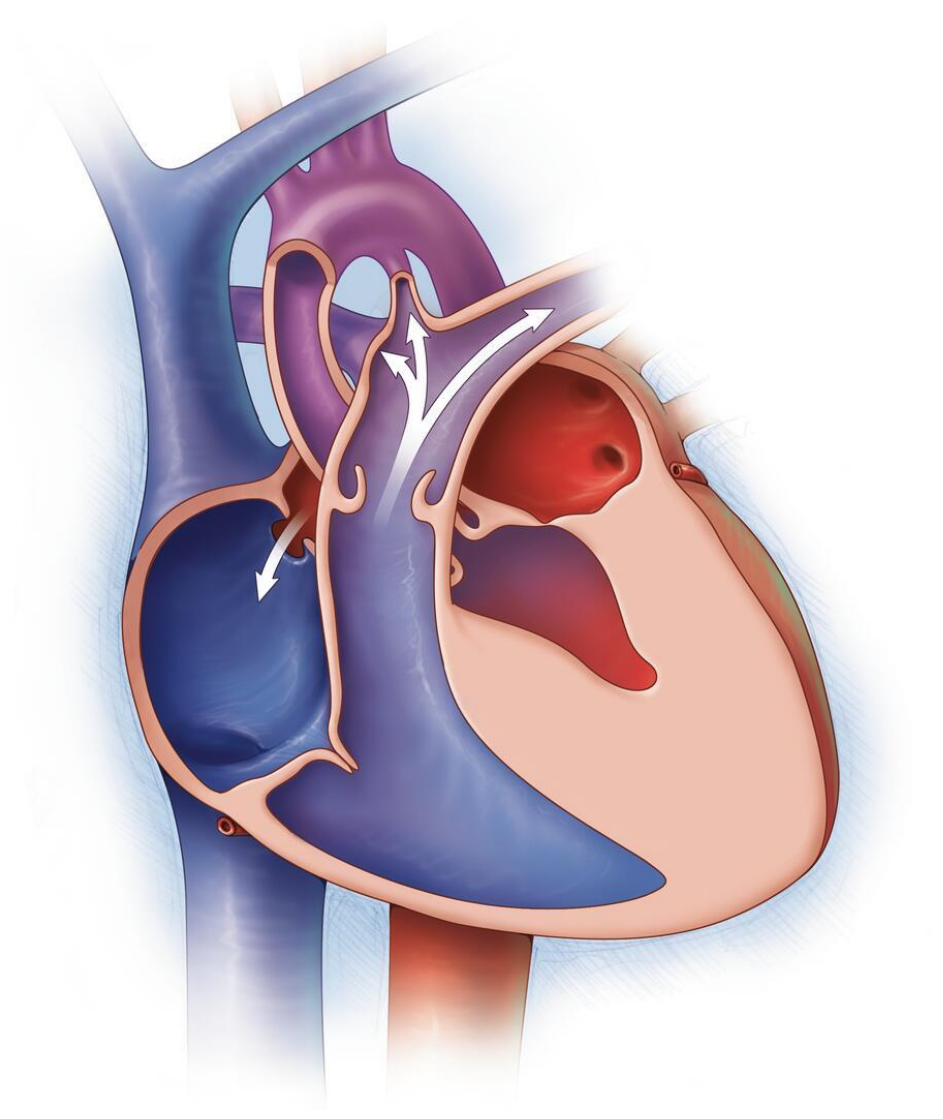
- Exercise training considerations

- Pulmonary hypertension
- Cardiac rhythm issues
- Ischemia
- Cyanosis
- Valvular heart disease and outflow tract obstruction
- Musculoskeletal issues
- Respiratory function
- Psychological considerations



Congenital Heart Disease

- Single ventricle physiology
 - Hypoplastic left heart syndrome



<https://mcmedia.mayo.edu/asset-management/241HRGTNPNN?WS=SearchResults>



Case Study – 19 yo male

- Cardiac transplant wait list patient-status 7 currently
- D-transposition of the great arteries with a right aortic arch
- Hypoplastic left (subpulmonic) ventricle with mitral and pulmonary atresia
- Systemic right ventricle with ejection fraction 50%
- Systemic AV (tricuspid) valve regurgitation, mild to moderate
- Extracardiac Fontan
 - Patent fenestration
 - Fontan conduit stenosis status post stent 04/2021
- Status post left pulmonary artery patch angioplasty with residual left pulmonary artery narrowing



Case Study – 19 yo male

Cardiac Surgeries and Interventions

- 1 Left modified Blalock Taussig Thomas shunt (8 do, 2004)
- 2 Balloon atrial septostomy (6w, 2004)
- 3 Right Glenn and LPA patch angioplasty, BT takedown (16mo, 2005)
- 4 Fenestrated extracardiac Fontan with 18mm Goretex conduit (3.5yo, 2008)
- 5 Coiling venovenous collaterals (2012)
- 6 Embolization R and L pulmonary AVMs (2016)
- 7 Occlusion of portosystemic shunt (2016)
- 8 Embolization of R pulmonary AVMs (2018)
- 9 Status post Fontan stenting with 39mm CPB stent (2021)



Case Study – 19 yo male

- Failing Fontan circulation complications
 - Growth restriction. BSA 1.5 BMI 19.6.
 - Cyanosis (baseline saturations 70s)
 - Fontan fenestration
 - Mediastinal venovenous collaterals with prior embolization 2012
 - Pulmonary AV malformations with prior attempts at embolization in 2016 and 2018
- Protein losing enteropathy diagnosed 2018, albumin 3.1
 - Malabsorption
 - Iron deficiency
- Hyponatremia
- Low bone mineral density for chronological age



Impressions:

1. Stress ECG was negative for ischemia.
2. No arrhythmias.
3. Limited peak VO₂ with both cardiac and pulmonary impairment to exercise.
4. Abnormal pulmonary responses include severely elevated VE/VCO₂ consistent with cardiac output impairment and right-to-left shunting along with significant desaturation due to right to left shunting.
5. Compared to test of 11/28/2022, results are similar.

Baseline CPET

Stress results evaluation:

	<i>Test result</i>	<i>Predicted</i>	<i>% predicted</i>	<i>Classification</i>
<i>Exercise time</i>	3.3 min	14.9 min	22.1%	Limited
<i>Peak METS, estimated</i>	3.3 METS	-	-	-
<i>Resting heart rate</i>	125 bpm	-	-	-
<i>Peak heart rate</i>	141 bpm	201 bpm	70%	Limited heart rate response
<i>Heart rate reserve</i>	16 bpm	≥ 126 bpm	13%	Abnormal chronotropic response (CI<0.8)
<i>Heart rate 1 min post exercise</i>	144 bpm	-	-	-
<i>Heart rate recovery</i>	-3 bpm	≥ 13 bpm	-	Abnormal heart rate recovery
<i>Peak systolic pressure</i>	104 mm Hg	141 - 214	-	Blunted blood pressure response
<i>Peak RER</i>	1.09	-	-	Near maximal cardiometabolic effort
<i>Peak VO₂</i>	0.59 L/min	-	-	-
<i>Peak VO₂/kg wt</i>	10.8 ml/(min·kg)	50.1 ml/(min·kg)	21%	Limited
<i>Peak METS, measured</i>	3.1 METS	-	-	-
<i>OUES</i>	696 ml/L	3026 ml/L	-	-
<i>O₂ pulse</i>	4.2 ml	-	-	Abnormal O ₂ pulse rise
<i>Anaerobic threshold (AT)</i>	494 ml/(min·kg)	-	-	-
<i>Peak ventilation</i>	32 L/min	153 L/min	21%	79% breathing reserve
<i>Minimum O₂ sat</i>	65%	$\geq 93\%$	-	Abnormal O ₂ saturation response
<i>VE/VCO₂ nadir</i>	45	19 - 31	-	Abnormal breathing efficiency
<i>VE/VCO₂ slope</i>	47.5	18.1 - 30	-	-



Frailty Assessment

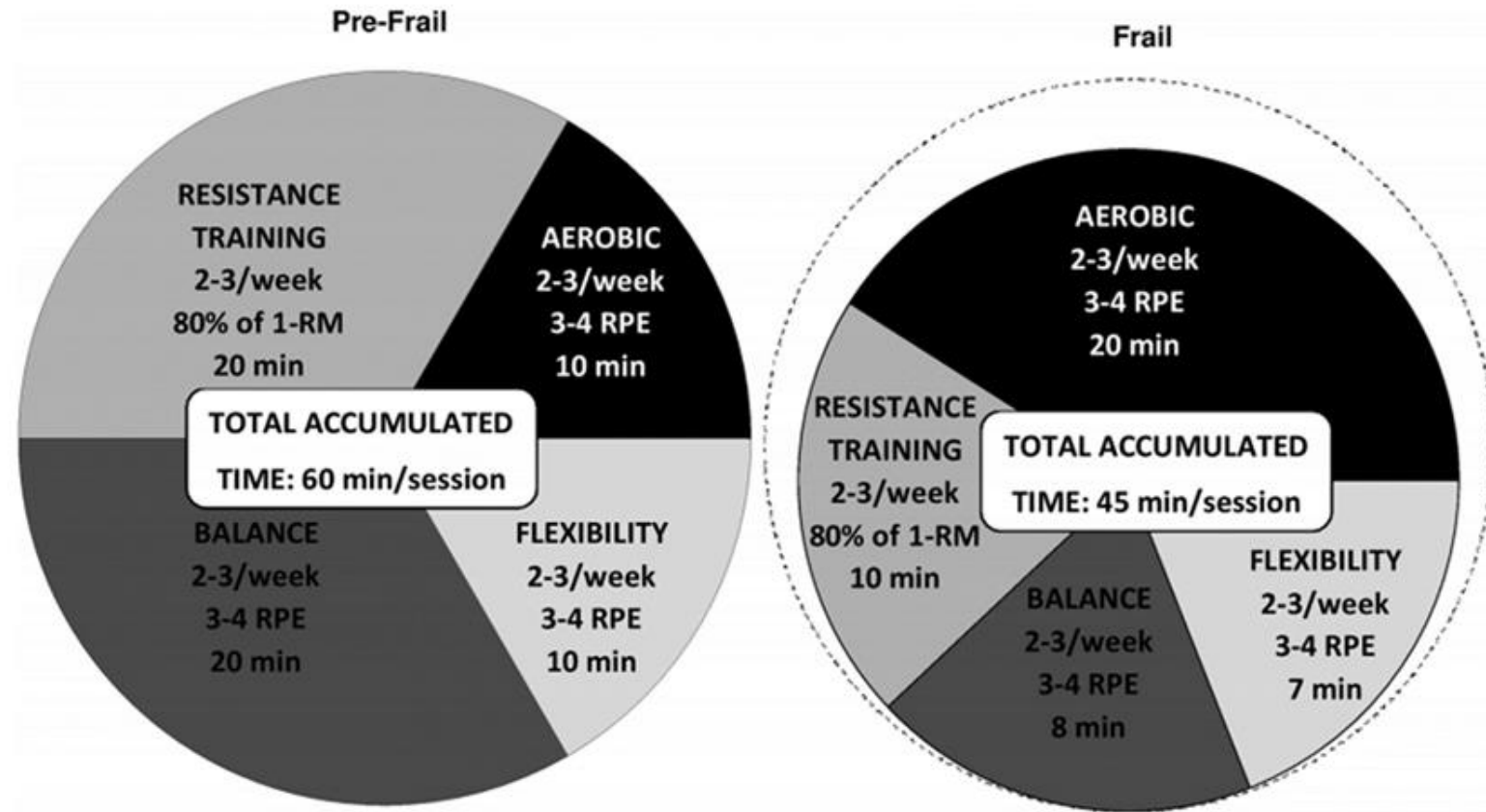
Frailty

Are you fatigued?	No
Are you exhausted?	No
Cannot walk up one flight of stairs?	No
Cannot walk one block?	No
Do you have more than five illnesses?	No
Have you lost more than 5% / 6-10 lbs of your weight in the last 6 months?	Yes
Frail Score	1
Frail Score Interpretation	Pre-Frail
Dynamometer position	2
Hand tested	Right
Strongest Hand Grip Strength	21.6
Weakness Criteria Met (Calculated)	Yes
Fastest walking time	6.41
Walking Velocity	0.78
Slowness Criteria Met?	Yes
Plan	Patient declined further frailty follow-up

ExRx – Frailty

- RT
 1. Mini squats
 2. Rowing
 3. Step downs/single leg stance
 4. Overhead press
 5. Farmer's walk
 6. Plank

- Aerobic exercise – start with 5-10 minutes; intermittent as needed.



ExRx Frailty

Balance/Agility

- Tandem stance
 - Add visual cues for progression
 - Looking side to side
 - Eyes closed
- Single leg stance
 - Eyes closed
- Split stance (goal is to progress to a lunge – transition from isometric to dynamic movement)
 - Step forward and recovery
 - Increase step distance
 - Progress to full lunge with return to standing
- Star drill (or other variations)
 - Add visual cues - looking forward instead of down at feet.
- Organized obstacle course
 - Stepping over, stepping down

First CR Session

HR	GLU	SYS	DIA	MTS	RPE	SO2	LO2	DYS	TIME	DEVICE	REAS	
122		92	54			88			1	Resting	PRE	
131		98	50	2.45		84			6	6MW 1000 FT	MAX	
137				Div0					2	URBI 1.0 / 11.0	MAX	
126				Div0	13				10	RSTP 1.0 / 10.0	MAX	
120									11	Recovery	POST	
TOTAL EXERCISE									18			
TOTAL SESSION									57			
TIME ADM/DSC 12:54 PM 01:50 PM												

ADDITIONAL COMMENTS: ECG: sinus tach

SYMPTOMS: none

HOME EXERCISE: walking

ISSUES: none

PROGRESSION: very interested in strength training, wii and back room in general

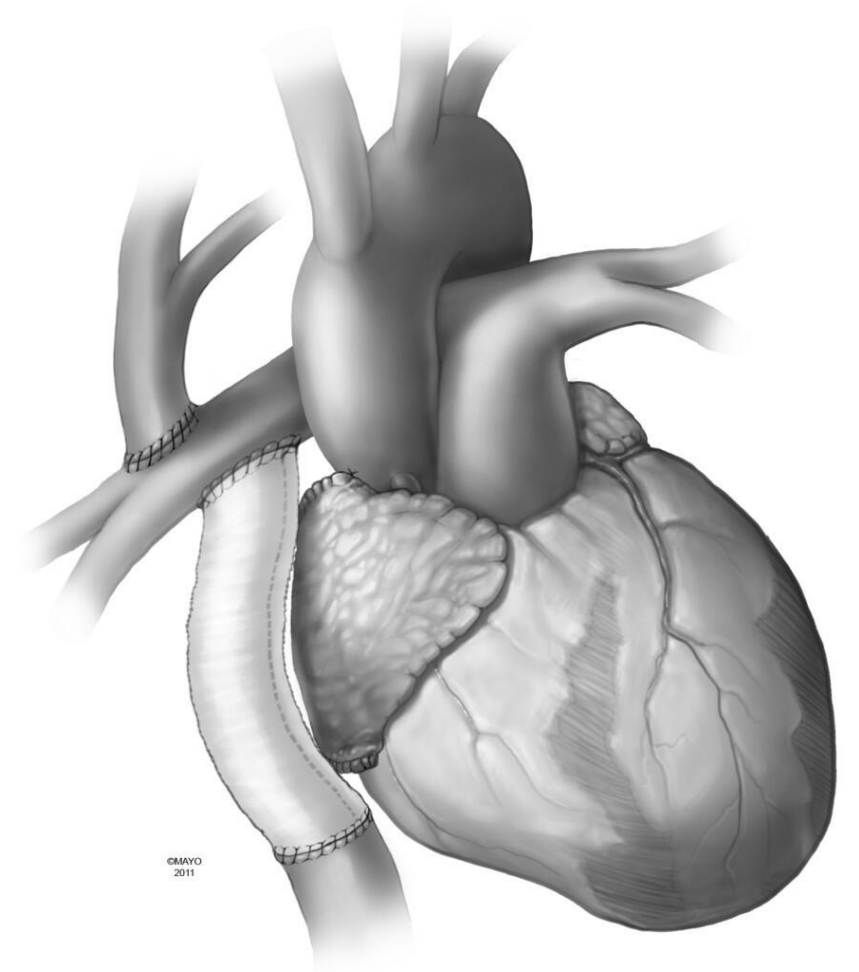
Resistance Training

	Baseline
Leg press	20 lbs x 10
Bicep curl	2 lbs x 7
Leg extension	10 lbs x 10
Tricep pushdown	7 lbs x 10
Seated row	10 lbs x 10
Chest press	10 lbs x 10



Congenital Heart Disease

- Extracardiac conduit Fontan
- Considerations for exercise training
 - Rely on respiratory bellows to draw blood into pulmonary vascular bed during inspiration
 - Cardiac output falls during positive pressure ventilation (reduced cardiac filling)
 - Rely on peripheral muscle pump for cardiac filling
- Perform daily activities well
- Limited at higher intensities



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Cordina et al., Int J Cardiol, 2012

<https://mcmedia.mayo.edu/asset-management/241HRGTDXFNX?WS=SearchResults>



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Session 10

HR	GLU	SYS	DIA	MTS	RPE	SO2	LO2	RPD	TIME	DEVICE	REAS	COMMENTS
126		84	1			76			1	Resting	PRE	
0				2.52					5	URBI 1.0/16.7	MAX	
141				3.08	11	69			12	TMW 2.0 / 2.0	MAX	
0									15	WTS 0.0/0.0	MAX	
0										Recovery	POST	
TOTAL EXERCISE									32			
TOTAL SESSION									56			
TIME ADM/DSC 01:50 PM 02:46 PM												

ADDITIONAL COMMENTS: ECG: non-monitored

SYMPTOMS: none

HOME EXERCISE: weights at home (MLPS), some walking

ISSUES: O2 sats are usually in 70s; complained of right knee discomfort today along with jaw pain due to tooth coming through.

PROGRESSION: Patient likes to do multiple modalities each session, Do strength training every session.

High-Intensity Resistance Training

- 11 Fontan subjects
- 20 weeks of high-intensity resistance training (n=6) – no additional aerobic training
- Muscle strength increased 43%
- Muscle mass, peak VO_2 , cardiac filling, stroke volume, and exercise capacity significantly improved



<https://mcmedia.mayo.edu/asset-management/241HRGMFI57PR?WS=SearchResults>

Cordina et al., Int J Cardiol, 2012



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Session 15

HR	GLU	SYS	DIA	MTS	RPE	SO2	LO2	DYS	TIME	DEVICE	REAS	COMMENTS
114		82	54			70			1	Resting	PRE	
124						75			20	WTS 0.0/0.0	MAX	
125				3.36		74			12	TMW 2.0/3.0	MAX	
0									1	Recovery	POST	
TOTAL EXERCISE									32			
TOTAL SESSION									58			
TIME ADM/DSC 01:54 PM 02:52 PM												

ADDITIONAL COMMENTS: ECG: non-monitored

SYMPTOMS: Fatigue

HOME EXERCISE: Walking frequently. Rode RB for 20 minutes, lvl 4 from home yesterday. Has free weights at home that he uses daily.

ISSUES: O2 sats are usually in 70s.

PROGRESSION: Patient likes to do multiple modalities each session, goal of 3-4 METS on each modality. Has stress test end of August, would like to emphasize TM. Do strength training every session.

Session 22

HR	GLU	SYS	DIA	MTS	RPE	SO2	LO2	RPD	TIME	DEVICE	REAS	COMMENTS
115		82	1			79			5	Resting	PRE	
129				3.87	15	68			13	TMW 1.8/6.0	MAX	
0									15	WTS 0.0/0.0	MAX	
0									3	Recovery	POST	
TOTAL EXERCISE									28			
TOTAL SESSION									52			
TIME ADM/DSC 01:58 PM 02:50 PM												

ADDITIONAL COMMENTS: ECG: non-monitored

SYMPTOMS: None

HOME EXERCISE: Active with walking to and from appts. Occasional free weights.

ISSUES: Describes a recent fall on Tuesday, August 15th evening. Patient has been feeling better over the last few days compared to days following recent fall.

PROGRESSION: Continue to increase MET level on TM in preparation for VO2 test.

Aerobic Exercise & Inspiratory Muscle Training

- 42 patients randomized (4-month supervised program)
 - Aerobic exercise training
 - Inspiratory muscle training
 - Non-exercise control
- Peak VO_2 improved in both exercise groups
 - 6MWT distance improved significantly in both groups
 - Aerobic increased hand grip strength
 - IMT increased MIP by 58%



<https://mcmedia.mayo.edu/asset-management/241HRGMRDQI7K>

Turquetto et al., Int J Cardiol, 2021



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Session 24

HR	GLU	SYS	DIA	MTS	RPE	SO2	LO2	DYS	TIME	DEVICE	REAS	
121		92	60			78			5	Resting	PRE	
127		102	64	2.57		86			6	6MW 1080 FT	MAX	
0									20	WTS 0.0/0.0	MAX	
120						75			5	Recovery	POST	
TOTAL EXERCISE									26			
TOTAL SESSION									55			
TIME ADM/DSC 02:00 PM 02:55 PM												

ADDITIONAL COMMENTS: ECG: non-monitored

SYMPTOMS: None

HOME EXERCISE: Walking most days 10-15 bouts, likely for appointments

ISSUES: Weight stable today, fatigue after stress test and frequent walking today

PROGRESSION: Establish strength routine with just BW and free weights during final session

Resistance Training

	Baseline	End of CR
Leg press	20 lbs x 10	120 lbs x 20
Bicep curl	2 lbs x 7	8 lbs x 20
Leg extension	10 lbs x 10	55 lbs x 15
Tricep pushdown	7 lbs x 10	17 lbs x 20
Seated row	10 lbs x 10	25 lbs x 20
Chest press	10 lbs x 10	25 lbs x 20



Impressions:

1. ECG showed sinus tachycardia at rest with incomplete RBBB throughout testing. Stress ECG was negative for ischemia in V4-V6.
2. Limited peak VO₂ with both cardiac and pulmonary impairment to exercise.
3. Reasons for low peak VO₂ likely include limited heart rate reserve and impaired cardiac output.
4. Abnormal pulmonary responses include severely elevated VE/VCO₂ consistent with cardiac output impairment and abnormal O₂ saturation.
5. Compared to test of 04/17/2023, results are similar.

Final CPET
2.9 ml/kg/min
increase

Stress results evaluation:

	Test result	Predicted	% predicted	Classification
Exercise time	9.7 min	29.8 min	32.6%	Limited
Peak METS, estimated	4.9 METS	-	-	-
Resting heart rate	112 bpm	-	-	-
Peak heart rate	142 bpm	201 bpm	71%	Limited heart rate response
Heart rate reserve	30 bpm	>/=126 bpm	24%	Abnormal chronotropic response (CI<0.8)
Heart rate 1 min post exercise	137 bpm	-	-	-
Heart rate recovery	5 bpm	>/=13 bpm	-	Abnormal heart rate recovery
Peak systolic pressure	104 mm Hg	141 - 214	-	Blunted blood pressure response
Peak RER	1.08	-	-	Near maximal cardiometabolic effort
Peak VO ₂	0.64 L/min	-	-	-
Peak VO ₂ /kg wt	13.7 ml/(min·kg)	50.1 ml/(min·kg)	27%	Limited
Peak METS, measured	3.9 METS	-	-	-
OUES	703 ml/L	2879 ml/L	-	-
O ₂ pulse	4.5 ml	-	-	Abnormal O ₂ pulse rise
Anaerobic threshold (AT)	515 ml/(min·kg)	-	-	-
Peak ventilation	46 L/min	151 L/min	30%	70% breathing reserve
Minimum O ₂ sat	63%	>/=90%	-	Abnormal O ₂ saturation response
VE/VCO ₂ nadir	51	19.1 - 28.6	-	Abnormal breathing efficiency
VE/VCO ₂ slope	69.7	18.2 - 30.1	-	-

ACHD Summary

1. Focus on lower extremity strength training
2. Include inspiratory muscle training
3. Adapt aerobic training to baseline fitness and cardiopulmonary abnormalities
 - Focus on increasing steps, intermittent exercise, and interval training



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Spontaneous Coronary Artery Dissection Case

Learning objectives



Define spontaneous
coronary artery
dissection



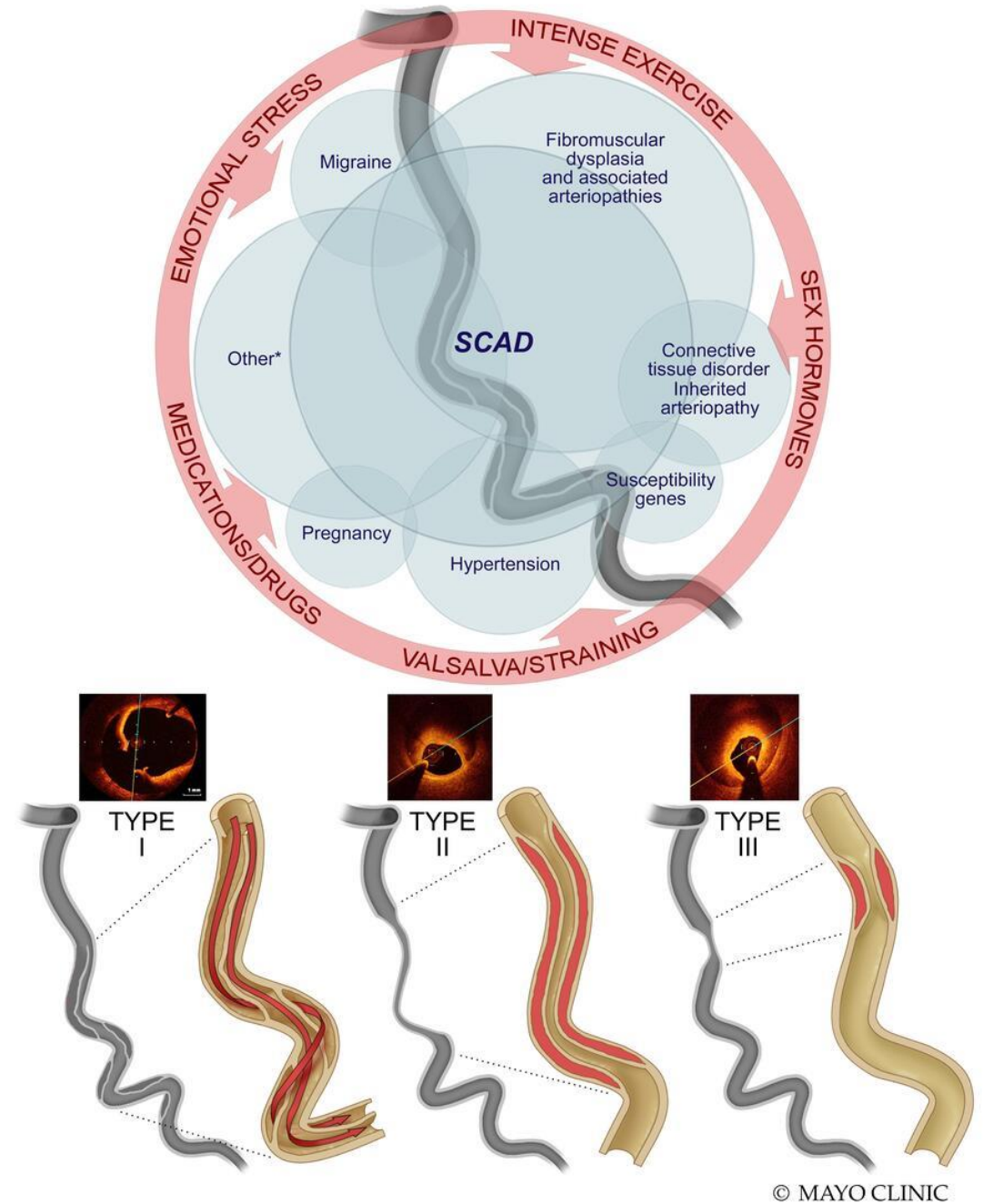
Discuss the AHA
Scientific Statement
related to exercise
and SCAD



Design an exercise
prescription

WHAT IS SCAD?

- Dissection of a coronary artery
 - Acute coronary syndrome
 - Myocardial infarction
 - Sudden death

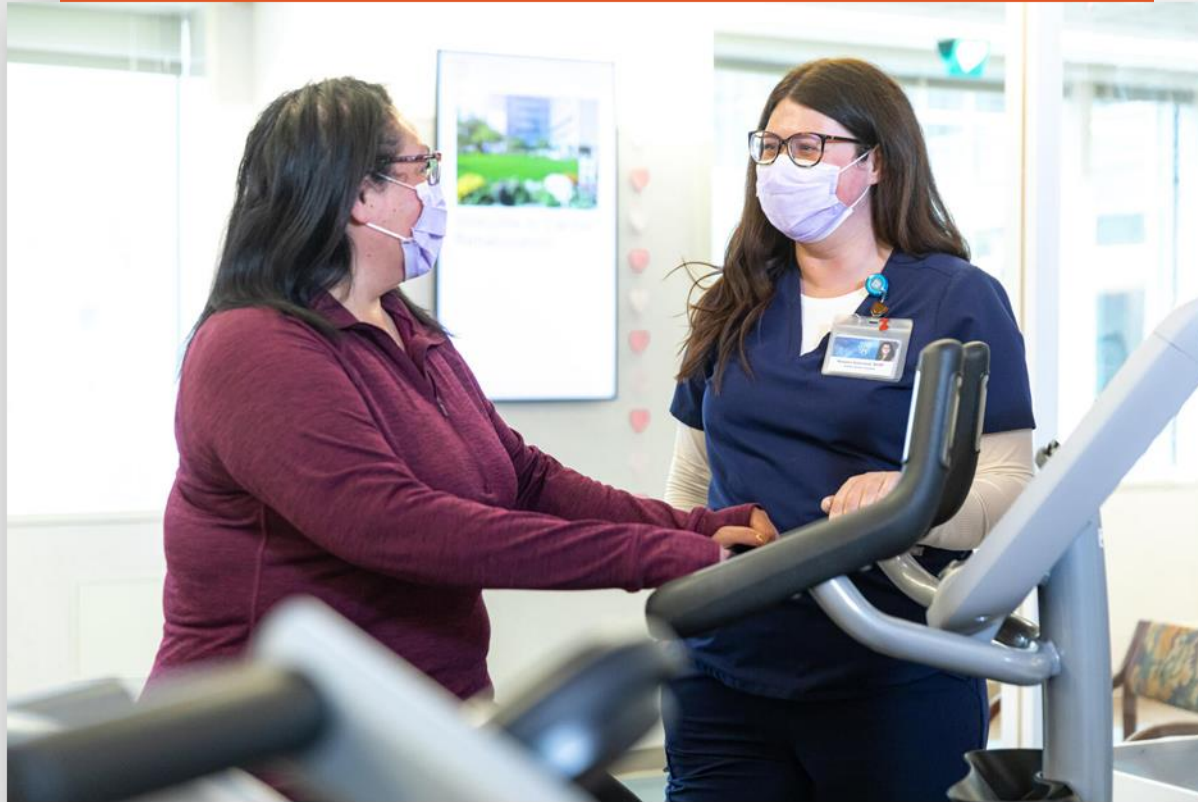


Case Study – 36 yo female

- Sudden onset, substernal chest pain
- Initial troponin elevated
- No ECG changes
- CT triple rule out
- 2nd troponin remained elevated
- Coronary angiogram – dissection of OM1
- Referred to CR in hospital



AHA Scientific Statement



- Cardiac rehabilitation for all
 - Physical and psychosocial wellbeing
 - 1-2 weeks after event – safe, feasible
- Acknowledge barriers
 - #1 barrier = lack of health care provider recommendation
- Absence of evidence for restrictions
 - Heart rate, blood pressure, weightlifting limits
- Short list of activities to avoid
 - All-out/high-intensity
 - Highly competitive/Contact Sports
 - Abrupt onset activities
 - Extreme temperatures
 - Straining/Valsalva

First CR Session

HR	GLU	SYS	DIA	MTS	RPE	SO2	LO2	DYS	TIME	DEVICE	REAS	COMMENTS
85		98	74			100			4	Resting	PRE	
110		112	80	3.52		100			6	6MW 1740 FT	MAX	
116				4.66	12				20	TMW 3.3 / 2.5	MAX	
93										Recovery	POST	
TOTAL EXERCISE									26			
TOTAL SESSION									51			
TIME ADM/DSC 07:46 AM 08:37 AM												

ADDITIONAL COMMENTS: ECG: NSR

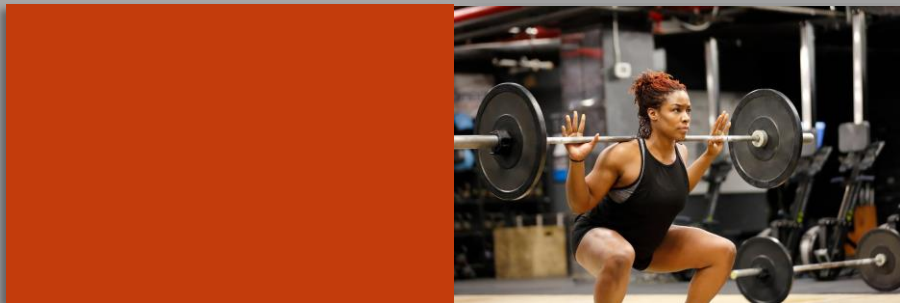
SYMPTOMS: None

HOME EXERCISE: Walking at RAC 15 minutes, walking dog at home

ISSUES: None

PROGRESSION: Continue increasing time on treadmill, introduce moderate intensity intervals and strength training

SCAD exercise prescription



Frequency

5-7 days per week

Intensity

Moderate intensity

Time

30-40 minutes

Type

Aerobic and Strength Training

Session 2

HR	GLU	SYS	DIA	MTS	RPE	SO2	LO2	DYS	TIME	DEVICE	REAS	COMMENTS
87		92	68						5	Resting	PRE	
120				4.33					26	TMW 3.2 / 2	MAX	
132				5.62	14				4	TMW 3.7 / 3.5	MAX	4x1 min moderate intensity intervals
99									10	WTS 0.0/0.0	MAX	
91										Recovery	POST	
TOTAL EXERCISE									40			
TOTAL SESSION									61			
TIME ADM/DSC 07:42 AM 08:42 AM												

ADDITIONAL COMMENTS: ECG: sinus rhythm

SYMPTOMS: none

HOME EXERCISE: walking/stair stepper, 45 min in total, 5 days per week

ISSUES: none

PROGRESSION: continue with moderate intensity intervals and resistance training

Session 6

HR	GLU	SYS	DIA	MTS	RPE	SO2	LO2	DYS	TIME	DEVICE	REAS	COMMENTS
83		104	66			98			5	Resting	PRE	
0				4.33					20	TMW 3.2/2.0	MAX	
118				7.30	17				10	ITMW 3.5 / 7.5	MAX	5 x 2 min intervals
0									14	WTS 0.0/0.0	MAX	
0									5	Recovery	POST	
TOTAL EXERCISE									44			
TOTAL SESSION									61			
TIME ADM/DSC 07:44 AM 08:45 AM												

ADDITIONAL COMMENTS: ECG: non-monitored

SYMPTOMS: None. Feels chest heaviness at peak workloads.

HOME EXERCISE: 4-5 days per week, 45 minutes walking, treadmill, or stair stepper with intervals + resistance training

ISSUES: None

PROGRESSION: As tolerated progress to 10 METs

Session 11

HR	GLU	SYS	DIA	MTS	RPE	SO2	LO2	RPD	TIME	DEVICE	REAS	COMMENTS
83		96	50						1	Resting	PRE	
0				4.33					20	TMW 3.2/2.0	MAX	
160				9.95	19				10	ITMW 3.5/13.0	MAX	Intervals: 5 @ 2 mins
0									20	WTS 0.0/0.0	MAX	
0										Recovery	POST	
TOTAL EXERCISE									50			
TOTAL SESSION									68			
TIME ADM/DSC 07:42 AM 08:49 AM												

ADDITIONAL COMMENTS: ECG: non-monitored

SYMPTOMS: None.

HOME EXERCISE: 4-5 days per week, 45 minutes walking, treadmill, or stair stepper or rowing with intervals + resistance training

ISSUES: None. Patient off Amlodipine

PROGRESSION: As tolerated progress to 10-11 METs

To be continued...



Take Away's

SCAD is an important cause of myocardial infarction

AHA Scientific Statement and recent publications provide guidance

Cardiac rehab and exercise should be prescribed for all



Thank You!