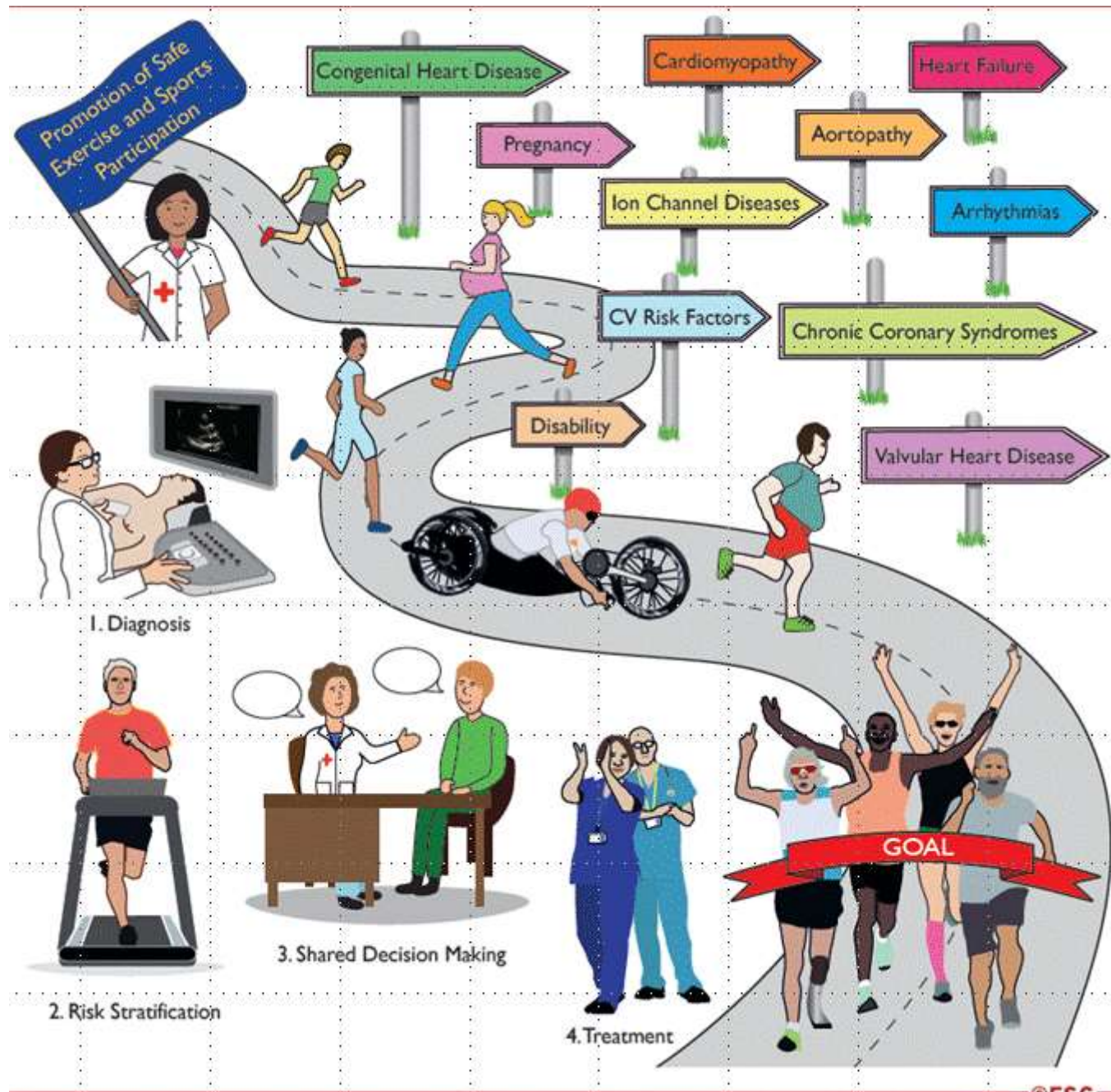


Sportcardiology

Sudden cardiac death

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ESC definition

Athletes:

an individual of young or adult age, either amateur or professional, who is engaged in regular exercise training and participates in official sports competition

Recreational athletes:

engage in sports for pleasure and leisure-time activity

Competitive athletes:

highly trained

greater emphasis on performance and winning

Elite athletes:

i.e. national team, Olympians, and professional athletes

exercise > 10h/week

Competitive' athletes:

i.e. high school, college, and older (master) club level

exercise > 6 h/week

Recreational' athletes:

exercise > 4 h/week

What do we need to exercising.....

adequate **muscle** (capillaries, venous dilatation)

adequate **heart** function and **circulation** (primarily systemic circulation)

adequate **respiration** (mechanics, diffusion in the pulmonary circulation)

Circulatory adaption to exercise

- Systolic blood pressure rises (the diastolic rather decreases)
- Cardiac output (5l/min vs. 35l/min) and the stroke volume increases (80ml/min vs. 180ml/min)
- Due to intensifying the sympathetic tone epinephrine will be produced, and based on the positive chronotropic effect the heart rate will rise
- The heart rate could be increased until the diastolic time decreases so far as the stroke volume starts to decrease
- Formation of new capillaries
- The resting pulse decreases (even sinus arrhythmia, escape rhythm), heart rate variability increases

Untrained individuals adapt by increasing the heart rate (inadequate coronary circulation), therefore will exhaust sooner by a lower intensity

Trained individuals increase primarily the cardiac output

- Venous constriction in the striped muscles, redistribution (even 80% of the cardiac output in the muscles), cerebral autoregulation (Cushing's reflex), renal autoregulation, decreasing splanchnic circulation
- Due to coronary vasodilatation the diastolic pressure decreases, the venous return increases, therefore the systolic pressure and cardiac output could increase even without increasing the heart rate

Respiratory adaptation to exercise

- By increased workload $p\text{CO}_2$ will be higher
- hypercapnia stimulates directly the medulla oblongata but reflex through chemoreceptors the respiratory rhythm generator in the pons
- **Untrained** individuals increase primarily the respiratory rate
- **Trained** individuals increase primarily the respiratory volume and vital capacity (increased alveolar diffusion)
- During exercise the intensity of metabolic processes increase immediately, the oxygen consumption follows it some later and increases promptly, then stabilizes after 2-4 minutes (can be further increased to a constant)
- At this constant value could maximal VO_2 be measured
- resting 3,5 ml/kg/min (1,2 kcal/min=1 **MET**), healthy, young individuals 45 ml/kg/min, endurance athletes 84 ml/kg/min
- Repayment of **oxygene debt** after the workload (lactate-ATP production)

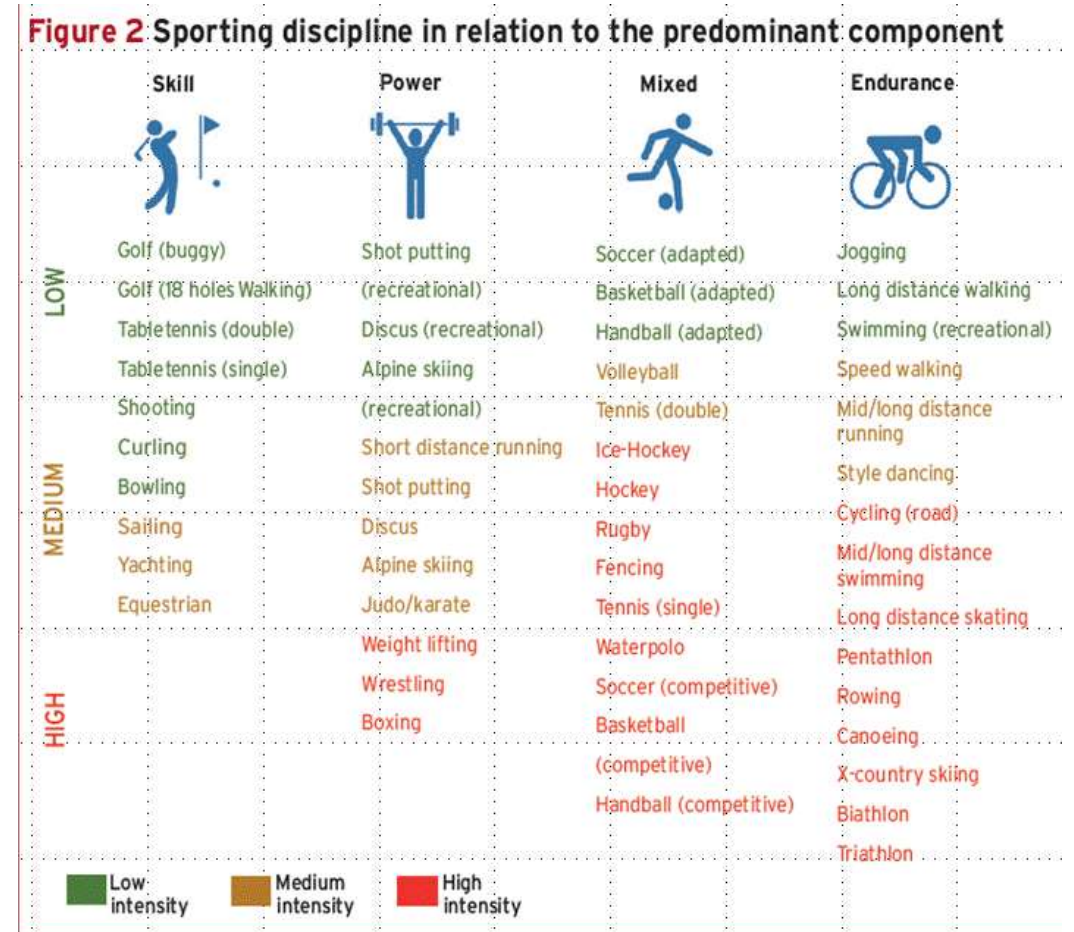
Characteristics of a training - FITT

Frequency: how many times a week

Intensity: maximal VO₂, maximal HR, repetition rate

Time: length of the sport sessions

Type: endurance, resistance, speed, flexibility, coordination – balance



Healthy individuals

- Weekly 150 minutes (up to 300 minutes) moderate intensity
- Or 75 minutes (up to 150 minutes) high intensity training
- weekly 4-5 days or even everyday

CV risk estimation

Very high:

Previous ACS, stroke, TIA, PAD
documented ASCVD

Diabetes with target organ failure or with a duration longer than 20 years

CKD (GFR < 30 mL/min/1,73 m²)

SCORE > 10%

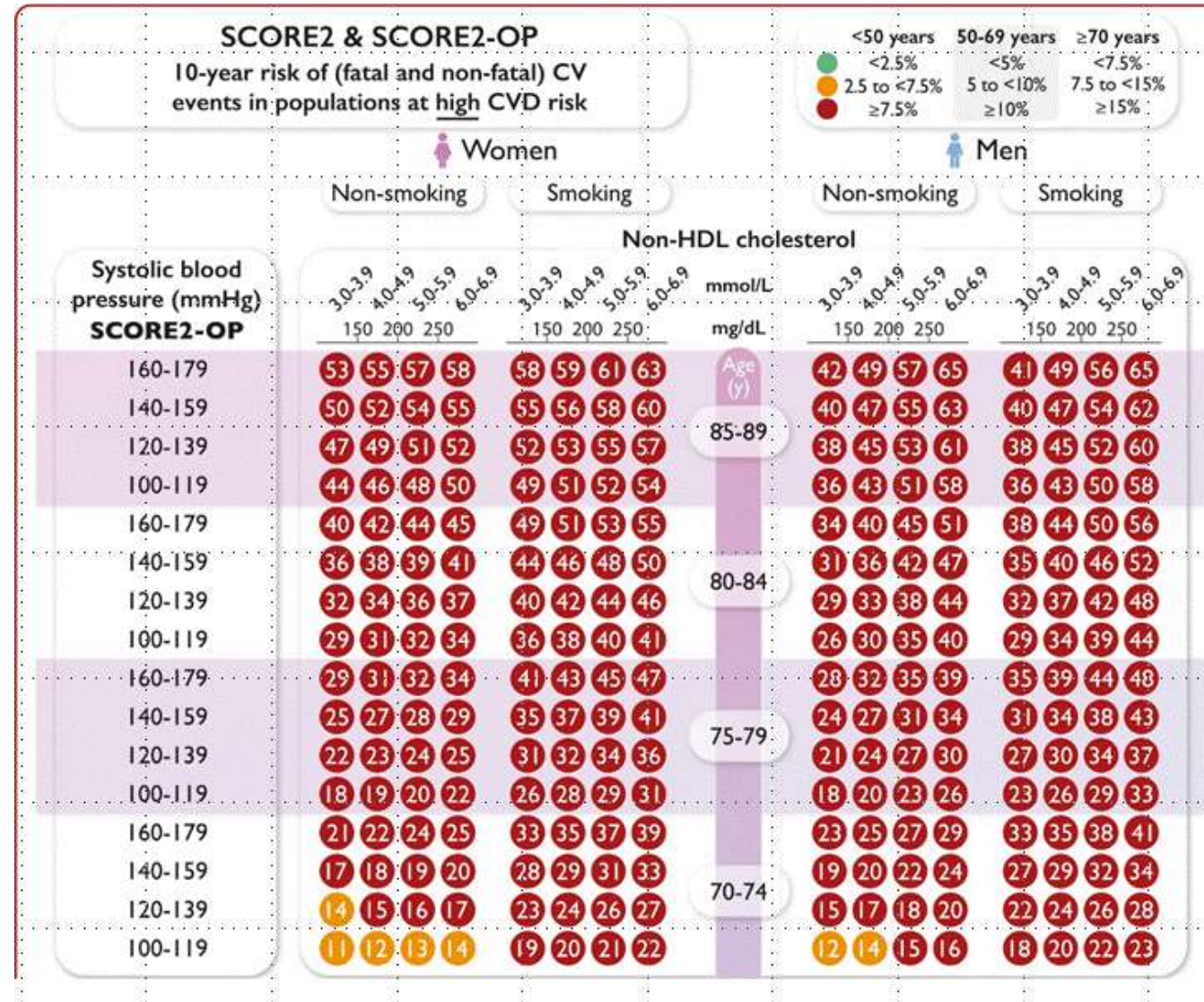
High:

High LDL (> 4,9 mmol/L), blood pressure (180/110 mmHg)

Diabetes without target organ failure, but duration longer than 10 years

Moderate CKD (GFR 30-59 mL/min/1,73 m²)

SCORE 5-10%



CV risk estimation

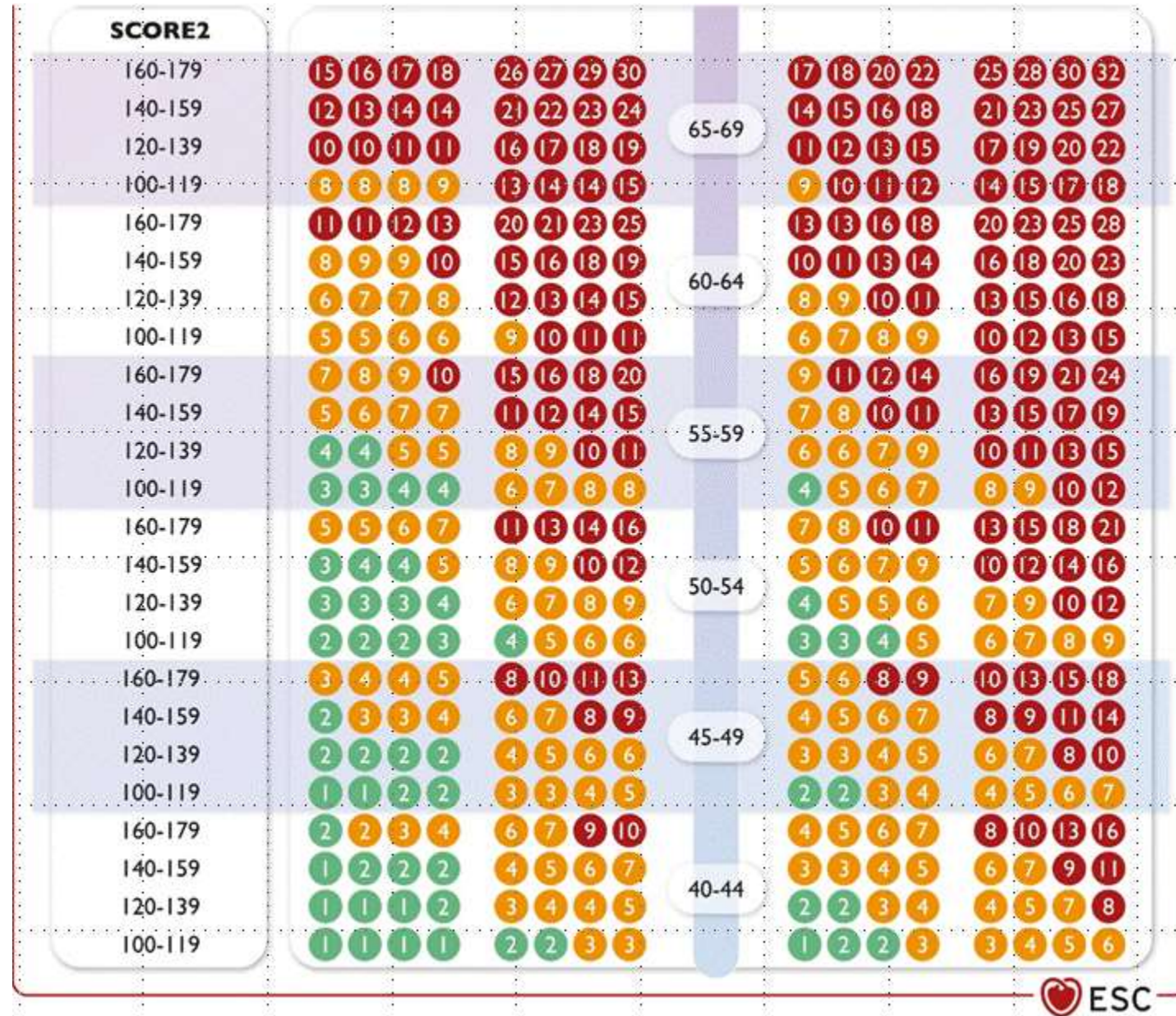
Moderate:

Young diabetic patients,
with duration shorter than
10 years

SCORE 1-5%

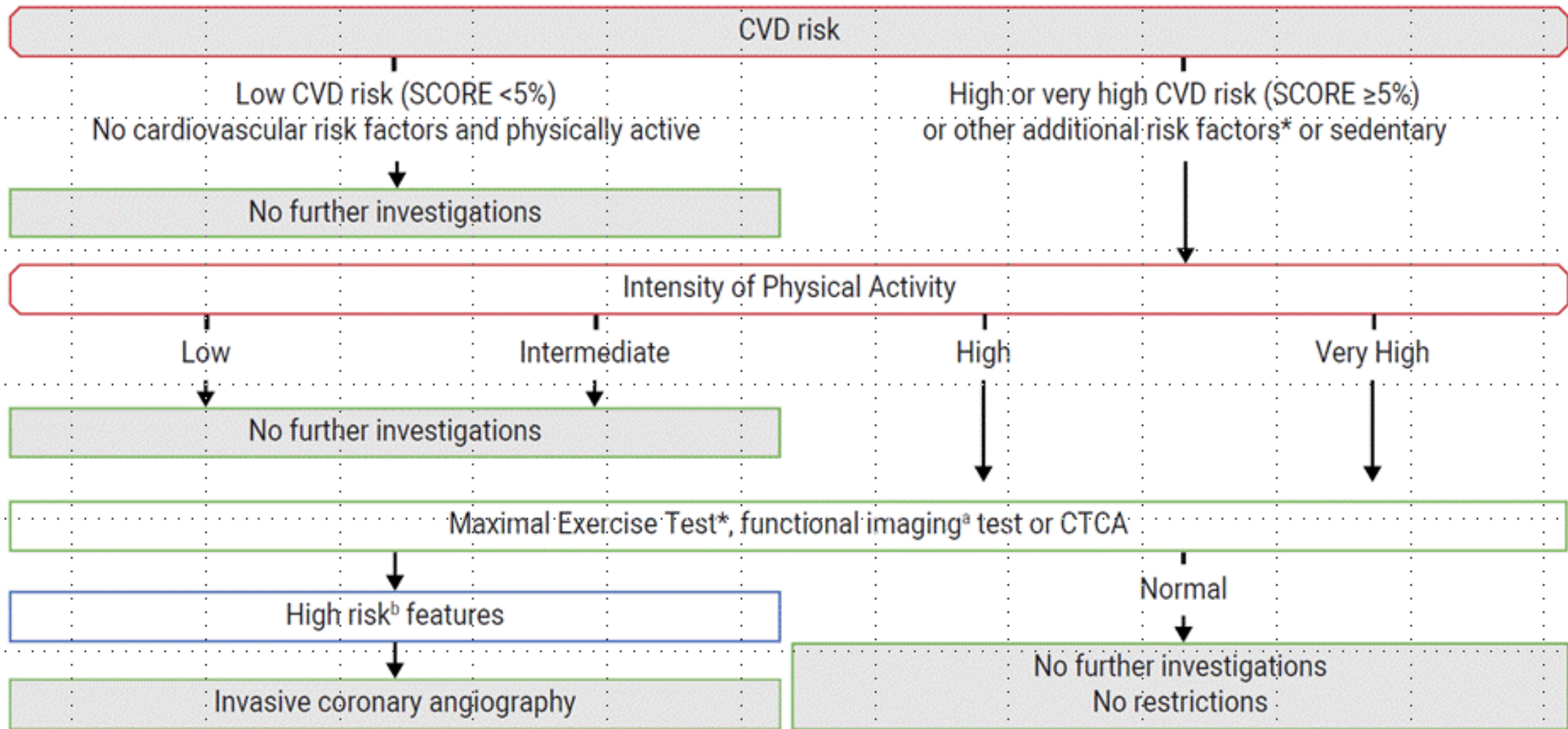
Low:

SCORE < 1%



Individuals older than 35 year

- **Low or moderate risk** groups could even engage competitive sport
- **High or very high** risk groups could only engage low intensity exercise without further diagnostic (i.e. physical examination, ECG, exercise test, coronary CT, invasive diagnostics)
- Cardiac screening is indicated in every competitive athletes (ECG, family history)
- In **symptom free CCS without inducible ischemia** every sport could be engaged



Individuals older than 65 years

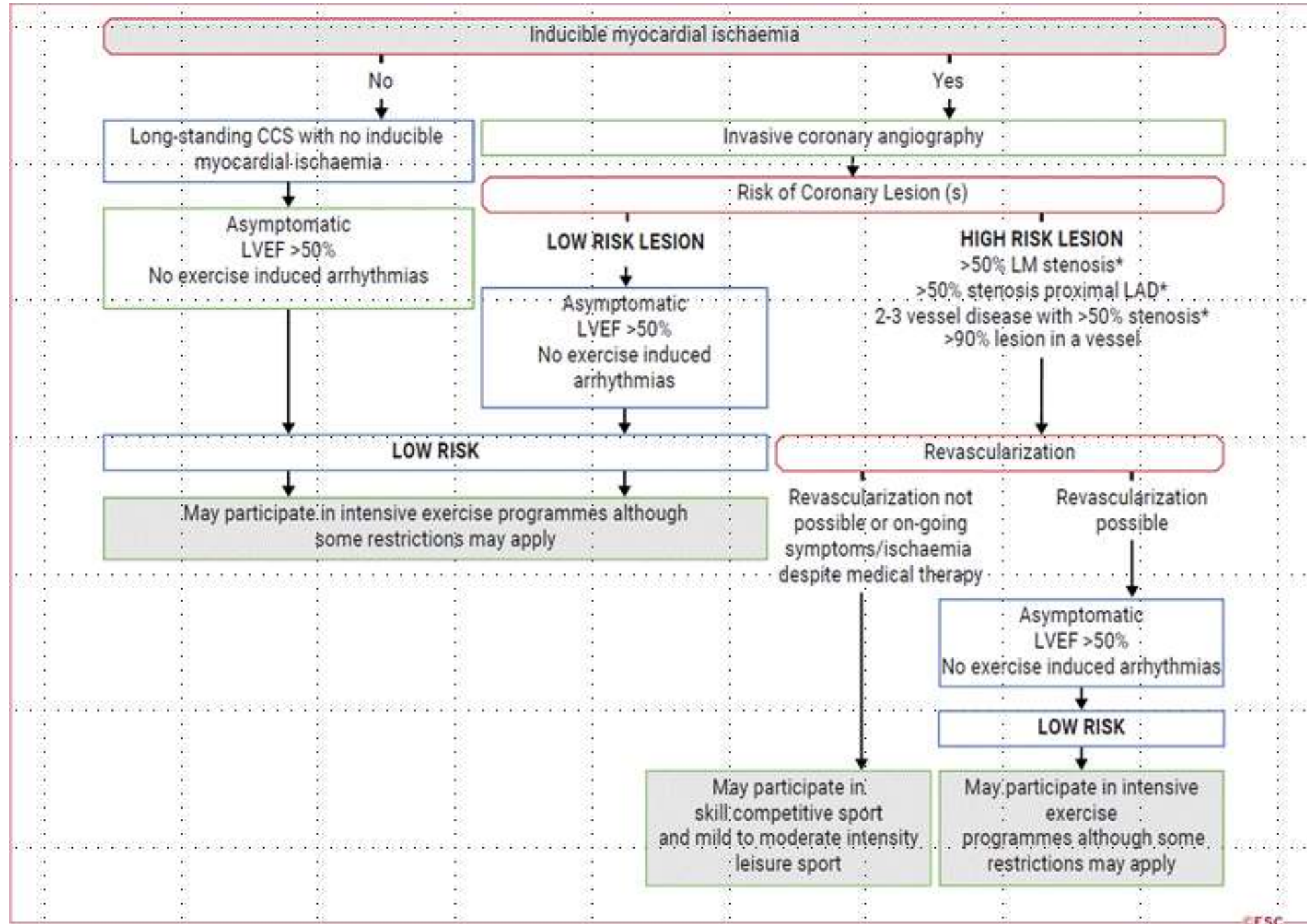
- **Healthy:** weekly 150 minutes, moderate intensity
- With **high risk of falling:** weekly 2 coordination-balance training
- Cardiac screening before high intensity training (exercise tests)
- Risks:
 - Arrhythmia, high blood pressure, myocardial ischemia, musculoskeletal injury or fracture, muscle pain, swollen joints, risk of falling
- **Type:**
 - Aerobic (weekly 3-5x), endurance (weekly 2x), flexibility and balance (weekly 2x)

Long-standing CCS patients

- Risk:
 - Competitive sport, individual fitness level, cardiovascular risk factors, exercise induced myocardial ischemia or arrhythmia
- Risk for high intensity exercise-induced adverse event:
 - 70% residual stenosis in a major coronary artery, 50% in left main
 - EF < 50% and wall motion abnormalities
 - Inducible myocardial ischemia during exercise
 - nsVT
 - ACS and PCI in the last 12 months

Long-standing CCS patients

- Cardiac screening and regular follow-up
- Leisure-time activity below the angina threshold even in patients with high risk for exercise-induced adverse event
- Competitive sport is **not recommended** in these patients!
- Following ACS exercise based cardiac rehabilitation
- Return to competitive sport 3-6 months after an ACS (based on CPET)



Sport and heart failure

- Exercise tolerance and QoL ameliorates significantly, all-cause and heart failure-specific mortality reduce, even hospitalization decreases
- **Not recommended:** hypotension or hypertension, instable condition despite of OMT, myocardial ischemia, severe or suboptimal treated pulmonary disease
- Baseline screening: BNP and echocardiography, CPET (ischemia, arrhythmia, fitness level), OMT, implantable devices if recommended
- Stable patients aerobic exercise
- In low risk patients even HITT
- Resistance training could complement aerobic training

	Aerobic exercise	Resistance exercise
Frequency	3–5 days/week, optimally daily	2–3 days/week; balance training daily
Intensity	40–80% of VO_{2peak}	Borg RPE <15 (40–60% of 1RM)
Duration	20–60 min	10–15 repetitions in at least 1 set of 8–10 different upper and lower body exercises
Mode	Continuous or interval	
Progression	A progressively increasing training regimen should be prescribed with regular follow-up controls (at least every 3–6 months) to adjust the duration and the level of the exercise to the reached level of tolerance	A progressively increasing training regimen should be prescribed with regular follow-up controls (at least every 3–6 months) to adjust the duration and the level of the exercise to the reached level of tolerance

Pregnancy and sport

- Without obstetric contraindication weekly 150 minutes moderate intensity training until delivery
- In moderate or high risk groups preliminary cardiac screening
- **Not recommended:**
 - Forceful physical contact sport, risk of falling or abdominal trauma, heavy lifting, scuba diving or exercise at high altitude
 - Vigorous exercise associated with a maximal predicted heart rate >90% of the predicted heart rate

Oncological patients and sport

Relative contra-indications	Absolute contra-indications
<ul style="list-style-type: none">• Recent weight gain (>2 kg during the 3 days preceding exercise)• Decrease in systolic blood pressure >10 mmHg during exercise• Ventricular arrhythmia at rest or during exercise• Resting heart rate ≥ 100 beats/minute• Neurological toxicity > grade 2• Asymptomatic central neurological lesions• Asymptomatic bone metastases	<ul style="list-style-type: none">• Progressive increase in dyspnoea at rest or during exercise for the 3–5 days preceding exercise• NYHA class IV• Uncontrolled diabetes mellitus• Acute disease or fever• Recent embolism• Untreated severe thrombophlebitis• Myocarditis or active pericarditis• Hematologic toxicity: platelets $< 50\,000/\text{mm}^3$, leucocytes $< 1500/\text{mm}^3$, haemoglobin $< 8\text{ g/dL}$• Symptomatic central neurological lesions• Osteolytic or painful bone metastases

Oncological patients and sport

- Regular exercise during and after cancer therapy is recommended to reduce cancer-related fatigue, and improve quality of life, physical fitness, and prognosis
- Among individuals treated with cardiotoxic medications, echocardiography, laboratory controls before participation in high-intensity exercise
- Cardiac screening before high intensity training
- CORE (cardio-oncology rehabilitation)

Return to sport

Competitive sport

- Competitive sport may be considered in low risk individuals
- Before return cardiac screening:
 - CPET
- Some competitive sport may be considered in symptom free HFpEF and HFmrEF patients on OMT and without exercise induced arrhythmia or hypotension
- Step-by-step increased training frequency
- Restriction may be needed in high intensity endurance, mixed sports
- In ability sports no need for restriction

Return to sport

Leisure-time sport

- Gradually increased training frequency
- Low or moderate intensity ability, endurance or mixed sports may be considered in every symptom free patients
- High intensity recreational sports may be considered in symptom free HFmrEF patients without no exercise induced arrhythmia or hypotension
- Low or moderate intensity ability sports and low intensity endurance sports may be considered in HFrEF patients on OMT
- Generally, low intensity endurance sports (i.e. jogging, cycling) may be considered for increasing exercise tolerance

Sudden cardiac death (SCD)

- Definition:
 - Unexpected, non-traumatic death at least 1 hour after start of the symptoms
 - VT, VF mostly, but also asystole, PEA, AVB
 - Significant financial burden
- SCA: sudden cardiac arrest occurs by the same reasons, patients reaches clinical death, but based on BLS or ALS it is non-fatal (50% of all SCD events)
- Among young athletes the most frequent cause of cardiac death
- Responsible for the most loss-of-healthy years

Sudden cardiac death (SCD)

- Under 35 year the incidence grows, above 75 decreased
- Under 65 year in men 3-7 times higher risk
- 6,2-7 event/1 million inhabitants (yearly incidence)

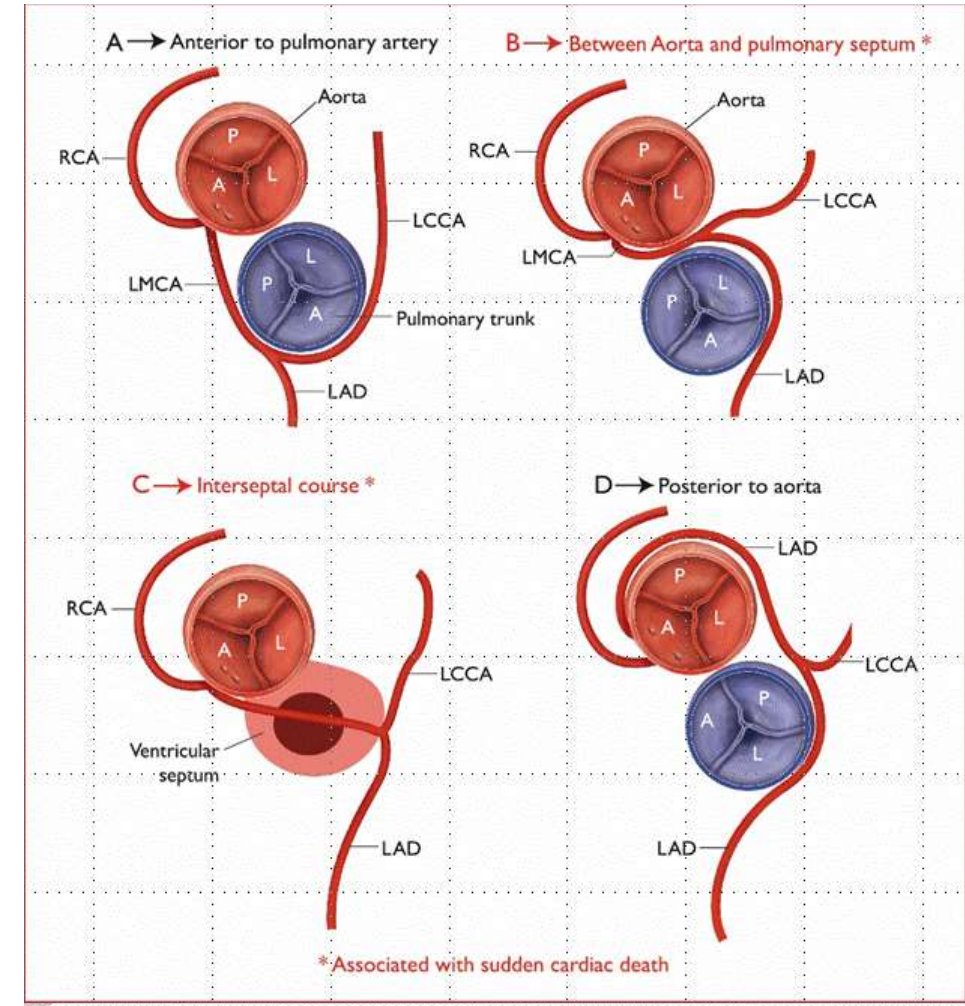
- 6-17% of all cases occur during high intensity training
- During regular exercise the risk is lower

Sudden cardiac death (SCD)

Atherosclerotic cardiovascular disease (ACS, CCS) is the leading cause of exercise induced cardiac events

SCD could be the first symptom of ASCVD in individuals above 35 year

Anomalous origin of coronary arteries (**AOAC**), myocardial bridge (**MB**), spontaneous coronary dissection (**SCAD**) could evoke myocardial ischemia



Structural Cardiac Abnormalities

- Hypertrophic cardiomyopathy
- Arrhythmogenic right ventricular cardiomyopathy
- Congenital coronary artery anomalies
 - Marfan syndrome
- Mitral valve prolapse/Aortic stenosis

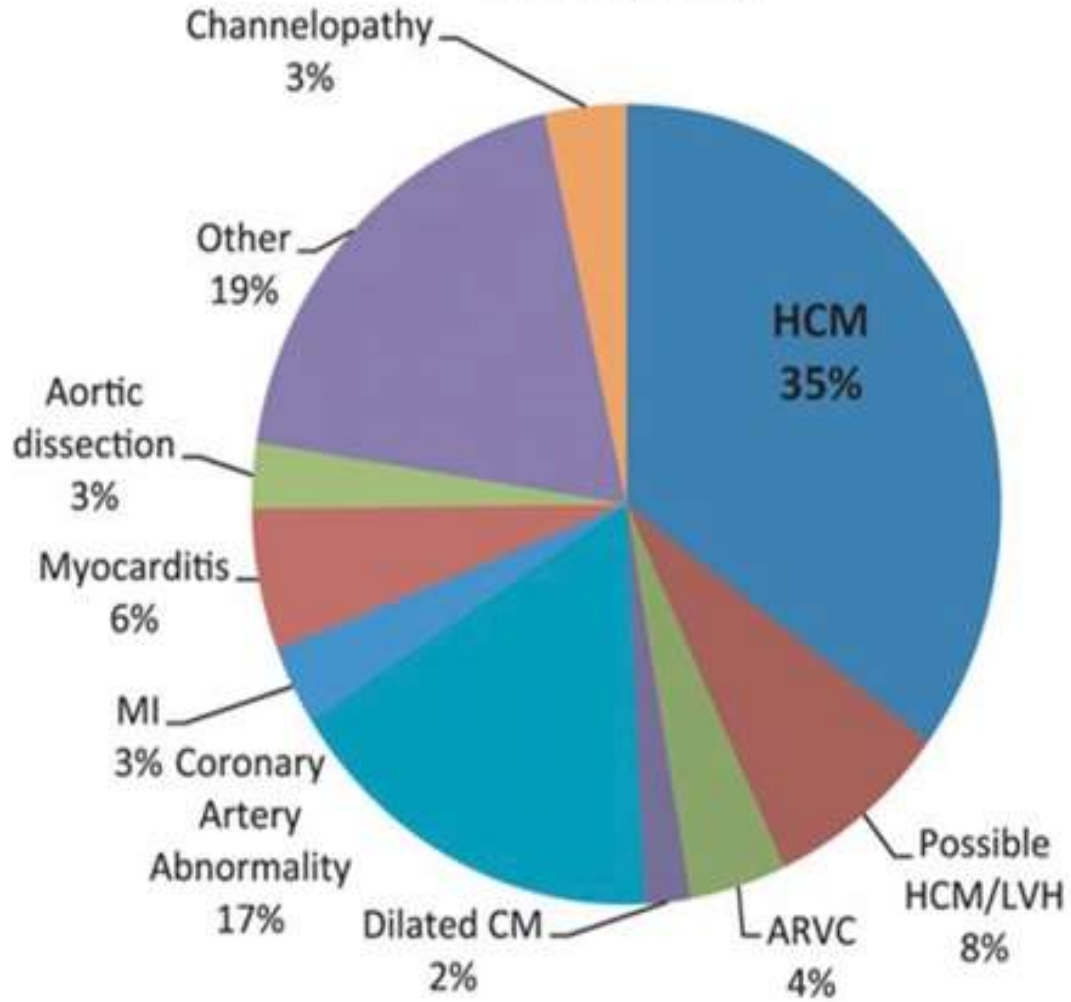
Electrical Cardiac Abnormalities

- Wolff Parkinson White syndrome
- Congenital long QT syndrome
 - Brugada syndrome
- Catecholaminergic polymorphic ventricular tachycardia

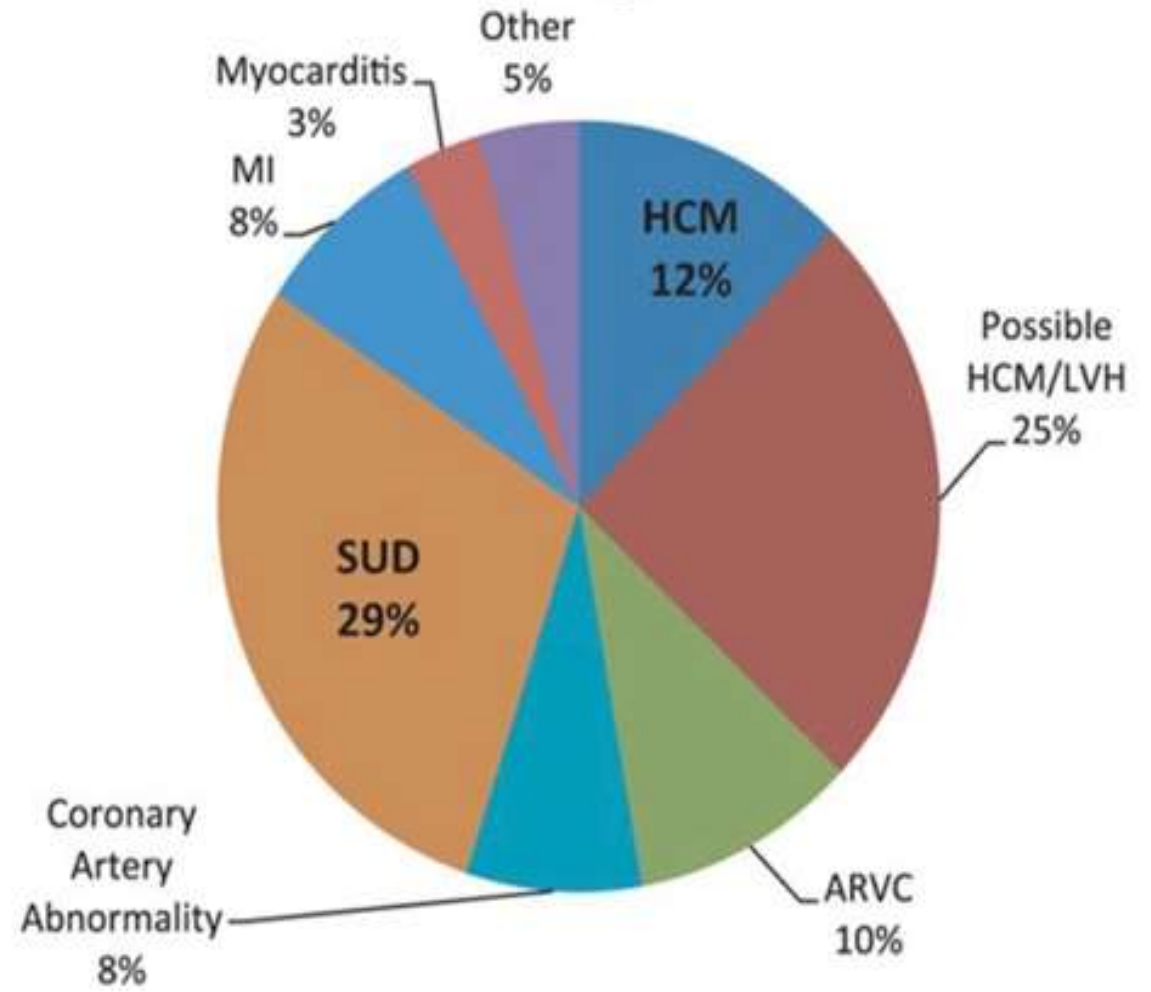
Acquired Cardiac Abnormalities

- Infection (myocarditis)
- Trauma (commotio cordis)
- Toxicity (illicit/performance enhancing drugs)
- Environment (hypo/hyperthermia)

US Registry




United Kingdom



Sudden cardiac death- HCM

- 1-3% of SCD cases
- **Risk estimation (5 year):**
 - age (more serious in childhood)
 - nsVT
 - maximal left ventricular wall thickness (highest risk by 30 mm)
 - Family history
 - Syncope (highest risk in the last 6 months)
 - Left atrial size
 - Left ventricular outflow tracked obstruction

Sudden cardiac death - HCM



HCM Risk-SCD Calculator

Age **Years** *Age at evaluation*

Maximum LV wall thickness **mm** *Transthoracic Echocardiographic measurement*

Left atrial size **mm** *Left atrial diameter determined by M-Mode or 2D echocardiography in the parasternal long axis plane at time of evaluation*

Max LVOT gradient **mmHg** *The maximum LV outflow gradient determined at rest and with Valsalva provocation (irrespective of concurrent medical treatment) using pulsed wave Doppler from the apical three and five chamber views. Peak outflow tract gradients should be determined using the modified Bernoulli equation: $Gradient = 4V^2$, where V is the peak aortic outflow velocity*

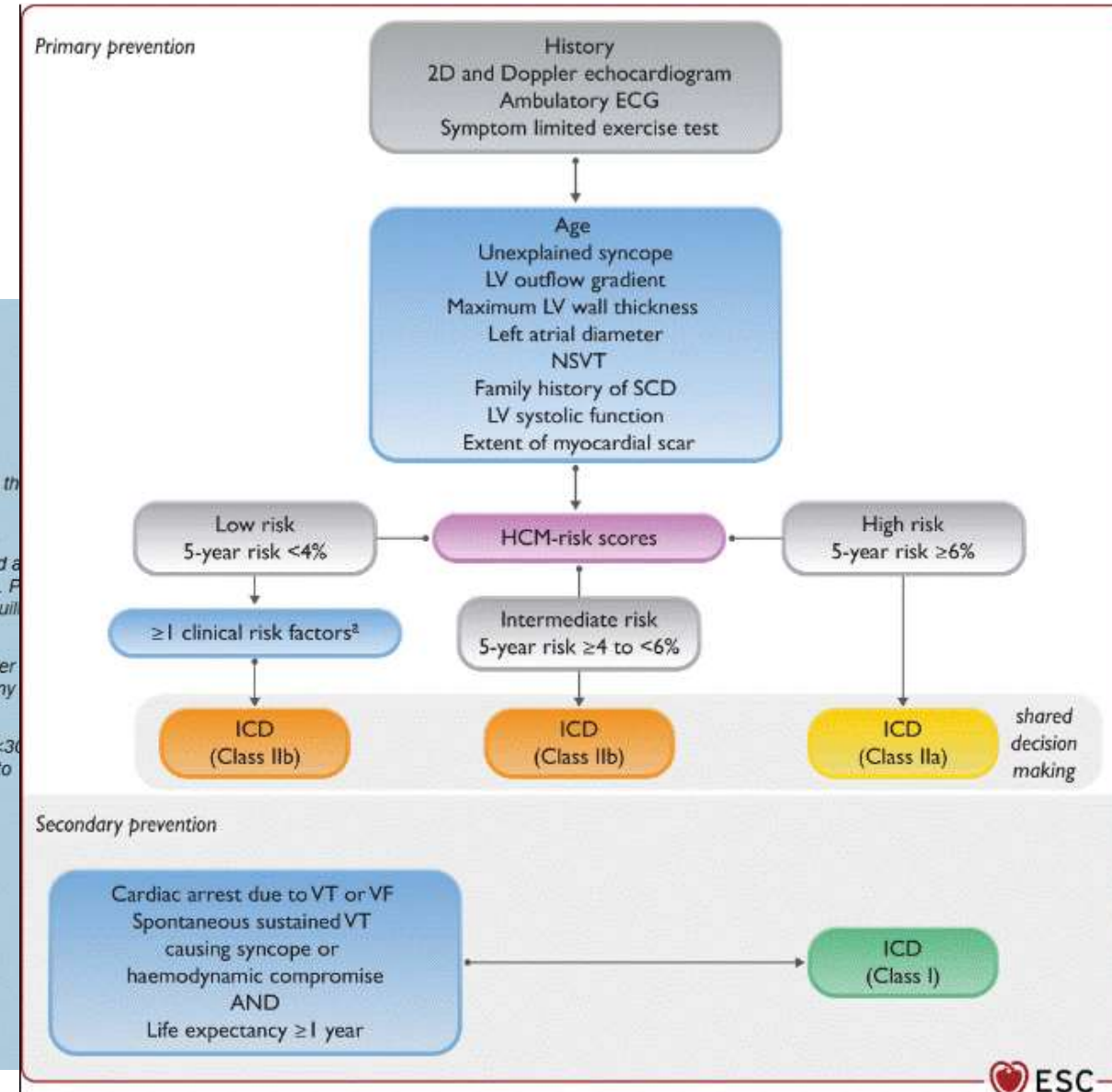
Family History of SCD No Yes *History of sudden cardiac death in 1 or more first degree relatives under years of age or SCD in a first degree relative with confirmed HCM at any (post or ante-mortem diagnosis).*

Non-sustained VT No Yes *3 consecutive ventricular beats at a rate of 120 beats per minute and <30 duration on Holter monitoring (minimum duration 24 hours) at or prior to evaluation.*

Unexplained syncope No Yes *History of unexplained syncope at or prior to evaluation.*

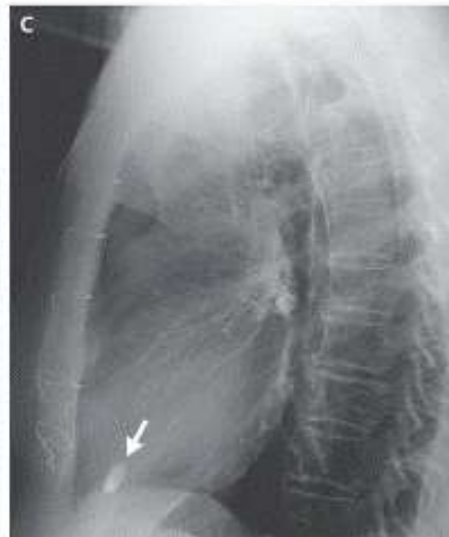
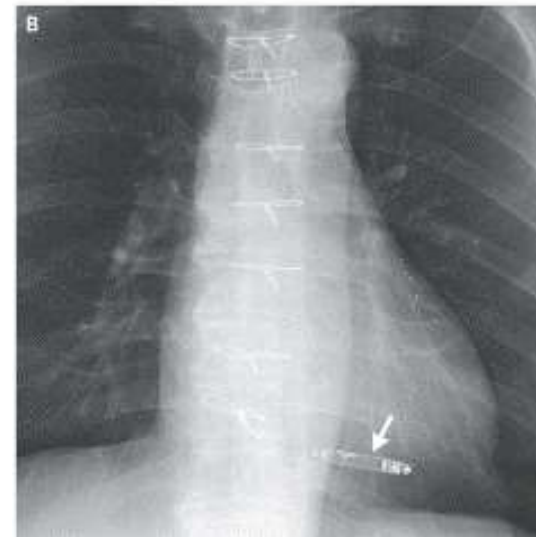
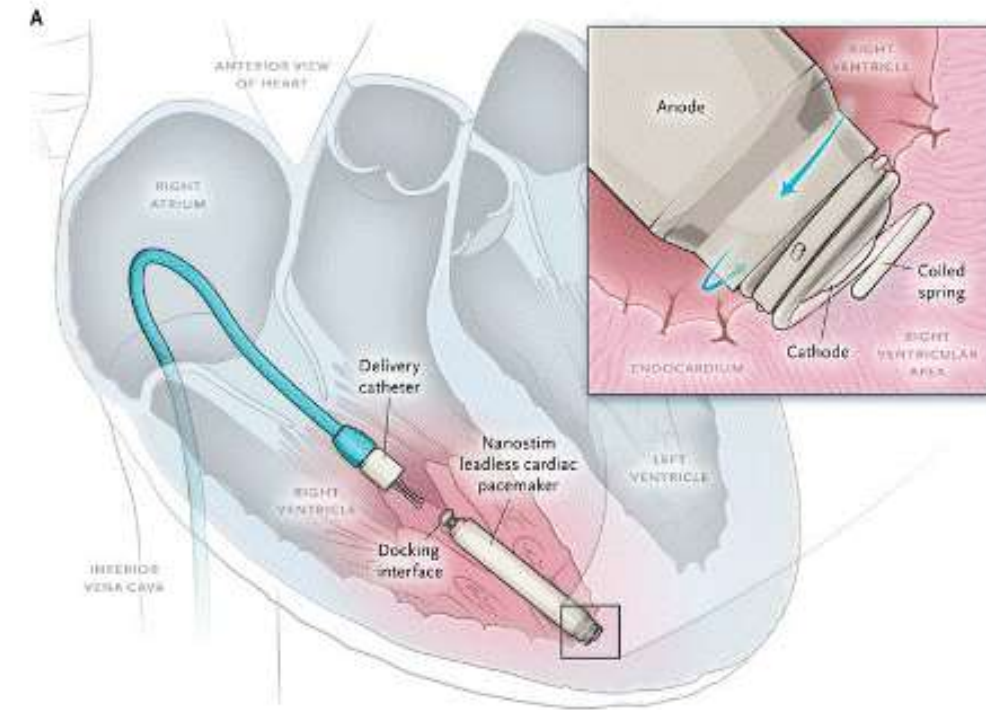
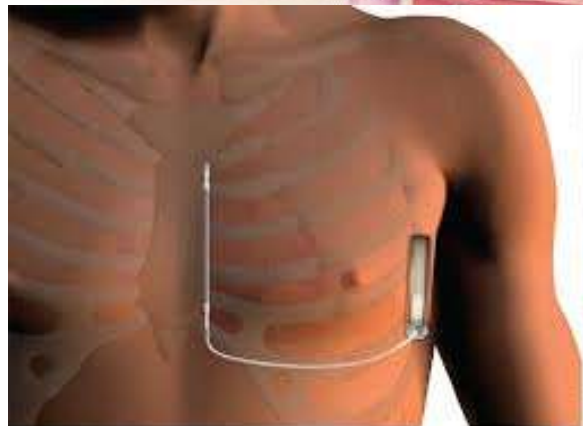
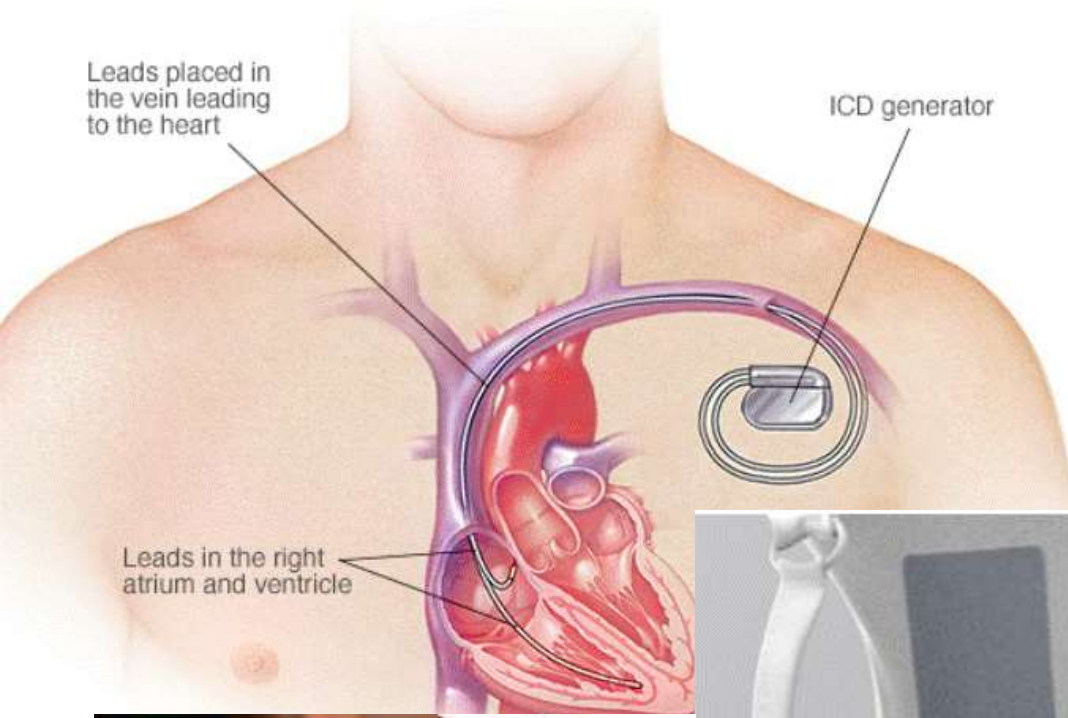
Risk of SCD at 5 years (%):

ESC recommendation:



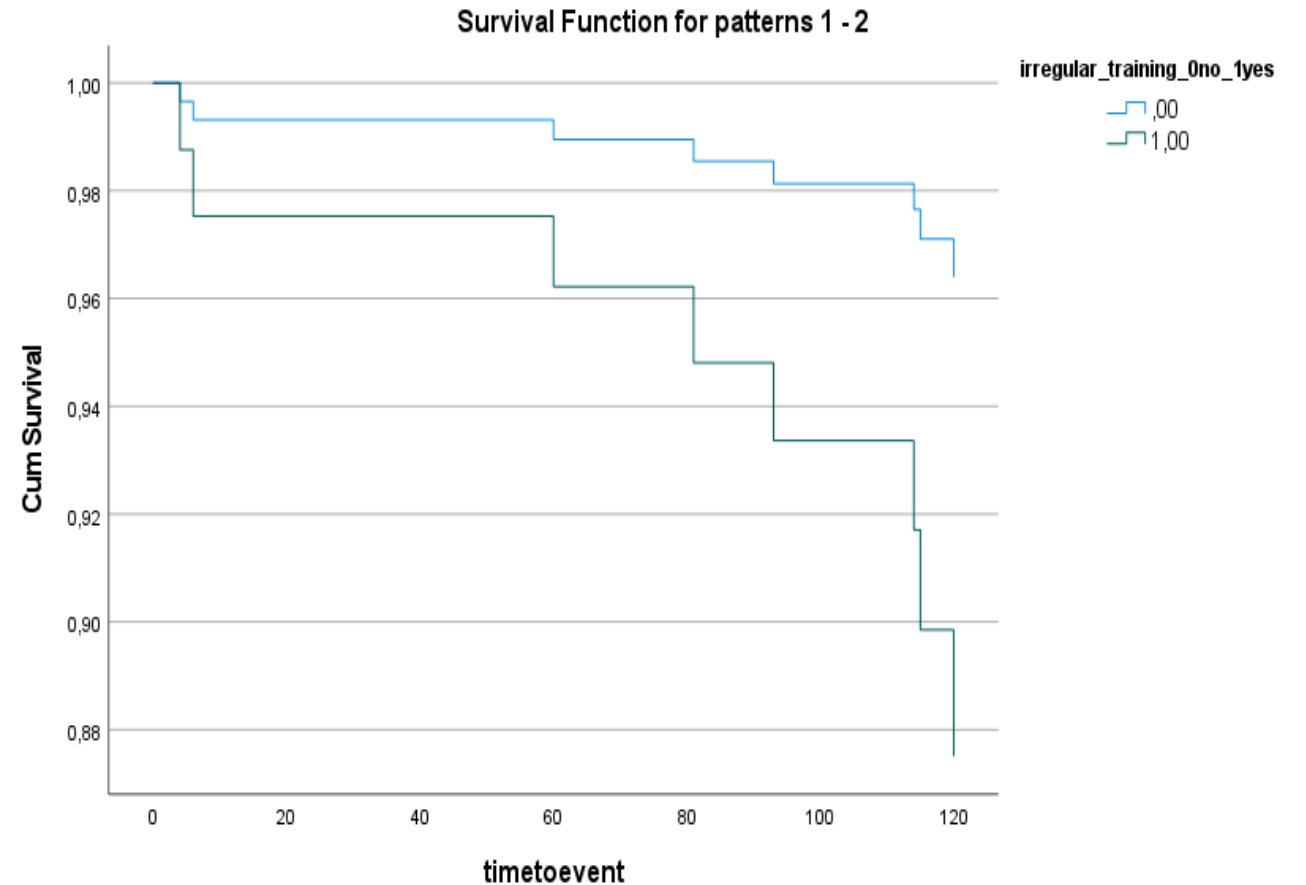
Clinical risk: extensive LGE (>15%) MR, LVEF <50%

ICD primary and secondary



135 CCS patients follow-up for 11 years

comorbidities/risk factors		SCD/SCA	control	significance
hypertension	1	100%	93.7%	p=0.464
	0	0%	6.3%	
diabetes mellitus	1	50%	47.2%	p=0.88
	0	50%	52.8%	
peripheral arterial disease	1	12.5%	7.09%	p=0.571
	0	87.5%	92.91%	
chronic kidney disease	1	25%	3.15%	p=0.004
	0	75%	96.85%	
smoking	1	50%	29.47%	p=0.307
	0	50%	70.53%	
irregular training	1	50%	17.3%	p=0,023
	0	50%	82.7%	

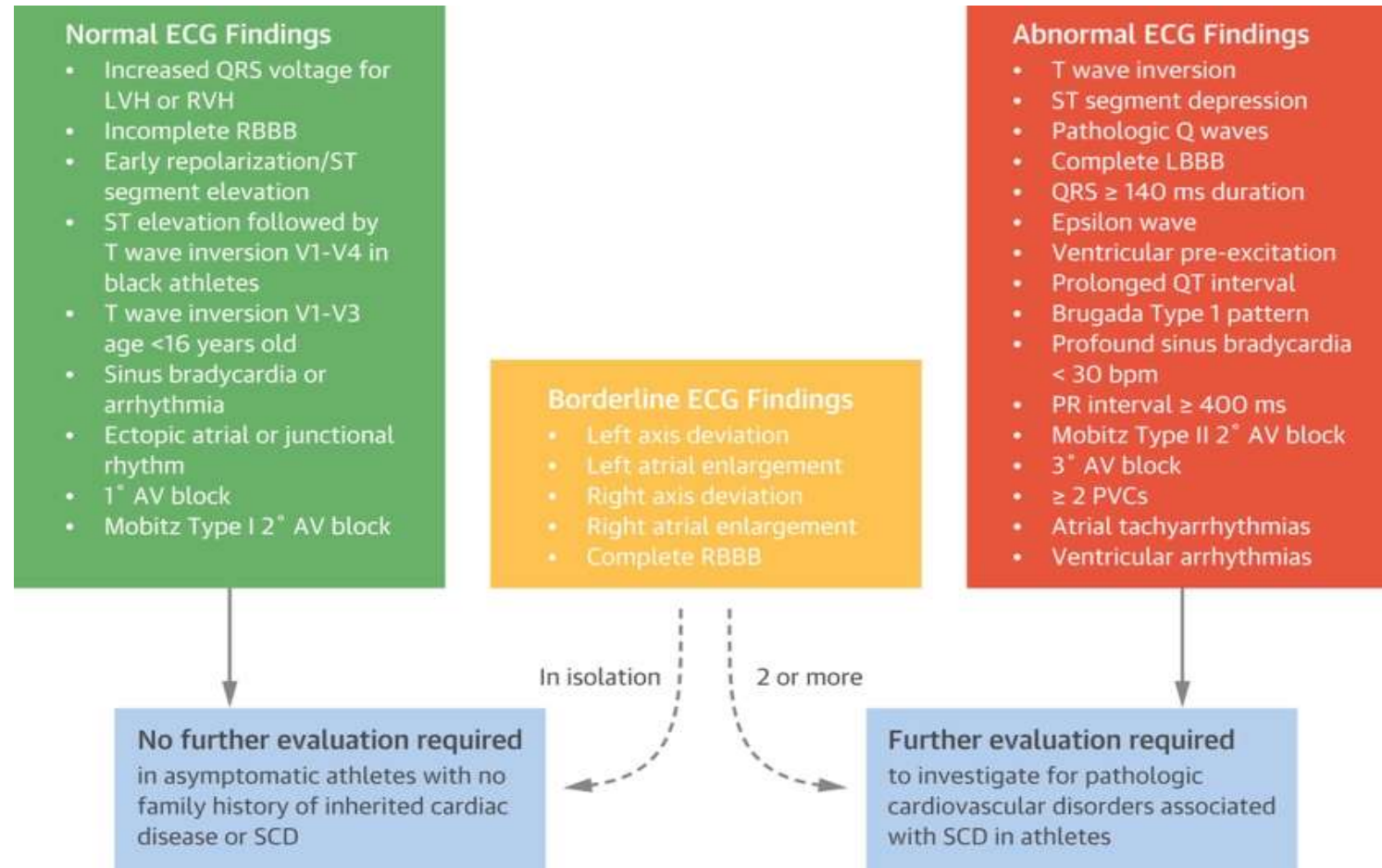


Sudden cardiac death (SCD)

- AOAC need imaging and exercise tests
- 3 months after AOAC surgical intervention and without inducible ischemia or arrhythmia every type of sports may be considered
- MB without inducible ischemia or arrhythmia every type of sports may be considered
- Mitral prolapse increases the risk of SCD:
 - reduced EF, severe MR, bicuspid prolapse, T wave inversion, arrhythmia (torsade), long-QT, positive family history

SCD - Prevention

- Regular sport medical check-ups
- Family history, ECG, physical examination, echocardiography, CT, MRT
- Exactly described exercise levels and maximal heart rate



Thank you for your attention!