Cardiac Events in World-Class Athletes

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The benefits of sports practice

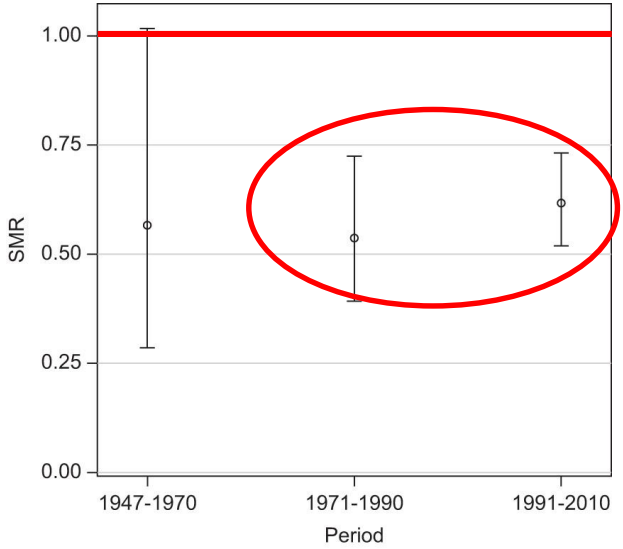
- **Moderate and regular sports** practice is associated with **cardiovascular benefits** and a **decrease in global morbidity and mortality**

- Those benefits have also been demonstrated in **elite athletes** as compared with the general male population, with a substantially and significantly **lower mortality**

Moreira JBN, et al. Nat Metab. 2020;2(9):829–39.
Marijon E, et al. Eur Heart J. 2013; 34(40):3145–50.
Runacres A, et al. Sports Med. 2021;51(2):289–301.

The Tour de France (1947-2012)

- 786 French cyclists who participated at least once



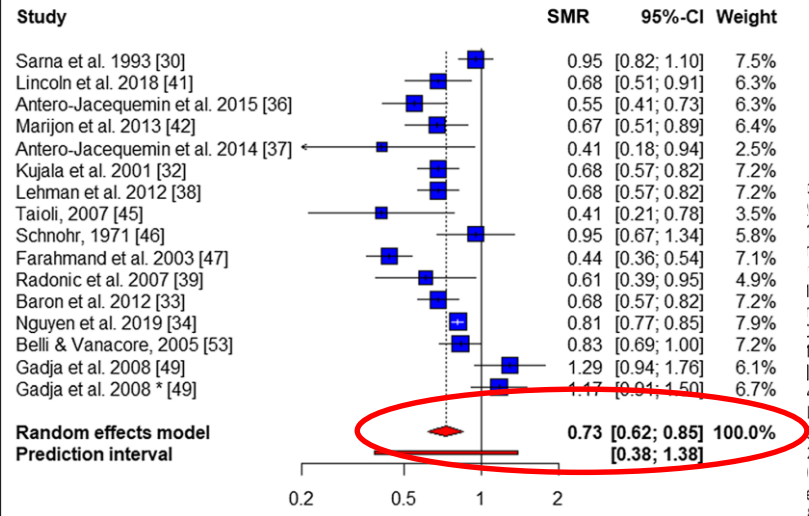
SMR:
standardized mortality ratio

- **41% Lower mortality in the cyclists** as compared to the male general population across the three time periods (1947–70, 1971–90, and 1991–2010)

Marijon E, et al. Eur Heart J. 2013; 34(40):3145–50

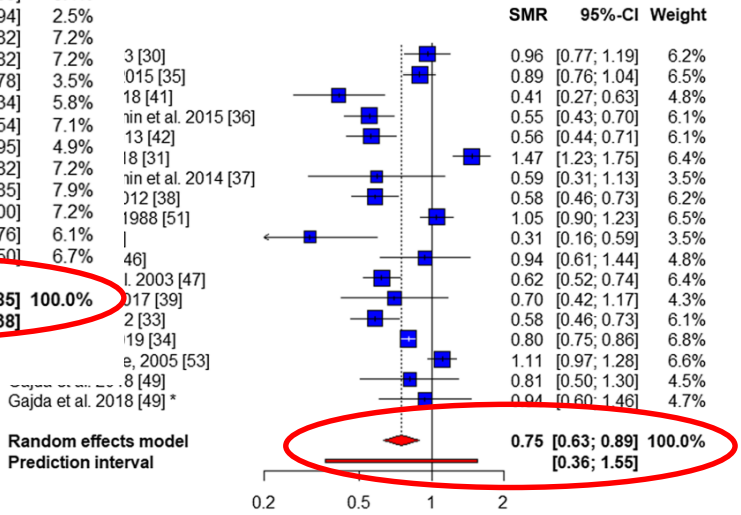
A Meta-analysis

- 165,000 former athletes



Male cardiovascular mortality

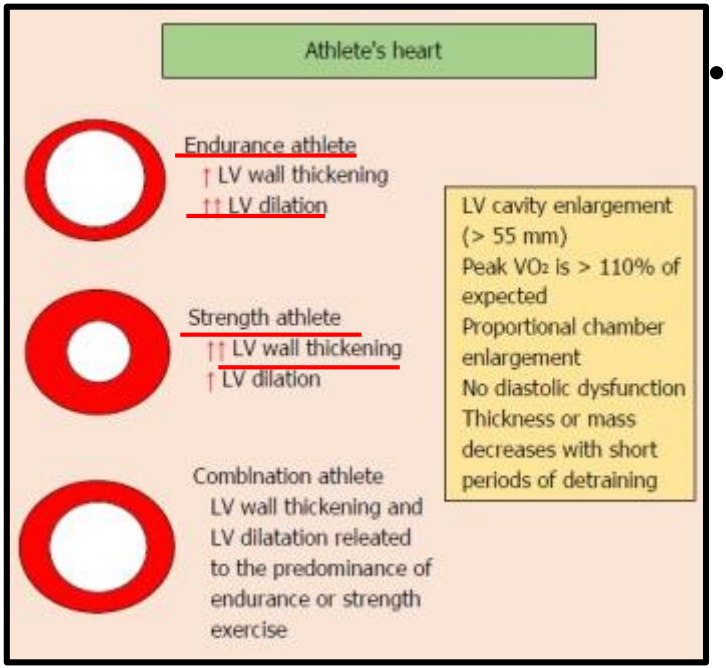
Male cancer mortality



Runacres A, et al. Sports Med. 2021;51(2):289–301.

Exercise induced cardiac remodeling

- **Enlargement and/or hypertrophy of myocardium** in response to repeated exercise stimuli



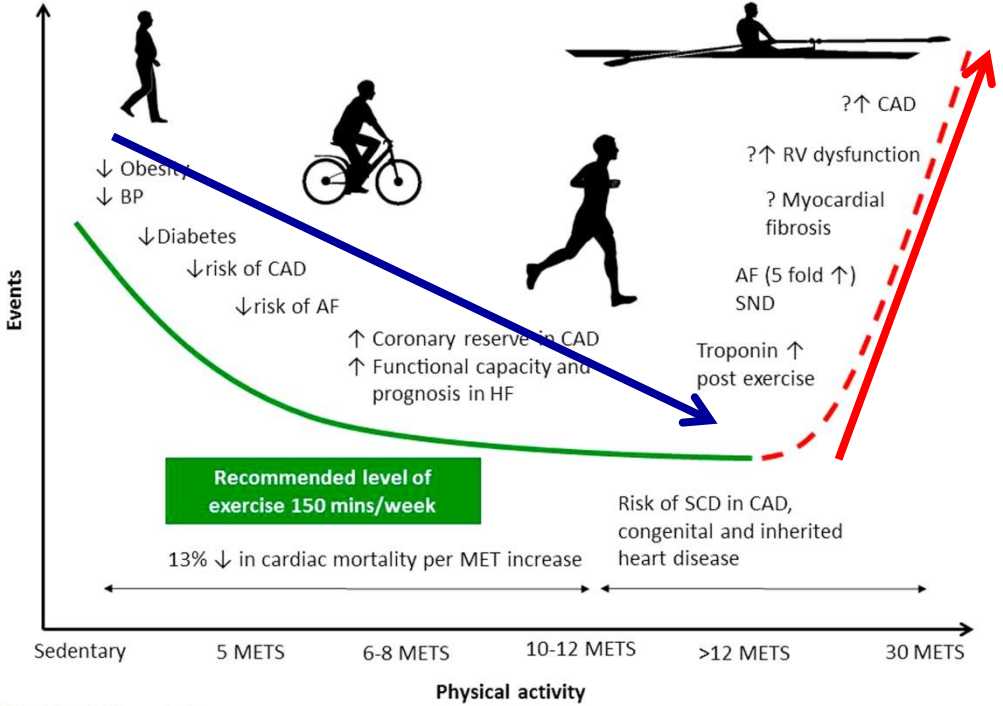
- Degree and characteristics of cardiac remodeling varies according to
  - Type of sport
  - frequency and intensity of athletic training
  - Gender/Age/Race

Shim JY et al. Korean Circ J. 2021:51(5);439-440.
Carbone A, at al. World J Cardiol. 2017;9(6):470–80.

The U-shaped curve

- Moderate exercise is better than no exercise, but

<u>vigorous exercise may be harmful</u> in some individuals



Merghani A, et al.Trends Cardiovasc Med. 2016;26(3):232–40.

Cardiac Events in World-Class Athletes: An Internet-Based Study

SOLÈNE LE DOUAIRON LAHAYE[1], ANNE LE CUNUDER[2], THIBAULT LACHARD[3], VINCENT MENARD[1], FRANÇOIS LHUISSIER[4], ANNE CHARLOTTE DUPONT[5], ANNE SOPHIE WURTZ[4], CLAUDE MARBLÉ[4,6,7], FRANÇOIS CARRÉ[3,8], and FRÉDÉRIC SCHNELL[3,8]

- To assess the prevalence of adverse **cardiac events** in **world-class athletes**, and the second aim was to identify a potentially sex-specific risk and/or sport-specific risk.

Med Sci Sports Exerc. 2022;54(12):2064-2072

Selection of sports and athletes

Selection of
Individual sports

When several disciplines
in one sport,
selection of the most popular in each sport type
(EAPC Guidelines, 2018)

Example: running
- 100m for power sports
- marathon for endurance sports

- **Individual sports** because of the difficulty to perform an individual ranking in team sports
- **Olympic sports** to benefit from their media coverage in the search for international rankings

Selection of sports and athletes

Selection of sports with a world ranking well defined and accessible on the Internet

Final selection of 30 sports

	Skill	Power	Mixed	Endurance
Olympic summer sports	Diving (10 m) Golf Horse trial	Artistic gymnastics (all-around) Rhythmic gymnastics (all-around) Sprint running (100 m) Sprint swimming (50 m freestyle) Synchronized swimming Track cycling sprint Trampoline	Badminton BMX racing Tennis	Cross-country cycling (XCO) Marathon (running)
Olympic winter sports	Freestyle skiing (all-around) Ski jumping Sledding	Alpine skiing Figure skating Speed skating (all-around) Snowboarding	Nordic combi	

- 20 summer and 10 winter sports

For each sport selected, identification of all the athletes (males and females) who entered the world Top 10 at least once between 2006 and 2018

Example:

ROAD CYCLING Ranking UCI Elite Men	2018 Ranking	2017 Ranking	2016 Ranking	2015 Ranking	2014 Ranking	2013 Ranking	2012 Ranking	2011 Ranking	2010 Ranking	2009 Ranking	2008 Ranking	2007 Ranking	2006 Ranking
Surname Name athlete 1	1	7	5	1	1	3	5			2	1	4	1
Surname Name athlete 2	2												
Surname Name athlete 3	3												
Surname Name athlete 4	4												
Surname Name athlete 5	5	3	1	8		4	8						
Surname Name athlete 6	6												
Surname Name athlete 7	7	1	3	9									
Surname Name athlete 8	8												
Surname Name athlete 9	9	9											
Surname Name athlete 10	10												
Surname Name athlete 11		2	2	5	7	2	7						
Surname Name athlete 12		4	7	2	8								
...													

Selected sport disciplines

	 Skill	 Power
Olympic summer sports	Diving (10 m) Golf Horse trial	Artistic gymnastics (all-around) Rhythmic gymnastics (all-around) Sprint running (100 m) Sprint swimming (50-m freestyle) Synchronized swimming Track cycling sprint Trampoline
Olympic winter sports	Freestyle skiing (all-around) Ski jumping Sledding	Alpine skiing Figure skating Speed skating (all-around) Snowboarding

 Mixed	 Endurance
Badminton BMX racing Tennis	Cross-country cycling Marathon (running) Modern pentathlon Open water marathon (10 km) Road cycling Rowing Short-distance triathlon
Nordic combined	Biathlon (all-around) Cross-country skiing

Identification of cardiac events

Identification of athletes affected by a cardiac event

For each athlete included,
internet search :
association of surname, name, sport, and each of the following key words:
- cardiac/heart disorder/problem",
- "cardiac/heart injury", "rhythm disorders",
- "arrhythmia", "sudden cardiac death"

Example: "surname, name athlete 1, cycling, cardiac disorder"

Characteristics of athlete's

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Type of Sport	Sport Disciplines	Overall (n = 2471)			Male (n = 1241)			Female (n = 1230)		
		Screened Athletes (n)	Age at Inclusion[a]	Age at Exclusion[b]	Screened Athletes (n)	Age at Inclusion[a]	Age at Exclusion[b]	Screened Athletes (n)	Age at Inclusion[a]	Age at Exclusion[b]
Skill 419	Diving (10 m)	68	21 ± 4	23 ± 4	33	20 ± 3	22 ± 3	35	22 ± 5	23 ± 4
	Golf	86	28 ± 7	31 ± 7	44	31 ± 6	34 ± 7	42	25 ± 6	28 ± 7
	Horse trial	43	37 ± 9	38 ± 9	22	39 ± 10	40 ± 10	21	35 ± 8	36 ± 8
	Freestyle skiing	103	25 ± 4	26 ± 5	54	25 ± 4	26 ± 4	49	25 ± 5	27 ± 5
	Ski jumping	76	24 ± 5	27 ± 5	48	26 ± 5	28 ± 4	28	22 ± 3	24 ± 4
	Sledding	43	26 ± 5	29 ± 5	23	27 ± 5	30 ± 5	20	25 ± 5	28 ± 5
Power 894	Artistic gym	130	20 ± 3	21 ± 4	65	22 ± 3	24 ± 3	65	18 ± 3	19 ± 3
	Rhythmic gym			Specific to women				46	20 ± 3	21 ± 3
	Sprint running	58	26 ± 4	27 ± 4	30	25 ± 4	27 ± 4	28	26 ± 4	28 ± 4
	Sprint swim	55	24 ± 5	26 ± 4	28	24 ± 3	26 ± 4	27	25 ± 6	26 ± 5
	Synchronized swim			Specific to women				33	23 ± 4	24 ± 3
	Track cycling sprint	107	24 ± 4	26 ± 4	58	25 ± 4	26 ± 4	49	24 ± 3	26 ± 4
	Trampoline	64	23 ± 4	26 ± 4	33	23 ± 4	25 ± 4	31	23 ± 5	26 ± 5
	Alpine skiing	80	26 ± 4	29 ± 4	41	28 ± 4	31 ± 4	39	25 ± 3	28 ± 3
	Figure skating	86	20 ± 3	22 ± 4	42	21 ± 3	23 ± 3	44	19 ± 3	21 ± 4
	Speed skating	96	25 ± 4	28 ± 4	45	25 ± 4	27 ± 4	51	26 ± 4	28 ± 5
	Snowboarding	139	24 ± 5	25 ± 5	68	24 ± 5	25 ± 5	71	24 ± 5	25 ± 5
Mixed 298	Badminton	87	24 ± 4	26 ± 4	45	26 ± 3	27 ± 4	42	23 ± 4	25 ± 4
	BMX racing	92	22 ± 3	24 ± 3	50	22 ± 3	24 ± 3	42	21 ± 3	23 ± 3
	Tennis	84	24 ± 3	27 ± 4	37	25 ± 3	28 ± 3	47	24 ± 3	26 ± 4
	Nordic combined		Specific to men		35	26 ± 4	29 ± 4	Specific to men		
	Cross-country cycling	84	26 ± 4	29 ± 4	44	27 ± 4	29 ± 4	40	27 ± 5	30 ± 7
Endurance 860	Marathon running	126	29 ± 5	30 ± 4	62	28 ± 5	29 ± 4	64	30 ± 4	31 ± 5
	Marathon swim	68	25 ± 3	26 ± 4	38	22 ± 3	24 ± 3	30	23 ± 4	25 ± 5
	Modern pentathlon	105	25 ± 4	27 ± 4	54	25 ± 3	27 ± 4	51	25 ± 4	27 ± 4
	Road cycling	103	27 ± 3	29 ± 4	61	27 ± 3	29 ± 4	42	27 ± 4	29 ± 4
	Rowing	77	27 ± 4	28 ± 5	33	26 ± 3	28 ± 4	44	27 ± 5	28 ± 5
	Triathlon	113	27 ± 4	29 ± 4	55	27 ± 4	29 ± 3	58	27 ± 4	29 ± 4
	Biathlon	90	26 ± 4	29 ± 4	41	27 ± 4	30 ± 3	49	27 ± 5	30 ± 7
	Cross-country skiing	94	28 ± 4	30 ± 4	52	28 ± 4	30 ± 4	42	22 ± 3	24 ± 4

Prevalence of cardiac events

- **Eighteen cases** of abnormal cardiac findings were identified, of those three were excluded
  - two because of congenital cardiac diseases (bicuspid aortic valve, Wolf–Parkinson–White)
  - one sudden death due to heat stroke,
- Thus, **15 adverse cardiac events** were identified **(prevalence of 0.61%)**

Characteristics of the 15 identified CE

		CE Characteristics	Athlete's Sex	Age at CE Occurrence	Impact on Sport Career
 Skill	Golf	Myocarditis-induced cardiac arrhythmia	M	29	No
 Power	Alpine skiing	Supraventricular arrhythmia (ablation)	M	25	No
 Mixed	Badminton	Cardiac arrhythmia	M	24	No
	Tennis	AF (ablation)	M	31	No
 Endurance	Road cycling	SCD	M	32	Yes
		Supraventricular arrhythmia (ablation)	M	28	No
	Triathlon	SCD	M	31	Yes
		AF (ablation)	M	41	No
		Supraventricular tachycardia (ablation)	M	28	No
		Cardiac arrhythmia	F	34	No
		Ventricular tachycardia (ablation)	F	28	No
		Supraventricular tachycardia (ablation)	F	24	No
		Supraventricular tachycardia (ablation)	F	40	No
	Biathlon	AF (ablation)	M	34	No
	Cross-country skiing	AF (ablation)	M	27	No

- The **prevalence of SCD was 0.08%,** and both SCD occurred in **males**:
- 1 aborted SCD during competition in **a road cyclist**
- the other SCD occurred at rest in **a triathlete** who had suffered from a previous cardiac arrest during a swimming training session

Characteristics of the 15 identified CE

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 Power	Alpine skiing	Supraventricular arrhythmia (ablation)	M	25	No
 Mixed	Badminton	Cardiac arrhythmia	M	24	No
	Tennis	AF (ablation)	M	31	No
 Endurance	Road cycling	SCD	M	32	Yes
		Supraventricular arrhythmia (ablation)	M	28	No
	Triathlon	SCD	M	31	Yes
		AF (ablation)	M	41	No
		Supraventricular tachycardia (ablation)	M	28	No
		Cardiac arrhythmia	F	34	No
		Ventricular tachycardia (ablation)	F	28	No
		Supraventricular tachycardia (ablation)	F	24	No
		Supraventricular tachycardia (ablation)	F	40	No
	Biathlon	AF (ablation)	M	34	No
	Cross-country skiing	AF (ablation)	M	27	No

- **5 SVT and 4 AF**, all were successfully treated with ablation
- 3 ventricular arrhythmias including the two SCD and **1 VT** successfully treated with ablation
- 3 cardiac arrhythmia-no further information

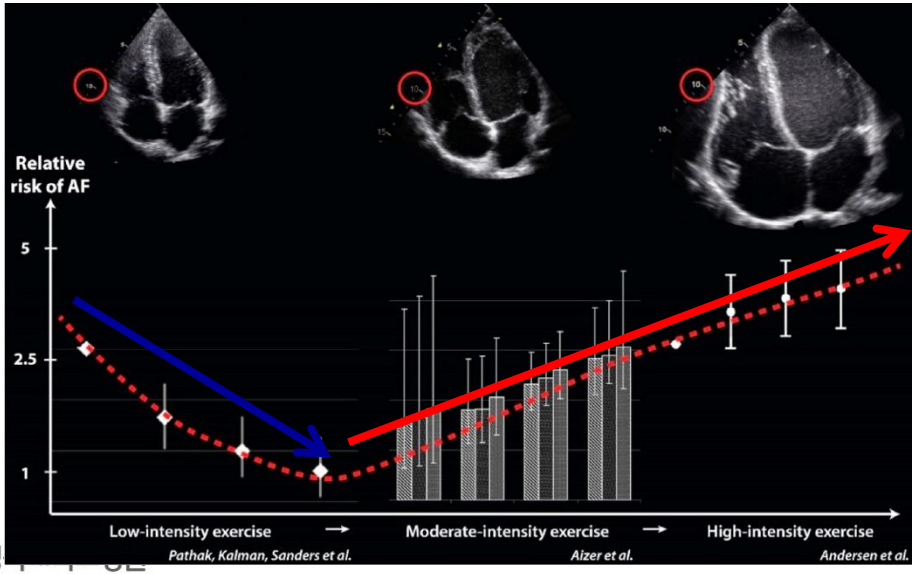
AVNRT in athletes

- **Usually** regarded as a **coincidence** when diagnosed in an athlete.
- However, 24 (34%) athletes had an atypical form vs. 302 of 1197 (17.6%) non-athletes ($P = 0.001$) from **unpublished observation**
- **Atypical forms of AVNRT** in athletes, which raises the question whether this might be the expression of the **structural remodeling of the athlete's heart**

Europace. 2018;20(9):1401–11.

AF in athletes

- Low and moderate intensity exercise has been associated with a lower risk of AF.
- In contrast, high intensity endurance training has been associated with an increased risk of AF



Flannery MD, et al. Heart Lung Circ. 2017; 26(9):983–9

AF in athletes

- There are many articles demonstrating that the risk of **AF is increased (2–10) in high-level** trained active or former veteran **male athletes**.
- The underlying pathophysiology seems multifactorial because of **atrial morphological remodeling, increased atrial fibrosis foci, and autonomic alteration** with vagal hypertonia.

Prevalence and description of CE

Type of sport	Sport Disciplines	Overall (n = 2471)			Male (n = 1241)			Female (n = 1230)		
		Athletes Screened (n)	CE (n)	CE (%)	Athletes Screened (n)	CE (n)	CE (%)	Athletes Screened (n)	CE (n)	CE (%)
Skill	Golf	86	1	1.2	4		2			0
Power	Alpine skiing	80	1	1.2	41	1	2.4	39	—	0
Mixed	Badminton	87	1	1.1	45	1	2.2	42	—	0
	Tennis	84	1	1.2	37	1	2.7	47	—	0
Endurance	Road cycling	103	2	1.9	61	2	3.3*	42	—	0
	Triathlon	113	7	6.2*	55	3	5.4*	58	4	6.9*
	Biathlon	90	1	1.1	41	1	2.4	49	—	0
	Cross-country skiing	94	1	1.1	52	1	1.9	42	—	0

0.89%

0.32%

- 11 events were identified **in men (0.89%)**, whereas 4 events were identified **in women (0.32%), (P = 0.12).**
- The **major sex difference** was **SCD** that only affected **male athletes.**

Cardiac events in female athletes

- **Lower prevalence** of cardiac events in **female athletes**

  - a superior protection against exercise-induced arrhythmias because of their **genetic and hormonal makeup**

  - sympathetic tone seems to be a trigger for ventricular arrhythmias, female athletes show a **higher vagal tone** at rest and a **lower sympathetic activation** in response to a challenging test than male athletes

Pelliccia A, et al. JACC Cardiovasc Imaging. 2017;10(9):973–5.
Schäfer D, et al Eur J Appl Physiol. 2015;115(10):2107–14.
Fürholz M, et alEur J Appl Physiol. 2013;113(3):631–40.

Prevalence and description of CE

Type of sport	Sport Disciplines	Overall (n = 2471)			Male (n = 1241)			Female (n = 1230)		
		Athletes Screened (n)	CE (n)	CE (%)	Athletes Screened (n)	CE (n)	CE (%)	Athletes Screened (n)	CE (n)	CE (%)
 Skill	Golf	86	1	1.2	44	1	2	42	—	0
 Power	Alpine skiing	80	1	1.2	41	1	2.4	39	—	0
 Mixed	Badminton	87	1	1.1	45	1	2.2	42	—	0
	Tennis	84	1	1.2	37	1	2.7	47	—	0
 Endurance	Road cycling	103	2	1.9	61	2	3.3*	42	—	0
	Triathlon	113	7	6.2*	55	3	5.4*	58	4	6.9*
	Biathlon	90	1	1.1	41	1	2.4	49	—	0
	Cross-country skiing	94	1	1.1	52	1	1.9	42	—	0

- **Endurance sports** were mostly affected by cardiac events (n = 11) **(73.3%).**
- The prevalence of reported 4 studied sport groups: **endurance: 1.28%,** skill: 0.24%, power: 0.11%, and mixed: 0.67%, (P = 0.012).

Prevalence and description of CE

Type of sport	Sport Disciplines	Overall (n = 2471)			Male (n = 1241)			Female (n = 1230)		
		Athletes Screened (n)	CE (n)	CE (%)	Athletes Screened (n)	CE (n)	CE (%)	Athletes Screened (n)	CE (n)	CE (%)
Skill	Golf	86	1	1.2	44	1	2	42	—	0
Power	Alpine skiing	80	1	1.2	41	1	2.4	39	—	0
Mixed	Badminton	87	1	1.1	45	1	2.2	42	—	0
	Tennis	84	1	1.2	37	1	2.7	47	—	0
Endurance	Road cycling	103	2	1.9	61	2	3.3*	42	—	0
	Triathlon	113	7	6.2*	55	3	5.4*	58	4	6.9*
	Biathlon	90	1	1.1	41	1	2.4	49	—	0
	Cross-country skiing	94	1	1.1	52	1	1.9	42	—	0

- The **highest prevalence (6.2%)** was noted in **triathlon,** whereas for other sports (including those with no cardiac events), it was always less than 2% ($P < 0.001$).

Endurance vs. nonendurance sport

- Among **endurance sports**, the training load of professional male road cyclists and of short-distance triathletes is about **30–35 h·wk^{-1}**.
- This is **twice more time than marathon** runners. Thus, it was demonstrated that triathletes present a higher risk of overtraining with both immunity and autonomic disturbances.

Mujika I. Int J Sports Physiol Perform. 2014;9(4):727–31.
Etxebarria N, et al. Sports (Basel). 2019;7(5):101.
Esteve-Lanao J, et al. Front Physiol. 2017;8:298.

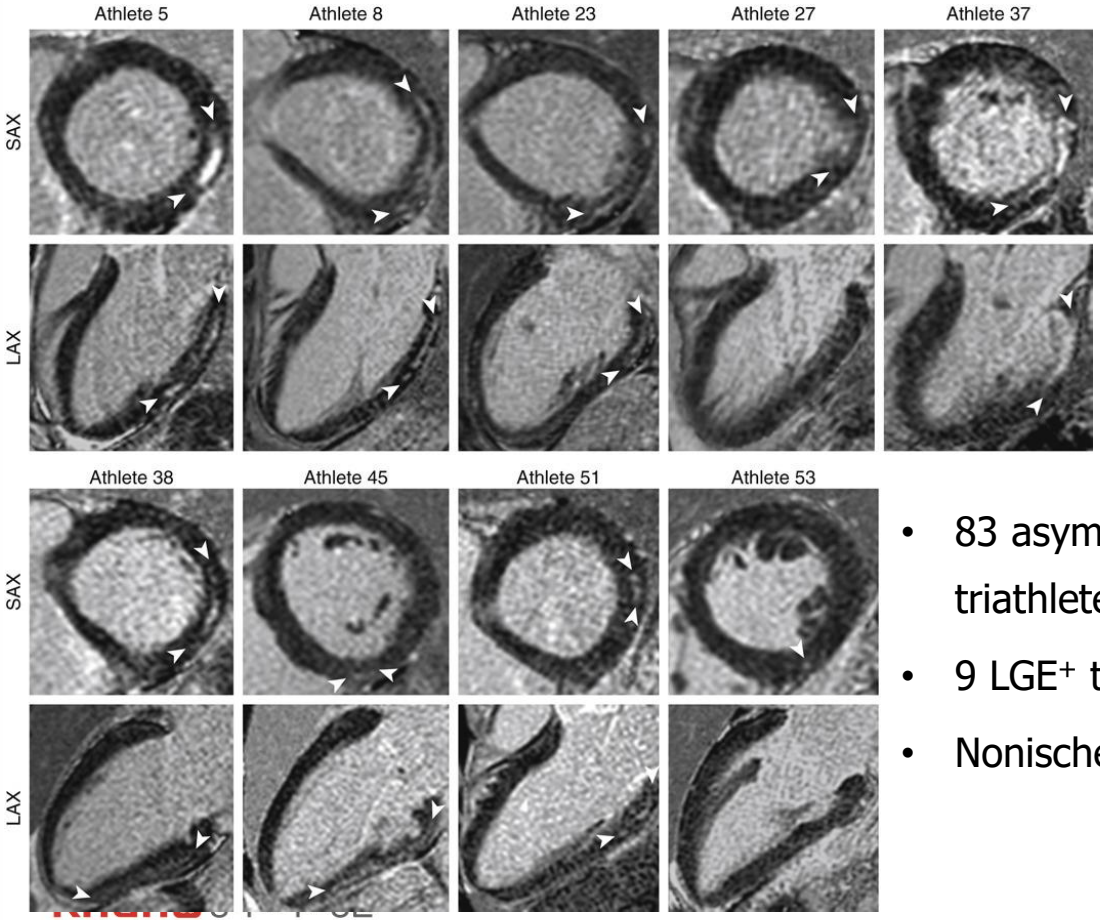
Ventricular arrhythmias in athletes

- Triathletes' and cyclist's hearts differ from runner's hearts.
- The **LV mass is higher** in triathletes than in marathon runner

	Triathletes (n = 20)	Long-distance runners (n = 20)	P value
LVEDV (ml)	210.3 ± 8.1	190.2 ± 5.9	0.0515
LVESV (ml)	84.4 ± 5.0	73.8 ± 3.3	0.0846
LVSV (ml)	126.0 ± 5.4	116.3 ± 4.8	0.1875
RVEDV (ml)	240.5 ± 10.5	218.1 ± 8.8	0.1103
RVESV (ml)	114.8 ± 7.1	102.6 ± 6.8	0.2202
RVSV (ml)	125.3 ± 5.6	118.2 ± 4.9	0.3473
LVEF (%)	60.0 ± 1.5	61.1 ± 1.4	0.6249
RVEF (%)	52.5 ± 1.6	53.9 ± 1.5	0.5118
MM (g)	154.3 ± 5.4	140.1 ± 4.7	0.0547
MM norm (g/m^2)	79.4 ± 2.0	73.5 ± 2.1	0.0538

Franzen E, et al. Heart Vessels. 2013;28(5):626–31.

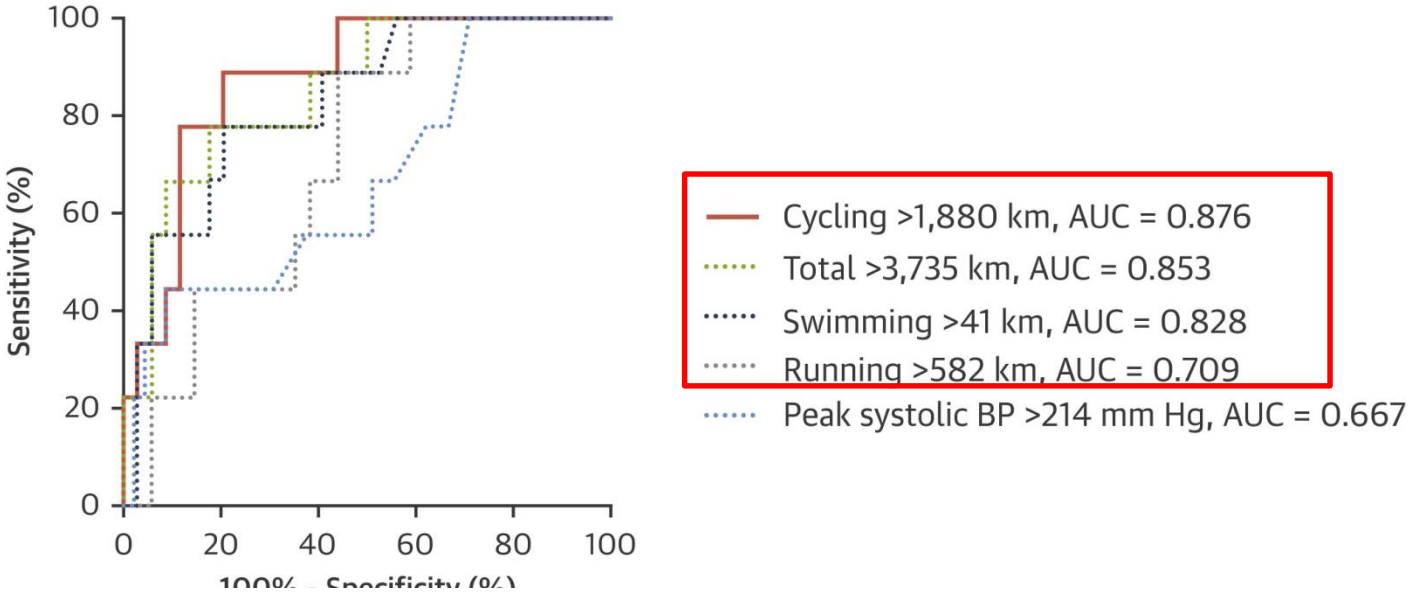
Myocardial fibrosis in triathletes



- 83 asymptomatic triathletes
- 9 LGE^{+} triathletes
- Nonischemic pattern

Tahir E, et al. JACC Cardiovasc Imaging. 2018;11(9):1260–70.

Myocardial fibrosis in triathletes



- Myocardial fibrosis in asymptomatic triathletes seems to be associated with the race distances.
- There appears to be a safe upper limit, beyond which exercise may result in myocardial fibrosis.

Tahir E, et al. JACC Cardiovasc Imaging. 2018;11(9):1260–70.

Ventricular arrhythmias in endurance athletes

- **Ventricular arrhythmias**
  - training load
  - exertional systolic hypertension
  - transient post-race immune function decline
  - increase of sympathetic outflow
- **Cardiovascular, immune, and neurohormonal alterations** reported in triathletes and male's road cyclists could participate to the increased prevalence of ventricular arrhythmias

Olympic triathlon

- 1.5 km swim, 40 km cycle, and 10 km run.

Type of sport	Sport Disciplines	Overall (n = 2471)			Male (n = 1241)			Female (n = 1230)		
		Athletes Screened (n)	CE (n)	CE (%)	Athletes Screened (n)	CE (n)	CE (%)	Athletes Screened (n)	CE (n)	CE (%)
 Endurance	Road cycling	103	2	1.9	61	2	3.3*	42	—	0
	Triathlon	113	7	6.2*	55	3	5.4*	58	4	6.9*
	Biathlon	90	1	1.1	41	1	2.4	49	—	0
	Cross-country skiing	94	1	1.1	52	1	1.9	42	—	0

- Only triathletes undergo the same training loads and participate to the **same race format** as those of their male counterparts, which could also partly explain the highest prevalence of **cardiac events observed in female triathletes** although a superior protection against exercise-induced arrhythmias in female athletes.

Summary

- A relatively unexpected **high prevalence of cardiac events in endurance elite athletes** was observed as compared with other sports, mainly, in male and female **triathletes**.
- These results highlight the need for **international longitudinal follow-up studies** in these kinds of athletes.

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Thank you for your attention!!