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Case Report

Resilience against exercise-related coronary atherosclerosis: A case study in a master athlete participating in 500 marathons

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ABSTRACT

Background and purpose: Lifelong endurance exercise is generally associated with cardiovascular health benefits. However, recent studies suggest that prolonged high-volume training may contribute to coronary atherosclerosis, even in athletes with low traditional cardiovascular risk. This case report aims to explore the cardiovascular status of a master endurance athlete with an exceptionally high lifetime training volume, in light of recent concerns raised in the literature.
Methods: We present the case of a 60-year-old recreational male marathon runner with no history of cardiovascular disease, who completed over 500 marathons between the ages of 30 and 60 years, covering ~127 000-km running. In 2024 alone, he completed 60 marathons. Cardiovascular evaluation included clinical risk assessment and coronary computed tomography angiography (CTCA).
Results: The runner was asymptomatic, had a low ESC-SCORE2 (3.3%), a favorable lipid profile, and normal levels of high-sensitivity C-reactive protein and lipoprotein (a). CTCA revealed no evidence of calcified, mixed, or non-calcified coronary plaques.
Conclusions: This case highlights that some master athletes may demonstrate resilience to coronary atherosclerosis despite decades of high training volume. In low-risk individuals, prolonged endurance training alone may not necessarily lead to coronary artery disease, emphasizing the need for individualized cardiovascular screening strategies.

1. Introduction

Cardiovascular diseases (CVDs) have been ranked as the leading cause of mortality worldwide, responsible for approximately one-third of all deaths[1,2] across both developed and developing nations.[3,4] Factors such as aging populations and the rising prevalence of risk factors like obesity and hypertension significantly contribute to the escalating mortality rates associated with CVDs.[5–7] Thus, comprehensive strategies for the prevention and management of cardiovascular diseases have become paramount to alleviating this widespread health crisis.[8–10] A healthy lifestyle plays a crucial role in the prevention of CVDs, where

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Abbreviations

CAC	Coronary Artery Calcium
CT	Computed Tomography
CTCA	Coronary Computed Tomography Angiography
CVDs	Cardiovascular diseases
HDL	High Density Lipoprotein
HRP	High Risk Plaques
SIS	Segment-Involvement Score
SSS	Segment Stenosis Score

the key components include maintaining a balanced diet,[11–13] engaging in regular physical activity and exercise,[14–16] and avoiding smoking and excessive alcohol consumption.[11,12,17]

A systematic review conducted by Lemez and Baker revealed a positive correlation between athletic involvement and longevity, demonstrating that elite athletes often exhibit lower mortality rates compared to their non-athletes.[18] So, it is fair to state that it is well known that athletes live longer than non-athletes[19] since they seem to have reduced mortality,[20] especially due to a reduced incidence of both cardiovascular diseases and cancer mortality compared to the general population.[21–23] This fact is most likely due to genetic difference, aerobic training for endurance elite sports, and a healthier lifestyle of athletes compared to the general population. Particularly, the genetic difference is important.[19,24] Specifically, rates of smoking[24] and tobacco-related cancer mortality are lower in athletes.[19] Moreover, regular endurance-exercise training has protective benefits against cardiovascular disease and premature death.[25–28]

Marathon running as a specific sports discipline seems to have many benefits regarding health, such as a decreased cardiovascular risk profile.[29] Marathon running training offers several benefits for different organ systems, reducing all-cause mortality.[29] Despite its cardiovascular benefits, marathon running also carries risks, as runners may experience heart attacks during training, races, or in the post-race period, which can, in some cases, be fatal.[29–31] The risk of sudden cardiac death during a marathon is considered very low,[32,33] with estimates ranging from one in 50 000 to one in 80 000, or ~0.41 per 100 000 finishers.[34–36] A sudden cardiac arrest due to coronary artery disease is more common in older male marathon runners and usually occurs in the last four miles of the race course.[37,38]

Although marathon running training seems to have health benefits, several studies in lifelong middle-aged male athletes showed a higher prevalence of high coronary artery calcium scores, and a higher coronary plaque burden compared with relatively sedentary healthy controls, raising speculation that lifelong intense exercise imposes chronic coronary stress on the heart.[39–46] It has been shown that lifelong endurance sport participation led in athletes to more coronary plaques, including more non-calcified plaques, than in fit and healthy individuals with a similar cardiovascular risk profile.[43,47,48] Based on these studies, intensity in training seems to be the most important risk factor for developing coronary artery sclerosis.[44,45] However, the number of years of training also seems to be prone to lead to an increased risk of coronary artery sclerosis.[46]

The possibility that long-term, high-volume training may increase coronary atherosclerosis[40,43,44,46] remains controversial, especially in Masters' athletes. Routine use of computed tomography (CT) coronary imaging is not recommended for asymptomatic individuals without risk factors, and there is no established evidence linking coronary artery calcium (CAC) measurements to clinically significant coronary artery disease outcomes in Masters' athletes.[47] The best approach to managing ischemia in asymptomatic Masters athletes remains unclear, highlighting the need for a shared, well-informed decision-making process when considering revascularization. These findings suggest that extensive endurance exercise, such as running multiple marathons over several decades, does not necessarily prevent the development of coronary artery plaques or calcifications, and some studies indicate a higher prevalence of CAC in long-term endurance athletes compared to their less active counterparts.[40,41] Therefore, it seems inconclusive whether older runners should be persistent with running as an activity or should consider changing.

A case study of high-volume marathon runners with a low cardiovascular risk profile may provide valuable insights into the long-term effects of endurance exercise on cardiovascular health. In this case study, we describe a 60-year-old master athlete with a low cardiovascular risk who has completed more than 500 marathons over the past 30 years. He was advised by his primary care physician to undergo a coronary CT angiogram.

2. Case description

2.1. Ethical approval

The athlete gave his informed written consent to use all his publicly available data provided on his personal website. The study was approved by Ethikkommission des Kantons St. Gallen (1-6-2010). The study was implemented in accordance with the Declaration of Helsinki.

2.2. Athlete profile

The subject is a 60-year-old recreational runner with no structured training program, who regularly participates in marathons, ultra-marathons, and triathlons. Notably, as a personal milestone, he completed 60 marathons in 2024 to celebrate his 60th birthday. His history with running began in school with short-distance events and progressed to his first marathon at age of 30. Between the ages of 30 and 60 years, he completed more than 500 events, including marathons, multi-stage ultra-marathons, duathlons, and IRONMAN® triathlons. Over the years, he also participated in observational research, such as the NURMI-Study and the ULTRA Study. While he does not maintain personal records of race times or placements, he reports his annual marathon completions to his national 100 Marathon Club. His longest event was a 6-day race. His personal best marathon time was 3 h 10 min at age of 30; his best time was 4 h 11 min at of 60.

He has worked shift schedules for over 20 years, which has not interfered with his training routine. He typically runs at least 30 km per session, without a fixed plan, and adapts his running to weather conditions avoiding rain, snow, or ice. He runs exclusively on roads and uses a bicycle ergometer indoors when necessary. His training pace averages 7.5 km·h^{-1}, with a maximum of 8.5 km·h^{-1}. He alternates between two circuits of 7 km and 8 km, each completed in under 60 min, allowing for breaks between loops. Clinically, he reports no history of cardiovascular disease, significant illness, or injuries requiring rest from training. He has always been a non-smoker, does not take any medication, and has remained consistently active. His family history is unremarkable for cardiovascular events or premature death. Both parents are alive at age of 90, independent in daily life, and treated for hypertension.

Due to recent publications[44,46] highlighting the potential risk of coronary artery sclerosis in lifelong endurance athletes, his primary care physician recommended cardiovascular screening. Although asymptomatic, he underwent coronary computed tomography angiography (CTCA) for risk stratification.

2.2. Investigations

Classical cardiovascular risk factors were assessed and the ESC-Score 2 was calculated. In addition, high-sensitive C-reactive protein and lipoprotein (a) was assessed.[49] A cardiac CT angiogram was performed using Somatom go top 64 (Siemens Healthineers International AG, Zürich, Switzerland) during daily routine in a radiology institute. Coronary arteries were assessed by CAC-scores with the Agatston method, visual plaque morphology (*i.e.* calcified, mixed, and non-calcified), extent of luminal stenosis, the presence of high-risk plaque (HRP) markers, and the number and location of plaques utilizing the segment stenosis score (SSS) and the segment-involvement score (SIS).

2.3. Statistical analysis

The normality of the dependent variables was tested using the Kolmogorov-Smirnov test. Using descriptive statistics, body composition, blood pressure and cholesterol levels were summarized and expressed as means and ranges, while training volume in running kilometers was expressed as means ± standard deviations (*SD*). The cholesterol values were compared with the reference ranges for the assessment. Linear and polynomial regression models were used to analyze the trend in annual running training volume over the last 30 years. Pearson correlation analysis was applied to examine the relationships between the annual number of marathons and running distances, including monthly averages and total annual distance. The correlation coefficients (r) were interpreted as weak (0.10–0.39), moderate (0.40–0.69), or strong ($\geq$ 0.70). Linear regression analysis examined the relationship between annual number of marathons and annual total distance and assessed the shared variance between the two variables. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS 26.0, IBM, Chicago, IL). The significance level was set at $p < 0.05$.

3. Results

The results of the Kolmogorov-Smirnov test showed that the dependent variables were normally distributed ($p > 0.200$).

The health care practitioner of the athlete provided measured data about anthropometry and laboratory results from his records. The runner has a body mass of 72–74 kg depending upon the time of year. With a body height of 177 cm, his body mass index is 23.0–23.6 $kg{\cdot}m^{-2}$. Blood pressure varies between 110/70 to 130/80 mm Hg depending upon the time of day. A first lipogram at the end of the 2024 season demonstrated elevated LDL-cholesterol (calculated by the Friedewald formula), while all other components, including HDL-cholesterol, were within the reference range (Table 1). The calculated 10-year risk of fatal and non-fatal cardiovascular events was 3.3%, indicating a low-to-moderate risk (SCORE2, Heart Score, EAPC, European Society in Cardiology). Also, lipoprotein (a) and hs-CRP were within the reference range.

Fig. 1 presents the running training volume in kilometers of the athlete in the last 30 years (1995–2024). The total volume in these 30 years was ~127 000 km with an average of (352 ± 77) km per month and an average of (4 233 ± 333) km per year, with an increase in the last years, where the highest volume was in 2024 with 7 160 km. Linear and polynomial regressions showed that the trend in running kilometers increased over the years. Linear regression explained 11.9% ($p = 0.062$), second-order regression explained 26.3% ($p = 0.016$), and third-order non-linear polynomial regression was the best fit for total running distance over the years, with the coefficient of determination explaining 62.3% ($p < 0.001$) of the variance.

Table 1
Cardiovascular risk profile.

	Reference	Measured value
Cholesterol total	3.88–5.66 ($mmol{\cdot}L^{-1}$)	5.64
Triglycerides	0.56–1.68 ($mmol{\cdot}L^{-1}$)	0.99
HDL-Cholesterol	0.93–1.55 ($mmol{\cdot}L^{-1}$)	2.16[a]
LDL-Cholesterol	1.60–3.40 ($mmol{\cdot}L^{-1}$)	3.03
Lipoprotein (a)	< 300 ($mg{\cdot}l^{-1}$)	74
hs-CRP	< 3 ($mg{\cdot}l^{-1}$)	0.5

[a] outside the reference range.

The average monthly running distance with linear and third-order polynomial regression models is shown in Fig. 2.

Similar to the overall trend over the entire 30-year period, the average annual running distance across months also showed an increasing trend according to the linear and polynomial regressions. The linear regression explained 31.5% ($p = 0.057$), the second-order regression 39.1% ($p = 0.107$), while a non-linear third-order polynomial regression best mapped the annual trend with the highest coefficient of determination and explained 56% ($p = 0.074$) of the variance.

The Pearson correlation analysis between the annual number of marathons and the running distance is shown in Fig. 3.

The correlation analysis revealed a moderate correlation between the average running distance in January and August and the annual number of marathons over the observed 30-year period. In addition, a high correlation was found between the annual number of marathons participated in and the distance run from April to June ($0.50 \leq r \leq 0.60$) as well as the total annual distance ($r = 0.70$). The scatter plot with the corresponding linear regression between the yearly number of marathons and the total annual distance is shown in Fig. 4.

The regression analysis between the annual number of marathons and the total annual distance also confirms the correlation analysis carried out previously by showing that these two variables share 49% ($p < 0.001$) of the variance.

Computed tomography findings are illustrated in Figs. 5–7, which present representative images showing no plaques or calcifications in the left coronary artery, right coronary artery, and the ramus circumflexus of the left coronary artery.

4. Discussion

This case study shows that a non-elite master athlete who has completed nearly 130 000-km running within 30 years, finished more than 500 marathons including ultra-marathons, multi-stage races etc. without any findings of coronary artery sclerosis. There are some potential explanations why this runner with ~350-km monthly running and ~4 200-km annual running during 30 years showed no signs of coronary artery sclerosis. First, he has an overall low cardiovascular risk profile, including a healthy lifestyle. Second, his relatively low intensity in training and competing may have provided sufficient recovery time for an overall low level of inflammation.

4.1. Training

Initially, an annual training volume of ~4 200 km over 30 years may seem high; however, it falls within the typical range observed in ultra-marathoners. A study investigating 1 345 current and former ultra-marathon runners showed that active ultra-marathon runners had a previous year median running distance of 3 347 km.[50] Most probably our subject needs regular running for normal life and is used since decades for this training volume.[51]

4.2. Lifestyle

The runner is a non-smoker and non-drinker, engaged in endurance sports since school and never stopped with sport. During all his lifetime he was never overweight or obese and never changed his eating or drinking habits. Generally, marathoners[52] and ultra-marathoners[53] seem to have a healthier lifestyle than the general population. A study investigating 1 212 ultra-marathoners showed that these runners appeared to gain less body weight with advancing age than the general population.[54] However, negative lifestyle behaviors exist in marathon runners despite their engagement in physical exercise through marathon running. Marathon running does not negate the long-term effects caused by past negative lifestyle behaviors.[55] Nevertheless, observational data indicate that higher fitness level is associated with lower incidence of

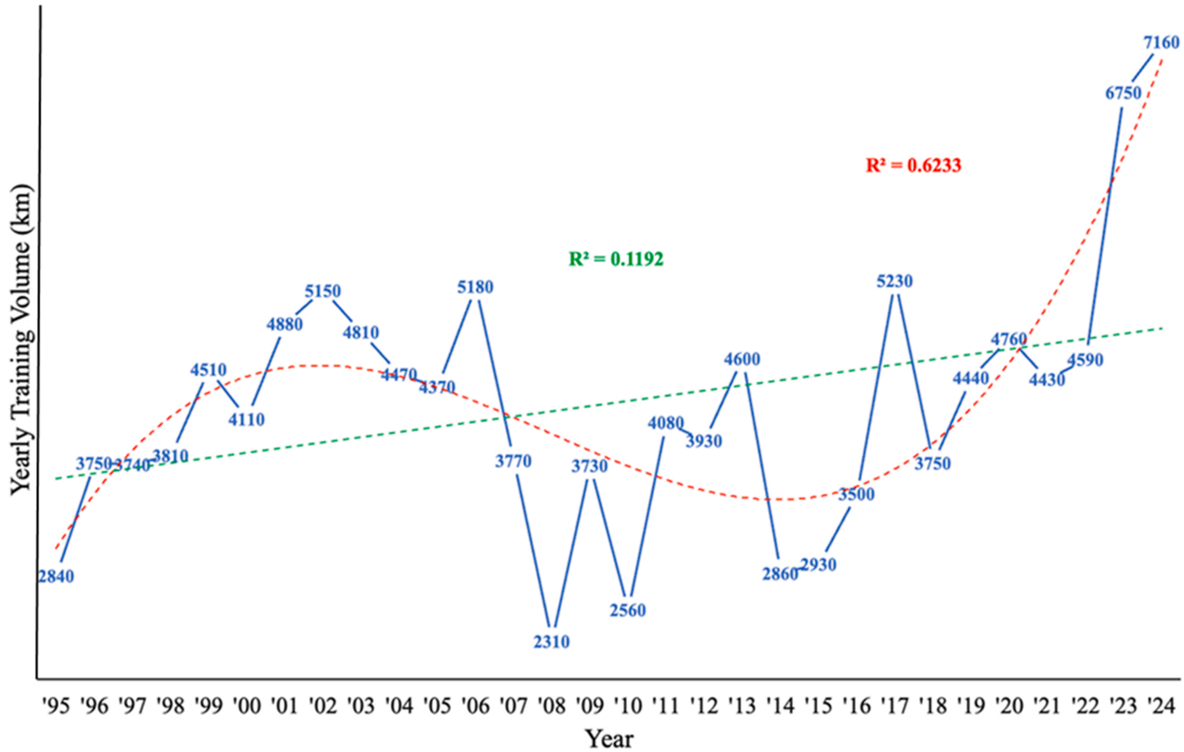

Fig. 1. Running training volume (km) in the last 30 years (1995–2024).

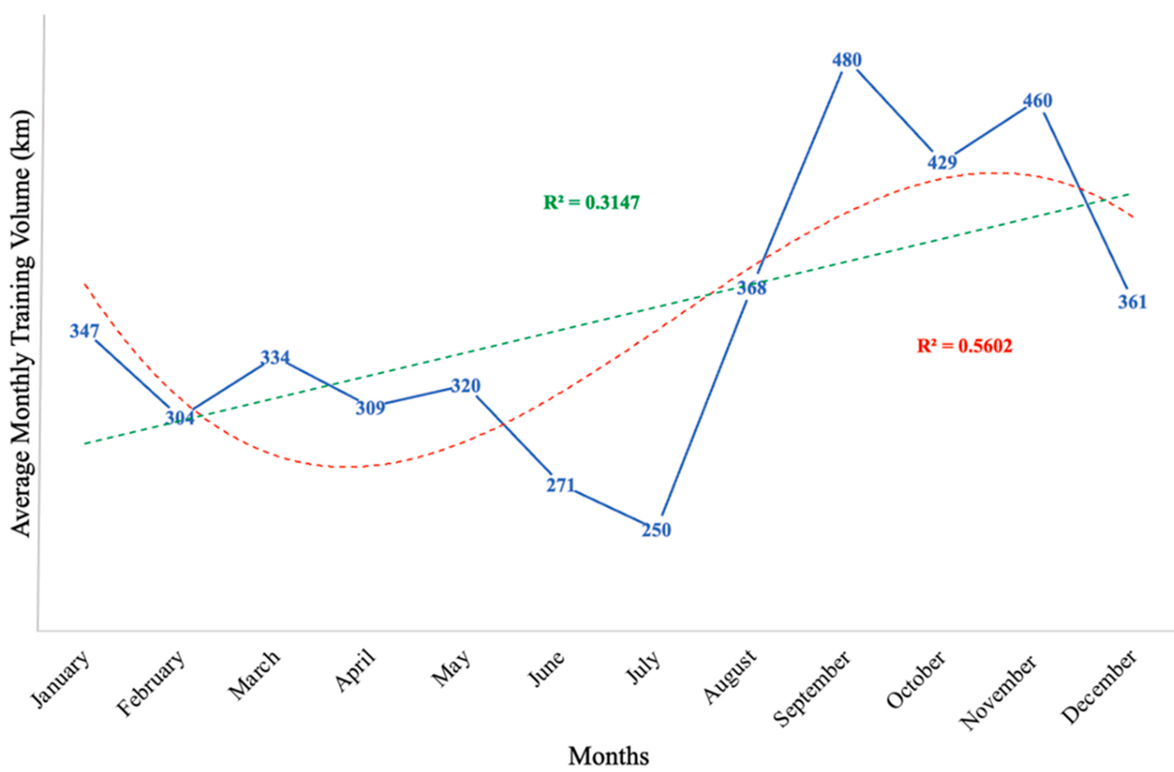

Fig. 2. Average running distance (km) per month from 1995 to 2024.

coronary events and in a majority of athletes should continue exercising after excluding the presence of symptoms and inducible ischemia.[47]

4.3. Consistency

The runner made no longer break in training and competing during these 30 years. From the age of 30 years (3 h 10 min) to the age of 60 years (4 h 11 min), he slowed down by 60 min in 30 years, or equal to ~2 min per year. It is possible that runners can maintain for a longer time a high marathon running speed. A study investigating the age-related decline in running performance of sub 3-h marathoners for five consecutive calendar decades showed a time difference in marathon

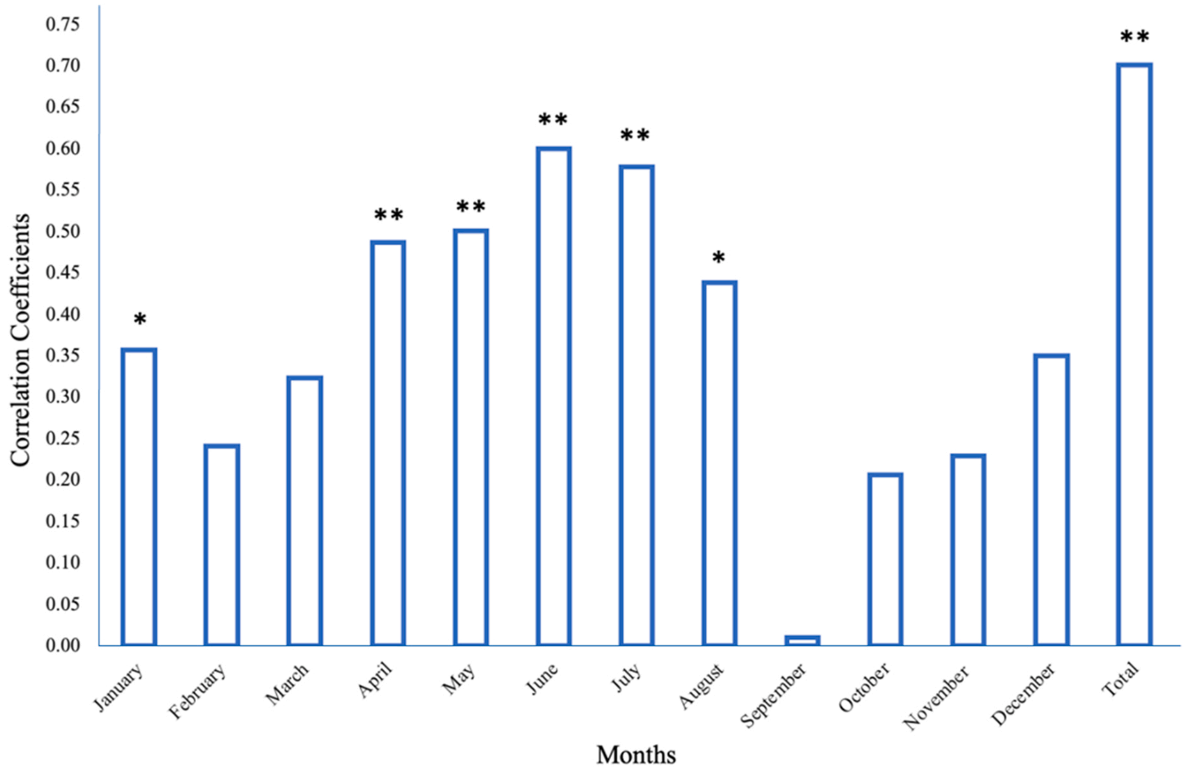

Fig. 3. The Pearson correlation coefficients between the annual number of marathons and the monthly and total average running distance (km) from 1995 to 2024. $*p < 0.05$, $**p < 0.01$.

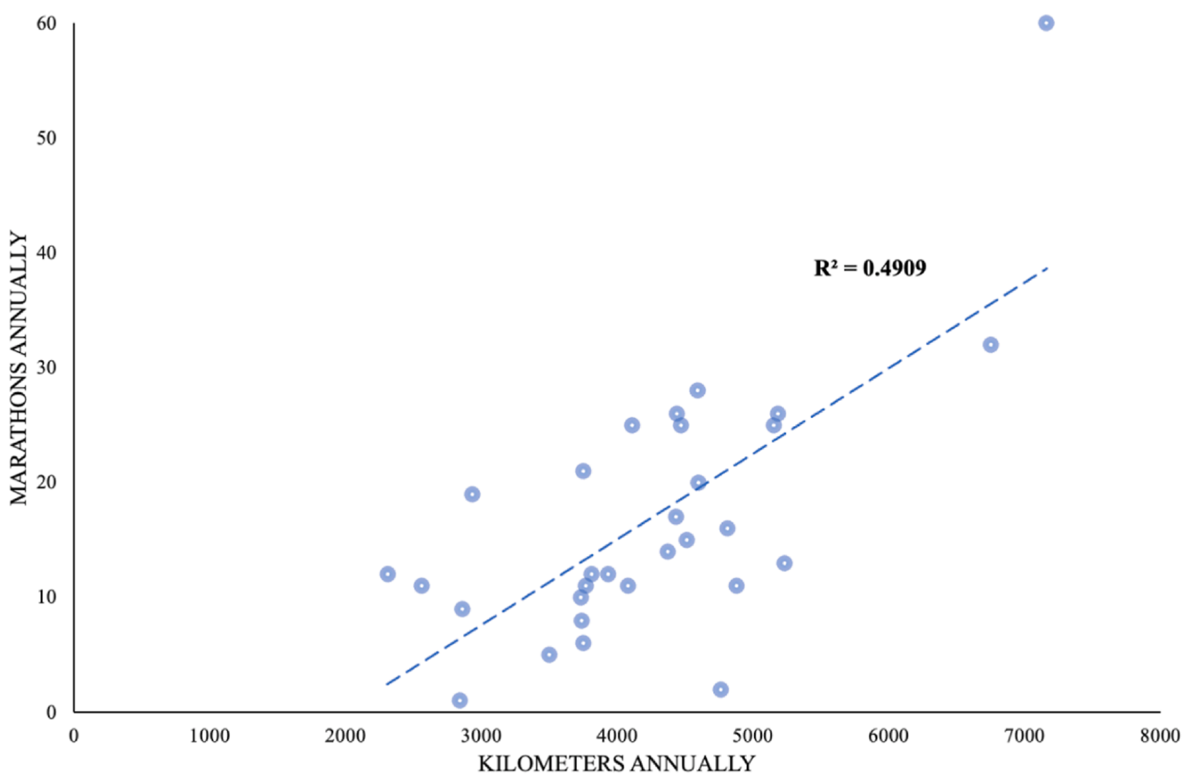

Fig. 4. The linear regression analysis between the annual number of marathons and the total annual distance (km) from 1995 to 2024.

Fig. 5. Computed tomography scan of the left coronary artery.

performance between the personal best and the worst performance during the 5th decade was (26 ± 9) min, corresponding to a mean annual increase of 1 min 4 s and equal to a decrease in running speed of 0.67% ± 0.29% per year.[56]

4.4. *Intensity in running during training and competing*

The subject has an average training running speed of 7.5–8.5 km·h^{-1} and a running speed of ~9.5 km·h^{-1} during competing. In the literature, conflicting results are presented regarding the influence of training load on coronary atherosclerosis in middle-aged athletes. Nevertheless, high-intensity exercise may lead to disruption of coronary patterns.[57] A study investigating 289 middle-aged male athletes showed that training load was associated with coronary artery atherosclerosis and calcification.[58] Intensity in training might be crucial in developing coronary artery sclerosis.[45] It has been shown that exercise intensity but not volume was associated with progression of coronary atherosclerosis in middle-aged male athletes.[44] A study investigating 284 middle-aged men showed that subjects with a higher activity had a higher prevalence of CAC and atherosclerotic plaques. The most active group had a more benign composition of plaques, with fewer mixed plaques and more often only calcified plaques.[59] However, also opposite findings regarding marathon running and cardiovascular diseases were published. A study investigating 97 middle-aged male marathon runners who had completed multiple marathon races showed no risk factors for a premature subclinical vascular impairment.[60] Furthermore, no independent associations of marathon finishing time, number of completed races or weekly and annual training distances with any vascular parameters were observed.[60] In addition, neither the number of finished marathons nor the years of running were related to coronary artery calcium scores but rather the risk factors for coronary artery disease.[41] Overall, the results in the studies seem to be inconsistent whether training volume or training intensity have a significant impact on the development of coronary artery sclerosis in middle-aged marathon runners.

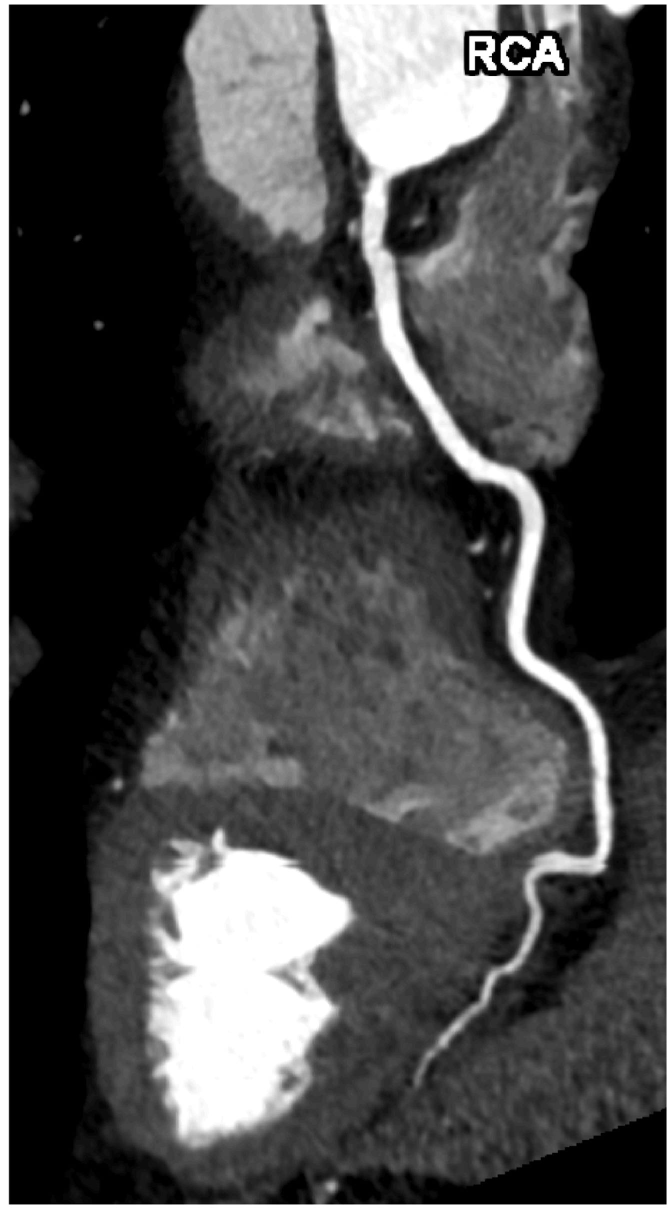

Fig. 6. Computed tomography scan of the right coronary artery.

4.5. *Low cardiovascular risk profile*

The subject seems to have a very low cardiovascular risk profile based upon his habits and history where his calculated 10-year risk of fatal and non-fatal CVD events is 3.3%. It has been shown that lifelong endurance sport participation led in athletes to more coronary plaques than fit and healthy individuals with a similarly low cardiovascular risk profile.[43] In the abovementioned study, one might assume that the selection of the subjects could have had a bias and/or the sample sizes were too small and/or the timeframe of observation was too short. In some instances, the study subjects seemed to have had an increased

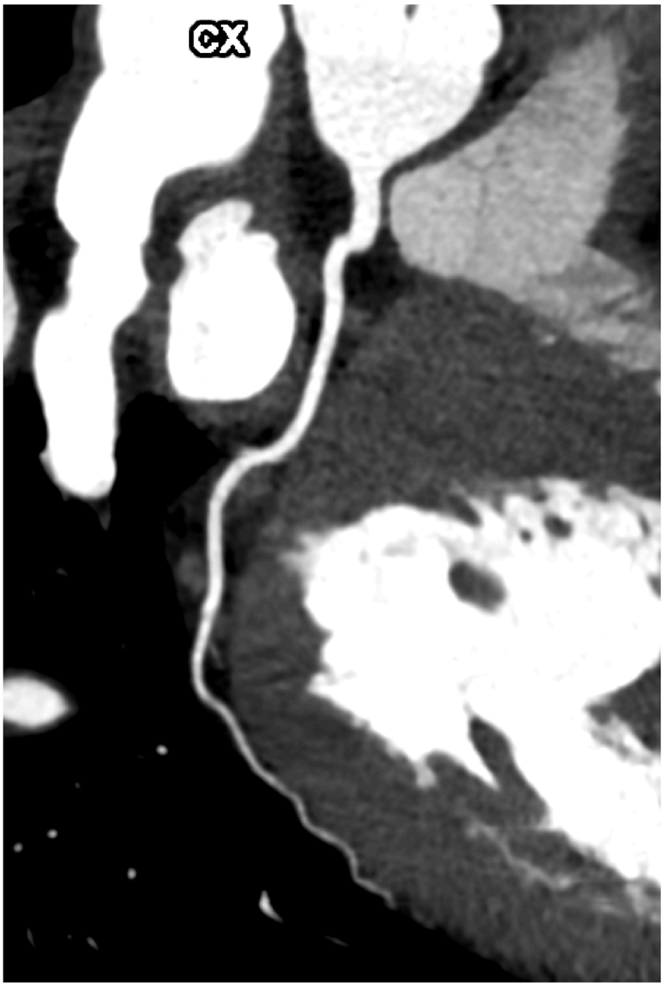

Fig. 7. Computed tomography scan of the ramus circumflexus of the left coronary artery.

cardiovascular risk profile.[41] Research on men marathon runners older than 45 years showed a prevalence of coronary atherosclerosis – assessed by coronary dual source CT angiography – in half of them.[61] A recent review of five original studies on a total of 862 men recreational marathon runners concluded that an actual negative lifestyle may mask the beneficial role of exercise, whereas an actual practice of endurance running may not nullify the longstanding effect of past unhealthy habits.[55] Furthermore, a comparison of runners competing in different race distances revealed a higher prevalence of coronary artery calcification in marathon and ultra-marathon runners compared to their counterparts of shorter race distances.[39]

4.6. *Are 500 marathons a lot in 30 years?*

At a first glance, more than 500 marathons within 30 years seems to be a lot. However, regarding the World Megamarathon Ranking 300+ where only marathon runners with more than 300 marathons are recorded, the runner would be actually listed around the 400th place worldwide and therefore more than 400 runners have more marathons than our subject.[62] Especially, the person with most marathons finished worldwide has already more than 3 200 marathons.[62]

Considering the studies showing an increased risk for coronary artery sclerosis in marathon runners having completed many, many marathons we must assume that all those runners with more than 500 marathons and ahead of our subject in this World Megamarathon Ranking 300+ are at risk to die of a heart attack especially since these runners are partially of a rather high age. Maybe there was a selection bias in the selection of the study subjects. In some instances, subjects with only a few marathons[48] and/or less than 200 marathons[41] were included in a study. Most likely these studies suggesting that running many marathons during lifetime will lead to a cardiovascular risk should be considered with caution. Study subjects could have smoked before their successful running career such as Jim Fixx[63] and have developed coronary artery disease later in life during their running career.

4.7. *Motivation*

The question remains about the motivation of the subject. The runner has no specific ambitions regarding a race time or a ranking in his age group. So, he makes no pressure upon himself. It has been described that marathon and ultra-marathon runners are motivated by internal psychological variables like self-esteem and personal exploration.[64] Specifically, experienced ultra-marathon runners prioritize personal achievements and health more than race time.[64–66]

4.8. *The aspect of inflammation*

The precise pathogenetic substrate for the existence of an increased coronary calcification burden among endurance athletes remains unclear.[67] We must be aware that running marathons and ultra-marathon leads to an inflammatory process[68] where a higher degree of inflammation occurs after an ultra-marathon compared to a marathon.[69] Too many weekly training units seemed to reduce the benefits of running training[70] most likely due to repetitive intense stimuli with individually too short recovery and thus persistently increased inflammatory markers.[71] High intensity exercise also impacts immune system, an increase in leukocytes and inflammatory mediators as tumor necrosis factor alpha and interleukins.[72–74] Notwithstanding, some Masters athletes may develop coronary artery calcification also due to the repetitive mechanical stress[75] exerted by exercise on the proximal coronary arteries, rather than as a result of inflammatory, lipid-rich atherosclerosis.

4.9. *Limitations, strength, and practical applications*

This is a case report, and more participants of this profile are needed for definite conclusions. A limitation of the present case study was that no information was available about the aerobic capacity (maximal oxygen uptake) and exercise intensity measures such as oxygen uptake, heart rate, rate of perceived exertion or lactate during training and race. Additionally, as this study is based on a single individual, the findings cannot be generalized to a broader population. Such information would provide a more detailed profile of the exercise stress imposed on the cardiovascular system. This is a case study and generalizations are impossible to create. On the other hand, strength of the study was the training information covering three decades of regular participation in exercise. Considering that the association of sudden death and the so-called Phidippides cardiomyopathy with strenuous exercise demanding a prolonged increase of cardiac output was already identified in the antiquity,[76] our findings may enhance our understanding of this intertemporal health issue. Finally, it is recommended that future studies analyze more athletes with similar training regimes and the exposition of CVDs.

5. Conclusion

Coronary artery disease is considered as the leading cause of sudden cardiac death in athletes $>$ 35 years of age. This case illustrates that selected master athletes may exhibit resilience to the development of exercise-related coronary atherosclerosis, likely attributable to their favorable cardiovascular risk profile, and genetic predisposition. Long-distance running per se may not directly initiate coronary atherosclerosis but rather serve as a promoter when combined with hereditary or acquired cardiovascular risk factors. Overall, high-volume endurance running appears to be safe, provided cardiovascular risk is properly assessed and risk factors are adequately controlled.

CRediT authorship contribution statement

Beat Knechtle: Writing – original draft, Conceptualization. **Sasa Duric:** Writing – review & editing, Formal analysis. **Volker Scheer:** Writing – review & editing. **Pantelis T. Nikolaidis:** Writing – review & editing. **Daniela Chlíbková:** Writing – review & editing. **Luciano Bernardes Leite:** Writing – review & editing. **Ivan Cuk:** Writing – review & editing. **Pedro Forte:** Writing – review & editing. **Matthias Wilhelm:** Writing – review & editing. **Katja Weiss:** Writing – review & editing. **Thomas Rosemann:** Writing – review & editing.

Ethics approval and consent to participate

The athlete gave his informed written consent to use all his publicly available data provided on his website. The study was approved by Ethikkommission des Kantons St. Gallen (1-6-2010). The study was implemented in accordance with the Declaration of Helsinki.

Declaration of competing interest

Beat Knechtle is an Editorial Board Member for Sports Medicine and Health Science and was not involved in the editorial review or the decision to publish this article. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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