What makes a 97-year-old man cycle 5 000 km a year?

Albert Einstein

"Life is like riding a bicycle. To keep your balance, you must keep moving"

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ABSTRACT

Background: The nature versus nurture debate is one of the oldest issues in the study of longevity, health and successful aging. *Objective*: We present a 97-year-old man (IK) as an example of the effects of habitual exercise on the aging process. *Methods*: Extensive assessments included medical examinations, interviews, musculoskeletal structure, performance characteristics, cognitive function and gut microbiota composition. *Results*: IK suffers from iatrogenic hypogonadism, prostate cancer, hypothyroidism and a history of deep popliteal thrombosis. Notwithstanding, he cycles up to 5000 km a year and participates in competitive sports. His musculoskeletal properties, athletic performance, cognitive function and gut microbiota are outstanding. Some traits even exceed those seen in middle-aged men. *Conclusions*: His long-term physical and intellectual active lifestyles combined with extensive social interactions have most likely contributed to his exercise capacity, despite his medical history.

Short title: Successful aging in the older athlete

Keywords: Aging, Cognition, Healthy aging, Lifestyle, Longevity, Sports

INTRODUCTION

Only 362 (0.9%) of all Finnish men born 1918 were still alive in 2014 [1]. Most of those who survive to age 90 have cardiovascular (ca. 80%), musculoskeletal (47%), cognitive (26%), and/or neurological (12%) conditions that limit their functional ability for independent living [2]. Previous studies have shown that, after age 80, a lifestyle that incorporates regular endurance training helps to maintain optimal functioning of numerous physiological systems [3]. Besides aerobic capacity, adequate muscle strength is crucial for functional status [4] and might, independent of aerobic capacity, increase longevity [5]. However, 'rest in old age' is a common paradigm and many elderly people remain well below their functional capacity potential owing to a sedentary lifestyle [6]. In this case report, we argue that the exceptional physical and cognitive functioning of a 97-year-old man (IK), despite chronic diseases, is due to the combination of healthy lifestyle factors that he has maintained from his early years onwards (**Figure 1**).

METHODS

Information on IK's family background, occupational history, living habits, social contacts, physical training and competition history were obtained through interviews. Competition performances were verified from official statistics. General health status was evaluated by a physician. Copies of earlier medical records, including the results of a 10-min exercise-tolerance test on a cycle ergometer were obtained from IK. Anthropometry, body composition (DXA), functional capacity were

assessed and muscle biopsies taken as described elsewhere [7]. Life-satisfaction was evaluated with Allardt's scale [8]. Cognitive function was determined by the CERAD and Trail-making (TMT) tests [9] and psychomotor speed with reaction time tests [10]. Gut microbiota composition was derived from sequences of the 16S rRNA gene in fecal DNA samples using ultra-high-throughput microbial community analysis on the Illumina MiSeq platforms [11]. The Ethics Committee of the Central Finland Health Care District approved the study. IK provided a written informed consent to use his personal data, including medical records, photographs and test results.

RESULTS

Life and occupational history

In January 2015, IK was 97, an age well above the average 43-year life expectancy of Finnish men born in 1918 [12]. IK married in 1943, had a family and was widowed in 2007. His parents died when he was young (his mother died in 1924 from pneumonia at age 37 and his father in 1930 from colon cancer at age 43). At age 12, IK and his siblings lived in foster families of similar socio-economic background to his biological family and lived in the countryside. He joined the army during the war (1939-1945), and obtained an engineering diploma in 1948. Most of his professional career (1950-1973) was spent as a land surveyor. In 1974, he became an associate professor at Helsinki University of Technology and retired in

1981. After retirement, IK maintained his interest in alcohol-related health issues, occasionally lecturing on healthy living.

IK is optimistic and has a positive attitude to work, colleagues, friends and life in general. To date, he is still living independently, using a bicycle and car to shop and meet friends, and traveling by train to participate in athletic competitions. He regularly takes part in weekly meetings with other war veterans. Other hobbies include singing in a church choir, piano playing and reading.

Health characteristics

IK was healthy throughout most of his childhood and adult working years. He has never smoked or used alcohol. He had gallstones in 1968 and spondylosis of the cervical/lumbar spine in 1978. He has been operated for left and right carpal tunnel syndrome and in 2010 was diagnosed with hypothyroidism. Prostate cancer was detected and treated effectively with radiotherapy in 2004, but recurred in 2012. The orchiectomy resulted in secondary hypogonadism and serum testosterone concentrations below the detection level. He had deep venous thrombosis twice (2012 and 2013), and now requires continuous oral antithrombotic medication. The medical records from the last two decades indicate that his resting blood pressure (130–145/74–80 mmHg), serum total cholesterol (4.4–4.9 mmol/L), triglycerides (1.3–1.4 mmol/L), S-HDLC (1.1–1.4 mmol/L), S-LDLC (2.8–3.2 mmol/L) and fasting blood glucose (5.7–6.1 mmol/L) values have all been in healthy levels.

IK has a well-balanced gut microbiota composition; he had a much lower proportion of Gram-positive *Firmicutes*, but a higher proportion of Gram-negative *Bacteroidetes* bacteria, than obese subjects (unpublished observations). Three-day food diaries indicated a 27% decline in daily total energy intake from 2270 kcal (carbohydrates 58%, protein 14% and fat 28%) in 2002 to 1650 kcal (carbohydrates 50%, protein 18% and fat 32%) in 2014.

Life-time exercise habits

From age six onwards he began his lifelong participation in sports, including cycling, track and field athletics, bandy ball, Finnish baseball, orienteering, cross-country skiing and gymnastics. During middle-age, he focused more on endurance-type sporting activities. After retirement, he resumed track and field athletics and continued competitive orienteering and skiing. At age 60, his major event was the decathlon. With advancing age, he shifted his interest to hurdles and lately to short sprints, long jump, triple jump, shot put and walking. The number of competitions he entered after age 70 is shown in **Figure 2a**. In 2000 and 2009, he was European and world champion hurdler. IK holds the world record for the 300-m hurdles in the 90-94 age group, and indoor world records for the 3000-m walk in the age groups 90-94 and 95-99. His jump performance declined significantly after age 75, whereas his sprint performance was not markedly impaired until his 90s (**Figure 2b and c)**. Furthermore, his annual outdoor cycling distances at ages 94-96 were 3900 km, 3700 km and 5200 km, respectively. By the end of November 2015, he had again already covered over 5100 km. Personal fitness and setting an

encouraging example that older people can do regular exercise even when suffering from severe diseases, are important reasons for IK to participate in sports. He emphasizes that external support is important to remain active.

Physical, musculoskeletal and performance characteristics

Between age 20 and 97, his height declined from 168 to 162 cm, but his body mass remained relatively stable (between 67 and 74 kg). At age 95, he had a lower body mass index (IK: 26.5 vs. 45-year-old men: 27.3 kg/m^2), and a higher proportion of fat-free mass (IK: 74.6 vs. 45-year-old men: 73.2%) and bone mass (IK: 4.1 vs. 45-year-old men: 3.8%) per unit of body mass than the average 45-year-old man. His total calf muscle cross-sectional area (76 cm^2) remained unchanged between 2002 and 2012. His decline in maximal muscle force was only a third of his loss of explosive strength and his average sprint speed over 60 and 100 m decreased by 31% and 37%, respectively, between 2002 and 2012 (**Figure 3**). The proportion of fast type II fibers in *m. vastus lateralis* decreased from 43% in 2002 to 19% in 2012. At age 86, his maximal workload in the exercise-tolerance test was 150 W, peak heart rate 139 b/min, and peak blood pressure 180/80 mmHg. His estimated Vo_{2max} was 27 mL/kg/min (7.7 MET). Six minutes later, his test blood pressure (130/80 mmHg) and heart rate (80 b/min) had returned to resting levels.

Cognitive function

Based on the CERAD results, his overall global cognition, language and memory were 15-50% better than those in other non-demented 95-year-olds [9]. IK's motor speed (TMT-A, 36 s) and mental flexibility (TMT-B, 126 s) scores surpassed those of age-matched subjects (85±43 vs. 241±78 s, respectively) [9]. His simple reaction time (visual signal; 451 ms) and choice reaction time (657 ms) were comparable to those in 31- to 35-year-old men (473±138 vs. 669±117 ms) in our laboratory using exactly the same tests and equipment [10]. Magnetic resonance imaging of his brain in 2015 revealed normal cortex structures, normal brain vasculature without microinfarcts or bleeds, but an age-related reduction in white matter volume.

DISCUSSION

We have described a 97-year-old man who still actively participates in athletic competitions, cycles up to 5000 km a year and lives independently, despite age-related medical conditions such as prostate cancer and hypothyroidism. This individual is an example of successful aging, and the comprehensive documentation of his life, career and sporting activities may help uncover the lifestyle factors responsible for high-level functioning in old age.

The exceptional functional capacities, health and longevity of IK may be attributable to his genetic constitution. Indeed, as a number of twin and family studies suggest that during aging various aspects of physical functioning, level of leisure time physical activity and health are

influenced by genotype [13]. While genetics may play some role, it is unlikely the most important factor, as he is the only one of his family who has lived to a very old age. We suggest that rather than a fortunate set of genes, IK's exceptional functional capacity, health and longevity is primarily attributable to a healthy lifestyle that includes high activity levels, a good diet that is associated with an advantageous microbiota composition, continued social interactions and the absence of other harmful risk factors.

IK's aerobic power at age 86 (27 ml/kg/min) was within the range reported for octogenarian lifelong endurance athletes [3]. His explosive muscle strength and speed performance, but not muscle mass, had decreased between age 82 and 92. This decline in rapid force production and sprint performance was probably due to the shift towards a slower fiber-type profile. Nevertheless, at 97, IK has no difficulties in daily life tasks, such as climbing stairs, and can even run a 100-m race. It is likely that his continued physical exercise has not only helped to overcome the potential negative effects of hypogonadism, hypothyroidism and prostate cancer, but also enabled him to cycle up to 5000 km a year and participate successfully in athletic competitions.

In 165 59-81-year-old men and women, high aerobic fitness was associated with larger hippocampal volumes and better spatial memory [14]. This and other studies suggest that exercise can reverse or attenuate the age-related cognitive decline. IK's overall global cognition, language and memory were 15-50% better than those reported in non-demented 95-year-olds and the difference in performance was even larger

in TMT tests requiring processing speed and executive functioning [9]. The maintenance of excellent cognitive abilities may partly be associated with lifetime exercise training. However, other factors such as educational background, social relations, studying and musical training into old age may also have contributed to IK's high cognitive function [15].

These data indicate that this elderly athlete has maintained exceptional overall physical and cognitive capabilities, and psychologic well-being, despite hypogonadism and other pathological conditions. His example suggests that an active lifestyle with a positive mental attitude and good health habits is the key to the successful aging.

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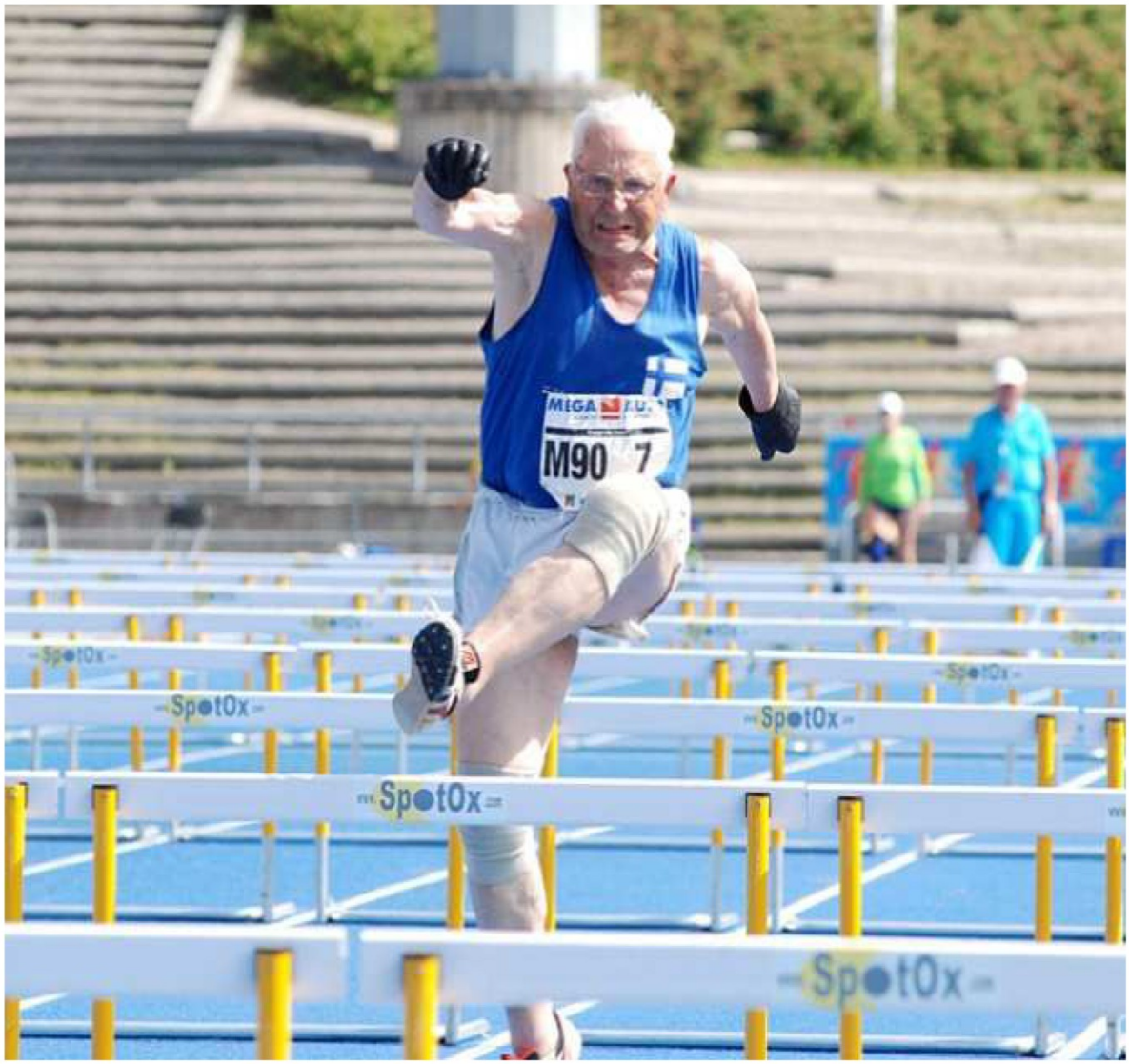
FIGURE LEGENDS

Figure 1 IK at age 91 in the World Masters Athletic Championships (2009, Lahti, Finland. Photo: Ken Stone/Masterstrack.com).

Figure 2. Frequency of participation in competitive sport events (*a*, dot represents competition times at given age) and personal best results in sprinting (*b*, dot represents speed records in seconds at given age) and jumping (*c*, dot represents jumping records in meters at given age) between the age 65 and 97.

Figure 3. Percentage change in maximal and explosive muscle strength, and in sprint performance over 10 years (from 2002 to 2012, age 85 to 95). Maximal isometric strength of right leg knee extensors (MVC_{KER}) and left leg knee extensors (MVC_{KEL}); right knee flexors (MVC_{KFR}) and left knee flexors (MVC_{KFL}); arm extensors (Bench Press); maximal rate of force development in isometric bilateral leg extension (RFD_{BLE}); vertical countermovement jump height



(CMJ); standing start triple jump (STJ) and running triple jump distance (RTJ); and average speed in 60- and 100-m sprint.

Figure 1.

Figure 2.

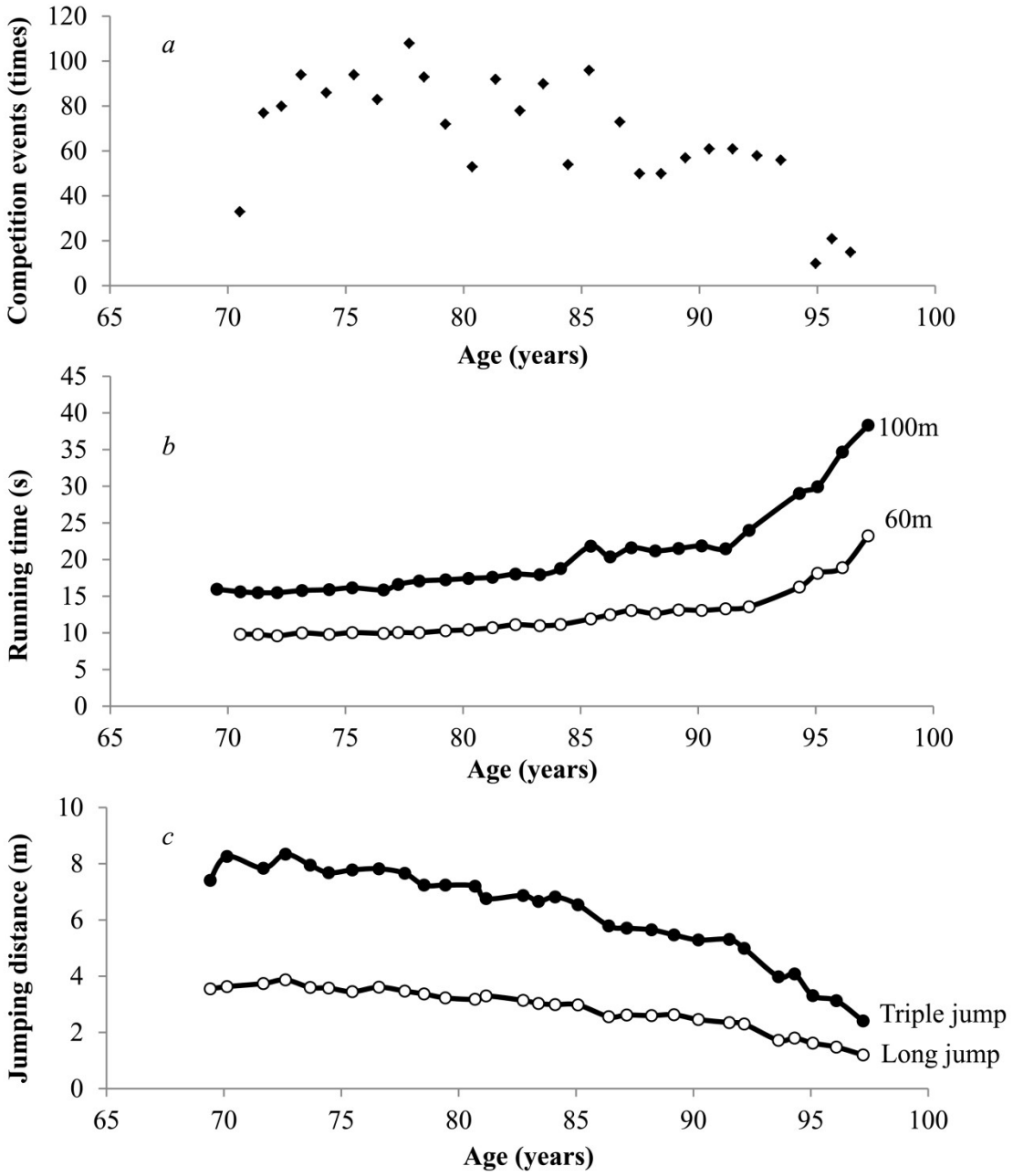
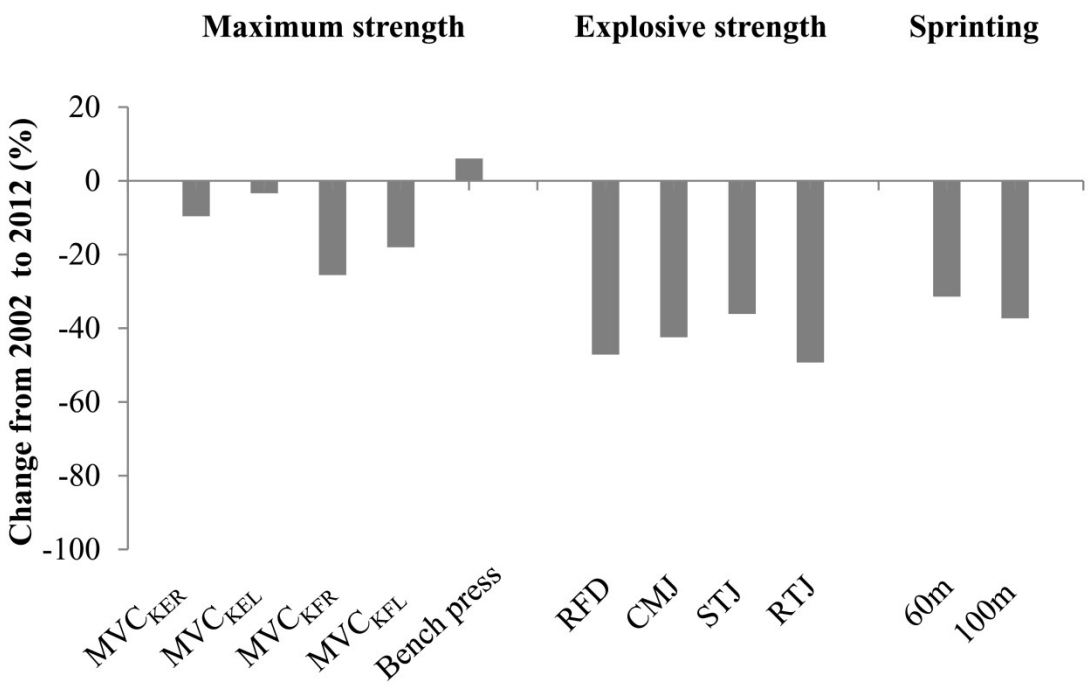

a
Competition events (times)
120
100
80
60
40
20
0
65
70
75
80
85
90
95
100
Age (years)
b
Running time (s)
45
40
35
30
25
20
15
10
5
0
100m
60m
Age (years)
c
Jumping distance (m)
10
8
6
4
2
0
Triple jump
Long jump
Age (years)

Figure 3.


Maximum strength
Explosive strength
Sprinting
Change from 2002 to 2012 (%)
20
0
-20
-40
-60
-80
-100
MVC KER
MVC KEL
MVC KFR
MVC KFL
Bench press
RFD
CMJ
STJ
RTJ
60m
100m