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Article

Genomic instability in a former high-performance athlete

Inestabilidad genómica en un exatleta de alto rendimiento

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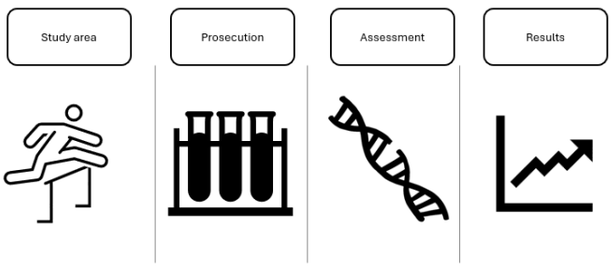
Abstract

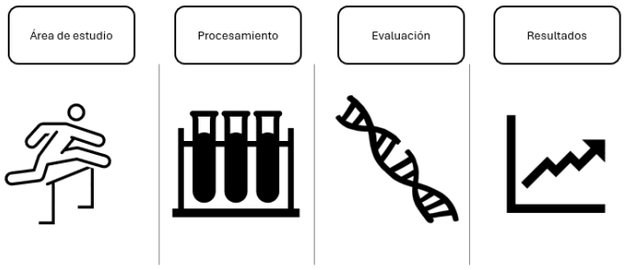
This study investigated the impact of high-intensity exercise on DNA damage. A former high-performance athlete was compared with individuals who performed moderate exercise, evaluating genetic damage using the comet single-cell gel electrophoresis assay in blood samples. The results indicated greater DNA damage in the former athlete, suggesting a possible relationship between exercise intensity and genetic damage. However, due to the limited sample size, larger studies are required to confirm these findings and determine whether factors such as type of sport or other variables could influence the results.



Quality of life, Sports, Health

Resumen

Este estudio investigó el impacto del ejercicio de alta intensidad en el daño al ADN. Se comparó a un exatleta de alto rendimiento con individuos que realizaban ejercicio moderado, evaluando el daño genético mediante el ensayo cometa en muestras de sangre. Los resultados indicaron un mayor daño al ADN en el exatleta, sugiriendo una posible relación entre la intensidad del ejercicio y el daño genético. Sin embargo, debido al tamaño limitado de la muestra, se requieren estudios más amplios para confirmar estos hallazgos y determinar si factores como el tipo de deporte u otros variables podrían influir en los resultados.



Calidad de vida, Deporte, Salud

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Introduction

Deoxyribonucleic acid (DNA) damage can be the product of agents internal or external to the cell. It can be observed in specific gene sequences, in labile regions called fragile sites, or can itself in specific chromosomal alterations, sometimes related to certain diseases and cancer (Feng & Chakraborty, 2017).

Exercise, despite its positive health effects, induces an increase in the production of reactive oxygen species (ROS), a type of molecule that is harmful to cells. This increase is a physiological response of the body to training and is necessary for the muscles to adapt and strengthen (Santovito et al., 2023).

In other research it has been shown that a moderate physical activity workload exerts positive effects in terms of reducing DNA damage (Soares et al., 2015). On the other hand, it is specified that high-performance sport can generate a negative physiological response for the health of athletes (Medrano Plana et al., 2019).

As athletes advance in their career, intense training places greater demands on their bodies, requiring not only good general health (Jalalova, 2024). However, to our knowledge, there are no reports of studies that quantify DNA damage in high-performance athletes.

There are various techniques to evaluate and quantify DNA damage, the comet assay being one of the most widely used due to its ability to provide detailed information on the degree of damage to the genetic material of individual cells.

With this methodology, single-strand damage is quantified in alkaline labile sites in the DNA and is interpreted by the length of the cauda, that is, the longer the cauda of the comet, the greater the damage to the DNA. These measurements can be subjective or quantified with image analysis software.

The main objective of the present study is to report a high-performance athlete in whom high values of DNA damage were found using the comet technique compared with two normal controls who only performed moderate aerobic exercise.

Methodology

Below is a detailed description of the participants included in the study:

Study subject: 29-year-old male, body mass index (BMI) 22.1, no medical history, denies smoking, alcohol intake, recent COVID, drug use, exposure to mutagenic agents at work and home, as well as radiotherapy and chemotherapies. Dedicated to the sport of high-performance Karate, practiced for eight years training 10 h per week, having presence in state, regional, national, and international competitions.

Control 1: 25-year-old male, BMI 23.5, no pathological history, denies smoking, medication intake, recent COVID, drug use, exposure to mutagenic agents at work and home, excessive alcoholism, radiotherapies, and chemotherapies. Moderate impact athlete in long-distance and middle-distance swimming events.

Control 2: 26-year-old male with a BMI of 20.5, no medical history, denies smoking, medication intake, recent COVID, drug use, exposure to mutagenic agents at work and home, excessive alcoholism, radiotherapies, and chemotherapies. Moderate impact athlete in middle distance swimming events.

Surveys were applied to the study subject and controls to know some anthropometric data such as weight, height, with which the BMI was calculated, using the Quetelet formula: weight of a person in kilograms divided by the square of the height in meters, we used the International Medical Corps (lMC) classification proposed by the World Health Organization (WHO).

The athletes were also asked about their medical history of chronic degenerative diseases such as cancer, hypertension, diabetes, and occupational or household exposure to known teratogens, radiotherapies, or chemotherapies. If they recently had COVID and if they took any medication daily. Intake of tobacco, alcohol, drugs, or any other product that could damage DNA stability was asked.

Subsequently, the comet assay was performed on the subject and controls, using lymphocytes from a peripheral venous blood sample anticoagulated with EDTA.

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Written informed consent was signed by all participants and the study is approved by the ethics and research committee of the Mexican Institute of Social Security (IMSS) with registration number R-2024-785-024. The methodology proposed by Cortés-Gutiérrez and collaborators (2012) was used.

The leukocytes were embedded in previously prepared agarose slides. The slides were immersed in different solutions to lyse the cells and expose the DNA. Subsequently, they underwent electrophoresis, at 23 V, where the DNA fragments form a cauda. The slides were fixed in a sequence of alcohols and allowed to air-dry for 24 h, protected from dust and light.

They were then stained with propidium iodide (PI) at a concentration of 1:1 and observed under a fluorescence microscope with a Texas red filter, specific for the light spectrum of the dye used. Photographs of the comets were taken on an Axio Scope Zeiss® microscope, equipped with a high-resolution camera.

These photographs were analyzed with image analysis software Image J version 1.4.3.6.76. The measurements were made taking as a starting point the center of the cell nucleus and up to the last fragment of the comet's cauda and were expressed in microns (µm). One hundred cells per study subject and controls were analyzed and average values were calculated in Microsoft Excel.

Results

The average of the study subject's measurements was 141 ± 16 µm (Figure 1).

Box 1

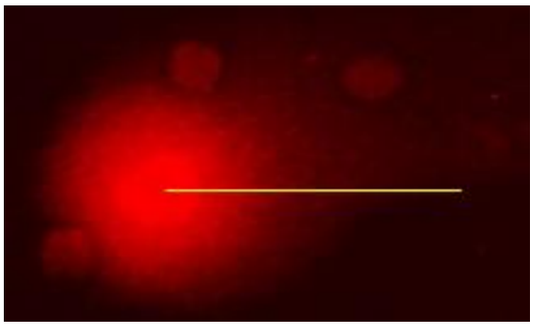

Figure 1

Alkaline comet from peripheral blood leukocytes of the study subject, a former high-performance athlete, stained with PI. Comet with a length of 363 µm.

Source: Own elaboration

The average of comet measurements in control 1 was 21 ± 5 µm. (Figure 2).

Box 2

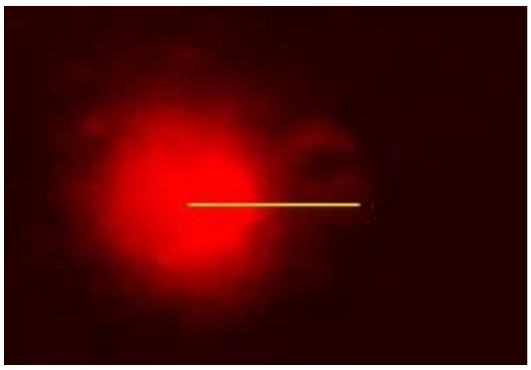

Figure 2

Alkaline comet of peripheral blood leukocytes from control subject 1, stained with PI. Comet with a length of 30 µm.

And finally, the average comet measurements from control 2 were 30 ± 6 µm (Figure 3).

Box 3

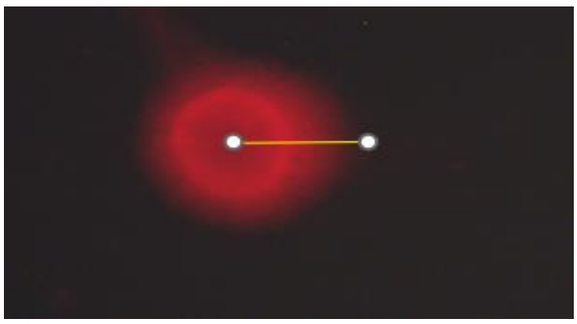

Figure 3

Alkaline comet from peripheral blood leukocytes stained with PI from control subject 2. Comet with a length of 23 µm.

Source: Own elaboration

Discussion of Results

Analysis of the comets revealed significantly higher average DNA damage in the former high-performance athlete compared to controls. The absence of other known risk factors suggests that high-performance physical exercise, practiced over a prolonged period, could have contributed substantially to the induction of this genomic damage, possibly through mechanisms associated with oxidative stress and inflammation.

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Similar results were found by Kim and collaborators (2018), in which these authors established that high-intensity and prolonged aerobic exercise generates DNA damage due to the duration and intensity of the exercise in athletes who practice triathlon.

This may be because exhaustive exercise can generate muscle injuries that imply an oxidative increase in immune cells, which leads to a rapid formation of free radicals and subsequently generates oxidative damage, which produces muscle fatigue and weakness, lipid peroxidation, mitochondria dysfunction, and DNA mutations (Steinbacher & Eckl, 2015).

However, authors such as Cash and collaborators (2014) refer to that the practice of activity experiences a marked increase in DNA damage immediately after performing acute aerobic exercise, and that this increase remains significant in the future, over the course of 2 h and during the first day after physical activity; however, the maintenance of DNA damage is not observed during the period from 5-28 days after exercise.

This pattern suggests a unique temporal response of the genetic material in the face of stress induced by exercise. These findings obtained are consistent with the idea that inadequate and non-individualized training planning may have generated excessive stress in the body, favoring DNA damage.

The absence of previous studies in similar populations limits the ability to establish a definitive causal relationship; however, the data obtained suggest that high-intensity and prolonged physical exercise, when not properly controlled, could represent a risk factor for health, long-term effects on athletes, determining DNA damage.

There are studies in which the potential of microRNA as biomarkers to evaluate sports performance and understand the molecular mechanisms behind training adaptation is evaluated (Paulucio et al., 2024).

This study constitutes a basis for future research in athletes and former high-performance athletes, since it will allow us to more precisely visualize how the body responds at a cellular level to various training stimuli, considering variables such as intensity, density, volume, frequency, and type of training.

Likewise, it will be essential to establish rigorous control groups and control external factors such as nutrition, to isolate the effect of exercise on DNA damage.

Because there is, to the best of our knowledge, no history of serious illnesses, ingestion of medications, or radio- or chemotherapies, etc., we rule out that DNA damage could derive from external physical factors and be due to training.

It is necessary to increase the number of participants of former high-performance athletes to corroborate the results obtained in the present study and to carry out appropriate statistical studies to demonstrate an association.

Conclusion

While the results suggest a relationship between high-performance exercise and DNA damage, it is important to emphasize that a definitive causal relationship cannot be established with the current data; the number of subjects needs to be increased.

Declarations

Conflict of interest

The authors declare that they have no conflict of interest. They have no known competing financial interests or personal relationships that could have influenced the article reported in this article.

Authors' contribution

The contribution of each researcher in each of the points developed in this research was defined based on:

Castañeda-Aguirre, Víctor Elías: Generation of the research idea and data collection.

Rangel-Colmenero, Blanca Rocío: Mentoring and supervision of data collection.

García-Vielma, Catalina: Mentoring and supervision of data collection.

Cortes-Gutiérrez, Elva Irene: Standardization of the Kite online educational assessment test and advice.

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Availability of data and materials

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Abreviaciones

Abbreviations

µm	Microliters
BMI	Body mass index
DNA	Deoxyribonucleic acid

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Basic concepts

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