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Epidemiological characterization of high-risk cardiovascular factors using data collected "Smart Health Kiosks" in participants of the "Por Tu Corazón" project: intergender analysis through artificial intelligence strategies

Caracterización epidemiológica de factores cardiovasculares de alto riesgo utilizando los datos recolectados de los "Kioskos de la Salud Inteligentes" de participantes del proyecto "Por Tu Corazón": un análisis intergénero a través estrategias de inteligencia artificial

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Abstract

According to the World Health Organization (WHO), cardiovascular diseases are the leading cause of death worldwide. Cardiovascular risk (CVR) is defined as the probability of developing cardiovascular disease (coronary heart disease, cerebrovascular disease) or peripheral arterial disease in a defined period, usually 10 years; whereas a "cardiovascular risk factor" only corresponds to a biological characteristic or comorbidity present in a person that is independently related to development. Recently, the start of the "Por Tu Corazón" ("For Your Heart) project has been proposed, an initiative of the Upjohn division of Pfizer whose objective is to raise awareness in the population about cardiovascular risk factors and the importance of early detection as part of the prevention of cardiovascular diseases. This project proposes the installation of digital kiosks for measuring cardiovascular risk in some companies with the support of the Business Council for Health and Well-being to offer their collaborators a diagnosis indicating the probability that a cardiovascular event will occur (cardiovascular risk). 734 workers were evaluated anonymously and voluntarily. This database represents an opportunity to learn about the main factors that generate an estimate of risk in a sample of the economically active population. This database can be efficiently analyzed. This project proposes the analysis of the database generated from cardiovascular risk factors and the calculation of cardiovascular risk obtained through the " Por Tu Corazón Project " and the comparative differences between the distinct genders.

Cardiovascular diseases, CVD, Cardiovascular risk, cardiovascular risk factors, For your heart, Database, Analysis by artificial intelligence, Economically active population

Resumen

De acuerdo con la Organización Mundial de la Salud (OMS), las enfermedades cardiovasculares son la causa principal de muerte a nivel mundial. Se define como riesgo cardiovascular como a la probabilidad de desarrollar una enfermedad cardiovascular (enfermedad coronaria, enfermedad cerebrovascular) o enfermedad arterial periférica durante un periodo definido de tiempo, usualmente 10 años; mientras que "el factor de riesgo cardiovascular" solo corresponde a una característica biológica o comorbilidad presente en una persona que esta independientemente relacionada a su desarrollo. Recientemente, se ha propuesto el inicio del Proyecto "Por tu Corazón", una iniciativa de la Upjohn, división de Pfizer, cuyo objetivo es concientizar de la población respecto a los factores de riesgo cardiovascular y la importancia de la detección temprana como parte de la prevención de las enfermedades cardiovasculares. Este proyecto propone la instalación de quioscos digitales para medir el riesgo cardiovascular en algunas compañías con el apoyo del Consejo Empresarial para la Salud y el Bienestar para ofrecer a los colaboradores un diagnóstico indicando la probabilidad que ocurra un evento cardiovascular (riesgo cardiovascular). Se evaluaron 734 trabajadores de manera anónima y voluntaria. Esta base de datos representa una oportunidad de aprender respecto a los principales factores que generan un riesgo estimado en una muestra de la población económicamente activa y que sean analizadas. Este proyecto propone un análisis de la base de datos generada desde los factores de riesgo cardiovascular obtenidos a través del "Proyecto Por Tu Corazón" y sus diferencias comparativas entre los distintos géneros.

Enfermedad cardiovasculares, ECV, Riesgo cardiovascular, Factores de riesgo cardiovascular, Por tu corazón, base de datos, Análisis por inteligencia artificial, Población económicamente activa

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Introduction

In Mexico and in the world, health challenges such as overweight, obesity, diabetes, high blood pressure, hyperlipidemia, and other chronic non-communicable diseases (NCDs) such as cardiovascular diseases, different types of cancer and mental disorders are being faced. Particularly in Mexico this is due of both to the current demographic change in its population (inversion of the population pyramid), as well as the adoption of unhealthy habits, such as sedentarism, poor diet, smoking, and alcohol consumption (1).

The cardiovascular diseases (CVD) are a group of disorders related with both the heart and the blood vessels, such as the coronary heart disease, cerebrovascular disease, the peripheral arteriopathies, rheumatic heart disease, heart malformations, deep vein thromboses and pulmonary embolism (1).

Within the CVDs, the ischemic diseases, generated by an oxygen supply/necessity imbalance in either the myocardium or the brain, provoke the highest mortality rates within the CVDs, and the most frequent cause of them are a vessel obstruction often due to atherosclerosis, resulting in anoxia and could trigger a heart attack or a cerebrovascular disease (1).

Heart attack or a cerebrovascular disease are generated by a by a combination of risk factors, such as smoking, unhealthy diets, physical inactivity, harmful use of alcohol, high blood pressure (HBP), diabetes mellitus (DM), and hyperlipidemia (HLD) (2).

Theorical framework

According to international health organizations, the CVDs are becoming one of the mayors if not the major mortality cause worldwide. The World Health Organization (WHO) reports that in 2008, the CVDs are the main death cause in the world, causing 30% of the worldwide deaths (17.3 million deaths) and, furthermore, a coronary event and cerebrovascular event occur every four and five seconds respectively in the world. Approximately 1.5 to 5% of the population with systemic arterial hypertension die directly from this condition each year (1,3,4).

Moreover, it is estimated that 23.3 million CVD-related deaths will occur by 2030 (22).

Additionally, the Pan American Health Organization (PAHO) estimates that 20.7 million deaths will occurs in America within the next ten years from cardiovascular diseases attributable to arterial hypertension, an important cardiovascular risk component. Respecting, Latin America and the Caribbean, CVDs account for a third of all deaths associated with Chronic Non-Communicable Diseases (CNCD) (3,4,5).

Due to the former situations, the risk calculation of the asymptomatic population respecting suffering either atherosclerosis or ischemic disease symptomatically is very important. Additionally, factors such as age, gender, family history, poor diet, smoking, overweight, obesity, systemic arterial hypertension (SAH), dyslipidemia (DLP) and DM are highly consequential for CVD development (6-10).

As a result, the development of different approaches, including CVD risk calculation algorithms is necessary.

The definition of risk factor, originally coined by the Framingham Health Study (FHS), is a measurable element or characteristic that is causally related to an increase in the frequency of a disease and constitutes an independent and significant predictive factor of the risk of contracting a disease. These consist in both behaviors such as physical inactivity, smoking, unhealthy diet and alcoholism which can manifest on the people as HBP, HLD, hyperglycemia, and having overweight or obesity. In contrast, other activities such as smoking cessation, salt and alcohol reduction, regular physical exercise, and consuming fruit and vegetables have shown to reduce the risk of CVD. On the other hand, drug treatment may be required (2,11-12).

Likewise, underlying determinants of chronic disease exist such as poverty, stress, and hereditary factors, which reflect the changing socioeconomic environment. Hence, enabling environments to ensure the affordability and availability of healthy options is pivotal.

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The definition of Cardiovascular Risk (CVR) is the probability of developing CVD with a period of time *usually 10 years, differing from the Cardiovascular Risk Factors which are biological characteristic or comorbidities independently related to the development of a CVD in a particular person (11-14).

Due to the preventability of CVD through the modification of behavioral risk factors, such as smoking, unhealthy diets and physical activity, the risk mitigation of people with CVD or high CVR through counseling services or drug administration is essential, and, therefore, the ability to assess the CVR of the individuals (2).

To the CVR assessment, the calculation created in the Framingham Health Study, it will be referred as the Framingham model (FM), is the most used, being capable of calculating both morbidity and mortality coronary risk within 10 years, however due to the FM's risk overestimation in many European countries, the SCORE project have been implemented in recent years. Additionally, the algorithm developed by the American College of Cardiology / American Cardiology Association (ACC/ACA), which assess the CVR within 10 years in three categories (high, medium, and low), is also highly accepted (9,10,15-18).

Particularly in Mexico, non-transmissible chronic diseases have been characterized epidemiologically thanks to national health surveys, showing a prevalence increase of obesity, hypercholesterolemia, arterial hypertension, and metabolic syndrome between 1993-2016. Therefore, the necessity CVR assessment through time is pivotal.

Due to the former, technological strategies have been developed for the CVR monitoring of the Mexican population.

The Center for Scientific Research and Higher Education (CICESE after its Spanish acronym) have created automatized health kiosk, later known as Smart Health Kiosk (KIS after its Spanish acronym) design to generate health awareness, to promote the prevention of CVD (see the Figure 1).

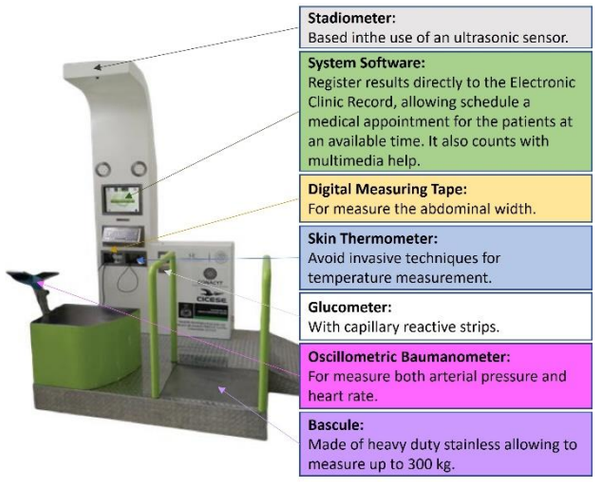

Figure 1 Smart Health Kiosk (KIS) and its features

The KIS main function is to recollect somatometric and clinical data, including abdominal circumference, temperature, height, weight, blood pressure, glycaemia (glucose in blood) and blood lipid profile, due to the enabling of the middleware adequate for rapid tests, in addition to behavioral data linked with the CVR. The system relies on a friendly interface and multimedia guidance and has a is capable of assess the CVR with the algorithm adopted by the ACC/ACA, which deliver to the user and then store encrypted in its system for further analysis.

Based in this technology, the division of Pfizer, Upjohn, in collaboration with the CICESE initiate the "*Por tu Corazón"* project (For your heart) as an awareness strategy respecting CVDs. This project consists in two phases: (1) the KIS installation for CVD assessment to the employees, and (2) the provision of information by experts with the support of the Business Council of Health and Wellbeing for communicate both the importance of the heart care and how to do it (20).

Then the results will be delivered to the respective participant, inviting them to realize a more wholesome medical diagnosis and providing them with recommendations to avoid the development of CVR.

Furthermore, the system will encrypt the data will and store only the data regarding the clinical condition and excluding any personal information, generating a case registry to each participating company. Subsequently, the database will be statistically processed to construct a CVR-status map of Mexico (20).

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The project will include workers with ages between 30 and 74 years from Guadalajara, Monterrey and Mexico City, and the expected total population is of at least 15,000 subjects at the end of the project (20).

Despite frustrating for a lot of physicians due to their complicated utilization, electronic medical records (EMR) have improved the data availability and now is considered part of Big Data, even if previous analysis, interpretation, and transformation is needed to acquire clinical value. EMR offers unprecedented opportunities which includes the development of new technologies for even healthcare automatization, making the EMR an very unexploited tool in the healthcare field (21-25).

Additionally, the use of Artificial Intelligence (AI) such as Artificial Neural Network (ANN) and Machine Learning (ML) is pivotal. ML has the potential to processing immense quantities of data and to be trained with the use of millions of records without attention gaps, provide comprehensive solutions for multi-view data, and generate predictive modeling with specific requirement by extracting and learning from patterns in the data (24,26-30).

Additionally, ANN have the advantage of their learning capacity due to multilayer neural networks with superior performance to traditional ML techniques due to the ability of automatic learning characteristics with greater complexity and representations. As a result, it encodes characteristics that researchers may not have previously known about (27).

The statistical features in the analysis are also to be considered. The least known characteristic to evaluate is the error which is measurable by the mean square error (R MSE) and / or the mean absolute relative difference (MARD). 31 On the other hand, the area under the receiver operating characteristic curve (AROC) allows to measure performance and comparing it between different models (23,32–34).

However, to understand the clinical applicability of the developed models, report other performance metrics such as sensitivity and specificity is needed, and, therefore, must be included along with the metrics to evaluate the model (30).

In addition, the Matthews Correlation Coefficient (MCC) values and the Clarke Error Grid (CEG) percentages will be reported. The MCC is a metric that combines the confusion matrix into a single value and is generally regarded as a balanced measure, even for unbalanced classification problems. The MCC index returns a value in the range of [-1, 1], where 1 is a perfect prediction and –1 is a misclassification. The CEG metric assesses the clinical significance of the deviation from the estimated values. The CEG uses a Cartesian diagram divided into five regions. The predictions within regions A and B are clinically acceptable, while even in the C, D and E regions are potentially dangerous and are considered clinically significant errors. (27.30)

Justification

Cardiovascular risk is an attempt to predict the future, based on mathematical algorithms following prospective studies to predict that individuals will develop cardiovascular disease throughout their lives, in a predetermined period. (19).

Since cardiovascular diseases are the main causes of morbidity and mortality in the Mexican population, it is of great interest to analyze the data obtained through the KIS regarding risk factors and cardiovascular risk calculation, which were obtained through the Health Kiosk to be used in the “ Por Tu Corazón Project ”. Analyzing a database obtained from workers in Mexican institutions will help to have an epidemiological overview of importance for public health and occupational health. The present project proposes to carry out this analysis through artificial intelligence strategies, which can help to observe unexpected and interesting association patterns for public health.

Problem

What are the main factors associated with the presence of cardiovascular risk (high, medium or low) in workers from various institutions in Mexico that participate in the *“Por Tu Corazón”* project?

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Objective

To establish the initial outcome of the *"Por tu Corazon"* Project respecting the CVDs health position on the work environment from diverse institutions with information collected through "Smart Health Kiosks" (KIS, after its Spanish acronym) in a sample of 734 persons.

Research methodology

The collection of real-world data using large platforms can be buggy, that is, despite the volume, the data can be missing or mislabeled. (24)

Data obtained in the clinical setting sometimes show missing data and erroneous information. This results in non-physiological discontinuities. To mitigate these events, the data must be processed. (27)

The data collected for this project is retrospective during the "*Por tu Corazón"* project capture period, where all patient identification information is rendered anonymous before the data is provided to researchers. These data include demographic information, anthropometric values, clinical laboratory measurements and some relevant clinical aspects. In addition to these individual data, there is a calculation of the cardiovascular risk of each patient.

Sample

The sample of 734 individuals participating in the initial phase of the *"Por tu Corazon"* Project. The former sample features consist in adults between 30 and 74 years of age, from the central, northern and bajío regions in public and private institutions that participate in the "*Por tu Corazón"* Project. The calculation is based on the number of variables and observations for those variables. Proposing as a minimum requirement the existence of 10 observations for each variable. (43–46)

Results

From the sample of 734 individuals, there was a proportion of 45.0% of males and 55.0% of females (see The Figure 2).

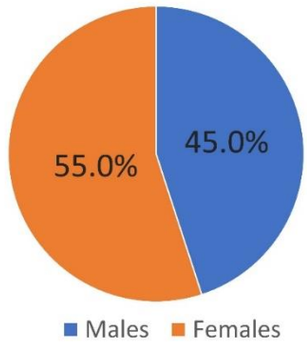

Figure 2 The proportion of males and females

All the data was segregated between genders. The somatometric and clinic data was processed and the basic statistics information (average, standard deviation and relative standard deviation) was tabulated and the data was shown for the total population (see Table 1) and separated between gender (see Table 2 and Table 3).

Variable	Average	SD*	RSD**
Age (years)	36.9	11.8	32.0%
Total cholesterol (mg / dL)	147.5	35.4	24.0%
HDL cholesterol (mg / dL)	47.2	12.4	26.3%
Triglycerides (mg / dL)	171.3	91.5	53.4%
LDL cholesterol (mg / dL)	70.7	27	38.2%
Systolic pressure (mmHg)	122.3	15.9	13.0%
Diastolic pressure (mmHg)	79	10.4	13.2%
Glucose (mg / dL) (Not always fasting)[a]	109.6	34.7	31.7%
Abdominal perimeter (cm)	92	15.4	16.7%
Weight (kg)	73.4	15.3	20.8%
Size (height, m)	1.63	0.08	4.9%
BMI	27.4	4.5	16.4%
Cardiovascular risk (%)	3.5	5.7	162.9%
Cardiovascular age (years)	34.9	16	45.8%

*Standard Deviation **Relative Stardard Deviation

Table 1 Average and standard deviation of the measurements performed in the kiosk during the deployment period (Total population)

Variable	Average	SD*	RSD**
Age (years)	35.9	11.5	32.0%
Total cholesterol (mg / dL)	151.1	34.4	22.8%
HDL cholesterol (mg / dL)	51.3	13	25.3%
Triglycerides (mg / dL)	154.2	81	52.5%
LDL cholesterol (mg / dL)	71.2	25.3	35.5%
Systolic pressure (mmHg)	116	13.7	11.8%
Diastolic pressure (mmHg)	76.2	9.8	12.9%
Glucose (mg / dL) (Not always fasting)[a]	108.4	33.1	30.5%
Abdominal perimeter (cm)	87.2	12.1	13.9%
Weight (kg)	66.4	12.1	18.2%
Size (height, m)	1.57	0.06	3.8%
BMI	26.7	4.6	17.2%
Cardiovascular risk (%)	2	2.7	135.0%
Cardiovascular age (years)	31.5	15.6	49.5%

*Standard Deviation **Relative Stardard Deviation

Table 2 Average and standard deviation of the measurements performed in the kiosk during the deployment period (Female)

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Variable	Average	SD*	RSD**
Age (years)	38.2	11.9	31.2%
Total cholesterol (mg / dL)	143	36	25.2%
HDL cholesterol (mg / dL)	42.2	9.5	22.5%
Triglycerides (mg / dL)	192.3	98.9	51.4%
LDL cholesterol (mg / dL)	70.2	29.2	41.6%
Systolic pressure (mmHg)	130	14.9	11.5%
Diastolic pressure (mmHg)	82.4	10.1	12.3%
Glucose (mg / dL) (Not always fasting)[a]	111.1	36.5	32.9%
Abdominal perimeter (cm)	98	17	17.3%
Weight (kg)	82.1	14.3	17.4%
Size (height, m)	1.69	0.06	3.6%
BMI	28.3	4.3	15.2%
Cardiovascular risk (%)	5.4	7.5	138.9%
Cardiovascular age (years)	39.1	15.5	39.6%

*Standard Deviation **Relative Stardard Deviation

Table 3 Average and standard deviation of the measurements performed in the kiosk during the deployment period (Male).

Respecting the behavioral data, both the total amount and the relative amount (percentage) of both the total population (see Table 4) and between genders (see Table 4 and Table 5).

Question	Amount	Percentage
Have you been diagnosed with hypertension blood by any doctor?	47	6.3%
Have you been prescribed treatment for hypertension?(b)	35	74.4%
Are you taking the treatment indicated by the doctor? [b]	33	70.2%
Smoking	110	14.9%
Have you been diagnosed with diabetes by any doctor?	32	4.3%
Has your doctor prescribed treatment for diabetes?[c]	10	31.2%
Are you taking the treatment indicated by the doctor?(c)	0	0.0%
¿Have you been diagnosed with high cholesterol by any doctor?	103	14.0%
Has your doctor prescribed treatment for high cholesterol?¿?[d]	53	51.4%
Are you taking the treatment indicated by the doctor?[d]	34	33.0%

Table 4 Number and percentage of users who answered affirmatively to the questions in the table (Full population)

Question	Amount	Percentage
Have you been diagnosed with hypertension blood by any doctor?	27	6.6%
Have you been prescribed treatment for hypertension?(b)	19	70.3%
Are you taking the treatment indicated by the doctor? [b]	18	66.6%
Smoking	52	12.8%
Have you been diagnosed with diabetes by any doctor?	19	4.7%
Has your doctor prescribed treatment for diabetes?[c]	6	31.5%
Are you taking the treatment indicated by the doctor?(c)	0	0.0%
¿Have you been diagnosed with high cholesterol by any doctor?	52	12.8%
Has your doctor prescribed treatment for high cholesterol?¿?[d]	25	48.0%
Are you taking the treatment indicated by the doctor?[d]	15	28.8%

Table 5 Number and percentage of users who answered affirmatively to the questions in the table (Full population)

Question	Amount	Percentage
Have you been diagnosed with hypertension blood by any doctor?	20	6.0%
Have you been prescribed treatment for hypertension?(b)	16	80.0%
Are you taking the treatment indicated by the doctor? [b]	15	75.0%
Smoking	58	17.5%
Have you been diagnosed with diabetes by any doctor?	13	3.9%
Has your doctor prescribed treatment for diabetes?[c]	4	30.7%
Are you taking the treatment indicated by the doctor?(c)	0	0.0%
¿Have you been diagnosed with high cholesterol by any doctor?	51	15.4%
Has your doctor prescribed treatment for high cholesterol?¿?[d]	28	54.9%
Are you taking the treatment indicated by the doctor?[d]	19	37.2%

Table 6 Number and percentage of users who answered affirmatively to the questions in the table (Full population)

Finally, all the data (both the clinic and the behavioral) was processed and the results (the cardiovascular age) was compared with their chronological age. The population was divided in three groups: (1) a population segment who's their cardiovascular age was less than their chronological age, (2) a population segment whose their cardiovascular age was equal to their chronological age, (3) a population segment whose their cardiovascular age was greater than their chronological age. These results were segregated between genders (see Figure 3 and Figure 4).

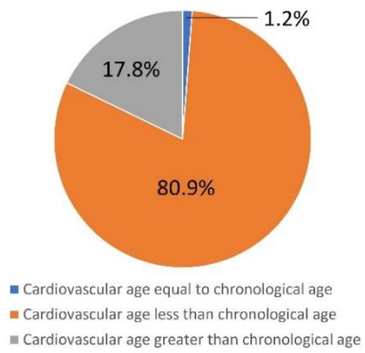

Figure 3 Population Comparison between the Cardiovascular age (Female)

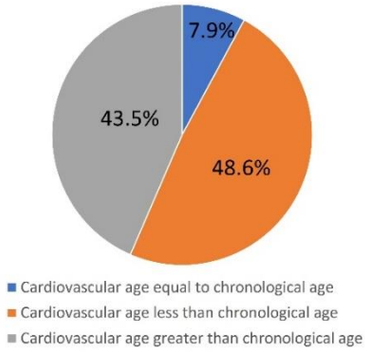

Figure 4 Population Comparison between the Cardiovascular age (Male)

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Afterwards, the data was processed furthermore. The abdominal perimeter was reduced to a ratio related with the cutoff of the respecting genders (86 cm for females and 90 cm for males). A t-test was applied to the obtained clinic data, obtaining that both groups are statistically distinct between then in each of the clinic features (sea Table 7).

df=732 $t^{100}_{\alpha=0.05}$=1.984	Δaverage	s2p	sp	t	$t > t^{100}_{\alpha=0.05}$
Age (years)	2.300	11.680	3.418	9.070	Yes
Total cholesterol (mg / dL)	8.100	35.119	5.926	18.421	Yes
HDL cholesterol (mg / dL)	9.100	11.427	3.380	36.281	Yes
Triglycerides (mg / dL)	38.100	89.045	9.436	54.415	Yes
LDL cholesterol (mg / dL)	1.000	27.053	5.201	2.591	Yes
Systolic pressure (mmHg)	14.000	14.239	3.774	50.001	Yes
Diastolic pressure (mmHg)	6.200	9.935	3.152	26.510	Yes
Glucose (mg / dL)	2.700	34.628	5.885	6.184	Yes
Abdominal perimeter (cm)	10.800	14.302	3.782	38.488	Yes
Relative Abdominal Perimeter	0.075	0.162	0.403	2.506	Yes
Weight (kg)	15.700	13.089	3.618	58.486	Yes
Size (height, m)	0.120	0.060	0.245	6.602	Yes
BMI	1.600	4.465	2.113	10.205	Yes
Cardiovascular risk (%)	3.400	4.857	2.204	20.791	Yes
Cardiovascular age (years)	7.600	15.555	3.944	25.970	Yes

Table 6 t-test performed of the clinic data

Discussion

The data show that there is a significant difference between each of the genders respecting the cardiovascular age (being the percentage of females which their cardiovascular age is higher than their chronological age of 17.8% and of 43.5% for males in the same respect).

Moreover, the statistical test performed to the clinical data shown that each feature of this information is distinct between genders, indicating that men have significantly higher risk of suffering of a CVD, at least in the Mexican work environment. Multiples factors could be acting respecting this gender gap. Studies show that men are less likely to participate and endure in dieting to lose weigh in comparison with women. Additionally, other studies show that men are more than twice as likely of suffering an myocardial infarction than women. (31, 32)

There is evidence that estrogen may provide protection against CVD. This is supported by the fact that postmenopausal women undergoing hormone replacement treatment have a 50% reduction in risk of a coronary event. (33)

Regardless of if the cause is either biological or behavioral, the importance of studying and considering the gender gap of CVR is pivotal to improve the healthcare provided to the people in the work environment.

Conclusions

The data reveals that there a difference between genders regarding CDR, being significantly higher in men than in women (43.5% vs 17.8%). Additionally, all the risk factors respecting the CVD are higher in men than in women, hinting to be the cause of the CVR between genders. However, further research must be done if this is had either biological causes such as the estrogen protective role in CVD or if there are behavioral aspects between men and women which could tip the balance regarding this issue.

Moreover, there may be both biological and behavioral aspects respecting this difference, which means that a more wholesome approach regarding CDR and cardiovascular prevention should be applied.

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