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**DOCTORAL (PhD) THESIS**

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# Biometric Screenings: Insights and their impact on Occupational Safety and Health

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**DOCTORAL SCHOOL ON SAFETY AND SECURITY SCIENCES**

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# DECLARATION

I, Lourdes Cecilia Ruiz Salvador, student of Obuda University, at Banki Donat Faculty and the Doctoral School on Safety and Security Sciences. Hereby declare that I entirely wrote this Ph.D. thesis, except where it is denoted in the references.

**Abstract**

Biometric characteristics such as fingerprints, palmprints, iris, or face recognition have been used at organizations to identify an individual, grant access to physical or digital facilities, and control employees' time and attendance. Nowadays, employers recognize the importance of workers' health. Hence, wellness programs are gaining popularity among enterprises. As part of these programs, other biometric traits such as height, weight, blood glucose, blood pressure, or blood cholesterol are acquired at biometric screening events. The primary objective of biometric screenings is to promote healthy habits within the workforce via early prevention and timely disease interventions. This work aims to present a detailed review of what biometric screenings are, their advantages, disadvantages, and stages of the process. Moreover, to go further from the health benefits that are broadly reported and analyze the screenings implications over occupational safety.

For this purpose, a literature review, preliminary research (survey), and a case study (biometric screenings) were carried out. Literature research and analysis conveyed relevant information regarding the application of biometrics in the workplace via biometric screenings. The revision of pertinent scientific documents delivered essential insights regarding the link between the biometric characteristics collected in a screening event and hazard identification that can affect occupational safety.

Concerning the experimental procedure, preliminary research carried out at a Hungarian company displayed the importance of workplace biometric screenings. Nearly 95% of the respondents stated that biometric screenings are important; more than 88% expressed interest in participating in a screening event. More than 70% of the employees believe that it is the responsibility of the company to safeguard their health. Approximately 90 % prefer an employer with health initiatives, and 61% trust an organization concerned about the worker's health.

Additionally, in the case study done at an Ecuadorian university, primary data from 409 employees were collected through biometric screenings and analyzed using descriptive and inferential statistics. Chi-square tests established statistically significant associations between type of occupation and biometric characteristics such as gender, body mass

index, blood and urine sample laboratory results, and age. Logistic regression determined two significant factors that contribute to occupational diagnosis (gender and physical exam results). The study identified clinical problems and pathologies related to mental work. These results were pivotal for identifying specific work hazards such as obesity, musculoskeletal disorders, eye problems, and metabolic diseases. Consequently, biometrics via biometric screenings enhance not only occupational health but also occupational safety by aiding in the prioritization of occupational safety procedures and policies through the identification of occupational hazards found in biometric screening results.

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# INTRODUCTION

Fingerprints, iris, palm print, and face recognition are biometric characteristics commonly used in the workplace for granting physical or virtual access to the facilities and controlling employees' time and attendance. The acquisition of biometric identifiers that characterize employees' health conditions is becoming prevalent in the workplace. Nowadays, companies collect different biometric traits to enhance safety and health at work via biometric screening events, which are part of workplace wellness programs.

Corporate wellness programs are gaining popularity within organizations. In the United States, 54% of employees working full time have access to a workplace health program, while Europe is 23%. The tendency is to upscale the existent programs and the introduction of new ones in multinational companies[1]

Biometric screenings fall under the scope of workplace wellness programs. These screenings are defined as the process of measuring biometric characteristics such as height, weight, blood pressure, cholesterol, blood glucose, physical activity tests, and more acquired at the workplace to assess the health condition of the workforce and monitor the changes throughout time[2]

Research about wellness programs and biometric screenings is predominantly health-based[3]. Regarding the employees, research focuses on health benefits such as early detection of chronic diseases[4][5], motivation into healthy behaviors[6], promotion of healthy lifestyles, and education [7][8]. As for the company, research topics include identification of the organizations benefits such as the return of investment, cut in corporate health plans[5][9][10], ways on how to deploy effective and successful screenings via participation rate[11][12][7] and incentives [13][14][15].

Research about the impact of biometric screenings on safety is not well documented. Some studies focus on one or two biometric characteristics such as height and weight to identify occupational risk and linkage to work-related diseases [16]–[19]. In other studies, self-assessment tools are used to identify relationships with occupational incidents and health risks[20][21]. However, research concerning the collection of several biometric characteristics at a biometric screening event and the subsequent analysis is incipient.

Consequently, a study detailing biometric screenings and how the health examination stimulates workplace safety is relevant. It can bring valuable insights to implementers towards new wellness practices and the importance of these biometric tests. Moreover, the inclusion of a survey and data of an actual biometric screening event complements the theoretical research. Its results can direct the establishment of specific hazards related to the type of occupation and serve as a tool for prioritizing occupational safety and health initiatives, procedures and policies.

The present work comprises of three elements:

1. Theoretical framework

   In this section, a literature review was performed to compile and critically analyze concepts concerning biometrics and occupational safety and health. It starts describing Biometrics, how this technology is used for identification purposes in the workplace. Then, how biometric characteristics acquisition shifted towards wellness practices such as biometric screenings.

   Moreover, as biometric screenings constitute a core topic in this research, a thorough review detailing the tests involved, advantages, disadvantages, and the whole biometric screening process detailing key actors and procedures at each step was carried out.

   Finally, occupational safety and health concepts were presented, given special attention to the impact of biometric screenings on safety. Thus, evaluating the current definitions and knowledge acquired in this framework, three hypotheses were formulated.

## 2. Experimental procedure

This part of the research aims to test the three hypotheses formulated as a result of the theoretical framework by analyzing statistically primary data collected in two case studies.

It comprises of two parts where antecedents, objectives, methodology, and results of each case study are detailed:

- Preliminary research executed in a Hungarian company, perceptions and opinions about wellness programs and biometric screenings were collected via a survey.
- Case study analyzing the biometric screening results of employees at an Ecuadorian university.

## 3. Discussion and Conclusions

In this section, the results obtained in the experimental procedure are reviewed. The findings in the preliminary research and the case study are thoroughly analyzed. The formulated hypotheses are discussed based on the experimental outcomes. Each hypothesis is evaluated in order to accept or reject them and draw conclusions.

## Problem Description

Biometrics is based on the measurement of the body. The collection of biometric traits has been used for identification purposes in different areas, including the workplace. Workers' biometric characteristics can serve as an element in recognition systems and as a tool for improving occupational safety and health. Hence, biometric screenings use body measures to characterize employees' health but can also affect safety.

Health and safety in the workplace constitute a concern and a cross-cutting topic in terms of economy, sustainability, and public health. According to the International Labor Organization (ILO), every year, 2.3 million deaths are caused by occupational injuries, accidents, or diseases. Moreover, 160 million workers are affected by occupational diseases, and 313 million suffer non-deathly injuries every year.

Workplace injuries, illnesses, and accidents have a severe impact on the productivity of the companies and its family. For this reason, it is necessary to research ways to improve current safety and health policies. Besides, find new inputs that can keep up with the latest trends that are shaping the workplace.

Most people spend at least one-third of the day working. Biometrics in the workplace constitutes an excellent approach to promote and enforce safety and health.

## Objectives

The main objectives of this study are:

- Examine how biometrics and occupational safety and health are related via biometric screenings
- Provide a detailed description of what biometric screenings are.
- Review the whole biometric screening process: before, during, and after the event. Determine essential guidelines to execute a successful screening.
- Extend the research about biometric screenings, go beyond the health benefits, and approach these practices safety benefits in the workplace.
- Perform experimental procedures detailing the importance of wellness programs and biometric screening.
- Analyze the biometric information collected in the experimental case study to find an association between characteristics.
- Identify how biometric screenings contribute to occupational safety and health.
- Unify occupational health and occupational safety concepts

## Research Methods

The research methods used in this work consisted of the following elements:

- A comprehensive review of current scientific literature about biometrics, occupational safety, health, biometric screenings, and corporate wellness programs.

- Preliminary research comprised of a  questionnaire about wellness programs and biometric screenings done in a Hungarian company

- Case study: biometric screening results analysis of biometric data collected at an Ecuadorian university.

# 1 THEORETICAL FRAMEWORK: BIOMETRICS, BIOMETRIC SCREENINGS, OCCUPATIONAL SAFETY AND HEALTH

This chapter unifies different concepts beginning with biometrics, its usage in working spaces. It continues with biometric screenings and procedures. Occupational safety and health concept is described, its importance, and briefly discusses the difference between workplace safety and health. It also explains the linkage between biometric screenings and occupational safety and health to serve as a basis for formulating the research hypotheses.

## 1.1 Biometrics

### 1.1.1 Introduction

The word "biometric" comprises two Greek words: bio, which means life, and metric related to measuring [22].

Biometrics is the science that measures and analyzes physical or behavioral traits in humans. Its objective is to determine the identity of a specific individual[23]. Biometric characteristics are defined as the metrics associated with human features or traits. Some examples include fingerprints, face, iris, retina, hand geometry, vein, gait, DNA, odor. [24][25].

Biometric technology takes advantage of the fact that physical or behavioral features in humans are unique. Thus the identification of a specific person is easier and effective by analyzing these characteristics[26]. Biometrics identification robustness resides in the concept of who the person is instead of what he or she has. Therefore, biometric systems offer higher security levels than traditional identification methods such as passwords, pins, or identification cards[27]. Additionally, these systems present accurate verification, so just authorized personnel can access secured information or places. The utilization of this technology also provides accountability. Hence, a particular action or event can be easily linked to a person. Duplication, sharing of information, and fraud are successfully prevented to enhance safety in an organizational environment[28].

A biometric trait should possess the following characteristics to be suitable for acquisition and analysis[29], [30]:

- Universality, all individuals should have the biometric feature
- Uniqueness, the biometric trait is exclusive for every individual
- Permanence, the biometric identifier cannot vary throughout time
- Collectability, the biometric identifier should be able to be obtained and digitalized using the suitable equipment
- Acceptability, the participants in a biometric system should accept the characteristic for authentication and identification purposes.

Biometric systems use pattern recognition. They comprise of two parts[23][24][31]:

1. Enrollment
   Biometric traits are collected from the individual; only distinctive features are acquired and stored in the database.
2. Recognition
   Biometric data is collected from the individual and compared with the information previously stored at the enrollment to recognize and authenticate its identity.

Biometric technology is widely used in different fields, such as forensics, banking, airport control, electronic commerce, social services, and others[32]. Some examples where this technology is applied are[23]:

- Commercial uses such as user authentication in online banking, services or in ATMs, credit card usage, mobile phone, distance learning, and access to healthcare systems
- For government identification purposes, including identification card issuance, driver licenses, access to social benefits, and border control.

- In forensics, for body identification, criminal purposes, parenting determination, and in case of missing people.

### 1.1.2 Biometric Uses in the Workplace

Biometric systems are employed in organizations for numerous purposes, described below:

- Background Check

  At the beginning of the hiring process, employers use biometric technology to access candidates' criminal records. In the United States (US), companies screen possible employees seeking a job position. In other countries, presenting a criminal record is a requirement at any point in the recruiting process.

  Law enforcement agencies such as the FBI in the US retrieve applicants' criminal history. This information guides the recruiter regarding a hiring decision. FBI uses two fingerprints and two names to run the background check[33].

- Staff Monitoring

  Fingerprint recognition equipment is predominantly used in companies for registering workers' time and attendance. The software present in these devices can accurately calculate working hours, punctuality, time breaks, sick days, absence, overtime, and payroll elements. Additionally, other devices can deny access to company technology and networks upon completion of the workday.

  Biometric-based equipment is faster regarding clocking in and out than other methods such as tokens or magnetic cards. Fraud and buddy punching are reduced while efficiency and productivity are boosted thanks to this technology[34].

- Access Control

  Authorized personnel recognition and access granting are performed by authenticating identity using biometric technology such as fingerprint, face recognition, and eye scanning. In terms of safety, biometric identification equipment restricts access to specific areas, such as places containing dangerous, valuable materials and sensitive information. Moreover, it offers increased security against trespassers by protecting buildings, computers, and networks. Devices that use fingerprint and facial recognition such as keyless locks, laptops, USBs, and mobile phones grant access and track workers' activities during the whole equipment usage to improve organizational safety [35][36].

- Tracking company assets

  Biometric identification equipment is used to track corporate property, such as vehicles, machinery, and smartphones. Real-time data on speed, location, and delivery time can be easily retrieved. These devices also provide traceability reports during the workday, which can be favorable in the event of accidents and responsibility claims. Additionally, biometric technology can monitor staff in the workplace at any time, promotes safe conduct and safety procedures usage [28].

As explained above, biometric characteristics such as fingerprints, hand geometry, face, iris scanning, and palm recognition are usually used in the workplace for identification purposes. Nowadays, via biometric screening events, organizations acquire other biometric traits such as height, weight, waist, hip circumference, and more to assess the workforce health conditions and monitor the changes throughout time[2]. The collection of these features provides health-based benefits to workers and employers and can contribute to workplace safety.

## 1.2 Biometric Screenings

Wellness programs have become very popular among medium and large enterprises. They consist of a series of activities developed at the workplace, aiming to improve the employees' well-being [13]. These programs can be categorized depending on the type of prevention efforts. Table 1 shows the wellness program classification, the targeted population, and several examples.

| **Type of Prevention** | **Target Population** | **Examples** |
|---|---|---|
| Primary | Employees that are healthy or susceptible to preventable diseases | • Exercise |
| | | • On-site fitness centers |
| | | • Healthy eating |
| | | • Adult vaccination campaigns |
| | | • Weight and stress management programs |
| Secondary | Employees that are at risk due to certain lifestyle habits | • Smoking cessation programs |
| | | • Weight loss programs |
| Tertiary | Employees that already have a health condition | • Disease management programs |
| | | • Medication compliance programs |

Table 1: Classification of wellness programs based on the type of prevention efforts [3]

Biometric screenings fall under the primary prevention program classification. They are an essential component of wellness and health-promoting initiatives. These tests provide an insight into the worker's health condition to arrange and put in practice prevention efforts[13].

Fingerprints, face, hand geometry, or palm recognition are biometric characteristics commonly used in the workplace. These characteristics are restricted to serve as identification tools. As part of a workplace wellness program, other biometric traits such as height, weight, blood pressure, cholesterol, and more are acquired to improve employees' welfare. This process is denominated: "Biometric Screening."

Biometric screenings encompass the measurement of physical characteristics applying a series of standardized tests to employees at the workplace, generally accompanied by a blood sample collection. Its main objective is to obtain a baseline of the employees' health through a series of biometric measures and evaluate them over the time spent working at the organization, detect changes and plan intervention processes[37]. Furthermore, it provides feedback to the employer concerning the whole workforce health status to implement tailored initiatives and policies according to the health and safety needs.

### 1.2.1 Advantages and Disadvantages

***Advantages***

Biometric screenings provide a quantitative value of the health condition of the employees. Moreover, the primary objectives of the organization towards deploying these screenings are reducing medical care costs and achieving a high return on investment (ROI). For instance, biometric screenings can identify high-risk individuals who have above average or abnormal values in the screening results[5]. Appropriate healthcare solutions tailored to these individuals will cut down costs in health plans by preventing or managing the development of chronic diseases[7]. Furthermore, the RAND corporation report on workplace wellness stated that a positive ROI value could be obtained by introducing wellness programs, including biometric screenings[38].

These screenings can also disclose valuable information regarding occupational injuries, diseases, unknown or chronic health conditions that can be asymptomatic. Moreover, a screening event is probably the only opportunity a worker has to detect a chronic illness; that without intervention can result in a catastrophic event. For example, pre-symptomatic type 1 diabetes can be recognized by detecting abnormal values of hemoglobin A 1c and fasting glucose thanks to analyzing a blood sample collected in a biometric screening event[4]. Additionally, high cholesterol levels, blood pressure, and obesity reveal cardiovascular disease risk leading to a heart attack or stroke. Due to timely biometric screening, these risks can be mitigated and treated[7].

Considering the nature of the tests administered during a biometric screening, they can objectively detect health risks compared with health risk assessments, which are a self-evaluation tool[9]. Another advantage relies on the technology used to collect biometric data. Thus, the results can be available in minutes, easing the detection and prevention of health conditions.

***Disadvantages***

Biometric screenings demand investment in technology such as equipment, personnel, training, space for sample collection and testing materials, which is expensive. In addition, the blood collection that accompanies the screening involves biohazard risks such as bloodborne pathogen exposition and medical follow-ups [5].

It can be problematic to achieve high participation rates in this type of wellness program. Moreover, privacy concerns related to collecting biometric traits, confidentiality, and sharing of this information to third parties hinder the employees' willingness to participate in this process[39]. Additionally, storing sensitive data such as biometric traits can be complicated if there is no effective procedure for uploading and synchronizing this information.

Furthermore, biometric screening results can provide false alarms in the detection of a health condition. Hence, the diagnosed individual feels exposed and can lead to unnecessary treatment[40].

### 1.2.2 Biometric Screening Measures and Tests

Below is listed and described several of the measures and tests performed on employees during a biometric screening event[41]:

- Height and Weight

Height and weight measures detect if an individual is healthy, overweight, or underweight by using weight and height ratios and calculating the body mass index (BMI) and the basal metabolic rate (BMR). BMI value is utilized for identifying people at risk of diseases such as hypertension and diabetes, while BMR helps in the development of personalized dietary regimes.

- Body Fat Percentage

This measure can indicate obesity, which is a risk factor for several chronic diseases such as stroke, diabetes, and heart problems

- Body Measures

Waist circumference, hip, or neck measures are acquired at screening events to detect overweight, obesity, and sleep apnea.

- Blood

A blood sample can deliver different results such as glucose level, triglycerides level, cholesterol, high-density lipoprotein (HDL), and low-density lipoprotein (LDL) cholesterol ratio. Cholesterol and triglyceride levels can detect the development of coronary and heart diseases such as heart attack. Glucose levels can indicate if a person suffers from hypoglycemia or hyperglycemia. It is a condition that can lead to diabetes if not prevented via health coaching and lifestyle changes.

- Blood pressure

Systolic and diastolic blood pressures reveal if the heart is working correctly and the risk of heart disease or a stroke.

- Cotinine Test

Cotinine is the major metabolite of nicotine. This test is used to establish if nicotine is present in the blood, urine, saliva, or hair. It gives a picture of the workforce smoking habits and can help develop smoking cessation programs and policies within the organization[42].

- Bone Density Test

This test is used for identifying individuals at risk of developing osteoporosis to provide education and timely treatment to diagnosed workers[43].

- Vision and hearing tests

These tests can be used for pre and post occupational screenings. They serve as a baseline tool for detecting the development of a work-related illness throughout the time spent at a company[44].

- Fitness Tests

These tests evaluate a worker's endurance and physical capabilities. It is crucial for job positions that require manual work and physical stress[45].

### 1.2.3 The Biometric Screening Process

The biometric screening process involves different actors, resources, and logistics deployed before, during, and after collecting biometric traits. It is essential to take into consideration some procedures described below to obtain the expected safety and health outcomes:

#### 1.2.3.1 Before the Process

The preparation of a biometric screening event entails different activities. Logistics and supplies can be easily coordinated by a third-party provider, which can also accommodate the tests screenings based on the organization's goals[46]. On the other hand, as implementers, it is necessary to focus on the two elements described below to ensure high participation rates:

- Communication

Before starting a biometric process, it is essential to set up goals, write a description of the different tests that are going to be administered to the employees, and state the purpose and benefits of these procedures.

Additionally, the biometric screening planning process should follow the principles of purpose and proportionality. These principles imply an analysis to know if the biometric data acquisition is necessary or other less intrusive methods can deliver the same purpose or outcome[47].

The workforce privacy right to protection should be considered starting at the planning phase, given the nature of the data that is going to be collected. Moreover, it is critical to know and comply with the laws concerning biometric data acquisition and usage established in the country or region where the screenings will be held.

In the European Union (EU), the General Data Protection Regulation (GDPR) is the legal framework used to regulate data protection and privacy. It is considered the most stringent data security framework in the world. Companies can face up to €20 million or 4% of the global turnover in fees for non-compliance. Biometric data is treated as personal data, which is any physical or behavioral characteristic of a person that proves that individual's unique identification. It consists of seven requirements[48]:

- Consent for data collection and usage should be obtained utilizing simple terms. Likewise, consent withdrawal must be easy to get.
- Data breach notification should be done within 72 hours.
- Right to access: Subjects have the right to be informed about personal data processing, and they can obtain a free electronic copy of the collected data.
- Right to be forgotten: Data must be deleted when it is no longer pertinent to the original purpose.
- Portability: Subjects can get and use their collected personal data within different IT environments.
- Data protection should be instated from the initial state of the process, applying the appropriate measures.
- Public authorities or large organizations should select data protection officers with more than 250 employees to monitor personal data processing.

Consequently, the whole biometric screening process should be carried out, considering privacy by design concept. It means to focus on data security since the beginning of the process and not include this aspect when the event is in progress[49]. Hence, creating and disseminating a data protection plan is vital to avoid privacy breaches and employees' concerns, such as misuse of the collected data, sharing, stealing, and connecting these traits with private information in other databases [50]. Every employee must sign a consent, stating their willingness to participate in the screening event. Additionally, the plan should specify that the acquired biometric information and results cannot be shared without a written consent that includes who will receive the information and how it will be used[51].

The screening program presented as a priority led by the management is necessary for engaging employee participation. Additionally, it is crucial to seek involvement on every level at the organization to join efforts towards a successful event.

The dissemination of essential information regarding the biometric screening process via flyers, emails, bulletin boards, social networks in the company, and frequently asked questions concerning the procedures should be transmitted regularly [9]. Moreover, these means of communication create awareness about the screening event and clear any doubts the workers may have.

- Incentives

Incentives are a fundamental part of the biometric process. They serve as engaging tools for increasing participation, which is a way of measuring wellness program success. Some examples of incentives include: lowering the contribution for insurance or medical plans, cash, gift cards, and prizes in raffles[52]. A biometric screening without any incentive can reach 30% of participation. In comparison, the usage of cash-related incentives can rise to 50%, and a health designed incentive plan can increase participation rates up to 80%[3].

#### 1.2.3.2 During the Process

The success in the execution of the screenings depends on different factors such as correct staffing, materials of the tests conducted, equipment, accurate scheduling. The effective combination of these factors will guarantee a smooth process flow.

Apart from these critical elements, it is fundamental to collect and effectively protect the information acquired during this process. Considering that the organization devoted economic resources and efforts, the workers dedicated their time and provided sensitive data that needed to be securely stored[53]. Hence, data processing, reporting, and safety are central issues to track during this stage. A unique identifier for each employee should be assigned at the moment of the data collection to protect the participant's privacy and report the results. Furthermore, privacy guidelines and laws should be strictly followed, and data security plans regarding clerical, physical, and technical risks should be taken in place to prevent breaches[54][47].

#### 1.2.3.3 After the Process

Biometric screenings results by themselves cannot accomplish a safety and health outcome within an organization. It is vital as screening promoters to go beyond the results and consider the following actions for the employees and the company:

- Personnel

1. Review and communication of the test results

   It is necessary to appoint meetings with each participant to review and communicate the test results to provide a complete screening solution [55].

2. Evaluation of the results

   The employees must understand the numbers beyond the tests administered to them. This evaluation is the first step for detecting, preventing, treating chronic illnesses, and getting motivated into a change of behavior towards healthier habits via informed decisions. The results can be evaluated by a physician or a health coach, depending on the severity of the effects [55].

3. Resource provision

   Depending on the results, the employees will receive information about their condition, treatment, and medicine management options. For prevention purposes, it is suggested to provide education, motivate lifestyle changes, and set personal goals for the participants. Additionally, suggesting and engaging workers in other company wellness initiatives is critical for accomplishing safety and health objectives[6].

4. Follow up

   This last step is critical for the success of the process and workforce welfare. Keeping track of the disease, medical management programs regarding chronic conditions, and review the participants' progress year by year will determine the effectiveness of the biometric screening process[37].

- Company

It is highly recommended to obtain an aggregate report detailing the information collected and the results of the screenings. This report shows trends regarding the workforce health status and how the workplace environment affects the employees. It provides feedback on how safety and health initiatives are developing each year. Moreover, the report can serve as an audit of the wellness programs implemented at the company. It is an exceptional opportunity for creating new safety and health policies, stating health priorities, eliminating the ones that are not effective, and integrating other wellness programs[56]

Figure 1 gives a graphic description of the various procedures to be taken into consideration before, during, and after a biometric screening process. It highlights the afterward steps which are crucial for getting the expected health and safety outcomes.

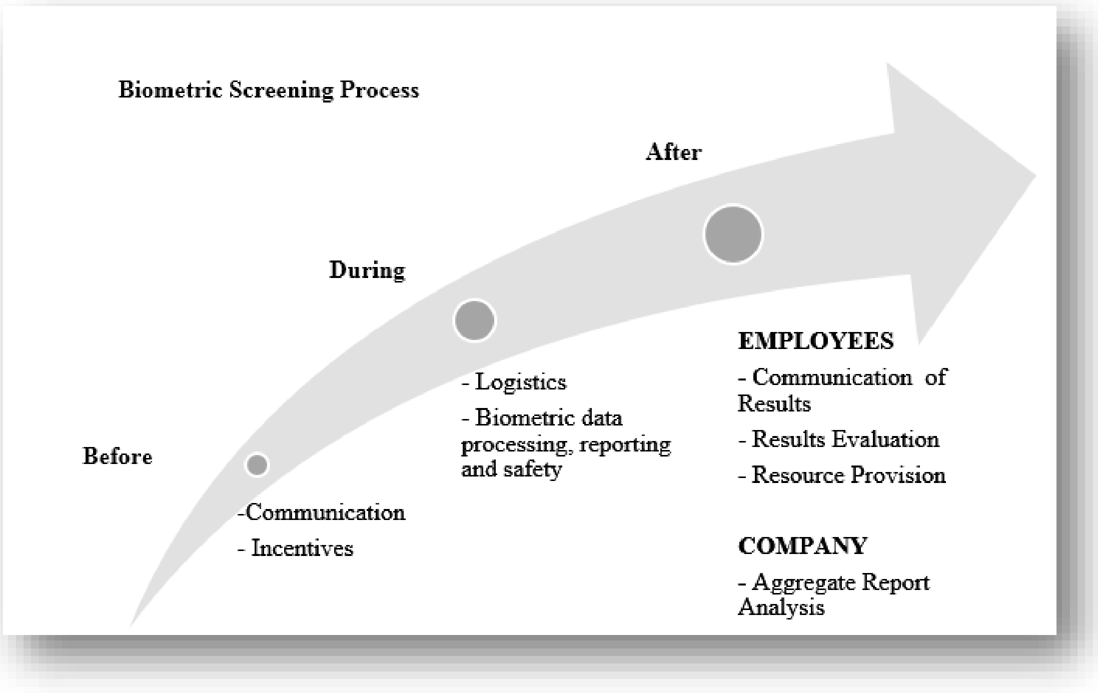



Figure 1: Biometric Screening Process Stages and Procedures

## 1.3 Occupational Safety and Health

Occupational Safety and Health (OSH) comprises different scientific disciplines that focus on analyzing, recognizing, and monitoring occupational hazards to protect and guarantee the workers' wellbeing. OSH examines all the parameters related to health and safety to prevent risks and hazards at work. Moreover, OSH encompasses laws and guidelines for safeguarding employees in the workplace. These laws have basic outlines but differ in severity depending on the country and region. Occupational accidents and fatalities can be prevented by applying safety procedures and methods that contribute to considerable benefits to society, businesses, and enterprises [57].

### 1.3.1 Importance

Economy development can be achieved thanks to working activities. Employees should be considered the most valuable asset in a company. Hence, accidents, injuries, work-related illnesses, and fatalities directly influence the economy and impose a heavy burden on the family and society[58].

OSH management systems provide various benefits to the company and the workforce. Some of the advantages are enumerated below[59], [60][61]:

Company

- As hazards, risks, and accidents are monitored and minimized. The company saves money in unplanned costs, health, insurance, fines, and compensations.
- The company image, reputation, and value are created and enhanced. OSH initiatives show social responsibility
- The return on investment is high. For one euro spent in OSH practices, at least two euros return as profit for the business.
- OSH procedures maximize productivity and competitiveness and enhance sustainable development.

Employees

- Employees are healthy and motivated, which stimulates a multiplier effect in the workplace and their personal life to overcome poverty.
- Turnover and absenteeism are reduced while retaining trained staff, and job satisfaction is enhanced.

### 1.3.2 Safety versus Health

Occupational Safety and Health is treated as a unified concept regarding policies, initiatives, management, and more. Nonetheless, safety and health in the workplace share some similarities; they differ in important aspects. Safety addresses situations that can cause immediate harm or injuries. It also involves hazards that can affect workers due to unforeseen or harsh conditions. Health mainly deals with circumstances that can cause diseases and unfavorable reactions to long-term hazards that are dangerous but not that severe as an accident[62].

Although safety and health have marked differences, these two concepts cannot be analyzed and understood separately under the occupational scope. OSH professionals should know these two topics to prevent and give timely responses to challenging work-related hazards such as stress or workplace violence.

Traditionally, OSH management systems were concentrated on preventing workplace accidents by utilizing different procedures such as training staff, implementing laws and regulations, designing ergonomic machinery[63], and more. Nowadays, this approach is becoming broader by considering the employees' well-being as the base of the whole safety and health efforts.

Wellness programs, including biometric screenings, are part of OSH initiatives. It aims to provide a safe and healthy work environment and, consequently, workforce welfare[58]. OSH procedures are a legal duty for the company, but most important, they are becoming a moral obligation for the employers.

Figure 2 illustrates how OSH embraces wellness initiatives and how biometric screenings are part of corporate wellness programs.

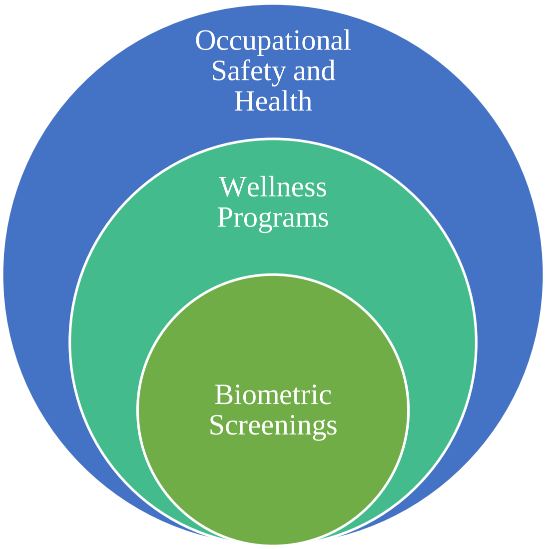



Figure 2: Diagram of the relationship between Occupational Safety and Health, Wellness programs and Biometric Screenings

## 1.4 Biometric Screenings and the implication in Occupational safety and health

Research about wellness programs and biometric screenings highlights its health significance but does not explain its safety benefits. This section first discusses industrial safety concepts and their development throughout the time into employee-focused programs such as biometric screenings. Also, it analyzes the implication of biometric screenings in occupational safety and health.

### 1.4.1 Industrial Safety Concepts

Occupational Safety and Health generally directs its attention to prevent and find the root cause of work-related accidents and injuries. Consequently, different theories have been developed to serve this purpose. Some of them are depicted below:

- Axioms of Industrial Safety

In the late 1920s, Herbert W. Heinrich formulated the 10 Axioms of industrial safety and the theory of accident causation known as the domino theory. The principles and theory were developed to explain the origin of accidents. Even though his research is outdated and poses various critics [64], it is relevant to understand the industrial safety basics.

The ten axioms of industrial safety are [62], [65]:

1. Injuries are the result of a series of factors.
2. Accidents can only occur due to an unsafe act (person) or a physical hazard.
3. Most accidents are the consequence of unsafe behavior.
4. Unsafe acts or hazards do not always result in an accident or injury.
5. Understanding the reasons why people commit unsafe actions can help develop guidelines and corrective procedures.
6. The severity of an injury is fortuitous, and the accident that caused it is preventable.
7. The best accident prevention techniques are analogous to the best quality and production techniques.
8. Management should assume responsibilities regarding safety to get the best results.
9. The key person for the prevention of industrial accidents is the supervisor
10. Accidents include direct and indirect costs.

Additionally, Heinrich's domino theory is summarized in two statements:

1. The action of preceding factors causes accidents.
2. The elimination of the main factor (unsafe act/ hazards) nullifies the action of the other factors; thus, accidents and injuries are prevented [62], [66]

- Human Factors Theory and Accident/ Incident theory

This theory explains the occurrence of an accident as a chain of events caused by a human error. The human error consists of three factors:

1. Overload such as noise, distractions, personal problems, stress, level of risk.
2. Inappropriate response
3. Inappropriate activities

The Accident/ Incident theory expands the human factors theory by adding new factors that can contribute to human error, such as ergonomic traps, decision to err, and system failures [62], [67].

- Epidemiological Theory

This theory states that the principles used to establish relationships between environmental factors and diseases can also analyze the causes of environmental factors and accidents[62].

- Systems Theory

This theory describes an accident as a system that consists of three main elements, such as a person, machine, and environment[68].

- Combination Theory

This theory relies on the fact that sometimes, the cause of an accident cannot be adequately explained by using a sole approach. Hence, it is necessary to work with different models to find an accident origin and prevent it [62].

### 1.4.2 Biometric Screenings and Safety

OSH initiatives such as wellness programs shifted the accident causation and prevention efforts to focus on the workers' wellbeing. Industrial safety theories depicted in the previous section consider the workforce as the primary source of accidents. Traditionally the employer believed that the sole responsibility for the workforce health is the employee. Nowadays, corporations accept the involvement in worker's health and how these health issues are affecting safety[69].

Biometric screenings are part of corporate wellness programs. They provide a complete characterization of the worker's health by acquiring various biometric measures, including blood, height, weight, and more[15]. Furthermore, biometric screenings focus on how the work affects the employees' health, and according to their results, taking timely and corrective actions.

Biometric screenings association in occupational health is well documented[70]. However, the effect of these screenings on occupational safety needs to be studied and described. Several concepts and examples are discussed below to explain the impact of biometric screenings on workplace safety.

### 1.4.3 Biometric Screenings as an Incentive tool

An incentive is defined as a valuable object, an action, or a desired event that incites an employee to accomplish more of what he/she is asked to do by the employer[14]. Incentive programs can help promote workplace safety[62].

Biometric screenings were usually just a path for obtaining financial incentives, prizes, and discounts in health plan packages or use incentives to increase the participation rate in this type of event [10][71]. However, these screenings by themselves can be used as a non-monetary incentive. This type of recognition is often more efficient than monetary prizes because it acknowledges what others had done [72].

Employees recognize the commitment the company is making towards workforce health. As a result, workers get motivated; productivity, loyalty, and safety behaviors are stimulated while reducing risks and health costs[73].

Biometric screening events can be effectively used as incentives given the following guidelines[62]:

1. Objectives and outcomes should be well established

2. Criteria on the quantity and how the reward will be granted should be well defined
3. Establish clear communication between the employees regarding how valuable biometric screenings are, the benefits, and long-term rewards.
4. Employees should be involved at all screening events stages, from planning to the evaluation.

### 1.4.4 Biometric Screenings and Performance Influencing Factors

Performance Influencing Factors (PIF) are different aspects that affect human performance in the workplace. These aspects should be monitored and optimized to enhance safety at work[74]. They can be divided into two groups:

- Internal factors

These factors are related to the employees' inner well-being. Some examples are emotional state, motivation, stress level, physical conditions, morale, and fatigue[75].

- External factors

These factors consider the environment and organization where the employee is working. Elements such as communication, inadequate procedures, routine tasks, unclear policies, poor supervision, peer pressure, poor work conditions constitute some examples of external factors[76].

Biometric screenings promote PIFs engagement among employees. Biometric test results combined with health education and interventions performed after the testing influence internal PIFs by promoting healthy behaviors, early disease intervention, treatment, reduction of sick leave, absenteeism, and presentism [3].

### 1.4.5 Biometric Screenings and Hazard Detection

Occupational Safety and Health overarching goal is to identify, prevent, and reduce workplace hazards[57]. However, hazards are prevalent in every work environment. An occupational hazard is defined as any object or event that has the potential to harm an employee. Hazards can be divided into two groups[77]:

1. Safety hazards, which have the potential to harm workers physically
2. Health hazards, which can potentially lead to diseases.

Biometric screenings take a step further in this classification by detecting nonconventional hazards such as health indicators and diseases. That can affect the workers' health and their ability to perform work duties and hinder safety behavior.

Biometric tests performed during the screenings classify each employee according to his/her health status. The early detection of health conditions such as high blood pressure, high triglycerides, and cholesterol can prevent serious health problems such as stress, physical and mental problems. These issues can lead to safety incidents and, in the long term, can become a burden to the company and society[78].

Abnormal biometric values, such as high blood pressure levels, can indicate high-stress levels [79]. Stressed individuals can be easily distracted from work, contributing to mistakes, unsafe behaviors, accidents, and workplace violence. Moreover, it can be the cause of chronic diseases such as cardiovascular affections. Stressed workers are more likely to make unhealthier choices, such as alcohol and tobacco consumption[80][81][82].

Cotinine tests performed on a blood sample during a biometric screening event can easily detect smoking prevalence among the workforce[83]. Besides the severe health issues related to tobacco usage, smoking can also be considered an occupational hazard. Smokers take more breaks during working hours than non-smoking employees, disrupting the working procedures, leading to injuries and accidents. Additionally, loss of productivity due to these breaks, presenteeism, absenteeism, and health insurance costs are higher for a smoker [84][85][86].

These screenings can easily detect if a person is overweight or obese by calculating the Body Mass Index (BMI). Obesity can also be linked to chronic diseases such as coronary affections, diabetes, sleep apnea, certain types of cancer, and even workplace injuries[18]. Over-weight individuals present deterioration in cognitive performance and more prolonged time reactions than normal-weight persons [87]. Additionally, obese people tend to unintentionally injure themselves more often and present impairment in work activities[88]. Overexertion and falls are the most frequent cause of work-related injuries and accidents. Higher BMI values are closely connected to missed workdays and absenteeism[16]. Obesity screening can help prevent occupational risks associated with occupational asthma, stress, immune response to chemical exposures, and diseases caused by occupational neurotoxins[19].

Prediabetes and diabetes can be quickly spotted at a biometric screening event by reading the results on blood glucose levels[89]. Prediabetes can often be reversed if it is timely diagnosed and health-based corrective actions are taken in place[90]. Diabetes is an indicator of serious complications such as blindness, kidney failure, heart disease, stroke, and loss of toes, feet, or legs[91]. Vision loss, dizziness, and loss of consciousness due to a glucose imbalance can be potential hazards for occupational incidents. Diabetes significantly impacts the ability to work; it can increase absenteeism and production loss. Diabetic individuals are more susceptible to fatigue, overweight, early retirement, and disability[92][93][94].

Biometric screenings offer a snapshot of the physical capabilities of the employees. This aspect is relevant in companies where manual labor is required, and fitness can be a breaking point in work safety, such as in the case of firefighters[17].

Furthermore, as computers are becoming an essential tool for executing any job, sitting, sedentary work, and low activity workplaces are rapidly expanding[95]. Biometric screenings can detect sedentary behavior among employees by analyzing biometric characteristics such as waist circumference, body mass index, triglyceride levels. Since workers spend at least eight hours per day sitting in an office without counting the commuting time to the workplace, sedentarism can be considered as an occupational hazard[96][97][98].

Sedentary behavior can lead to non-communicable chronic diseases such as diabetes, cardiovascular diseases, cancer, and premature mortality. Moreover, musculoskeletal disorders, overweight, obesity, poor cognitive function can also be associated with a sedentary work environment[99][100][101][102].

Biometric screenings serve as an assessment tool to check if the workplace conditions are safe. Screenings report common health trends among the employees that can be caused by the work environment. These commonalities can pinpoint unsafe conditions such as ergonomic problems or lack of safety procedures. Additionally, as these screenings are performed every year, it is possible to detect an increasing trend in work-related illnesses due to the workplace environment, prevent and treat them via specific safety and health interventions in machinery or workspace design[98][103].

### 1.4.6 Biometric Screenings: Overlapping concepts between Health and Safety at work

Occupational safety and health are two elements that are interconnected. Workforce health is closely linked to performance and safety in an organization[79]. Employees that enjoy good health are more productive, resilient, and less prone to safety incidents. Screenings boost morale within the workers. They understand and appreciate the organization's efforts towards their health, which is translated into employee retention, a feeling of ownership to the business, and motivation towards safety behaviors[104]. Furthermore, according to the survey on the future of wellness at work, employees who recognize the company's efforts towards their health report decreased stress levels and improved job satisfaction[1].

McLellan et al. study [11] found that participation rates in biometric screenings are positively correlated with safety perception at work. A combination of a positive perception of safety and an adequate health plan in the organization anticipates higher participation rates in biometric screenings. High participation rates are decisive for measuring the effectiveness and success of a program. It also contributes to a fair promotion and instauration of safety and health policies that benefit the majority of the employees. If a predominant number of employees participate in a biometric screening event, the results will sufficiently portray the workforce necessities and direct towards customized initiatives. Thus, biometric screenings and safety in the workplace operate together in a cycle where safety perception is enhanced as biometric screenings are implemented.

Figure 3 shows a summary of the main aspects of how biometric screenings contribute to occupational safety and health outcomes.

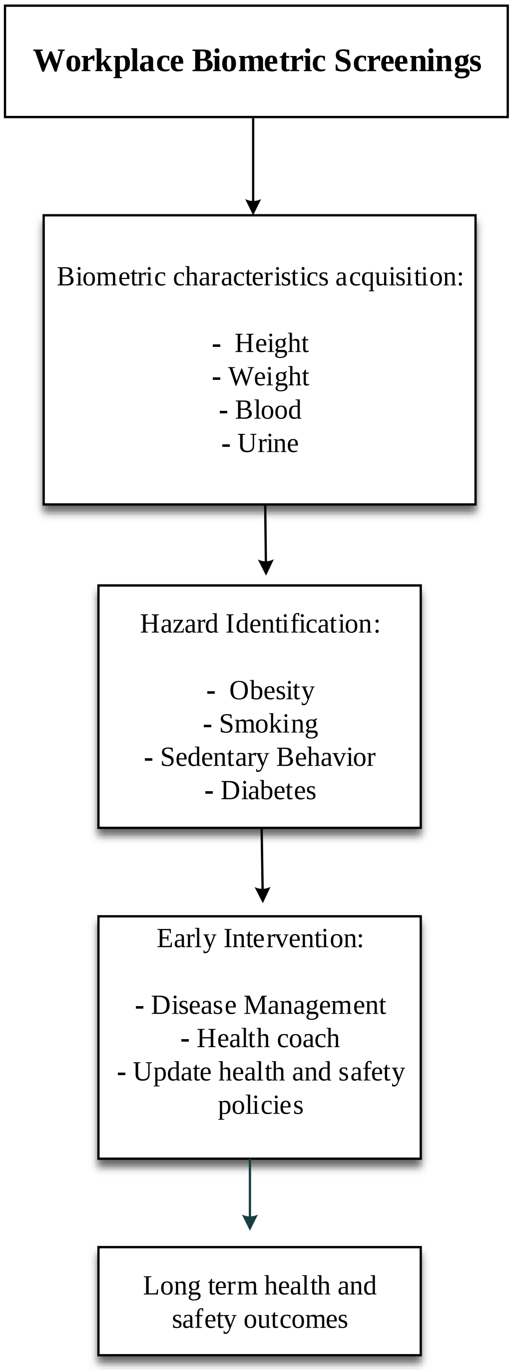



Figure 3. Scheme of how biometric screenings work towards health and safety outcomes at the workplace.

## Hypotheses

The following hypotheses were formulated considering and understanding the theories and concepts described in the theoretical framework presented in the previous chapter:

- Hypothesis 1: Biometrics via workplace biometric screenings can serve as a tool for improving workforce health and occupational safety by prioritizing occupational safety and health initiatives, procedures, and policies.

- Hypothesis 2: Biometric characteristics can be related to the employees' ability to perform their job.

- Hypothesis 3: Biometric screening results can help identify hazards that affect Occupational Safety and Health.

# 2 EXPERIMENTAL PROCEDURE

The experimental procedure primary objectives were to test the hypotheses enumerated in the previous section and gain experiential knowledge regarding biometric screenings in the workplace and the analysis of two case studies listed below:

1. Preliminary Research

   This study captured employees' opinions in a Hungarian company regarding wellness programs, health initiatives, and biometric screenings via a survey. The data analysis highlighted the workers' perception concerning biometric screenings importance, participation, and the potential to implement these kinds of events in the company.

2. Case Study: Biometric screenings results analysis

   This study was performed at an Ecuadorian university, employees' biometric data was acquired in a biometric screening event. The collected data was organized, processed, and analyzed. Descriptive statistics were used to display the collected data and provide a summary of the main findings. Furthermore, inferential statistic tests were carried out to find associations between the biometric characteristics and occupational diagnosis.

## 2.1 Preliminary Research

### 2.1.1 Antecedents

This research was done in a multinational company located in Budapest- Hungary. This company has multiple wellness programs. They consisted of several health-based activities such as tobacco cessation programs, disease screening, fruit availability in the workplace, on-site fitness activities, and discounts in gyms and physical activity centers. Additionally, it has a web-based component, where the employees can register and be part of a healthy community. In this community, health advice, interaction with other members, access to a mobile wellness application, and the possibility to pair fitness devices is provided. Regarding biometric screenings, these events are not regularly performed. Some biometric characteristics are collected and analyzed during specific health-oriented activities.

Wellness activities at this organization were dispersed without feedback and follow-ups regarding the fulfillment of objectives or outcomes. Therefore, an exploratory procedure collecting employees' perceptions and requirements regarding health initiatives was needed to concentrate efforts and provide effective occupational and safety solutions.

### 2.1.2 Objective and Rationale

This part of the experimental work aimed to explore the employees' perceptions regarding wellness programs, especially biometric screenings. It also captures their opinions and needs concerning wellness programs and ways to improve them.

Workers' involvement at every wellness program implementation stage promotes safety and health outcomes[62][105]. Suggestion programs and surveys are beneficial because they collect data from the most reliable source. Workers are the people that know the most about their health, safety necessities and workplace hazards. Moreover, these programs empower employees and get them actively involved in safety and health initiatives[106][107].

### 2.1.3 Methodology

The preliminary research comprised a thirty-one-question survey, addressing the company needs regarding data about the opinion, suggestions, and employees' requirements concerning wellness programs and health. The questions included demographic data, Likert scale questions, close and open-ended questions. The survey comprised four components enumerated below:

1. Personal Information
2. Health Habits
3. Biometric screening questions
4. Workplace Health Initiatives

The entire questionnaire is presented in Appendix 1.

Invitations to complete the survey were sent to the employees via a social networking service exclusively used at the corporation. The survey was available for two months, from December 2017 until January 2018.

### 2.1.4 Results

After retrieving and cleaning the data, eighty nine respondents were used to present the data below. Descriptive statistics were applied to summarizing the data obtained in the survey. Microsoft Excel and SPSS were used for calculating means, standard deviations, percentages, and frequencies.

The data were divided into five groups for a better understanding of the results:

- Demographic data
- Employees' health information

- Biometric Screenings perceptions
- Wellness initiatives' ranking and perceptions
- Other data

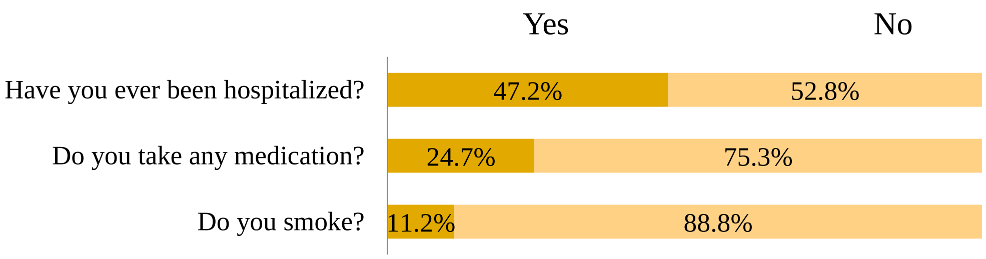
### 1. Demographic Data

| Characteristic | Value |
|---|---|
| **Gender (%)** | |
| Male | 46,1 |
| Female | 53,9 |
| **Mean Age (Standard Deviation)** | 36, 69 (9,168) |
| **Marital Status (%)** | |
| Married/ In a relationship | 76,4 |
| Single | 23,6 |
| **Children (%)** | |
| Yes | 36 |
| No | 64 |

Table 2: Demographic Data Preliminary Research

The demographic data presented in Table 2 shows a slightly higher percentage of women compared with men. The average age is 37 years. Marital status is higher for married/ in a relationship while having children was reported by 36% of the sample surveyed.

### 2. Health Information



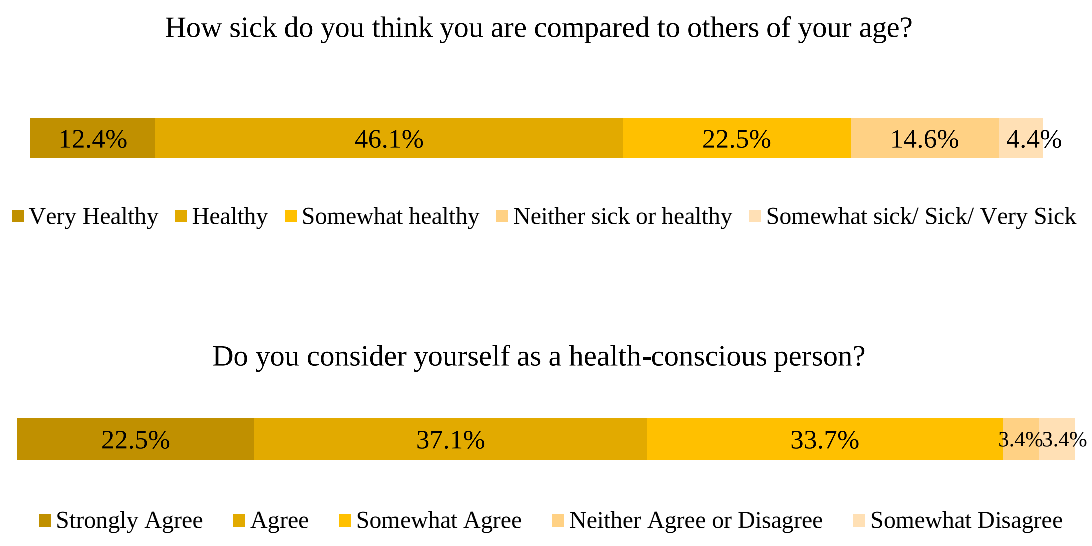



Figure 4: Health Data

Regarding health data, Figure 4 shows several health habits and perceptions among respondents. Health habits such as smoking and medicine intake present low percentages, while hospitalization is 47%. Concerning health perception, 81% think that they are healthy, and nearly 94% agreed that they are conscious about their health.

### 3. Biometric Screenings

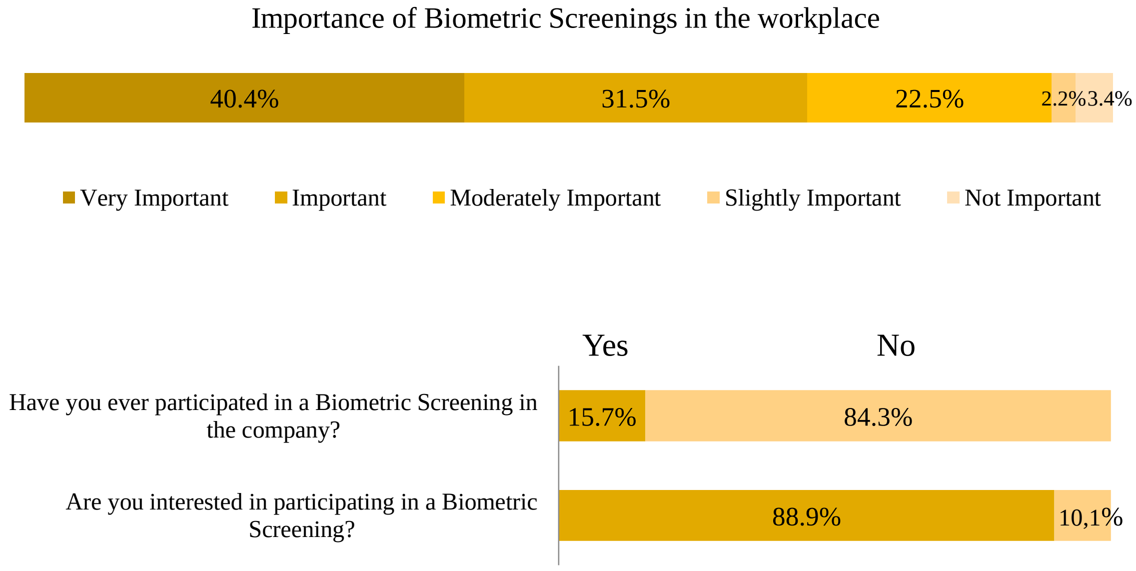



Figure 5: Biometric Screenings Information

Figure 5 presents data regarding the respondents' opinions about biometric screenings. More than 90% believe biometric screenings are important in the workplace. Concerning willingness to participate, nearly 89% are interested in being part of a biometric screening event, while only 15.7% participated in screenings inside the company.

## 4. Wellness Initiatives

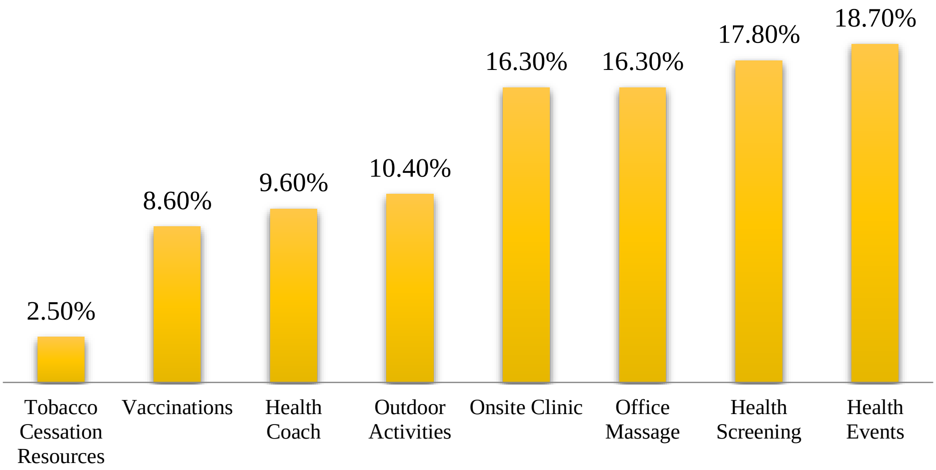



Figure 6: Wellness Programs Importance

Figure 6 ranks the importance of different wellness programs, according to the respondents. Health-related events, screenings, and health coach are ranked higher than other tobacco cessation resources and vaccinations.

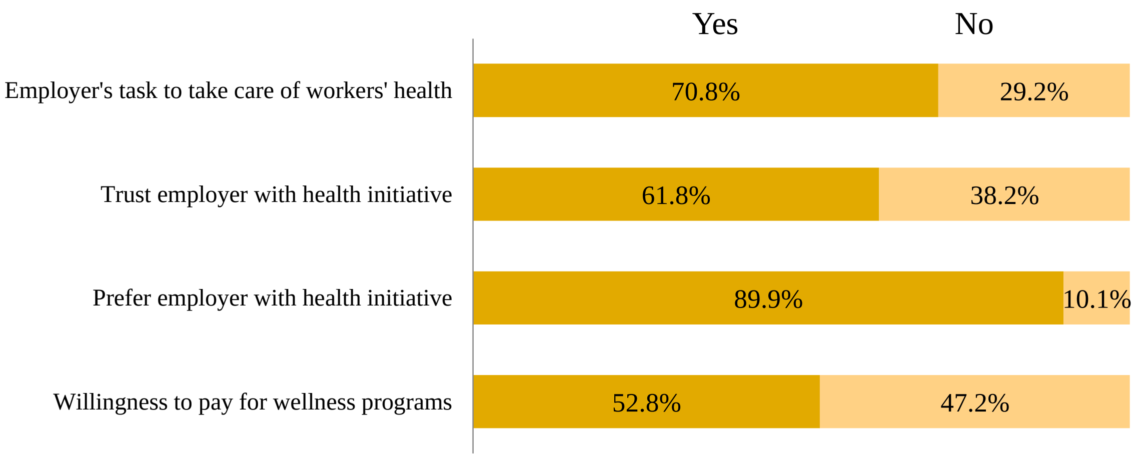



Figure 7: Wellness programs opinion

Figure 7 shows several impressions regarding wellness programs. Concerning the employer's role in wellness programs, the answers portray an employee preference towards a company that pays attention to workforce health. Additionally, more than half of the respondents are willing to pay for these programs.

**5. Other Data**

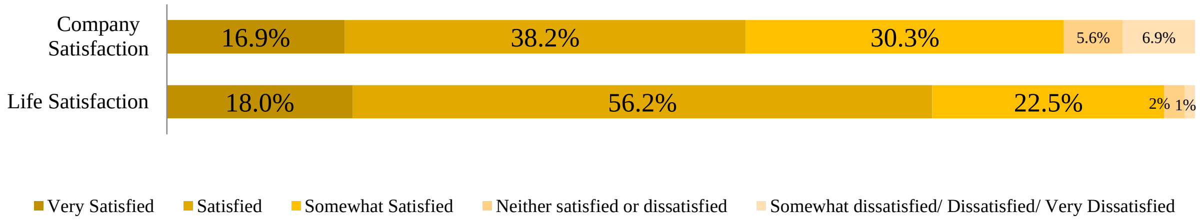



Figure 8: Company and Life Satisfaction

Figure 8 displays information concerning the respondents' level of satisfaction in life and the company. More than 85% of the employees answered that they are satisfied with the company with a minor percentage dissatisfied while nearly 97% are satisfied with their lives, and just 1% are dissatisfied.

## 2.2 Case Study: Biometric screenings results analysis

### 2.2.1 Antecedents

This study was developed in collaboration with Dr. Richard Perez, the occupational doctor at Universidad Tecnica de Cotopaxi (UTC), located in Latacunga - Ecuador. It consisted of biometric data collection through an occupational screening event and statistical data results analysis. The biometric data was collected during a year in 2017. In 2018, the data was compiled, organized, categorized, and cleansed for data analysis.

Regarding data security, Ecuador does not have a biometric data protection legal framework. However, in September 2019, a draft of the organic law of personal data protection was presented to the Ecuadorian Assembly for analysis and discussion. It has some nuances of the European framework, in which it assures personal data protection as a citizen's right and not of the companies that collect the data[108]. As of January 2021, this law has not been discussed or approved.

### 2.2.2 Objective

This research had a hands-on approach. Workers' biometric characteristics were acquired and processed. The biometric screenings results were compiled and statistically analyzed to get a picture of workforce health, identify how these characteristics relate, influence the worker's ability to perform his/her job duties, and ultimately contribute to the workplace's safety health.

### 2.2.3 Methodology

Biometric traits were acquired as part of the annual occupational exams offered by UTC to the employees. Every year the university provides free health screenings to the workers. The employees have to arrange an appointment in the occupational health office where biometric characteristics such as height, weight, age, blood, and urine samples were acquired. Blood and urine samples were sent for laboratory tests. Additionally, an appointment with the occupational doctor was scheduled to obtain data about drug consumption and perform a physical examination. The laboratory test results and other biometric characteristics were tabulated and saved in an excel database to analyze and later report the workforce's whole health status.

The doctor established an occupational diagnosis stating if the worker is fit, fit with limitations, or unfit to work. This diagnosis is a clinical evaluation that contrasts the workers' health with the working conditions, environment, and specific work duties to assure that the workers do not constitute a hazard for themselves, their colleagues, and the organization[109], [110].

The outcome of the whole biometric screening process was presented and discussed with each of the employees. Health advice regarding eating habits, physical activity, intervention, and prevention procedures was offered and explained in case of abnormal results.

Table 3 contains a detailed description of the collected biometric characteristics, classification, and the methods used in each category and subcategories.

| **Characteristics** | **Categories** | **Subcategory** | **Observations** |
|---|---|---|---|
| Occupation | Mental Work | N/A | Mental work comprises tasks that require cognitive or mental activities[111]. It includes job positions such as professors, deans, office assistants. |
| | Physical Work | | Physical work is manual labor characterized by the muscles and bones usage in the body[112]. It includes job positions such as gardener, security guard, cleaning staff. |
| Gender | Male | N/A | N/A |
| | Female | | |
| Age Range | 15-41 years | N/A | The age categorization was done according to the guidelines of the ministry of public health in Ecuador. This classification divides the individuals into group ages to provide integrated health attention in each life cycle. [113],[114],[115] |
| | Greater than 41 years | | |
| Height | N/A | N/A | Unit of measure: meter (m) |
| Weight | N/A | N/A | Unit of measure: kilogram (kg) |
| Body Mass Index (BMI) | N/A | N/A | BMI was calculated using the formula: $\frac{weight(kg)}{[height(m)]^2}$ [90] |
| BMI Classification | Normal Weight | N/A | The categorization was done using the World Health Organization (WHO) classification [116]. |
| | Overweight | | |
| | Obesity | | |
| | Morbid Obesity | | |

| | | | |
|---|---|---|---|
| Blood and Urine | Laboratory Exams | High Hematocrit | Blood and urine samples were acquired and sent for laboratory tests. These tests are the ones usually performed in a routine health checkup. They consist of hematocrit, hemoglobin, glucose, lipid profile, urea, kidney function in case of blood[117][118], the elemental, microscopic test in case of urine[119], and the prostatic specific antigen for man over 40 years old[120].<br>The subcategories enumerate the abnormal results obtained in the laboratory exams. |
| | | Low Hematocrit | |
| | | Urea | |
| | | Glucose | |
| | | Cholesterol | |
| | | Triglycerides | |
| | | Uric Acid | |
| | | Glutamic-Oxaloacetic Transaminase (GOT) | |
| | | Glutamate Pyruvate Transaminase (GPT) | |
| | | Prostatic Specific Antigen (PSA) | |
| | | Urine test | |
| Physical Examination | Problems detected in the Physical Examination | Eyes | The occupational doctor performed a standard physical examination to identify the employees' physical problems [121][122]. |
| | | Hearing | |
| | | Nose | |
| | | Abdomen | |
| | | Shoulders | |
| | | Arms | |
| | | Elbows | |
| | | Forearm | |
| | | Wrists | |
| | | Hands | |
| | | Hips | |
| | | Thighs | |
| | | Knees | |
| | | Legs | |
| | | Feet | |
| | | Neck | |
| | | Back | |
| | | Veins | |

| | | | |
|---|---|---|---|
| Drug Consumption | Alcohol | Consumption | The diagnosis of alcohol and tobacco consumption was made following the parameters established by the former Technical Secretary of Integral Prevention of Drugs, the Ministry of Work, and the Ministry of Public Health of Ecuador[123][124]. Additionally, for alcohol screening, the CAGE questionnaire[125][126] was used, and for tobacco, the Fagerstrom test for nicotine dependence was applied[127]. |
| | | No consumption | |
| | Tobacco | Consumption | |
| | | No consumption | |

Table 3: Biometric characteristics collected in the case study.
N/A: Not applicable

Since the biometric traits are health data, the employees signed informed consents. They voluntarily permit to collect their biometric data, and it guarantees data confidentiality between the doctor and the patient. Consequently, the only person that has access to the workers' identity was the occupational doctor[128]. For the data results analysis, information that reveals the patients' identity (first names, last names, identity card numbers, specific work position) was not shared and removed from the statistical analysis datasets.

The biometric screening results were compiled and categorized using descriptive statistics. Microsoft Excel and SPSS were used to calculate means, standard deviations, frequencies, and percentages.

Additionally, SPSS software was utilized to perform the following statistical tests:

1. Cronbach's alpha coefficient reliability test
2. Chi-Square test
3. Logistic regression

### 2.2.4 Results

The biometric screening results of 409 individuals were used for analysis after data organizing and cleansing. The employees in UTC are approximately 500. Hence, 82% of the population was evaluated in this study.

#### 2.2.4.1 Descriptive Statistics

In this section, the primary data collected through biometric screenings are summarized and displayed in tables and graphics to obtain an overview of the main findings regarding demographic information and occupational problems.

Table 4 outlines the results obtained during the biometric screening event. It enumerates frequencies, means, standard deviation, and percentages in terms of participants' gender, age, occupation, height, weight, BMI, alcohol, drug consumption, the results of the blood and urine tests, and the physical examination.

| Characteristic | Value |
|---|---|
| **Gender** | |
| Female count (%) | 161 (39,4) |
| Male count (%) | 248 (60,6) |
| **Age** | |
| 15- 41 years count (%) | 240 (58,7) |
| Greater than 41 years count (%) | 169 (41,3) |
| **Occupation** | |
| Physical work count (%) | 48 (11,7) |
| Mental work count (%) | 361 (88,3) |
| **Mean Height (Standard Deviation)** | 1,63 (0,08) |
| Mean Height Male (Standard Deviation) | 1,67 (0,71) |
| Mean Height Female (Standard Deviation) | 1,58 (0,07) |
| **Mean Weight (Standard Deviation)** | 71,45 (12,98) |
| Mean Weight Male (Standard Deviation) | 75,73 (11,86) |
| Mean Weight Female (Standard Deviation) | 64,86 (11,85) |
| **Mean BMI (Standard Deviation)** | 26,61 (3,95) |
| Mean BMI Male (Standard Deviation) | 27,12 (3,75) |

| | |
|---|---|
| Mean BMI Female (Standard Deviation) | 25,83 (4,15) |
| **BMI Classification** | |
| Normal % | 38,9 |
| Overweight % | 44 |
| Obesity % | 16,4 |
| Morbid Obesity % | 0,7 |
| **Abnormal Results Laboratory Exams** | |
| No Problems % | 24,2 |
| 1 Problem % | 24 |
| 2 Problems % | 24,2 |
| 3 Problems % | 14,9 |
| 4 Problems % | 5,4 |
| 5 Problems % | 5,1 |
| 6 Problems % | 1,5 |
| 7 Problems % | 0,5 |
| 8 Problems % | 0,2 |
| **Clinical Problems** | |
| Sedentarism % | 57 |
| Polycythemia % | 56,5 |
| Hypercholesterolemia % | 46,2 |
| Hypertriglyceridemia % | 36,7 |
| Hyperuricemia % | 10,5 |
| Fatty liver % | 9,1 |
| Hypertension % | 7,6 |
| Anemia % | 5,1 |
| Urinary tract infection % | 3,4 |
| Hyperglycemia % | 2,2 |
| **Problems detected during the Physical Exam** | |
| No Problems % | 50,4 |
| 1 Problem % | 34,2 |
| 2 Problems % | 8,1 |
| 3 Problems % | 3,9 |

| | |
|---|---|
| 4 Problems % | 2,2 |
| 5 Problems % | 1 |
| 8 Problems % | 0,2 |
| **Pathologies** | |
| Metabolic % | 78 |
| Hematologic % | 55, 3 |
| Ophthalmological % | 38,6 |
| Musculoskeletal % | 19,1 |
| Urinary-genital % | 3,9 |
| Vascular % | 2,7 |
| Gastrointestinal % | 1,5 |
| **Alcohol Consumption** | |
| Yes count (%) | 34 (8,3) |
| No count (%) | 375 (91,7) |
| **Tobacco Consumption** | |
| Yes count (%) | 13 (3,2) |
| No count (%) | 396 (96,8) |
| **Occupational Diagnosis** | |
| Fit count (%) | 341 (83,4) |
| Fit with limitations count (%) | 68 (16,6) |

Table 4: Summary of the Biometric Screening Results

Regarding the participants' characteristics, males constitute a larger percentage of employees compared with females. Concerning age group, participants in the range of 15 to 41 years represent a higher percentage than their colleagues over 41 years old. A relatively small number of participants (12%) perform physical work than mental work (88%). This matter is explained by the fact that the study was executed in a university where office work is prevalent for professors, assistants, and office managers.

Concerning the measured biometric traits such as height and weight, the mean height values for males and females are within the normal ranges for Ecuadorians, which are 1.67 and 1.54 meters, respectively, according to WHO [129]. There are extreme values to pay attention to obesity and diseases; this is reflected in the high standard deviation values, representing variation in the mean weight group.

Therefore, the mean BMI values for females (25.83) and males (27.11) fall into the range of pre obesity, according to WHO (25-29.9), which shows that the workforce is slightly overweight. The standard deviation values are high, which is essential to pay attention to employees under extreme BMI classifications, such as for obesity and morbid obesity[116]. Besides, the overall BMI classification shows a considerable percentage (60%) of overweight or obese employees, and nearly 40% have a normal BMI.

The laboratory exam results show that nearly 25 % are within the normal parameters regarding the blood and urine samples, while almost 50% of the participants present 1 or 2 abnormal results. In contrast to 0.7%, that has 7 or 8 problems of the 11 analyzed results. The physical exams indicated that 50% of the employees do not have physical issues, and just 1% have 5 or 8 problems over the 18 problems presented in the whole university community.

In addition, the occupational doctor diagnosed clinical problems and pathologies through the analysis of the laboratory and physical exam results. Clinical problems such as polycythemia, sedentarism, hypercholesterolemia, and hypertriglyceridemia are prevalent among university workers. As for the pathologies, metabolic, hematologic are predominant. Ophthalmologic and musculoskeletal pathologies comprise significant percentages (38.6 %, 19%), respectively.

Alcohol and tobacco consumption presented minimal values of 8% and 3%. Finally, the occupational analysis revealed that nearly 84% of the employees are apt to work in their current job position, more than 16% are apt to work but with specific restrictions. Consequently, there are no cases of employees that are classified as unfit to work.

The graphics presented below exhibit some biometric traits and associations with laboratory tests and the physical examination results.

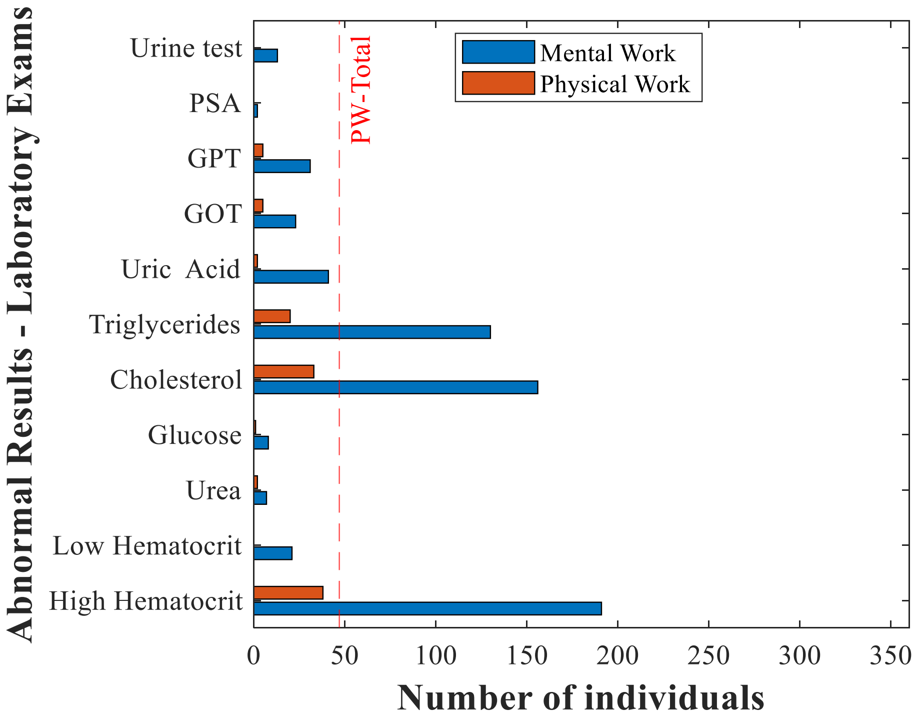



Figure 9: Occurrence of abnormal laboratory test results by occupation
*PW-Total: Total number of individuals that perform physical work.*

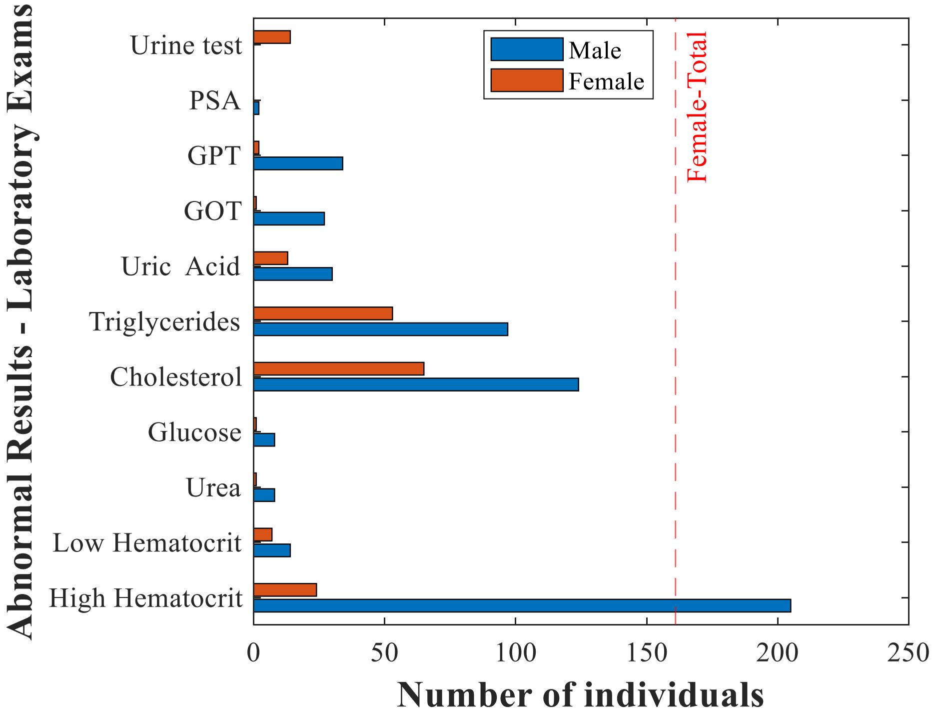



Figure 10: Occurrence of abnormal laboratory test results by gender
*Female- Total: Total number of females*

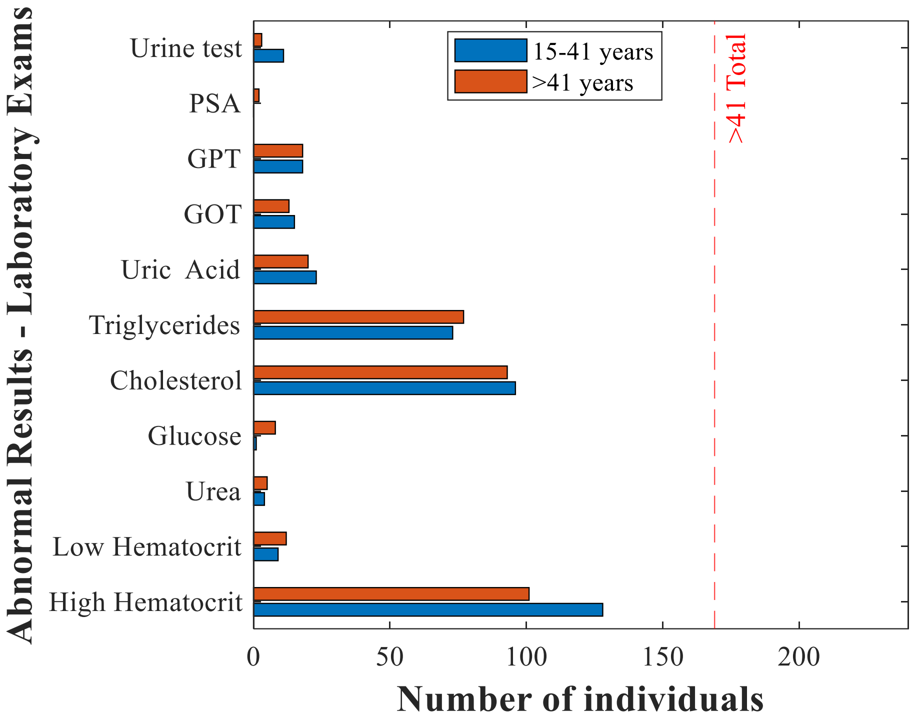



Figure 11: Occurrence of abnormal laboratory test results by age
*>41 Total: Total number of individuals that are 41 years old and higher.*

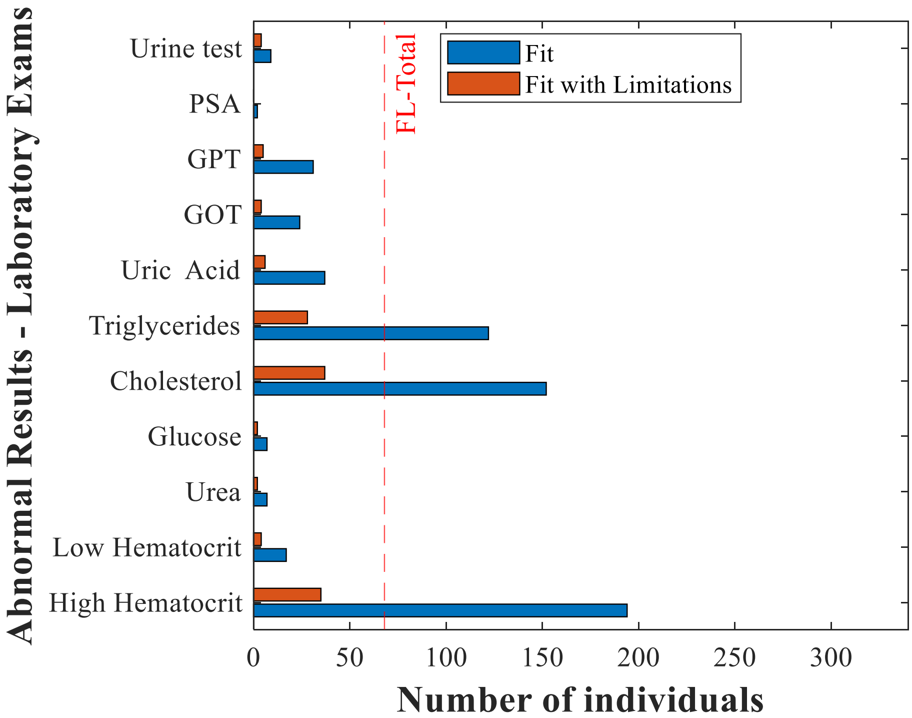



Figure 12: Occurrence of abnormal laboratory test results by occupational diagnosis
*FL-Total: Total number of individuals that are fit with limitations.*

Figures 9, 10, 11, and 12 show the abnormal results detected in the laboratory exams performed on the blood and urine samples. Each graphic dashed lines serve as a reference point to the specific category total number.  For example, in Figure 9, the dashed line represents the total number of individuals that perform physical work (48). At the same time, the x-axis displays the total number of individuals that carry out mental work (more than 350), of which approximately 200 have a high hematocrit count.

The high count of hematocrit is a preponderant abnormal result in the laboratory exams for the whole workforce, followed by high cholesterol and triglycerides. Regarding the type of occupation displayed in Figure 9, the three abnormalities (hematocrit, cholesterol, and triglycerides) are prevalent for mental and physical work. Simultaneously, high uric acid, GOT, and GPT affect more mental work individuals than physical work.

Figure 10 shows a considerable high hematocrit count, cholesterol, and triglycerides in the male population compared with the females. Regarding the age in Figure 11, there is no clear distinction between the laboratory exam abnormalities and the age range.  In the case of occupational diagnosis presented in Figure 12, abnormal parameters identified in the laboratory alone do not affect the fitness to work classification.

Figures 13, 14, and 15 reveal the problems determined during the physical exam and biometric traits such as gender, age, type of occupation, and occupational diagnosis.

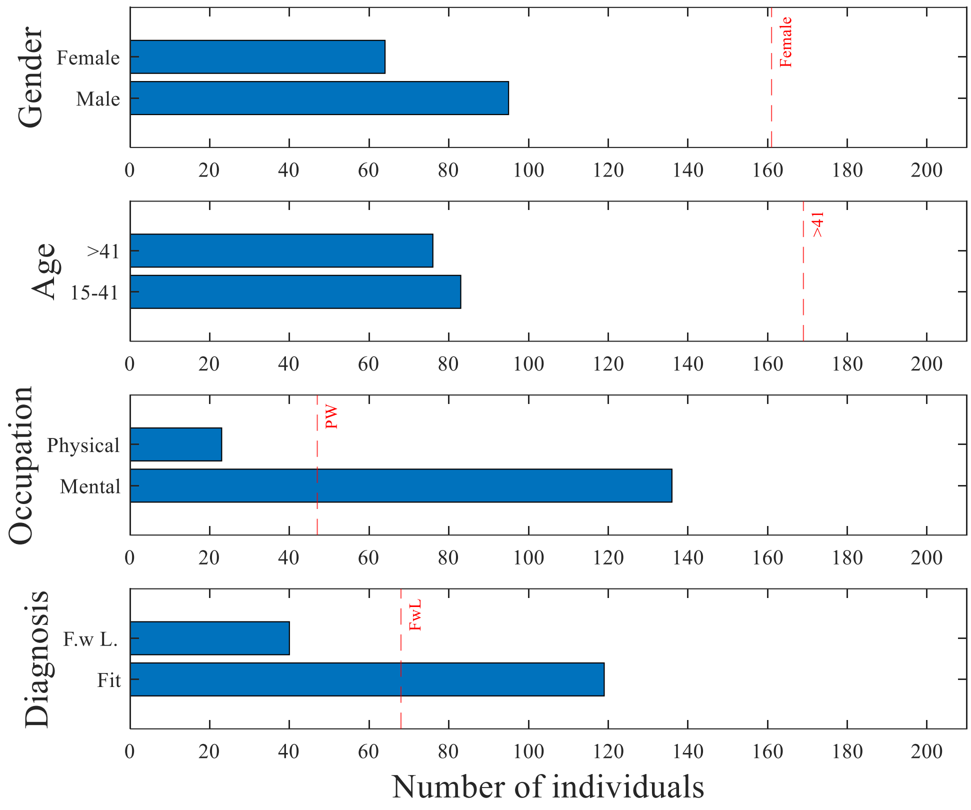



Figure 13: Occurrence of problems in the eyes by gender, age, occupation, and occupational diagnosis
*Female: Total number of females*
*<41: Total number of individuals that are  41 years old and higher*
*PW: Total number of individuals that perform physical work*
*FwL: Total number of individuals that are fit with limitations*

Eye problems, which were the most encountered issue among the workforce, are depicted in Figure 13. Concerning gender, there is a higher proportion of males with eye problems than females. There is a minor difference regarding age. Employees in the age range of 15 to 41 years present more eye problems than their older colleagues. In terms of occupation, a considerable proportion of employees perform mental work and suffer a decrease in visual acuity.

Figures 14 and 15 show a summary of the physical exam results divided into the upper and lower body. Although eye affections were higher than physical problems, the upper and lower body issues are essential for recognizing work-related musculoskeletal disorders.

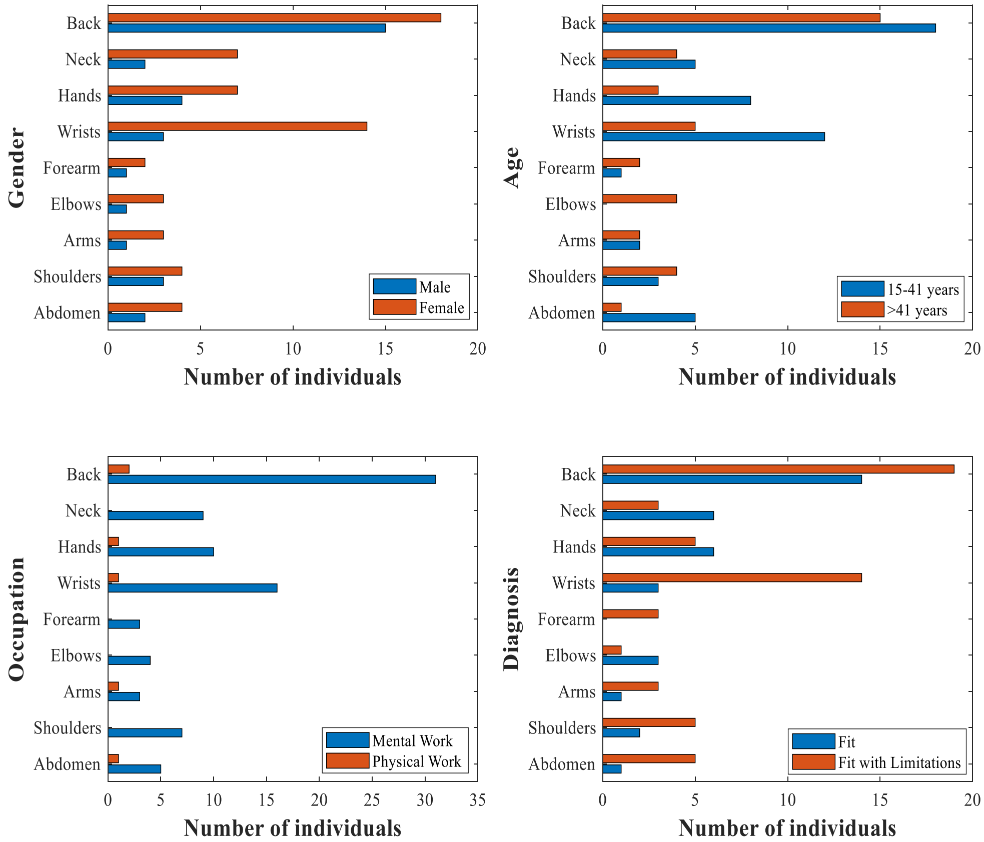



Figure 14:Occurence of problems in the upper body by gender, age, occupation and occupational diagnosis

Upper limb problems portrayed in Figure 14 show a significant proportion of back problems in all the categories. Female workers suffer more upper body problems (back, neck, wrists) than males. More individuals in the age range of 15 to 41 years old suffer upper body problems than workers older than 41. Mental work presents a higher count of cases in contrast to physical work. Back and upper limb problems are more significant in employees that are categorized as fit but with limitations.

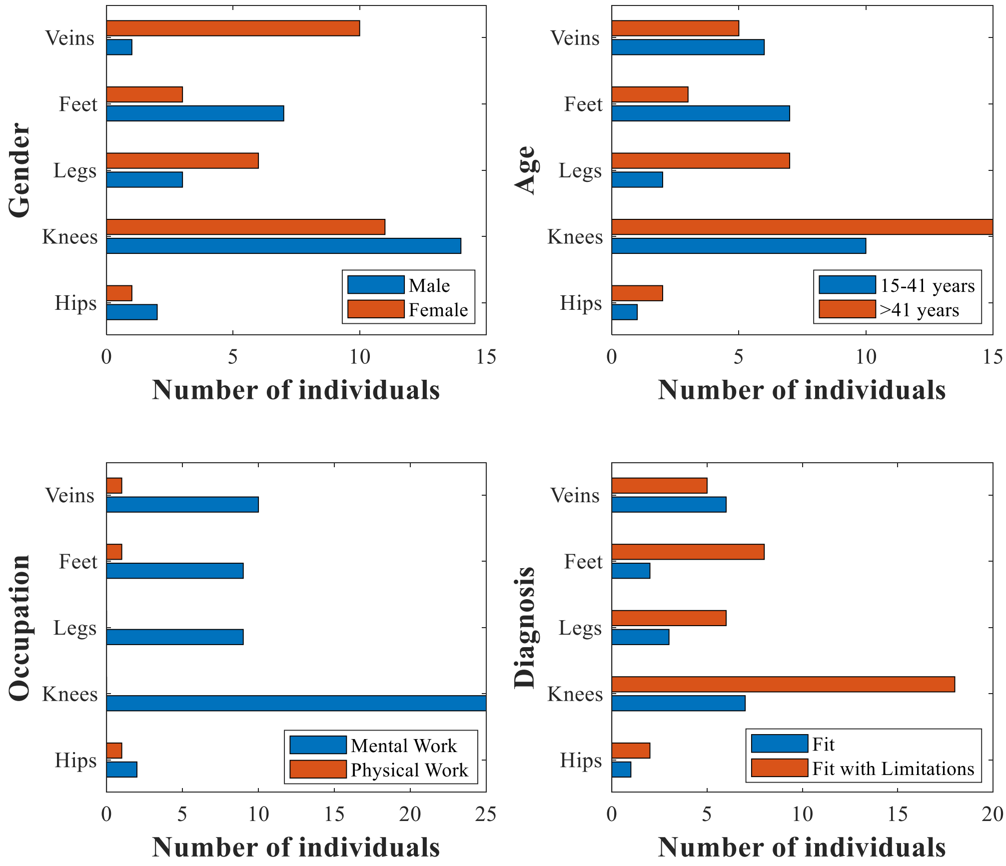



Figure 15: Occurrence of problems in the lower body by gender, age, occupation, and occupational diagnosis

Problems in the lower body depicted in Figure 15 occurred with less frequency than eyes and upper body issues. Problems in knees are predominant in males, individuals older than 41 years old, mental work, and fit with limitations. On the type of occupation, legs, feet, veins, and hip problems dominate for employees in mental work positions. Moreover, there is a larger number of individuals with problems in the lower parts of the body that are categorized as fit with limitations than fit to work.

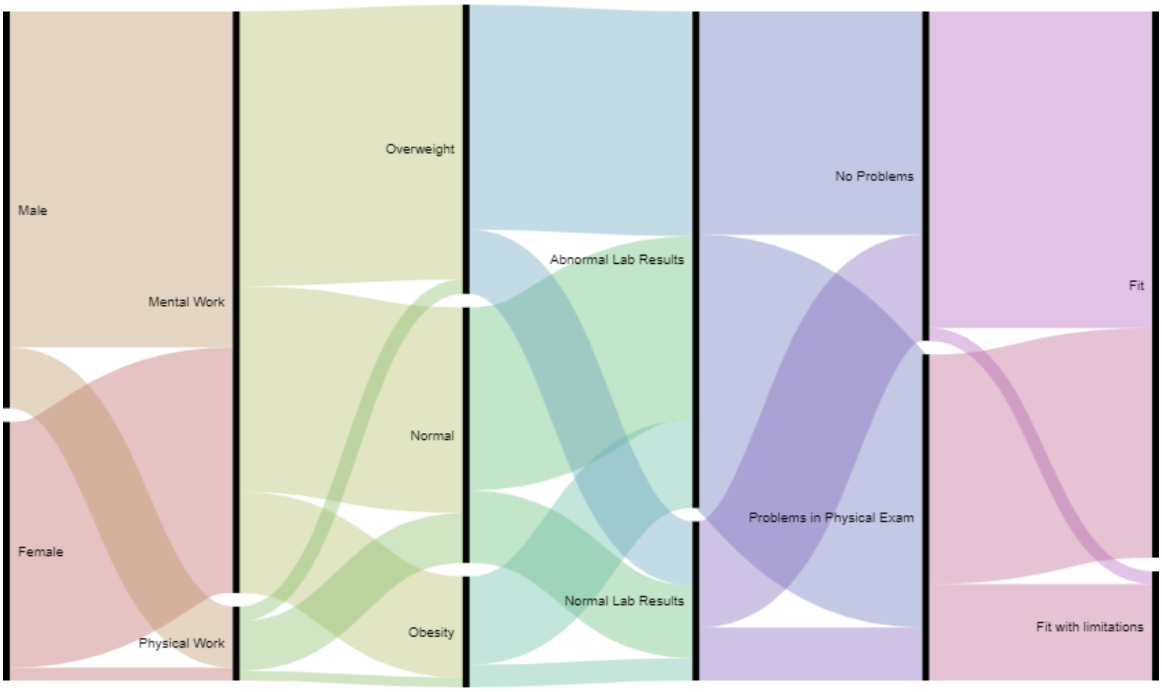



Figure 16:Visualization of how biometric characteristics determine Fitness to work

The scheme presented in Figure 16 shows a summary of several biometric characteristics and the study results. It compares biometric features (gender, BMI classification, results obtained from the blood and urine tests) using an alluvial diagram[130]. It eases the visualization of how these characteristics are related to each other and the flow towards the final categorization on whether an employee is apt or apt with limitations to work.

The graphic shows the distribution of workers in each of the categories, sorted by size. A large proportion of individuals perform mental work. From this category, a significant portion is overweight or obese. Concerning the laboratory results, a high percentage of the individuals present abnormal results in the blood and urine exams, while the proportion is diminished in the physical examination problems. Only a small portion of the workforce is fit to work, but with some limitations.  There are no cases where the employee is not fit to work.

#### 2.2.4.2 Inferential Statistics

In addition to the descriptive statistics shown in the previous section. Inferential statistics were used for hypotheses testing. These tests were performed considering that the majority of the acquired primary data is categorical.

The tests presented below were executed using IBM SPSS 20 statistic software package.

1. ***Cronbach's alpha coefficient reliability test***

*Purpose*

The reliability of a measurement resides on how consistent it measures a concept. Cronbach's alpha coefficient test constitutes a method to measure the internal consistency strength or the reliability of the items within a group or a concept.

Alpha (α) coefficient values range from zero to one[131][132]. Values near zero indicate that the items measured are independent of each other, whereas values that reach one demonstrate consistency in the items measuring the concept [133], [134].

In this case, the studied concept is the occupational diagnosis: whether an employee is fit to work, fit with limitations, or unfit to work.

*Data Used*

The items used for calculating the α coefficient value were the biometric screening outcomes listed below:

- Laboratory exam results
- Physical exam results
- Pathologies
- Clinical problems

The coding of the variables in SPSS ranged from zero to eight. Zero indicates the absence of problems in the laboratory exams, physical exams, pathologies, and clinical problems. From one to eight, it indicates the number of abnormal results in laboratory exams, physical exams, encountered pathologies, and clinical problems detected in the worker.

*Results*

The α value calculated for the four items is 0.797, which is considered a reasonably high value[135][136].

Appendix II shows the outputs obtained in SPSS software.

### 2. Chi-Square Test

*Purpose*

Chi-Square ($\chi^2$) test for independence was performed on the acquired biometric characteristics. It explores the relationships between the acquired characteristics and establishes if two categorical variables are statistically independent[136].

Chi-square tests are used to carry out hypothesis testing in nominal and ordinal data, in which the hypotheses are:

- Null Hypothesis ($H_0$): Two variables tested are statistically independent.
- Alternative Hypothesis ($H_1$): Two variables tested are statistically related.

This test contrasts the observed frequencies (number of observations acquired in each category) and expected frequencies (number of expected observations in each category considering the null hypothesis as true). Chi-square is calculated using the following equation[137]:

$$\chi 2 = \sum \frac{(O - E)^2}{E}$$

*O* = number of observed frequencies

*E*= number of expected frequencies

The calculated value is compared with the critical chi-square distribution value that depends on the degrees of freedom and the alpha level. Hence, if the critical value is less than the calculated chi-square value, the null hypothesis is rejected. The alternative hypothesis is accepted, concluding that there is a relationship between the two studied variables.

*Data Used*

The variables enumerated in Table 5 were used for determining what biometric characteristics are related and which ones are independent of the variables: type of occupation and occupational diagnosis. Table 5 also includes the categories of each variable and the coding used in SPSS.

| **Variables** | **Categories** | **Coding in SPSS** |
|---|---|---|
| Type of Occupation | Physical Work | 1 |
| | Mental Work | 0 |
| Occupational Diagnosis | Fit | 1 |
| | Fit with Limitations | 0 |
| Gender | Female | 0 |
| | Male | 1 |
| Age | 15-41 years | 0 |
| | > 41 years | 1 |
| BMI Classification* | Normal | 1 |
| | Overweight | 2 |
| | Obese | 3 |
| Laboratory Results* | Normal | 0 |
| | Abnormal Results | 1 |
| Physical exam results* | No problems | 0 |
| | Problems | 1 |

Table 5: Variables and categories used for chi-square analyses
** collapsed variables*

The variables BMI classification, blood and urine laboratory results, and physical exam results were collapsed in order to meet the chi-square test assumption of the minimum expected cell frequency. Any cell should be five or more, and in tables 2x2 (two categories for each variable), the expected frequency should be at least ten. Moreover, SPSS shows at the end of the analysis in footnote a, if this assumption was violated, see Appendix II [136].

The majority of the analyses, besides the one including BMI classification, were done for tables 2x2. In this case, an adjustment to the chi-square called "Yates' continuity correction" calculated in SPSS was used to determine if there is an association between the two studied variables. The continuity correction value is calculated to compensate for the overestimate of the chi-square value obtained in tables 2x2[136][138].

*Results*

Table 6 and Table 7 display chi-square test results and enumerate the biometric characteristics that have a significant relationship and which are not related to the variables: type of occupation and occupational diagnosis.

| **Characteristic** | **Chi-Square tests of Independence** | **Result** |
|---|---|---|
| Gender | $\chi^2 = 11.738$ | Statistically Dependent |
| | Continuity correction=10.685 | |
| | Critical $\chi^2$ score= 3.841 | |
| | $p<0,05$ | |
| | degrees of freedom=1 | |
| | Number of cases= 409 | |
| BMI Classification | $\chi^2 = 17.136$ | Statistically Dependent |
| | Critical $\chi^2$ score= 5.992 | |
| | $p<0,05$ | |
| | degrees of freedom=2 | |
| | Number of cases= 409 | |
| Laboratory Results | $\chi^2 = 11.903$ | Statistically Dependent |
| | Continuity correction= 10.697 | |
| | Critical $\chi^2$ score=3.841 | |
| | $p<0,05$ | |
| | degrees of freedom=1 | |
| | Number of cases= 409 | |
| Age | $\chi^2 = 4.999$ | Statistically Dependent |
| | Continuity correction= 4.326 | |
| | Critical $\chi^2$ score= 3.841 | |
| | $p<0,05$ | |
| | degrees of freedom=1 | |
| | Number of cases= 409 | |
| Physical Exam Results | $\chi^2 = 2.416$ | Statistically Independent |
| | Continuity correction= 1.962 | |
| | Critical $\chi^2$ score= 3.841 | |
| | $p<0,05$ | |
| | degrees of freedom=1 | |
| | Number of cases= 409 | |

Table 6: Results from Chi-Square tests between collected biometric characteristics and type of occupation

| Characteristic | Chi-Square tests of Independence | Result |
|---|---|---|
| Gender | $\chi^2 = 9.323$ | Statistically Dependent |
| | Continuity correction=8.512 | |
| | Critical $\chi^2$ score= 3.841 | |
| | p<0,05 | |
| | degrees of freedom=1 | |
| | Number of cases= 409 | |
| Physical Exam Results | $\chi^2 = 23.071$ | Statistically Dependent |
| | Continuity correction= 21.813 | |
| | Critical $\chi^2$ score= 3.841 | |
| | p<0,05 | |
| | degrees of freedom=1 | |
| | Number of cases= 409 | |
| BMI Classification | $\chi^2 = 1.565$ | Statistically Independent |
| | Critical $\chi^2$ score= 5.992 | |
| | p<0,05 | |
| | degrees of freedom=2 | |
| | Number of cases= 409 | |
| Laboratory Results | $\chi^2 = 2.866$ | Statistically Independent |
| | Continuity correction= 2.365 | |
| | Critical $\chi^2$ score=3.841 | |
| | p<0,05 | |
| | degrees of freedom=1 | |
| | Number of cases= 409 | |
| Age | $\chi^2 = 1.108$ | Statistically Independent |
| | Continuity correction= 0.842 | |
| | Critical $\chi^2$ score= 3.841 | |
| | p<0,05 | |
| | degrees of freedom=1 | |
| | Number of cases= 409 | |
| Type of Occupation | $\chi^2 = 0.694$ | Statistically Independent |
| | Continuity correction= 0.393 | |
| | Critical $\chi^2$ score= 3.841 | |
| | p<0,05 | |
| | degrees of freedom=1 | |
| | Number of cases= 409 | |

Table 7: Results from Chi-Square tests between collected biometric characteristics and Occupational Diagnosis

The outputs retrieved from SPSS, detailing contingency tables and chi-square test results, are reported in Appendix II.

### 3. ***Logistic Regression***

*Purpose*

Logistic regression is used to model the relation between a discrete outcome and a group of continuous and categorical variables or a mix. It estimates the probability of an event occurrence for a randomly picked observation than the probability of the event not occurring. It also predicts the effect of several variables on a dichotomous dependent response and classifies the observations via the probability estimation of an observation falling into a particular category[139][140].

The estimated regression equation is[141]:

$$\hat{Y}_i = \frac{e^u}{1 + e^u}$$

$\hat{Y}_i$ = estimated probability *i*th case is in one of the categories ($i = 1, \ldots, n$)

$u$= linear regression equation:

$$u = A + B_1X_1 + B_2X_2 + \cdots + B_kX_k$$

$A$= constant

$B_j$ = coefficients

$X_j$ = predictors for $k$ predictors

$j = 1, \ldots, k$

Logistic regression was used to determine which biometric characteristics predict the outcome (occupational diagnosis), how these characteristics affect the occupational diagnosis, and if a particular characteristic or characteristics increase or decrease the probability of the outcome or if there is no effect on it.

*Data Used*

The dichotomous categorical outcome was: Occupational diagnosis. The predictors used were a mix of categorical and continuous variables. The categorical variables are:

- Gender
- Age
- Alcohol consumption
- Tobacco consumption
- Laboratory results
- Physical exam results
- Pathologies
- Clinical problems
- Type of occupation

The continuous variables are:

- Height measured in meters
- Weight measured in kilograms

The outcome and categorical variables codification facilitate the interpretation of the final results. Hence, a convenient way of coding is to consider the characteristic of interest, assigning a higher code (1) to the category of the variables most associated with the outcome category: the occupational diagnosis: Fit with limitations.

As shown in Table 8, the coding for the categories in occupational diagnosis is one for Fit with limitations and zero for Fit. Likewise, the categories of the variables associated with Fit with limitations such as alcohol, tobacco consumption, physical exam problems, abnormal laboratory results, and others are also coded one. In contrast, the categories associated to Fit are coded zero.

| Variables | Categories | Coding in SPSS |
|---|---|---|
| Occupational Diagnosis | Fit | 0 |
| | Fit with Limitations | 1 |
| Gender | Female | 0 |
| | Male | 1 |
| Age | 15-41 years | 0 |
| | > 41 years | 1 |
| Alcohol Consumption | Yes | 1 |
| | No | 0 |
| Tobacco Consumption | Yes | 1 |
| | No | 0 |
| Laboratory Results | Normal | 0 |
| | Abnormal Results | 1 |
| Physical exam results | No problems | 0 |
| | Problems | 1 |
| Pathologies | Yes | 1 |
| | No | 0 |
| Clinical Problems | Yes | 1 |
| | No | 0 |
| Type of Occupation | Physical Work | 1 |
| | Mental Work | 0 |

Table 8: Categorical variables used in Logistic Regression Analysis

In order to test multicollinearity, collinearity diagnostics were performed using Collinearity Statistics in SPSS. Table 9 indicates the tolerance values for the variables used in the logistic regression analysis. Low tolerance values (less than 0.1) show high correlations between that variable and other variables in the model[136]. As displayed in Table 9, none of the variables tolerance values are below 0.1, which indicates that the studied variables do not present high correlations with each other or multicollinearity.

| Variables | Tolerance |
|---|---|
| Gender | 0.663 |
| Age | 0.926 |
| Alcohol Consumption | 0.884 |
| Tobacco Consumption | 0.883 |
| Laboratory Results | 0.801 |
| Physical exam results | 0.899 |
| Pathologies | 0.75 |
| Clinical Problems | 0.665 |
| Type of Occupation | 0.872 |
| Height | 0.264 |
| Weight | 0.146 |

Table 9: Collinearity Statistics variables Logistic Regression

Logistic regression was carried out using the SPSS procedure denominated Binary Logistic because the outcome studied (occupational diagnosis) has two categories (Fit and Fit with limitations). The Forced Entry Method was employed, which consists of testing all the predictors in one block to examine their predictive ability while controlling the effects of other predictors in the model.

*Results*

The model including all the predictors was statistically significant $\chi^2 = 46.694$, degree of freedom (df) = 11, $p<0.001$, N=409. Additionally, the Hosmer-Lemeshow Goodness of Fit indicates a good fit with a significance value of 0.499 (greater than 0.05), as shown in Table 10, which supports the model.

| Chi-Square | df | Sig |
|---|---|---|
| 7.36 | 8 | 0.499 |

Table 10: Hosmer and Lemeshow Test Results

Table 11 enumerates the different variables used in the model and their contribution as predictor variables. Column B displays the B coefficients used in the estimated regression equation to calculate the probability of a case falling in a specific outcome category. Negative or positive B values indicate the direction of the relationship between the outcome and the factors.

Column P indicates the factors that are significant to the model. The two main factors influencing Fit with limitations are gender p=0,000 and physical exam results p=0.000. The odds ratio for gender is 0.295 and for physical exam results is 3.879. These values indicate that being a male employee decreases by a factor of 0.295 the odds of being diagnosed as Fit with limitations. While employees having problems in the physical exams were 3.879 times more likely to be diagnosed as Fit with limitations than those without problems in the physical exam, controlling all of the other factors in the model. The rest of the biometric characteristics do not significantly contribute to the variable occupational diagnosis[141].

| Variables | B | Wald | df | P | Odds Ratio | 95.0% C.I. for Odds Ratio | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower | Upper |
| Gender | -1.219 | 12.125 | 1 | 0.000 | 0.295 | 0.149 | 0.587 |
| Age | 0.257 | 0.767 | 1 | 0.381 | 1.293 | 0.727 | 2.299 |
| Alcohol Consumption | -0.859 | 1.748 | 1 | 0.186 | 0.423 | 0.118 | 1.514 |
| Tobacco Consumption | -0.369 | 0.106 | 1 | 0.744 | 0.691 | 0.075 | 6.347 |
| Laboratory Results | 0.340 | 0.674 | 1 | 0.412 | 1.405 | 0.624 | 3.162 |
| Physical exam results | 1.356 | 17.382 | 1 | 0.000 | 3.879 | 2.051 | 7.336 |
| Pathologies | 1.803 | 2.913 | 1 | 0.088 | 6.068 | 0.765 | 48.105 |
| Clinical Problems | -0.147 | 0.033 | 1 | 0.857 | 0.857 | 0.175 | 4.261 |
| Type of Occupation | 0.44 | 1.067 | 1 | 0.302 | 1.552 | 0.674 | 3.577 |
| Height | 0.338 | 0.022 | 1 | 0.883 | 1.402 | 0.016 | 126.445 |
| Weight | 0.010 | 0.537 | 1 | 0.464 | 1.010 | 0.984 | 1.037 |
| Constant | -4.996 | 2.101 | 1 | 0.147 | 0.007 | | |

Table 11: Logistic Regression Predicting the Likelihood of being diagnosed as Fit with limitations

# DISCUSSION

In this section, the results obtained through the experimental methods (preliminary research and case study) are first examined and explained. Additionally, the hypotheses previously formulated are discussed and contrasted with the experimental results to validate or reject the research hypotheses.

## Preliminary Research

The preliminary research objective was to acquire a baseline regarding wellness programs aspects, especially biometric screenings. The survey administered to the employees gathered their perceptions, opinions, and suggestions to make wellness initiatives, including biometric screenings, as valuable for the company as they are for the employee.

The survey participation rate was low. The answers of 89 respondents were used to present the results. Even though the availability of wellness programs and initiatives is continuously increasing in corporations[142], workers' participation is low[143][144]. For this particular survey, more advertisements and a more extended period to collect data could have given better results. In addition, targeting groups such as young[145] [146]or health-conscious employees[70] can increase participation rates.

This survey helped the company know about the employees' perceptions of health programs and their primary needs regarding its health initiatives. For example, a high percentage of the respondents trust and prefer an employer concerned about workforce health. Moreover, employees mainly suggested health-based wellness programs such as screenings and health coaches. Furthermore, it served as a baseline to create an action plan towards workplace health necessities and avoid dispersed wellness activities.

Regarding Biometric Screenings, one of the critical findings in the survey was to know how important these screenings are for the employees. More than 90% of the respondents think biometric screenings are very important, important, or moderately important. Furthermore, a significant percentage of the respondents expressed their interest in participating in this type of event, while just nearly 16% participated in a biometric screening in the company.  Therefore, it opened an opportunity to plan and execute a biometric screening event in the company and constituted the first step to researching biometric screenings and their impact on occupational safety and health.

## Case Study Biometric Screenings: Data analysis

The biometric data collection and analysis described in the previous section was valuable for understanding the impact of biometric characteristics on the occupational diagnosis.

Regarding blood and urine collection and the subsequent laboratory results, the dominant problems detected in the laboratory exams were:

- High hematocrit
- High cholesterol
- High triglycerides

The hematocrit test is a blood characterization analysis that evaluates the proportion of red blood cells. It can detect diseases such as anemia and certain cancers. Factors such as genetics, smoking, and respiratory problems can affect hematocrit levels. Another factor that contributes to this abnormality is living in high altitudes[147][148], such as Latacunga- Ecuador (2760 meters), where this research was executed. This aspect can explain the prevalence of high hematocrit count in laboratory exams. Abnormal results in cholesterol and triglycerides coincided with the BMI values stating that the university employees are pre-obese.

The alcohol and tobacco screening results exhibit a low consumption percentage of 8.3% and 3.2%, respectively. These results do not coincide with the national percentage of alcohol consumption: 41%[149] and tobacco: 8.8%[150]. This issue can be explained by the fact that self-assessment questionnaires were administered. Blood tests such as cotinine analysis will show more realistic results and determine if there is an alcohol or tobacco problem among the workforce.

Musculoskeletal, ophthalmological pathologies, and sedentarism need to be paid special attention. These affections were considerably high among the employees and can be caused by mental work. During the physical exam, a decrease in visual acuity was detected as its most recurrent issue. Nearly 160 workers presented this problem, which indicates that the employee needs to wear glasses or change the eye prescription. Mental workers are prone to eye problems due to extended hours in front of a screen, which is typical for the job position they perform. Additionally, upper body problems such as back, neck, wrists, and hands are also predominant in employees performing mental work.

The division of the physical problems in the upper and lower body in the results section responds to identifying possible musculoskeletal disorders. Almost all types of work demand hands and arms usage and analyze their safety and health implications. Therefore, 19% of the workers were diagnosed with musculoskeletal disorders. These disorders are generated by the overuse of muscles, tendons, and nerves. Back, neck, shoulder, and knee pain are some problems related to them. Activities that are repetitive or involve uncomfortable positions cause these disorders that are painful and affect work capability regardless of age[151].

Furthermore, sedentarism was present in 57% of the workforce. Since the deployment of desktops in the workplace, sedentary jobs have increased along with chronic diseases and mortality. Mental work occupies a considerable proportion of the study type of occupation, with over 88%. University and office jobs have been linked to a sedentary lifestyle[152], [153]. As a solution, wellness programs, including physical activity during office hours such as elliptical workstations, sit-stand, or treadmill desks, are introduced in workspace design nowadays[98].

**Statistical Analyses**

Since the majority of the acquired data are categorical, non-parametric statistical techniques were carried out and discussed below:

*Cronbach's alpha coefficient reliability test*

The first test performed on the data was the Cronbach's alpha reliability test. It aims to measure the consistency strength of the studied items towards a concept, particularly occupational diagnosis. The elements used for calculating this coefficient comprise the data and results obtained through biometric screenings. The coefficient value calculated was 0.797. It shows that the collected biometric characteristics are indeed measuring occupational diagnosis.

*Chi-Square Tests*

The Chi-Square test constitutes a first approach to determine the association between the biometric characteristics analyzed. Statistically significant relationships at $p<0.05$ were established. Table 12 enumerates the relations identified between the type of occupation, occupational diagnosis, and several biometric characteristics.

| | Gender | BMI Classification | Laboratory Results | Age | Physical Exam Results |
|---|---|---|---|---|---|
| **Type of Occupation** | Dependent | Dependent | Dependent | Dependent | Independent |
| **Occupational Diagnosis** | Dependent | Independent | Independent | Independent | Dependent |

Table 12: Summary Chi-Square Results

As Table 12 portrays, type of occupation showed a robust association with four of the five biometric traits examined: gender, age, BMI classification, and the results obtained via blood and urine tests, while physical exam results are independent. Occupational diagnosis is statistically related to gender and physical exam results, while characteristics such as BMI classification, laboratory results, and age do not share a relationship with occupational diagnosis. Conversely, gender is statistically dependent for type of occupation and occupational diagnosis. Furthermore, the chi-square test performed between the type of occupation and occupational diagnosis determined that these two characteristics are statistically independent.

Chi-Square tests help identify two categorical variables dependency, but they cannot establish the nature, direction, or strength of this relationship. Consequently, other methods, such as logistic regression, are needed to understand how these biometric traits influence occupational diagnosis[154].

*Logistic Regression*

Logistic regression is popular among health sciences. In comparison to Chi-square tests that analyze two categorical variables at a time, logistic regression can analyze a mix of variables (continuous, categorical) and determine their effect on a discrete outcome.

For the case study, logistic regression was performed to assess the factors that influence occupational diagnosis. The biometric characteristics acquired during the biometric screening event were used in the model. The model comprises eleven predictors: nine categorical variables (gender, age, alcohol, tobacco consumption, laboratory results, physical exam results, pathologies, clinical problems, and type of occupation) and two continuous variables (height and weight). The model was statistically significant ($\chi^2$=

46.694, df= 11, p<0.001, N=409), which means that it could differentiate between the employees diagnosed as fit to work and fit with limitations to work.

As indicated in Table 11, the two major factors influencing occupational diagnosis are gender and the results obtained via physical exams. Physical exam results are a sturdy predictor of the model with an odds ratio value of approximately 4, suggesting that workers who present physical exam problems are four times more likely to be diagnosed as fit with limitations to work. Concerning gender, the odds ratio value was 0.295, which indicates that a person's odds to be diagnosed as fit with limitations to work decreases by a factor of 0.295 for a male employee; all other factors in the model are controlled.

## Hypotheses Discussion

***Hypothesis 1: Biometrics via workplace biometric screenings can serve as a tool for improving workforce health and occupational safety by prioritizing occupational safety and health initiatives, procedures, and policies.***

Biometrics is defined as the science that measures human features for identification purposes. Biometric technology in the workplace uses biometric characteristics such as fingerprint, iris, face recognition systems to access the company facilities, and monitor employees' tardiness and attendance. The acquisition of other biometric characteristics such as height, weight, blood, and urine has become predominant in the workplace by introducing biometric screening events. Employers recognize the importance of OSH initiatives within a business. Therefore, wellness programs that encourage healthy behaviors are becoming attractive to organizations, including biometric screenings.

Research on biometric screenings is mainly oriented to the health benefits given to employees and the organization. This study aimed to explain what biometric screenings are, go beyond the health approach, and analyze the benefits of these tests in occupational safety. As described in the previous sections, health and safety at the workplace are directly connected since healthy employees are motivated to safety behaviors, which decrease work-related accidents.

Screening results provide critical health information to prevent and execute timely interventions regarding diseases and unhealthy habits within the workforce. Additionally, the processes that come after the tests, such as education, health providers' appointments, follow-ups, and medical resources, are essential for the success of the screenings. It is necessary to consider that the results obtained through biometric screenings need to be interpreted by a medical practitioner and understood by the worker to achieve health and safety outcomes in the workplace.

Aggregate reports detailing the workforce health status provide compelling insights into the work conditions in an organization. They offer health tendencies that may be affecting the employees and helpful feedback about wellness programs and OSH policy effectiveness. They can pinpoint weaknesses referring to workplace environmental safety to remediate, intervene, and establish safer strategies that benefit the workers' health.

In the case study examined, biometric screening results analysis and data visualization indicate workforce primary health conditions. Descriptive statistics pointed out preponderant issues suffered by the university employees. As displayed in Figure 17, more than half of the workers are overweight or obese. This fact explains the major clinical problems encountered, such as sedentarism, hypercholesterolemia, and hypertriglyceridemia, as shown in Figure 18. Eyes and upper body affections are the most frequent problems found in the physical examination, as illustrated in Figure 19, which can trigger two of the dominant pathologies (opthalmological and musculoskeletal) presented in Figure 20.

Moreover, logistic regression identified two significant factors that impact occupational diagnosis: gender and physical exam results. Occupational diagnosis is an assessment that reports if the employees can perform the job or task safely for what they were hired. The physical examination reports upper body problems as the second leading issue within the employees.

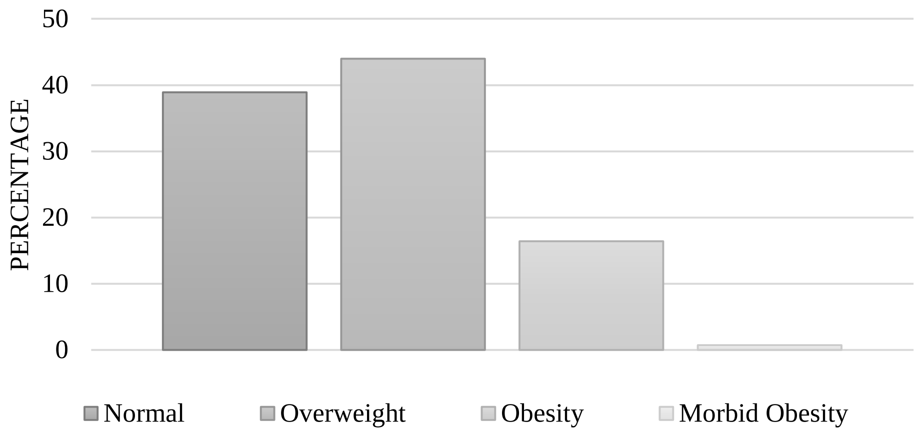



Figure 17: BMI Classification

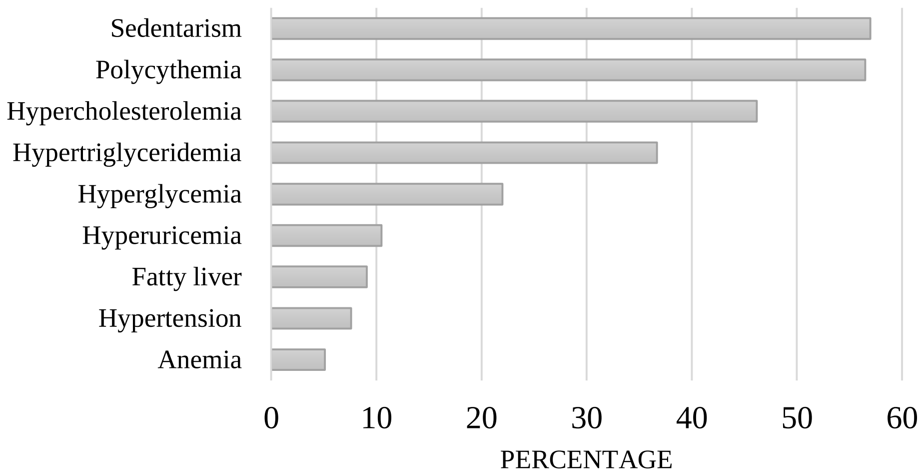



Figure 18: Clinical Problems

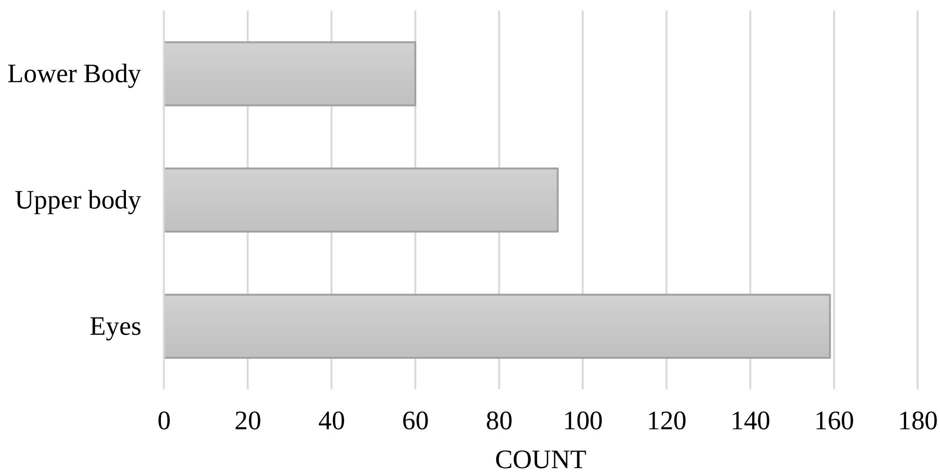



Figure 19: Problems found in the Physical Examination

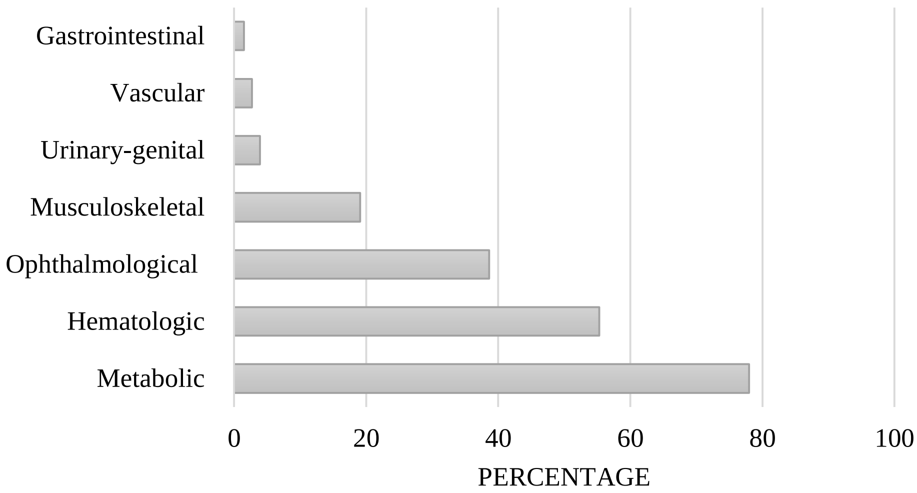



Figure 20: Pathologies

The outcomes generated by the descriptive and inferential statistical analysis were submitted to the university occupational safety and health area for revision. The biometric screening results analysis aided in making several decisions regarding occupational safety and health initiatives. For example, the university implemented a pilot plan focusing on musculoskeletal disorders in the upper body. This plan consisted of training regarding active pauses during the work schedule; hand, wrists, and forearm exercises; ergonomic mouse usage; and a trimestral follow-up. Musculoskeletal disorders in the upper body constitute a main occupational problem in mental work (administrative, office jobs) shared by a high percentage of university employees.

Consequently, based on the theoretical framework and the case study results described in section two. The following thesis can be formulated:

**Thesis 1: Biometrics via workplace biometric screenings can serve as a tool for improving workforce health and occupational safety by prioritizing occupational safety and health initiatives, procedures, and policies.**

***Hypothesis 2: Biometric characteristics can be related to the employees' ability to perform their work***

The case study presented in section two collected different biometric characteristics of 409 university employees in Ecuador, which are listed below:

- Occupation
- Gender
- Age
- Height
- Weight
- Blood
- Urine
- Body Examination

These characteristics were analyzed, and biometric screening results were summarized and presented in the following categories:

- BMI classification
- Blood and Urine Laboratory Results
- Physical Exam Results

Additionally, after reviewing the results, the occupational doctor categorized the employees into two groups: fit to work and fit to work but with limitations. There was not any case of employees that were not fit to work.

The event delivered valuable information regarding the university workforce's health. Biometric screening results pointed out commonalities in abnormal laboratory results, physical exams, clinical problems, and pathologies. These results and the occupational diagnosis were used to perform inferential statistical analyses such as chi-square tests.

Chi-Square tests are used for hypothesis testing. In the specific case study analyzed, the type of occupation and occupational diagnosis were tested with the following biometric characteristics: gender, age, BMI classification, laboratory results, and physical exam results.

The null hypotheses are:

- Type of occupation is not statistically related to the biometric characteristics: gender, age, BMI classification, laboratory results, and physical exam results
- Occupational diagnosis is not statistically related to the biometric characteristics: gender, age, BMI classification, laboratory results, and physical exam results

The alternative hypotheses are:

- Type of occupation is statistically related to the biometric characteristics: gender, age, BMI classification, laboratory results, and physical exam results
- Occupational diagnosis is statistically related to the biometric characteristics: gender, age, BMI classification, laboratory results, and physical exam results.

Chi-square test results indicated a significant association between the type of occupation and gender, BMI classification, laboratory results, and age. Physical exam result was the only characteristic when the null hypothesis was accepted, signifying that the occupation type is independent of physical exam results. Conversely, regarding occupational diagnosis, the alternative hypothesis was accepted for gender and physical exam results. The null hypothesis was accepted for BMI classification, laboratory results, and age, meaning that these traits do not share a statistical relationship with the occupational diagnosis.

Therefore the type of occupation (mental, physical work) is related to the following biometric characteristics: gender, BMI classification, laboratory results, and age, while occupational diagnosis (fit to work, fit with limitations) is related to the biometric characteristics of gender and physical exam results.

In addition, logistic regression identified two main factors that impact the occupational diagnosis: gender and physical examination. Therefore, in this specific case having problems in the physical exam and gender can influence the ability to perform a job.

Based on the inferential statistical analysis described, the following thesis can be formulated:

**Thesis 2: Biometric characteristics are related to the employees' ability to perform their job.**

***Hypothesis 3: Biometric screening results can help identify hazards that affect Occupational Safety and Health***

The literature review and the experimental procedure described in the previous chapters indicate that biometric screening results can identify intrinsic hazards in the employees, affecting their health and contributing to unsafe behaviors.

Biometric screening results provide accurate and medically verified information regarding a person’s health status. These results are tangible proof of the workers’ health, but they also contribute to detecting unexpected hazards. Figure 21 illustrates how biometric data collection and biometric screenings supply critical information for recognizing hazards that can lead to long-term safety incidents. In this case, four biometric characteristics indicate overweight, obesity, high-stress levels, which can lead to serious long-term health problems such as diabetes or coronary affections and affect workplace safety such as work-related injuries, overexertion, and accidents.

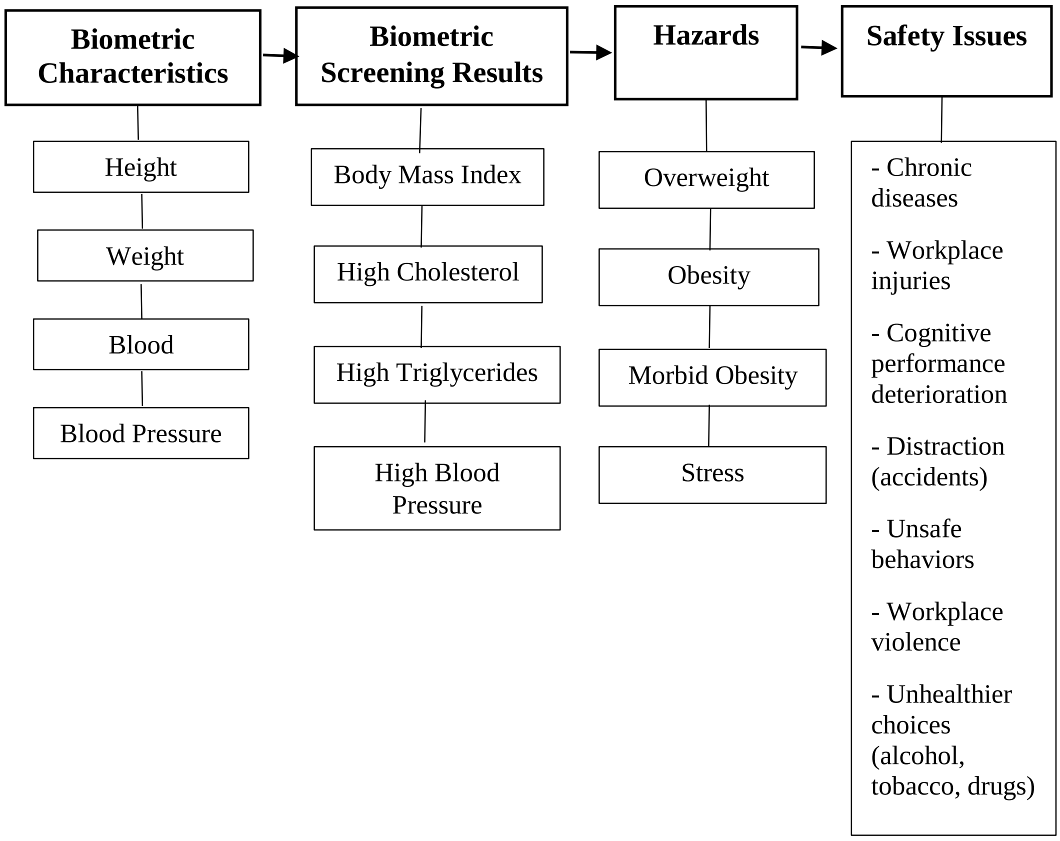



Figure 21: Conceptual Framework on hazard detection and safety issues

In the case study carried out in an Ecuadorian university, the majority of employees perform mental work (88%) such as office assistant, professor, administrative work, and others. This type of occupation is linked to specific hazards due to the nature of the work. In this particular case study, the following mental-related work hazards were identified and presented in Figure 22.

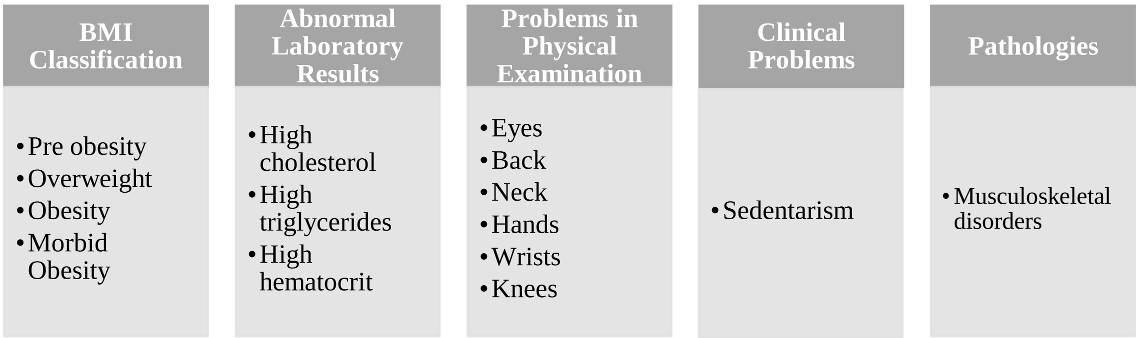



Figure 22: Mental work Hazards

Moreover, logistic regression determined the two principal factors predicting or explaining occupational diagnosis: gender and physical exam results. A male employee's odds of being diagnosed as fit to work with limitations decrease by a factor of 0.295 compared with a female. Also, if an employee reports problems in the physical exam, the odds of being diagnosed as fit to work with limitations increase by a factor of 3.879 in contrast to an employee who does not have problems in the physical exam, all other factors in the model being equal.

Female employees represent 39% of the university workforce and constitute a large proportion of mental work. Although female workers are relatively younger than males, as shown in Figure 23, they suffer more upper body and lower body problems than men, as displayed in Figure 24. In the case study, inferential statistical methods such as logistic regression pointed the main aspects that affect an employee's fitness to work. Consequently, it creates awareness of these unexpected hazards in the early stages, digs more in-depth on the root causes, and leads to the planning of timely interventions because workplace accidents do not occur unexpectedly. They happen for one or multiple reasons.

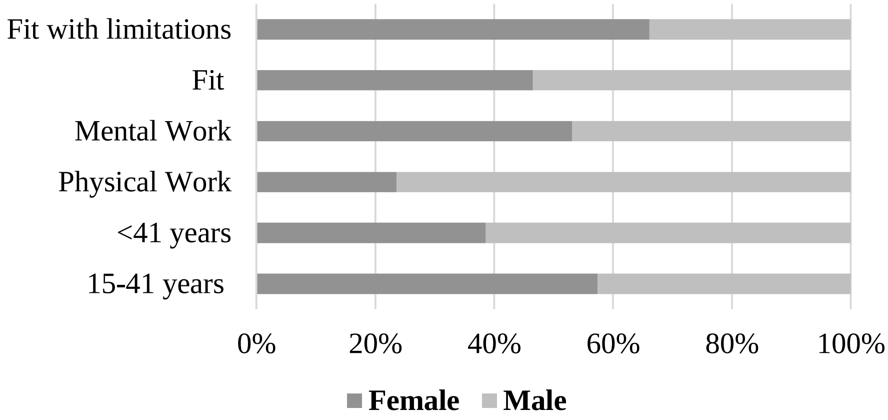



Figure 23: Gender and biometric characteristics

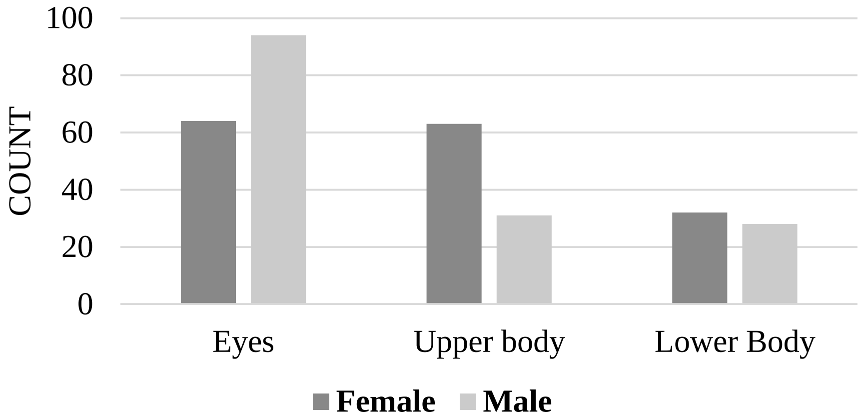



Figure 24: Gender and problems in the physical examination

These results also prove how a particular work affects the employees' health, which should be a clear reason for making changes in the work environment that can impact workplace safety and health.

The first step in a risk assessment is hazard identification[155]. Thanks to biometric screenings, bounded employee hazards can be easily spotted. Moreover, the analysis of the results can provide a tailored hazards profile of the specific job position. This identification creates awareness and can aid in hazard prioritization.

The hazard identification serves as the grassroots for directing safety and health policies in the university. Additionally, it researches the causes, provides evidence of the hazards related to desk-bound professions, and identifies specific actions and policies to treat and manage these conditions.

The case study findings coincide with a report entitled: "The work colleague of the future" [156]. This report summarizes the hazards linked to an office workstation, which will be the most common workplace environment. In this report, generally, long-term health problems in the eyes, nose, hands, wrists, legs, veins, back, and also overweight are forecasted for the office employee in 2040. Thanks to the results found in a biometric screening event, the company can identify the specific hazards among their employees and invest in policies to eliminate or control them.

As a consequence of the pandemic started in 2020, mental work drifted to households, posing different challenges and changing the occupational safety and health dynamics. Teleworking has several advantages, such as schedule flexibility, lack of commuting, and the possibility of working from any location. However, it can provoke several problems such as more distractions, less productivity, loneliness, and unsafe work environments in terms of ergonomics, extended screen time, and difficulty to disconnect from work tasks (overworking)[157], [158]. Biometric screening results can help identify home office hazards and the actual health and safety consequences among workers due to the Covid-19 outbreak.

Biometric screenings can be a primary tool for choosing or keeping employees in safety-sensitive positions. Work roles such as operating heavy machinery, jobs where firearms are employed, or driving emergency vehicles in which the individual and coworkers and public safety are at risk. Furthermore, new high-risk jobs regarding the level of exposure to the virus emerged amid the Covid-19 crisis drifting healthcare staff and essential workers as professions that require immediate occupational safety and health protection[159].

Based on the theoretical framework and experimental work, the following thesis can be formulated:

**Thesis 3: Biometric screening results help identify hazards that affect Occupational Safety and Health**

# CONCLUSIONS

The purpose of biometrics is to serve as a means of identification. The present work aimed to extend this concept by identifying the hazards within the employees and how these hazards affect occupational safety and health.

The workforce is a crucial element in organizations and for the economy well functioning. Employees spend at least a third of the day at a company without counting the commuting or extra hours. For this reason, health-promoting programs are becoming a must at any organization. Employees' health is highly connected to productivity, satisfaction, safety practices, and savings in healthcare costs. Nevertheless, these benefits, the employer has the moral duty of providing a safe and healthy environment at the workplace.

Biometric screenings constitute a vital part of wellness programs. At one event, it is possible to collect several biometric characteristics such as height, weight, blood pressure, heart rate, and others. The screening results provide a holistic vision of the workforce's health status. Moreover, it represents an opportunity to detect chronic diseases or health risk factors to prevent and treat them. The impact of this specific program keeps present after the screenings. It goes beyond health benefits because it also aids in the identification of hazards, which are critical elements in risk analysis and consequently enhance safety behaviors at the workplace.

Biometric screening outcomes represent the first step in developing a safety attitude among the workforce. These results create awareness of the workers' health condition. Furthermore, as part of OSH initiatives, the worker receives the information and resources needed to change lifestyle habits. These habits are endangering their health and triggering unsafety behaviors. As an organization, wellness initiatives motivate the employees towards achieving healthy actions, which generate a cascade effect on safety.

The effectiveness of OSH initiatives in place or the introduction of new ones at an organization can be easily assessed by revising the biometric screening results. The results can indicate which OSH interventions benefit the workforce health over time, which ones need to be changed or updated by evaluating biometric markers such as blood pressure, weight, cholesterol, and more.

Biometric screenings are just one step to attain workers' health and safety. They do not replace an appointment with a physician but motivate a better lifestyle by making informed decisions about their health and change into healthy and safer behaviors. Its results need to be integrated with other components such as work processes and hazard assessments to providing motivating, satisfying, and quality jobs.

Concerning the case study in Ecuador, it is crucial to annotate that the study was carried out in a public university, where the budget is limited. For this reason, the effort of the university to provide biometric screenings is worthwhile. Biometric screenings take health exams to the workplace and make them available to people who will not access these tests in another case. Additionally, the analysis of the results can help rank hazards and prioritize safety and health initiatives when having a low budget.

Biometric screening results can help create a customized hazards model specific to the type of job or industry. Therefore they can serve as a decision-making tool for identifying the characteristics that influence the occupational diagnosis.

Regardless of the moral and legal duty, a company has to provide a safe and healthy workplace; this study wanted to look forward to the employees' health and analyze the implications on safety, which can be an incentive for corporations to invest in redesigning workstations and working procedures.

As for the upcoming trends in acquiring biometric characteristics in the workplace, biometric screenings constitute a vital part of wellness programs nowadays. However, tracking devices such as smartwatches or mobile fitness applications that collect the number of steps, heartbeat, calories burned, distance, and hours of sleep are gaining popularity among big enterprise companies. These devices can also accommodate each employee's different health necessities, such as pregnancy, diabetes, high cholesterol, blood pressure, or fitness, to create a program that motivates them and shows health improvement. Moreover, the usage of wearable tracking devices as part of a wellness program suggests a statistically significant reduction in body mass index values in employees [160]. Furthermore, biometric authentication and identification have been diversified in smartphones. It does not just use biometric sensors for security purposes but for health monitoring to measure biometric characteristics such as heart rate, steps, lung sounds [25][161].

Nowadays, biometric screenings are utterly needed to assess the remote and onsite workers' wellbeing and analyze how the pandemic is affecting them. Screenings can detect long-term effects in an infected employee case or identify specific health conditions in workers more vulnerable to the virus to instate preventive measures and plan better treatment options. Moreover, it is vital to pay extra attention to new high-risk professions such as essential service employees that comprise healthcare, the food industry, and public transportation. These covid-19 risk jobs take a disproportionate toll on racial and ethnic minorities that require occupational safety protection. OSH initiatives and policies, including safety procedures during biometric screening events, need to be generated and adapted to the new workplace reality to supply safe and healthy workspaces.

Health and safety at work are closely related since healthy employees are productive, commit fewer mistakes, are guided to safety behaviors, and fewer accidents. The ultimate goal of a biometric screening event is to promote health within the participants, which increases the perception of safety. Therefore, the purpose of this study was to present biometric screenings as an essential tool for improving occupational safety and the starting point for the introduction of wellness initiatives and policies.

# IMPORTANCE OF THE STUDY

The present study constitutes the first approach to linking health and safety in the workplace. It uses actual biometric data instead of self-assessment data collected in surveys or questionnaires to evaluate the extent to which work affects the employees and, therefore, the safety of the organization. It opens up the opportunity to discuss until what point the employer is responsible for the worker's health, lifestyle choices, and habits.

Demographic shifting worldwide will affect workplace practices. By 2020 in the European Union, people 60 years and older will account for one in five population [162]. Additionally, by 2050 people older than 60 will represent 22% of the world's population[163]. Thus, there will be a considerable proportion of workers aged 60 and over with daunting expectations of health problems and chronic diseases. Biometric screenings can contribute to change this phenomenon and aid employees to live a longer and healthier life. Moreover, reach sustainable employment targets, pension systems, and reduction of occupational injuries and accidents.

The impact of sedentary jobs on workers' health is catching the public's attention. Health policies are trying to shape the work environment, but they do not provide enough incentives to the corporations. Biometric screenings can be the initial point for improving health and giving the employer motivation by offering data that can impact safety that, in the long term, reduces costs and improves the workforce morale and the company image.

Biometric screening results and, therefore, hazard identification direct to proactive operations concerning workplace safety and health. Anticipation, timely elimination, and hazard control prevent long-term safety incidents in contrast to a reactive approach when the reaction occurs as the problem happens and can cause economic costs, demands, and more.

Furthermore, this study is relevant to three of the United Nation's Sustainable Development Goals (SDG) number 3,8 and 16[164][165]:

- *Good health and well- being*

  One of the main research topics in this work is biometric screenings, specifically concentrated on the employees' health by providing health exams to help identify diseases.

- *Decent work and economic growth*

  This study tackles explicitly target 8.8, which aims to protect labor rights and promote safe and secure working environments.

- *Peace and justice through the development of competent, reliable, and transparent institutions*

  The present work examines how biometric screenings can constitute a tool for promoting occupational safety and health. Consequently, contributing to the completion and OSH regulations update, which can diminish workplace fatalities and occupational illnesses.

Investing in occupational safety and health is crucial for achieving SDG targets. It contributes to improving the organization's image and reputation in terms of the workforce and the stakeholders. Soon, sustainable development will be decisive for making business and reaching economic and productive growth.

# NEW SCIENTIFIC CONTRIBUTIONS

The present work is composed of three elements that together contribute to scientific knowledge. They are described below:

1. Theoretical Framework

   The theoretical framework narrowed the research scope and helped to unify the existing knowledge about Biometrics, Biometric Screenings, and Occupational Safety and Health. It consisted of a thorough literature revision of relevant scientific documents to understand how biometrics via biometric screenings are linked to workplace safety and health. It served as the basis to formulate three hypotheses regarding biometric screenings and occupational safety and health.

2. Experimental Procedure

   The experimental procedure was performed to test or modify the hypotheses. It consisted of two case studies:

   - The preliminary research collected data about Hungarian employees' opinions and perceptions towards corporate wellness practices, including biometric screenings. It served as a baseline to unify wellness initiatives efforts and the importance of biometric screenings from the worker's perspective.
   - A case study in which primary data from biometric screenings at an Ecuadorian university were collected and analyzed through descriptive and inferential statistical tests. These tests are vital for drawing conclusions from the available data collected.

3. Discussion and Results Analysis

At this part of the research, the statistical analyses performed to the acquired data set described in the experimental procedures section were explained in order to validate or reject the hypotheses proposed in section one.

Consequently, based on the theoretical framework and the statistical analysis results, the three hypotheses formulated were accepted. The hypotheses explained that biometrics, specifically biometric screenings, do not just enhance occupational health but also occupational safety by detecting hazards that can help prioritize OSH initiatives, procedures, and policies. Moreover, statistically significant relationships between biometric characteristics, type of occupation and occupational diagnosis were established.

Chi-square tests indicate that type of occupation is related to four biometric characteristics (gender, BMI classification, laboratory results, and age). In comparison, occupational diagnosis is related to two biometric characteristics (gender and physical exam results). Also, logistic regression identified two biometric characteristics that influence occupational safety. Thus, biometric characteristics impact how an employee can safely perform his/her job.

In addition, this research went further and provided all case study data summary and statistical results to OSH key actors and decision-makers to evaluate them and make informed decisions based on real facts that benefit the employees' health and occupational safety.

# FURTHER RESEARCH, RECOMMENDATIONS, LIMITATIONS

In order to get a complete understanding of the effect of biometric screenings on occupational safety and health, it is necessary to research aspects such as workplace accidents, fatalities, health but other topics not obvious such as turnover, employee engagement, motivation, and feedback about the screenings. Moreover, research that analyzes how the workplace and the type of occupation affect the employees' mental health, which can trigger serious safety issues, is vital to be carried out to find ways to prevent the causes and enhance safety.

The case study presented in this research concentrates on a university population; the data can serve as an example for other Ecuadorian universities but cannot be generalized to larger populations. It is essential to research how biometric screenings can detect hazards in industries where manual labor is high or high-security levels should be in place.

Further research involving two or more years of biometric screenings results regarding the effectiveness is needed to understand how the screenings impact safety and health at the workplace. Also, compiling the long-term outcomes and results obtained through biometric screenings over the years will exhibit if health behaviors persist after 1 or 2-year intervention and the effect over safety incidents.

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# APPENDICES

## Appendix I: Preliminary Research Survey

Dear Participant,

Thank you for your interest in this survey. Please take a few minutes to fill out this form. All the answers are confidential.

This survey collects important information regarding wellness programs. We are eager for your feedback in order to improve our Health programs.

**Personal Information**

1. Gender: M F
2. Please write the year you were born:
3. Marital status
   - single
   - married/in relationship
   - divorced
   - widowed
4. Do you have children? Yes-No
5. If yes, what are their ages?

**Health Habits**

6. Do you smoke? Yes- No
7. If Yes, how often do you smoke?
   - Once a day
   - Several times per day
   - Several times per week
   - Socially
8. Do you take any medication? Yes- No
9. If Yes, What kind? For what reason?
10. How sickly do you think you are compared to others of your age?

    - Very sick

- Sick
- Somewhat sick
- Neither sick or healthy
- Somewhat healthy
- Healthy
- Very Healthy

11. Have you ever been hospitalized?
12. If yes, for what reason?
13. Do you consider yourself as a health-conscious person?
    - Strongly disagree
    - Disagree
    - Somewhat disagree
    - Neither agree nor disagree
    - Somewhat agree
    - Agree
    - Strongly agree
14. Please list the three most expensive medical treatments (dentist, GP, pediatrician, …) in your life on an annual basis, and indicate how much You spend on them on an annual basis!

    **1, ……………… …………….**

    **2, ……………… …………….**

    **3, ……………… …………….**

**Biometric Screening**

Biometric screening is defined as "the measurement of physical characteristics such as height, weight, body mass index, blood pressure, blood cholesterol, blood glucose, and aerobic fitness tests that can be taken at the worksite and used as part of a workplace health assessment to benchmark and evaluate changes in employee health status over time."

15. Please rate how important do you think Biometric Screening is at the workplace?
    - Very important
    - Important
    - Moderately Important
    - Slightly Important
    - Not important
16. Are you interested in participating in a Biometric Screening? Yes-No
17. Have you ever participated in a Biometric Screening in the company? Yes-No (If yes, please go to question 8, if no, please go to question 12)
18. Did you get/ check the results of your Biometric Screening in the company? Yes-No (If yes, please go to question 9, if no, please go to question 12)
19. Have you reviewed the results of your Biometric Screening in the company by doctor/physician? Yes- No (If yes, please go to question 10, if no, please go to question 12)
20. Have you made any change in your life or health (exercise, diet, medication, etc) due to the evaluation of your Biometric Screening results in the company? Yes-No (If yes, please write what type)
21. Do you feel more motivated to work for the company as a company that cares for you after the Biometric Screening evaluation? Yes- No
22. Have you ever participated in a Biometric Screening outside the company? Yes-No.( If yes, please write what type)

**Wellness Initiatives**

23. Please distribute 100 points into the Health programs based on the importance for you (the more points You give to an item the more important it is for You):

- Office Massage
- Tobacco Cessation resources
- Health Coach
- On-site Clinic
- Family-oriented health events
- Health Events

- Vaccinations
- Health Screenings
- Outdoors activities

24. What kind of Health program would you be interested in receiving in the company?
25. Are you willing to pay for this program? Yes- No
26. If yes, how much? quantify the amount in forints per month
27. How satisfied are you with the company?

- Very satisfied
- Satisfied
- Somewhat satisfied
- Neither Satisfied or Dissatisfied
- Somewhat Dissatisfied
- Dissatisfied
- Very Dissatisfied

28. How satisfied are you with your life?

- Very satisfied
- Satisfied
- Somewhat satisfied
- Neither Satisfied or Dissatisfied
- Somewhat Dissatisfied
- Dissatisfied
- Very Dissatisfied

29. Do you prefer an employer with a Health initiative to another without? Yes- No
30. Do you trust an employer with a Health initiative more than another without? Yes- No
31. Do you think it is a task of an employer to take care of its employees' health issues? Yes- No

# Appendix II: Results Inferential Statistics SPSS

## 1.Cronbach's alpha coefficient reliability test

Scale: Occupational Diagnosis

| Case Processing Summary | | | |
|---|---|---|---|
| | | N | % |
| Cases | Valid | 409 | 100.0 |
| | Excluded[a] | 0 | .0 |
| | Total | 409 | 100.0 |

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

| Cronbach's Alpha | N of Items |
|---|---|
| .797 | 4 |

**2.Chi-Square Tests for Independence**

- ***Statistically Related to Type of Occupation***

| Type of Occupation * Gender | | | | | |
|---|---|---|---|---|---|
| | | | Gender | | Total |
| | | | Female | Male | |
| Occupation | Mental Work | Count | 153 | 208 | 361 |
| | | Expected Count | 142.1 | 218.9 | 361.0 |
| | | % within Occupation | 42.4% | 57.6% | 100.0% |
| | | % within Gender | 95.0% | 83.9% | 88.3% |
| | | % of Total | 37.4% | 50.9% | 88.3% |
| | Physical Work | Count | 8 | 40 | 48 |
| | | Expected Count | 18.9 | 29.1 | 48.0 |
| | | % within Occupation | 16.7% | 83.3% | 100.0% |
| | | % within Gender | 5.0% | 16.1% | 11.7% |
| | | % of Total | 2.0% | 9.8% | 11.7% |
| Total | | Count | 161 | 248 | 409 |
| | | Expected Count | 161.0 | 248.0 | 409.0 |
| | | % within Occupation | 39.4% | 60.6% | 100.0% |
| | | % within Gender | 100.0% | 100.0% | 100.0% |
| | | % of Total | 39.4% | 60.6% | 100.0% |

| Chi-Square Tests | | | | | |
|---|---|---|---|---|---|
| | Value | df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
| Pearson Chi-Square | 11.738[a] | 1 | .001 | | |
| Continuity Correction[b] | 10.685 | 1 | .001 | | |
| Likelihood Ratio | 13.052 | 1 | .000 | | |
| Fisher's Exact Test | | | | .000 | .000 |
| Linear-by-Linear Association | 11.709 | 1 | .001 | | |
| N of Valid Cases | 409 | | | | |

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 18.89.

b. Computed only for a 2x2 table

| Type of Occupation * BMI Classification | | | | | | |
|---|---|---|---|---|---|---|
| | | | BMI Classification | | | Total |
| | | | Normal | Overweight | Obesity | |
| Occupation | Mental Work | Count | 128 | 171 | 62 | 361 |
| | | Expected Count | 140.3 | 158.9 | 61.8 | 361.0 |
| | | % within Occupation | 35.5% | 47.4% | 17.2% | 100.0% |
| | | % within BMI class | 80.5% | 95.0% | 88.6% | 88.3% |
| | | % of Total | 31.3% | 41.8% | 15.2% | 88.3% |
| | Physical Work | Count | 31 | 9 | 8 | 48 |
| | | Expected Count | 18.7 | 21.1 | 8.2 | 48.0 |
| | | % within Occupation | 64.6% | 18.8% | 16.7% | 100.0% |
| | | % within BMI class | 19.5% | 5.0% | 11.4% | 11.7% |
| | | % of Total | 7.6% | 2.2% | 2.0% | 11.7% |
| Total | | Count | 159 | 180 | 70 | 409 |
| | | Expected Count | 159.0 | 180.0 | 70.0 | 409.0 |
| | | % within Occupation | 38.9% | 44.0% | 17.1% | 100.0% |
| | | % within BMI class | 100.0% | 100.0% | 100.0% | 100.0% |
| | | % of Total | 38.9% | 44.0% | 17.1% | 100.0% |

| Chi-Square Tests | | | |
|---|---|---|---|
| | Value | Df | Asymp. Sig. (2-sided) |
| Pearson Chi-Square | 17.136[a] | 2 | .000 |
| Likelihood Ratio | 17.710 | 2 | .000 |
| Linear-by-Linear Association | 7.241 | 1 | .007 |
| N of Valid Cases | 409 | | |

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.22.

| Type of Occupation * Laboratory Results | | | | | |
|---|---|---|---|---|---|
| | | | Laboratory Results | | Total |
| | | | Normal | Abnormal | |
| Occupation | Mental Work | Count | 97 | 264 | 361 |
| | | Expected Count | 87.4 | 273.6 | 361.0 |
| | | % within Occupation | 26.9% | 73.1% | 100.0% |
| | | % within Laboratory Results | 98.0% | 85.2% | 88.3% |
| | | % of Total | 23.7% | 64.5% | 88.3% |
| | Physical Work | Count | 2 | 46 | 48 |
| | | Expected Count | 11.6 | 36.4 | 48.0 |
| | | % within Occupation | 4.2% | 95.8% | 100.0% |
| | | % within Laboratory Results | 2.0% | 14.8% | 11.7% |
| | | % of Total | 0.5% | 11.2% | 11.7% |
| Total | | Count | 99 | 310 | 409 |
| | | Expected Count | 99.0 | 310.0 | 409.0 |
| | | % within Occupation | 24.2% | 75.8% | 100.0% |
| | | % within Laboratory Results | 100.0% | 100.0% | 100.0% |
| | | % of Total | 24.2% | 75.8% | 100.0% |

| Chi-Square Tests | | | | | |
|---|---|---|---|---|---|
| | Value | Df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
| Pearson Chi-Square | 11.903[a] | 1 | .001 | | |
| Continuity Correction[b] | 10.697 | 1 | .001 | | |
| Likelihood Ratio | 15.908 | 1 | .000 | | |
| Fisher's Exact Test | | | | .000 | .000 |
| Linear-by-Linear Association | 11.874 | 1 | .001 | | |
| N of Valid Cases | 409 | | | | |

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 11.62.
b. Computed only for a 2x2 table

| Type of Occupation * Age | | | | | |
|---|---|---|---|---|---|
| | | | Age | | Total |
| | | | >41 years | 15-41 | |
| Occupation | Mental Work | Count | 142 | 219 | 361 |
| | | Expected Count | 149.2 | 211.8 | 361.0 |
| | | % within Occupation | 39.3% | 60.7% | 100.0% |
| | | % within Age | 84.0% | 91.2% | 88.3% |
| | | % of Total | 34.7% | 53.5% | 88.3% |
| | Physical Work | Count | 27 | 21 | 48 |
| | | Expected Count | 19.8 | 28.2 | 48.0 |
| | | % within Occupation | 56.2% | 43.8% | 100.0% |
| | | % within Age | 16.0% | 8.8% | 11.7% |
| | | % of Total | 6.6% | 5.1% | 11.7% |
| Total | | Count | 169 | 240 | 409 |
| | | Expected Count | 169.0 | 240.0 | 409.0 |
| | | % within Occupation | 41.3% | 58.7% | 100.0% |
| | | % within Age | 100.0% | 100.0% | 100.0% |
| | | % of Total | 41.3% | 58.7% | 100.0% |

| Chi-Square Tests | | | | | |
|---|---|---|---|---|---|
| | Value | df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
| Pearson Chi-Square | 4.999[a] | 1 | .025 | | |
| Continuity Correction[b] | 4.326 | 1 | .038 | | |
| Likelihood Ratio | 4.915 | 1 | .027 | | |
| Fisher's Exact Test | | | | .029 | .019 |
| Linear-by-Linear Association | 4.987 | 1 | .026 | | |
| N of Valid Cases | 409 | | | | |

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 19.83.

b. Computed only for a 2x2 table

- ***Statistically Independent to Type of Occupation***

| Occupation * Physical Exam Results | | | | | |
|---|---|---|---|---|---|
| | | | Physical Exam Results | | Total |
| | | | Normal | Abnormal | |
| Occupation | Mental Work | Count | 186 | 175 | 361 |
| | | Expected Count | 180.9 | 180.1 | 361.0 |
| | | % within Occupation | 51.5% | 48.5% | 100.0% |
| | | % within Physical Exam Results | 90.7% | 85.8% | 88.3% |
| | | % of Total | 45.5% | 42.8% | 88.3% |
| | Physical Work | Count | 19 | 29 | 48 |
| | | Expected Count | 24.1 | 23.9 | 48.0 |
| | | % within Occupation | 39.6% | 60.4% | 100.0% |
| | | % within Physical Exam Results | 9.3% | 14.2% | 11.7% |
| | | % of Total | 4.6% | 7.1% | 11.7% |
| Total | | Count | 205 | 204 | 409 |
| | | Expected Count | 205.0 | 204.0 | 409.0 |
| | | % within Occupation | 50.1% | 49.9% | 100.0% |
| | | % within Physical Exam Results | 100.0% | 100.0% | 100.0% |
| | | % of Total | 50.1% | 49.9% | 100.0% |

| Chi-Square Tests | | | | | |
|---|---|---|---|---|---|
| | Value | Df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
| Pearson Chi-Square | 2.416[a] | 1 | .120 | | |
| Continuity Correction[b] | 1.962 | 1 | .161 | | |
| Likelihood Ratio | 2.431 | 1 | .119 | | |
| Fisher's Exact Test | | | | .127 | .080 |
| Linear-by-Linear Association | 2.410 | 1 | .121 | | |
| N of Valid Cases | 409 | | | | |

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 23.94.

b. Computed only for a 2x2 table

- ***Statistically Dependent to Occupational Diagnosis***

| Occupational diagnosis * Gender | | | | | |
|---|---|---|---|---|---|
| | | | Gender | | Total |
| | | | Female | Male | |
| Occupational diagnosis | Fit with Limitations | Count | 38 | 30 | 68 |
| | | Expected Count | 26.8 | 41.2 | 68.0 |
| | | % within Occupational diagnosis | 55.9% | 44.1% | 100.0% |
| | | % within Gender | 23.6% | 12.1% | 16.6% |
| | | % of Total | 9.3% | 7.3% | 16.6% |
| | Fit | Count | 123 | 218 | 341 |
| | | Expected Count | 134.2 | 206.8 | 341.0 |
| | | % within Occupational diagnosis | 36.1% | 63.9% | 100.0% |
| | | % within Gender | 76.4% | 87.9% | 83.4% |
| | | % of Total | 30.1% | 53.3% | 83.4% |
| Total | | Count | 161 | 248 | 409 |
| | | Expected Count | 161.0 | 248.0 | 409.0 |
| | | % within Occupational diagnosis | 39.4% | 60.6% | 100.0% |
| | | % within Gender | 100.0% | 100.0% | 100.0% |
| | | % of Total | 39.4% | 60.6% | 100.0% |

| Chi-Square Tests | | | | | |
|---|---|---|---|---|---|
| | Value | df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
| Pearson Chi-Square | 9.323[a] | 1 | .002 | | |
| Continuity Correction[b] | 8.512 | 1 | .004 | | |
| Likelihood Ratio | 9.115 | 1 | .003 | | |
| Fisher's Exact Test | | | | .003 | .002 |
| Linear-by-Linear Association | 9.300 | 1 | .002 | | |
| N of Valid Cases | 409 | | | | |

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 26.77.
b. Computed only for a 2x2 table

| Occupational diagnosis * Physical Exam Results | | | | | |
|---|---|---|---|---|---|
| | | | Physical Exam Results | | Total |
| | | | Normal | Abnormal | |
| Occupational diagnosis | Fit with limitations | Count | 16 | 52 | 68 |
| | | Expected Count | 34.1 | 33.9 | 68.0 |
| | | % within Occupational diagnosis | 23.5% | 76.5% | 100.0% |
| | | % within Physical exam results | 7.8% | 25.5% | 16.6% |
| | | % of Total | 3.9% | 12.7% | 16.6% |
| | Fit | Count | 189 | 152 | 341 |
| | | Expected Count | 170.9 | 170.1 | 341.0 |
| | | % within Occupational diagnosis | 55.4% | 44.6% | 100.0% |
| | | % within Physical exam results | 92.2% | 74.5% | 83.4% |
| | | % of Total | 46.2% | 37.2% | 83.4% |
| Total | | Count | 205 | 204 | 409 |
| | | Expected Count | 205.0 | 204.0 | 409.0 |
| | | % within Occupational diagnosis | 50.1% | 49.9% | 100.0% |
| | | % within Physical Exam | 100.0% | 100.0% | 100.0% |
| | | % of Total | 50.1% | 49.9% | 100.0% |

| Chi-Square Tests | | | | | |
|---|---|---|---|---|---|
| | Value | df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
| Pearson Chi-Square | 23.071[a] | 1 | .000 | | |
| Continuity Correction[b] | 21.813 | 1 | .000 | | |
| Likelihood Ratio | 24.087 | 1 | .000 | | |
| Fisher's Exact Test | | | | .000 | .000 |
| Linear-by-Linear Association | 23.015 | 1 | .000 | | |
| N of Valid Cases | 409 | | | | |

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 33.92.
b. Computed only for a 2x2 table

- ***Statistically Independent to Occupational Diagnosis***

| Occupational diagnosis * BMI Classification | | | | | | |
|---|---|---|---|---|---|---|
| | | | BMI Classification | | | Total |
| | | | Normal | Overweight | Obesity | |
| Occupational diagnosis | Fit with limitations | Count | 31 | 27 | 10 | 68 |
| | | Expected Count | 26.4 | 29.9 | 11.6 | 68.0 |
| | | % within Occupational diagnosis | 45.6% | 39.7% | 14.7% | 100.0% |
| | | % within BMI classification | 19.5% | 15.0% | 14.3% | 16.6% |
| | | % of Total | 7.6% | 6.6% | 2.4% | 16.6% |
| | Fit | Count | 128 | 153 | 60 | 341 |
| | | Expected Count | 132.6 | 150.1 | 58.4 | 341.0 |
| | | % within Occupational diagnosis | 37.5% | 44.9% | 17.6% | 100.0% |
| | | % within BMI classification | 80.5% | 85.0% | 85.7% | 83.4% |
| | | % of Total | 31.3% | 37.4% | 14.7% | 83.4% |
| Total | | Count | 159 | 180 | 70 | 409 |
| | | Expected Count | 159.0 | 180.0 | 70.0 | 409.0 |
| | | % within Occupational diagnosis | 38.9% | 44.0% | 17.1% | 100.0% |
| | | % within BMI classification | 100.0% | 100.0% | 100.0% | 100.0% |
| | | % of Total | 38.9% | 44.0% | 17.1% | 100.0% |

| Chi-Square Tests | | | |
|---|---|---|---|
| | Value | df | Asymp. Sig. (2-sided) |
| Pearson Chi-Square | 1.565[a] | 2 | .457 |
| Likelihood Ratio | 1.546 | 2 | .462 |
| Linear-by-Linear Association | 1.321 | 1 | .250 |
| N of Valid Cases | 409 | | |

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 11.64.

| Occupational diagnosis * Laboratory Results | | | | | |
|---|---|---|---|---|---|
| | | | Laboratory Results | | Total |
| | | | Normal | Abnormal | |
| Occupational diagnosis | Fit with limitations | Count | 11 | 57 | 68 |
| | | Expected Count | 16.5 | 51.5 | 68.0 |
| | | % within Occupational diagnosis | 16.2% | 83.8% | 100.0% |
| | | % within Laboratory results | 11.1% | 18.4% | 16.6% |
| | | % of Total | 2.7% | 13.9% | 16.6% |
| | Fit | Count | 88 | 253 | 341 |
| | | Expected Count | 82.5 | 258.5 | 341.0 |
| | | % within Occupational diagnosis | 25.8% | 74.2% | 100.0% |
| | | % within Laboratory results | 88.9% | 81.6% | 83.4% |
| | | % of Total | 21.5% | 61.9% | 83.4% |
| Total | | Count | 99 | 310 | 409 |
| | | Expected Count | 99.0 | 310.0 | 409.0 |
| | | % within Occupational diagnosis | 24.2% | 75.8% | 100.0% |
| | | % within Laboratory exams | 100.0% | 100.0% | 100.0% |
| | | % of Total | 24.2% | 75.8% | 100.0% |

| Chi-Square Tests | | | | | |
|---|---|---|---|---|---|
| | Value | df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
| Pearson Chi-Square | 2.866[a] | 1 | .090 | | |
| Continuity Correction[b] | 2.365 | 1 | .124 | | |
| Likelihood Ratio | 3.081 | 1 | .079 | | |
| Fisher's Exact Test | | | | .120 | .058 |
| Linear-by-Linear Association | 2.859 | 1 | .091 | | |
| N of Valid Cases | 409 | | | | |

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 16.46.

b. Computed only for a 2x2 table

| Occupational diagnosis * Age | | | | | |
|---|---|---|---|---|---|
| | | | Age | | Total |
| | | | >41 years | 15-41 | |
| Occupational diagnosis | Fit with limitations | Count | 32 | 36 | 68 |
| | | Expected Count | 28.1 | 39.9 | 68.0 |
| | | % within Occupational diagnosis | 47.1% | 52.9% | 100.0% |
| | | % within Age | 18.9% | 15.0% | 16.6% |
| | | % of Total | 7.8% | 8.8% | 16.6% |
| | Fit | Count | 137 | 204 | 341 |
| | | Expected Count | 140.9 | 200.1 | 341.0 |
| | | % within Occupational diagnosis | 40.2% | 59.8% | 100.0% |
| | | % within Age | 81.1% | 85.0% | 83.4% |
| | | % of Total | 33.5% | 49.9% | 83.4% |
| Total | | Count | 169 | 240 | 409 |
| | | Expected Count | 169.0 | 240.0 | 409.0 |
| | | % within Occupational diagnosis | 41.3% | 58.7% | 100.0% |
| | | % within Age | 100.0% | 100.0% | 100.0% |
| | | % of Total | 41.3% | 58.7% | 100.0% |

| Chi-Square Tests | | | | | |
|---|---|---|---|---|---|
| | Value | df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
| Pearson Chi-Square | 1.108[a] | 1 | .293 | | |
| Continuity Correction[b] | .842 | 1 | .359 | | |
| Likelihood Ratio | 1.098 | 1 | .295 | | |
| Fisher's Exact Test | | | | .345 | .179 |
| Linear-by-Linear Association | 1.105 | 1 | .293 | | |
| N of Valid Cases | 409 | | | | |

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 28.10.
b. Computed only for a 2x2 table

| Type of Occupation * Occupational diagnosis | | | | | |
|---|---|---|---|---|---|
| | | | Occupational diagnosis | | Total |
| | | | Fit with limitations | Fit | |
| Occupation | Mental Work | Count | 58 | 303 | 361 |
| | | Expected Count | 60.0 | 301.0 | 361.0 |
| | | % within Occupation | 16.1% | 83.9% | 100.0% |
| | | % within Occupational diagnosis | 85.3% | 88.9% | 88.3% |
| | | % of Total | 14.2% | 74.1% | 88.3% |
| | Physical Work | Count | 10 | 38 | 48 |
| | | Expected Count | 8.0 | 40.0 | 48.0 |
| | | % within Occupation | 20.8% | 79.2% | 100.0% |
| | | % within Occupational diagnosis | 14.7% | 11.1% | 11.7% |
| | | % of Total | 2.4% | 9.3% | 11.7% |
| Total | | Count | 68 | 341 | 409 |
| | | Expected Count | 68.0 | 341.0 | 409.0 |
| | | % within Occupation | 16.6% | 83.4% | 100.0% |
| | | % within Occupational diagnosis | 100.0% | 100.0% | 100.0% |
| | | % of Total | 16.6% | 83.4% | 100.0% |

| Chi-Square Tests | | | | | |
|---|---|---|---|---|---|
| | Value | df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
| Pearson Chi-Square | .694[a] | 1 | .405 | | |
| Continuity Correction[b] | .393 | 1 | .531 | | |
| Likelihood Ratio | .659 | 1 | .417 | | |
| Fisher's Exact Test | | | | .411 | .258 |
| Linear-by-Linear Association | .693 | 1 | .405 | | |
| N of Valid Cases | 409 | | | | |

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 7.98.
b. Computed only for a 2x2 table

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