An Analysis of Ergonomic Risks of Undergraduate Students During Virtual Education in the wake of the COVID-19 Pandemic: A Prospective Review

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Abstract

The COVID-19 pandemic brought a series of changes in people's daily activities. Among them, education was one of the most affected since there was a mandatory transition from face-to-face to virtual education, even though some educational institutions carried out this practice. Although the study centers had optimal clothing so their students could receive their classes properly, this would not necessarily be fulfilled at home, affecting their health or academic performance. Therefore, this research focuses on this problem to identify the most relevant ergonomic risk factors and their future implications through a structural analysis using the MICMAC software. It then deepens into the most critical factors and examines possible future scenarios in 5 years. The results found that the most likely scenario is where students do not maintain good ergonomic practices, and their health could be compromised. However, the following most likely scenario shows an opposite scenario, in which it is hoped that this research will serve as a basis for other studies so that the ideal scenario becomes a possible reality.

Keywords
Ergonomics, COVID-19, Education sector, MICMAC, Prospective

1. Introduction
At the end of 2019, there was an alarm in China about a SARS (severe acute respiratory syndrome) family virus, SARS-Cov-2, to be distinguished from SARS-Cov that emerged in 2003. This virus causes breathing difficulties and general malaise, among other symptoms, and can even lead to death. Within three months of discovering this virus, the World Health Organization (WHO) classified it as a global health problem, giving rise to the COVID-19 pandemic, which spread worldwide.

COVID-19 prevented the population from carrying out their daily activities, typically since the slightest contact with an infected person could transmit the virus immediately. Due to this pandemic, people of different ages and professions had to stop their activities to stay at home. Among them, students who were attending their classes in person at their respective centers, such as schools, universities, or institutes, had to change their mode of study, making a transition from traditional education to virtual education, mainly due to government restrictions to close all establishments where there is a high agglomeration of people (restaurants, entertainment centers, educational centers, among others).

In line with the above, some students had the facilities to take their classes virtually; however, others needed help carrying them out, such as a lack of connectivity, technological devices, or furniture. Likewise, students needed time to adapt to the new modality and learn from their homes.

Therefore, the need is created to have the appropriate conditions to carry out online classes from an ergonomic perspective, and, in this way, this new learning modality is not harmed. In addition, it has been shown that an inappropriate study environment leads students to develop musculoskeletal problems such as neck, back, and waist pain due to being in an inadequate position for a long time, as well as hearing and vision problems and mental fatigue.

Currently, educational institutions maintain some of the measures taken during the pandemic, such as hybrid education (i.e., face-to-face, and virtual education) and entirely virtual education.
After all that has been described, this research is relevant to find out the most probable scenario in the next five years regarding virtual education, considering the ergonomic practices of university students.

1.1 Objectives

Considering the above, the main objective of this research is to find the most probable future scenario regarding virtual education and the associated ergonomic risks in undergraduate university students. To achieve this objective, we will find the main ergonomic risks generated during the virtual education of undergraduate university students and then determine the possible future scenarios that will be developed around this study.

2. Literature Review

Jouvenel (1993) states that there are two ways of seeing the future: the first, as a single reality, typical of oracles, prophets, and soothsayers; the second, as a multiple reality. These are the possible futures that he called "futuribles". Similarly, Godet and Durance (2009) mention that strategic foresight is undoubtedly a forecasting (predictive and proactive) that makes it possible to clarify present actions in the light of possible and desirable futures. These possible futures are denoted in the literature as scenarios. According to Godet and Durance (2009), a scenario is formed by describing a future situation and by the series of facts allowing one to move from the original situation to the future.

On the other hand, the term ergonomics comes from the Greek words ergon (work) and nomos (law or norm); the first reference to ergonomics appears in the book by the Pole Wojciech Jastrzebowki (1857) entitled Compendium of Ergonomics or of the science of work based on truths taken from nature, which according to a translation by Pacaud (1974) states: "to begin a scientific study of work and to elaborate a conception of the science of work as a discipline, we must not subordinate it at all to other scientific disciplines... so that this science of work, which we understand in the sense not unilaterally of physical work, of labor, but of total work, drawing simultaneously on our physical, aesthetic, rational and moral faculties..."... (Pedro Mondelo 1999).

Thus, we can group the different definitions of the concept of ergonomics as follows (Pedro Mondelo 1999): i) ergonomics as a cumulative tradition of organized knowledge of the interactions of people with their work environment; ii) ergonomics as a set of experiences, empirical and laboratory data; many definitions are placed under this heading. From this conception, ergonomics is a set of planned and prepared activities for the conception and design of new workplaces and the redesign of existing ones; iii) ergonomics, as a technology, is an approach resulting from the attempt to apply scientific management to work and leisure; and iv) ergonomics as an instructional plan, emphasizing people's mental processes.

Along the same lines, ergonomic risk factors are the work conditions that determine the physical and mental demands that the task imposes on the worker, increasing the probability of harm occurring (Instituto Regional de Seguridad y Salud en el Trabajo 2019). These include i) psychosocial factors derived from inadequate work organization; ii) unfavorable environmental conditions (temperature, humidity, lighting); iii) deficient characteristics in the work environment, workspace, order, and cleanliness; and iv) the individual variables of each operator, (body dimensions, sex, age, experience, training).

Besides, distance learning is denoted as a technological system of bidirectional (multidirectional) communication, which can be massive, based on the systematic and joint action of didactic resources and the support of an organization and tutoring, which, physically separated from the students, propitiate independent (cooperative) learning in them (Lorenzo García 2009).

This mode of study has certain advantages, such as taking remote classes at other universities around the world without the need to travel or be on the premises of the study center. Also, students can arrange their schedule or study routine in case classes are asynchronous. However, the lack of interaction between students and professors can lead to a certain degree of academic stress. In this sense, according to Flores and Sánchez (2022), among the variables associated with academic pressure, it is possible to highlight those strictly related to the educational context, those linked to the environmental or social context, and those related to the individual, either due to sociodemographic characteristics or personal traits.

3. Methods

This research is prospective, a concept previously defined. In that sense, it is intended to find possible scenarios around virtual education and the ergonomic risks associated with undergraduate university students.

It is important to emphasize that the broad and flexible set of prospective tools requires knowledge of qualitative methods based on evidence, experience, interaction, and creativity, which are considered complementary and not exclusive. Foresight is usually carried out through punctual exercises or projects; however, the systematic or recurrent staging of foresight is done through the execution of specialized processes that seek the adaptation of methods to specific contexts of action. (Medina et al. 2014).

Thus, this research has a qualitative type of approach. This is because a structural analysis will be conducted around the relevant factors for this study. Likewise, an analysis of the scenarios found will be carried out to determine the best possible one and, in addition, to contrast whether this is the most probable one.

Finally, an exploratory and descriptive scope is maintained, and techniques such as unstructured interviews and document review will be used. In addition, the following instruments will be used: validation matrices, the MICMAC, SMIC-PROB-EXPERT, and Microsoft Excel software.

3.1 Research phases

Within the research framework, a specific order of the activities to be carried out must be followed to have a better overview of the research's beginning and culmination. Therefore, the two main phases that will structure our research will be presented. Likewise, details will be given on the scope, objective, techniques to be used, and the unit of analysis for each.

Regarding the initial phase of the research, its scope will be exploratory and descriptive since relevant information will be gathered on the possible factors that will affect the study of the problem. Consequently, its objective is to investigate the main ergonomic risk factors influencing the students' health. For this purpose, the MICMAC structural analysis software will be used. However, there is no specific unit of analysis.

Finally, the scenario approach will be carried out in the final phase. The scope will be exploratory and descriptive, as in the previous phase. Therefore, its objective is to propose future scenarios around the research topic. To achieve this, the SMIC-PROB-EXPERT software will be used.

4. Data Collection

A structural analysis of the factors related to the subject was chosen to recognize the ergonomic risks that have the most significant influence within the educational environment. A compilation of 20 factors from different sources (primarily scientific articles) was made to obtain a list of the potential factors involved. However, this list was validated by experts in the field, finally obtaining 18 factors. Likewise, the MICMAC software was used, and the stages of the process to conclude will be detailed later.

According to what was previously described, the list of the 18 validated factors related to the ergonomic risks of undergraduate university students is presented in Table 1.

Table 1. List of factors

F°	Factors	Code
F1	Position of the spine when sitting	Pos_Column
F2	Maintenance of a static sitting posture	Mant_Post
F3	Repetitive movements due to keyboard and mouse operation	Mov_Repet
F4	Neck flexion when typing and/or looking at the computer screen	Exces_Flex
F5	Support of arms and wrists while typing on the computer keyboard	Apoyo_Bra
F6	Lighting of the environment	Ilum_Amb
F7	Location of technological equipment and desk accessories	Ubi_Tecno
F8	Absence of ergonomic chair	Aus_Silla
F9	Calibration of the illumination of the studio equipment screen	Calib_Ilum
F10	The visual distance to the screen	Dist_Vis
F11	Exposure to the light source (screen)	Expo_Lumin
F12	Active pauses during study hours	Pausa_Act
F13	Loss of concentration due to mental fatigue	Per_Concen
F14	Use of hearing aids	Audifon
F15	Monotony	Monot
F16	Environmental stress	Est_Entor
F17	Noise levels	Niv_Rui
F18	Ventilation of study environment	Vent_Amb

Table 2 shows the relationship between the factors, according to the impact of one on the other, according to various academics. The influences take a score from 0 to 3, with the possibility of indicating potential influences (with the letter P): 0 = Without Influence, 1 = Weak, 2 = Medium, 3 = Strong, and P = Potential.

Table 2. Cross-Influence Matrix

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18
F1	0	P	2	3	3	0	2	3	1	3	2	2	2	0	1	2	1	1
F2	P	0	2	P	2	0	2	3	1	1	1	P	2	0	2	2	1	1
F3	2	2	0	3	2	2	1	1	1	1	1	2	2	0	3	1	1	1
F4	P	P	2	0	2	2	1	2	3	3	3	3	2	1	2	2	1	1
F5	3	3	3	2	0	2	2	3	2	1	1	2	1	0	2	2	1	1
F6	1	1	1	2	0	0	2	0	3	2	2	2	2	0	2	2	1	1
F7	2	2	1	1	2	2	0	0	1	2	2	2	1	0	2	2	1	1
F8	P	P	2	P	3	1	1	0	1	2	1	3	1	0	2	2	1	1
F9	2	1	1	3	0	3	2	0	0	3	P	2	2	0	1	2	1	1
F10	3	3	1	P	1	2	2	2	3	0	3	2	1	0	1	2	1	1
F11	2	2	1	3	1	3	2	0	2	3	0	2	2	0	2	2	1	1
F12	3	3	2	2	2	2	1	1	1	1	1	0	3	0	3	2	1	1
F13	2	1	2	2	1	1	1	2	1	1	1	3	0	1	2	2	2	1
F14	0	1	0	1	0	0	0	0	0	0	0	1	2	0	2	2	3	1
F15	2	2	3	2	1	2	1	1	1	1	1	P	3	2	0	2	2	1
F16	2	2	1	2	1	1	1	1	1	1	1	3	3	2	2	0	2	2
F17	1	1	1	1	1	1	0	1	1	0	0	2	3	3	2	3	0	1
F18	1	1	1	1	1	1	0	1	1	1	0	2	2	1	2	2	1	0

Then, to establish the structural aspects related to the ergonomic risks of undergraduate students, the graphs of influence and dependence between the factors are shown in Figure 1. In this way, the factors and their interaction employ the plane of direct influence.

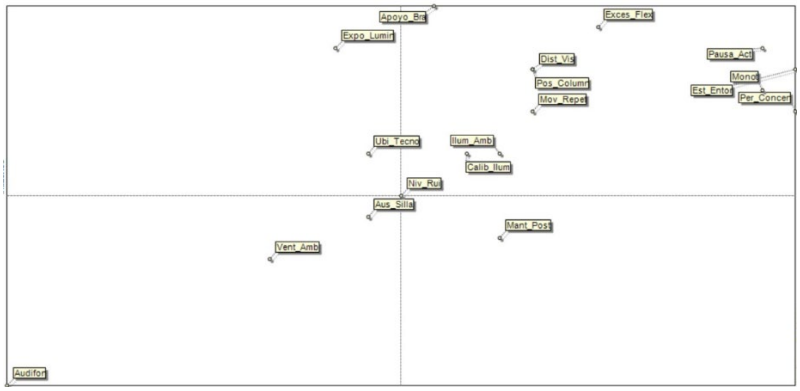


Figure 1. Direct influence plane

Afterwards, to find relationships that are not shown in the Direct Impacts Matrix, the Indirect Impacts Matrix is also established. In it, the indirect influence that some factors have on others is observed, according to Figure 2.

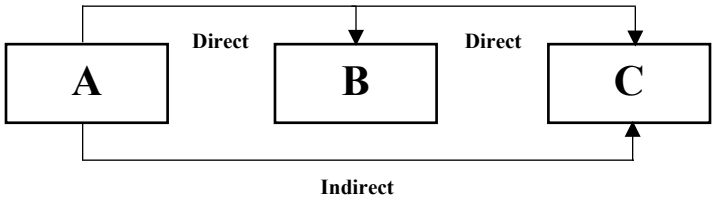


Figure 2. Exemplification of indirect influences

The indirect influence plane is shown in Figure 3, which was prepared using MICMAC software.

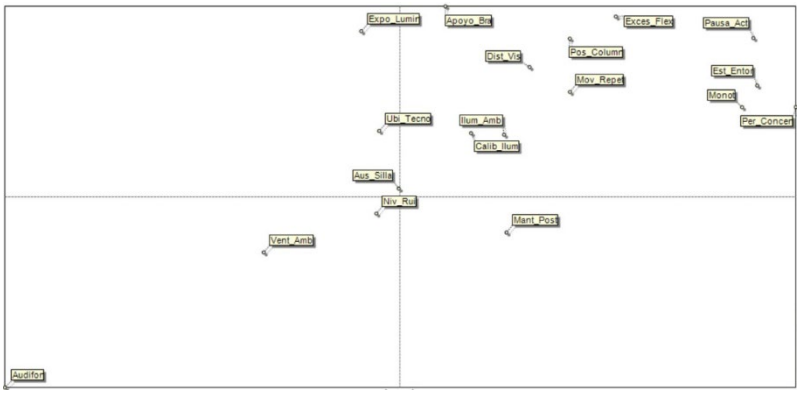
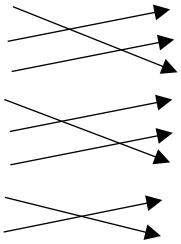


Figure 3. Indirect influence plane

With the help of the above graphs, it was possible to rank the 18 research factors according to their level of influence (both direct and indirect). Therefore, for the second phase of the research, the four factors at the top of the list will be used according to the order of priority mentioned, shown in Table 3.

Table 3. List of factors sorted by influence

F°	Factors
F1	5 – Apoyo_Bra
F2	4 – Exces_Flex
F3	11 – Expo_Lumin
F4	12 – Pausa_Act
F5	1 – Pos_Column
F6	10 – Dist_Vis
F7	16 – Est_Entor
F8	15 – Monot
F9	3 – Mov_Repet
F10	13 – Per_Concen
F11	6 – Ilum_Amb
F12	7 – Ubi_Tecno
F13	9 – Calib_Ilum
F14	17 – Niv_Rui
F15	8 – Aus_Silla
F16	2 – Mant_Post
F17	18 – Vent_Amb
F18	14 – Audifon



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F13	6 – Ilum_Amb
F14	8 – Aus_Silla
F15	17 – Niv_Rui
F16	2 – Mant_Post
F17	18 – Vent_Amb
F18	14 – Audifon

5. Results and Discussion

5.1 Numerical Results

In this phase, having obtained the most important factors for the research in the previous phase, we will evaluate different scenarios of occurrence within five years to validate our hypothesis based on the opinions of various experts in the field.

First, different scopes of the four factors mentioned above were presented as Table 4 shows, so that the experts could know the current situation regarding these factors and thus give their opinion.

Subsequently, the experts' opinions will be reflected in a questionnaire showing the simple and conditional probabilities (both positive and negative) of the occurrence of each scenario on a scale of 0% to 100%. After that, using the SMIC-PROB-EXPERT software, the overall probability for each of the 16 possible scenarios will be obtained.

Table 4. Key Factors of the Research System

FACTORS (EXPLANATIONS)	SCOPE OF ITS EVOLUTION AND/OR CURRENT SITUATION
F5. Support of arms and wrists while typing on the computer keyboard	**65.0%** (39 out of 60) of university students, on average, have the necessary support when typing on the computer keyboard.
F4. Neck flexion when typing and/or looking at	**43.3%** (26 out of 60) of university students, on average, flex

the computer screen	their neck while using the computer.
F11. Exposure to the light source (screen)	**62.3%** (66 out of 106) of college students, on average, suffer from Computer Vision Syndrome (set of ocular and visual signs and symptoms related to the use of electronic devices for a prolonged period, according to the American Optometric Association).
F12. Active pauses during study hours	**40.0%** (16 out of 40) of college students, on average, take active breaks during study hours.

The results obtained from the software are shown in Tables 5, 6, and 7, based on the criteria of each expert.

Table 5. Simple probabilities

Factors	Probabilities
F5 – Apoyo_Bra	51.70%
F4 – Exces_Flex	50.70%
F11 – Expo_Lumin	49.10%
F12 – Pausa_Act	52.40%

Table 6. Conditional probabilities

Factors	F5 – Apoyo_Bra	F4 – Exces_Flex	F11 – Expo_Lumin	F12 – Pausa_Act
F5 – Apoyo_Bra	51.70%	63.60%	76.60%	79.80%
F4 – Exces_Flex	62.40%	50.70%	54.60%	67.80%
F11 – Expo_Lumin	72.70%	52.80%	49.10%	73.50%
F12 – Pausa_Act	80.90%	70.10%	78.50%	52.40%

Table 7. Negative Conditional probabilities

Factors	F5 – Apoyo_Bra	F4 – Exces_Flex	F11 – Expo_Lumin	F12 – Pausa_Act
F5 – Apoyo_Bra	0.00%	39.50%	27.80%	20.80%
F4 – Exces_Flex	38.20%	0.00%	47.00%	31.90%
F11 – Expo_Lumin	23.80%	25.20%	0.00%	22.10%
F12 – Pausa_Act	22.80%	34.30%	27.30%	0.00%

5.2 Graphical Results

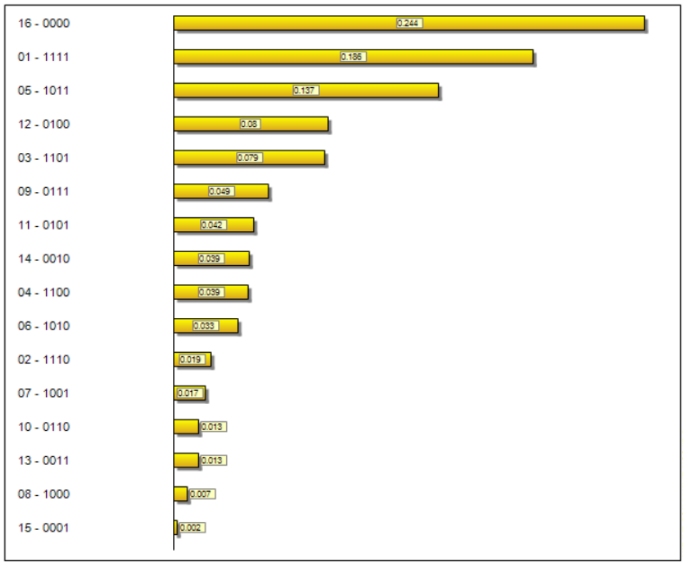

Figure 4. Probability histogram

Thus, by combining the probabilities of occurrence of the hypotheses, as shown in Figure 4, the following results were obtained in Table 8.

Table 8. Probability of occurrence of future scenarios

Scenarios	Probability
01 – 1111	0.1860
02 – 1110	0.0190
03 – 1101	0.0790
04 – 1100	0.0390
05 – 1011	0.1370
06 – 1010	0.0330
07 – 1001	0.0170
08 – 1000	0.0070
09 – 0111	0.0490
10 – 0110	0.0130
11 – 0101	0.0420
12 – 0100	0.0810
13 – 0011	0.0130
14 – 0010	0.0390
15 – 0001	0.0020
16 – 0000	0.2440

Scenarios	Probability	Accumulated
16 – 0000	0.2440	0.2440
01 – 1111	0.1860	0.4300
05 – 1011	0.1370	0.5670
12 – 0100	0.0810	0.6480
03 – 1101	0.0790	0.7270
09 – 0111	0.0490	0.7760
11 – 0101	0.0420	0.8180
14 – 0010	0.0390	0.8570
04 – 1100	0.0390	0.8960
06 – 1010	0.0330	0.9290
02 – 1110	0.0190	0.9480
07 – 1001	0.0170	0.9650
10 – 0110	0.0130	0.9780
13 – 0011	0.0130	0.9910
08 – 1000	0.0070	0.9980
15 – 0001	0.0020	1.0000

According to the Pareto principle, attention should be paid to probabilities of occurrence whose cumulative sum is at least 80%. This corresponds to seven of the sixteen scenarios. However, it was decided to focus on the first five scenarios, whose overall probability is 73%.

Thanks to the average of the probabilities defined by all the specialists for each image, it is possible to define a hierarchy of the images and, consequently, the most probable scenarios.

Among these scenarios, 3 or 4 should be chosen, including at least one reference scenario (i.e., with a high average probability) and contrasting scenarios whose probability may be low but whose importance for the organization should not be excluded (Godet and Durance 2009).

5.3 Discussion

After identifying the first five scenarios, a prospective analysis will be made for each of them towards 2028. A detail of each scenario is shown below.

Scenario N°1 (0000) Probability: 24.4%.

Students do not consider the importance of having support in their arms or wrists while studying virtually. This leads to the development of some musculoskeletal diseases, such as Carpal Tunnel Syndrome, tendinitis, or suffering from chronic pain.

In addition, students are bending their necks excessively while using the computer during their classes. This causes neck and headaches, which have repercussions on their student and personal lives—for example, loss of concentration and poor academic performance.

On the other hand, Computer Vision Syndrome (CIS) becomes more frequent in students due to the number of hours spent in front of the computer screen. In addition, students manifest various symptoms linked to CIS due to the visual exhaustion they are exposed to. Some of these symptoms are visual fatigue, eye irritation and dryness, blurred vision, and hypersensitivity to light.

Finally, the active breaks taken by students while taking virtual classes lost relevance over time. Consequently, the level of stress to which students are subjected increased substantially, which impacted their academic life and health.
Scenario N°2 (1111) Probability: 18.5%.

Many of the students have ergonomic implements, allowing them to develop their classes with greater comfort. In this sense, at least 80% of the students use chairs with armrests or have tables with the appropriate height to rest their arms.

Also, most students improved their position in front of the screen by using an adjustable computer stand, thus avoiding repeated neck bending. This reduced the proportion of students performing this action to a maximum of 20%.

On the other hand, several students were aware of the visual damage that prolonged use of technological devices can cause them. Therefore, the time of exposure to the computer screen decreased because the students began to use rest lenses, better calibrate the screen lighting, and adequately control the time of use of electronic devices. This reduced the proportion of students who maintained prolonged exposure to a light source to a maximum of 30%.

Finally, many students began to consider the benefits of active breaks. They started to use them on their initiative, regardless of whether they were in class or doing other activities in front of the computer. In this sense, the proportion of students who take active breaks during their classes is at least 70%.

Scenario N°3 (1011) Probability: 13.7%.

The same ideal conditions of Scenario N°2 are given, except for the neck flexion while typing or looking at the computer screen. Students perform excessive neck flexion while using the computer during their classes. This causes neck and headaches, which have repercussions on their student and personal lives—for example, loss of concentration and poor academic performance.

Scenario N°4 (0100) Probability: 8.0%.

The same non-ideal conditions of Scenario N°1 are present, except for neck flexion when writing or looking at the computer screen. Most students improved their position in front of the screen using an adjustable computer stand,

thus avoiding repeated neck flexing. In this way, the proportion of students performing this action was reduced to a maximum of 20%.
Scenario N°5 (1101) Probability: 7.9%.

The same ideal conditions of Scenario N°2 are given, except for the exposure to the light source. Computer Vision Syndrome (CIS) becomes frequent in students due to the number of hours spent in front of the computer screen. In addition, students manifest various symptoms linked to CIS due to the visual exhaustion they are exposed to. Some of these symptoms are visual fatigue, eye irritation and dryness, blurred vision, and hypersensitivity to light.

After examining various future scenarios, we can see a strong sense of negativity reflected in the most likely scenario. Undoubtedly, the actions we must take from now on must be aimed at modifying this pessimistic perspective that prevails in the main scenario. Prospectively, it is essential to opt for one of the alternatives to this most probable scenario, and without a doubt, the option that we should consider as ideal is Scenario N°2.

It should be noted that these scenarios resulted from an exhaustive analysis and may not necessarily occur in the future. However, this research could serve as a basis for carrying out other studies to make the ideal scenario possible.

6. Conclusion

Among the factors found in various sources of information, there was a tendency towards factors related to the study environment, such as lighting, temperature, or furniture, that are useful for students when conducting their classes. Also, these factors can trigger certain ergonomic risks that could affect students' health if an adequate ergonomic design is not considered. Among these risks are problems related to musculoskeletal disorders or visual disorders.

Although the most probable scenario, based on expert opinion, is Scenario N°1 (pessimistic scenario), we consider the second scenario with a higher probability since it shows us an ideal future based on the good ergonomic practices that students could adopt in the coming years. In this sense, if students and universities know these ergonomic risks, strategies can be devised to minimize the negative impacts on students' health.

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