A novel distance learning ergonomics checklist and risk evaluation methodology: A case of Covid-19 pandemic

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Abstract
Many governments decided to cancel face-to-face teaching and learning activities in schools and universities. They replaced them with online teaching and distance learning activities to prevent the spread of Coronavirus disease 2019 (COVID-19). Due to this sudden change, students experienced some anthropometric, environmental, and psychosocial difficulties at home during the distance learning process. This study focuses on determining the importance of anthropometric, environmental, and psychosocial factors in the distance learning process during the COVID-19 pandemic. This study presents main factors and their subfactors affecting ergonomic conditions of university students during distance learning. A novel distance learning ergonomics checklist is proposed based on the Occupational Safety and Health Administration checklists. The data are collected via a questionnaire filled by 100 university students who attend the Ergonomics course online. Then, the integrated methodology includes Voting Analytic Hierarchy Process integrated Pythagorean Fuzzy Technique for Order Preference by Similarity to An Ideal Solution method is adopted to prioritize the factors determined. Thirty-nine different subfactors are evaluated under five titles, and the most important factors are determined using the proposed methodology. With the results achieved, it is seen that the suggested checklist and proposed methodology can be used by public and private education organizations as a guide for improving their distance learning strategies.

KEYWORDS
COVID-19, distance learning, ergonomics, Pythagorean Fuzzy TOPSIS, Voting AHP

1 | INTRODUCTION

At the end of 2019, the pneumonia epidemic, which is first seen in China due to the newly defined SARS-CoV-2 factor, is defined as Coronavirus disease 2019 (COVID-19) (Li et al., 2020). The epidemic spreads rapidly, and the existence of the virus was confirmed on all continents except Antarctica on January 26, 2020 (WHO, 2020a). The World Health Organization (WHO) announced on March 11 that COVID-19 had become a pandemic (Yalcin et al., 2020). According to WHO reports, there are more than 49 million confirmed cases and more than one million deaths in earlier November 2020 (WHO, 2020b). Studies for the treatment of this pandemic affecting the whole world are still ongoing.

COVID-19 is transmitted from person to person very quickly by droplets (Carlos et al., 2020; Chang et al., 2020; D. Wang et al., 2020). For this reason, individual measures such as the use of...
personal protective equipment, social isolation, and social distancing (at least 1 m) become vital in preventing contamination (Chen et al., 2020). Undoubtedly, the COVID-19 pandemic changes people’s lives all over the world (Njiri, 2020). When the measures taken to rearrange human movements in public life areas are examined, compulsory changes are seen in human life. The pandemic has negative impacts on local and global business, human lives and psychologies (Restubog et al., 2020). The increasing population density in cities, close contact among people, high mobility, public transportation, and common areas are the causes of the rapid spread of infection. In this context, countries have started to apply different methods to prevent the COVID-19 pandemic. Therefore, many governments have decided to cancel face-to-face teaching and learning activities in schools and universities to prevent the spread of COVID-19 (Sahu, 2020), and replaced face-to-face activities with online and distance learning activities (Iyer et al., 2020). Thus, the importance of online and distance learning activities increases in the world. Most authors define online learning as access to learning experiences through specific technologies (Moore et al., 2011). It is often referred to as "e-learning" among other terms. However, online learning is just one type of "distance learning"; represents learning at a distance, not in a traditional classroom. Distance education/e-learning platforms were used in many universities, even partially, before the COVID-19 pandemic for some courses (Panda & Mishra, 2007). However, the number of universities using distance learning systems in all courses was almost nonexistent before the pandemic (Owusu-Boampong & Holmberg, 2015).

Distance learning activities have some advantages and disadvantages. Some of the main advantages of distance learning activities, especially for e-learning, are as follows: Distance learning activities are very flexible in terms of time and place. Students have the opportunity to choose the place and time suitable for them, apart from in-person class (Smedley, 2010). Distance learning activities can increase the efficiency of the course, thanks to the ease of accessing enormous amounts of information via the internet (Arkorful & Abaidoo, 2014). Distance learning is cost-effective because students and lecturers do not have to travel and no extra building construction is needed (Holmes & Gardner, 2006). Despite the advantages of distance learning activities, there are also some disadvantages. Personal interaction between students and teachers cannot be realized ideally in distance learning (Young, 1997). Therefore, strong inspiration and time management skills are required to mitigate the effects of lack of communication. It is difficult to control or regulate undesirable activities such as cheating in tests for evaluations in e-learning (Arkorful & Abaidoo, 2014). Distance learning can also cause some websites to be congested or used intensively (Akkoynulu & Yilmaz Soylu, 2006).

The learning environment is one of the variables that affect the learning performance of the student. The learning environment should contain as few factors as possible that disrupt the learning process. In the computerized learning processes, an arrangement should be handled to stimulate the learning process and take into account students’ physical and psychosocial health (Kailash et al., 2011). Students cannot learn effectively while using computers that they are uncomfortable with (Oyadeyi, 2018). Students may experience discomforts such as eye ailments, hand and wrist pains, waist, back and neck injuries and headaches while studying in front of the computer screen for a long time (Alaydrus & Nusraningrum, 2019; Portello et al., 2012; Talwar et al., 2009). Failure to set the environment according to anthropometric criteria causes these disorders to occur.

In the distance learning process, students’ performances are affected by psychosocial factors besides anthropometric and environmental factors (Barattucci, 2019; W. Liang et al., 2019; Pereira et al., 2021). The International Labor Organization (ILO) has defined psychosocial factors based on the interaction between job satisfaction, job organization and management, environmental and organizational conditions, and the expertise and needs of workers (Joint ILO/WHO Committee Health, 1986). These interactions pose a danger to human health with their perception and experiences. Exposure to physical and psychosocial hazards can affect physical and psychological health (Smith & Freedy, 2000). These can affect people directly physically, or indirectly through stress (Amponsah-Tawiah et al., 2014). These two effects are not alternatives to each other; on the contrary, in most cases, they act together, interact and complement each other or reinforce each other's influence and have dramatic effects on the performances of people (Ferri et al., 2016). Therefore, both psychosocial and anthropometric factors should be considered when evaluating the general studying environment, especially in the distance learning process.

Reichert et al. (2001) investigate the effects of distance learning on project team performance. For this purpose, the performances of two project teams, one using traditional face-to-face teams and the other using distance learning, are compared. The coordination of the project is found to be correlated with the performance of distance learning. Rathod (2005) tests student learning levels with multimedia distance learning. It is determined that multimedia distance learning is more effective than traditional ways. Ryu et al. (2007) focus on learning styles for web-based education from two different perspectives, individually and culturally. Bentaib et al. (2019) argue that distance education systems are not satisfactory for all students. They cite ergonomic, aesthetic, practical, and time-based concerns as the reasons for this situation. Jaukovic Jocic et al. (2020) present a multicriteria decision-making methodology (MCDM) to solve the e-learning course selection problem, considering seven criteria: content level, presentation methods, teaching methods, e-learning environment, learning materials, quality of multimedia contents, group work and interactivity. They show that there is no significant difference between the relative importance of these seven criteria. Siew et al. (2021) evaluate different learning methods through the integrated MCDM methodology. The quality management system, information quality, flexibility, learning and teaching, and attractiveness are the main criteria for evaluating three different learning systems. E-learning system is chosen as the best learning system during the pandemic. Alqahtani and Rajkhan (2020) aim to determine critical success factors for e-learning during the COVID-19
pandemic. Blended learning, flipped classroom, ICT-supported face-to-face learning, synchronous learning, and asynchronous e-learning systems are evaluated considering ten different factors, and blended learning is determined as the best alternative.

It is essential to determine the importance of anthropometric, environmental, and psychosocial factors in the distance learning process. The importance levels of these factors can be used to develop strategies to increase the performance of students. Apart from reviewed studies, this study focuses on identifying the importance of anthropometric, environmental, and psychosocial factors in the distance learning process during the COVID-19 pandemic, and it is handled as an MCDM problem. This study presents the main factors and sub-factors that affect university students’ ergonomic conditions during distance learning. For this purpose, a novel distance learning ergonomics checklist is created. The data are collected using an Occupational Safety and Health Administration (OSHA) checklist-based questionnaire by 100 university students participating in Ergonomics classes. Then, the Voting Analytic Hierarchy Process (VAHP) integrated Pythagorean Fuzzy Technique For Order Preference By Similarity To An Ideal Solution (PF-TOPSIS) method is used to prioritize the factors.

The rest of the paper is organized as follows: The literature review is presented in Section 2. The proposed VAHP integrated PF-TOPSIS methodology is explained in Section 3. Section 4 presents the questionnaire and the real case application of the proposed method. Results and discussion are presented in Section 5. Finally, the conclusions and future recommendations are given in the last section.

2 | LITERATURE REVIEW

Checklists developed by OSHA are used in studies to evaluate different ergonomic factors. For example, Ranasinghe et al. (2011) evaluate psychosocial and physical risk factors based on the OSHA Visual-Display-Terminal workstation checklist. Logistic regression analysis is used to investigate relationships between risk factors. Coelho et al. (2014) apply the OSHA checklist to identify occupational risk factors in the production line considering a real case study. Kremer et al. (2009) propose a risk assessment methodology for the university research laboratory. Major risk categories are defined based on academic literature, OSHA checklists, and industrial applications. Sanda and Nugble (2020) employ the OSHA hazard assessment checklist to evaluate both noise and ergonomic factors related to welding operations. Experts evaluate three different companies according to the checklist. Sahu et al. (2019) use the OSHA evaluation checklist to assess the effects of work postures on the musculoskeletal systems of computer users. Also, Rapid Upper Limb Assessment technique is used to understand health-related discomfort caused by incorrect postures of users. Chowdhury et al. (2018) use the OSHA Computer Workstations eTool-Evaluation Checklist to assess university computer workstations to make an ergonomic assessment of work postures.

Unlike the papers reviewed, we evaluate the proposed new checklist by applying the VAHP integrated PF-TOPSIS methodology in this study. The VAHP method is easy to understand and use to gain weight of the factors determined. It offers all experts the opportunity to assess the acceptability of rankings and to examine the calculation of priority weights from voters’ initial responses. Experts reassess the input data when the results seem unreasonable so that the sources of inconsistencies can be identified and appropriate changes are made. The VAHP method uses the ranking of votes instead of constructing the pairwise comparison matrix to determine weights and measure inconsistency. Using pairwise comparisons to determine factor weights in the Analytic Hierarchy Process (AHP) takes much more time than voting in VAHP (Taskin Gumus & Yilmaz, 2010). Therefore, VAHP is utilized with different applications in various studies. Liu and Hai (2005) use VAHP to determine the ranking of suppliers. Mahdavi et al. (2008) use VAHP to identify the most desirable features for mobile phones, then employ TOPSIS to compare mobile phone alternatives. Azadeh et al. (2009) develop an integrated VAHP, Data Envelopment Analysis (DEA) and Delphi to evaluate different information technologies. Taskin Gumus and Yilmaz (2010) select the best sea vessel alternative for high-speed public transportation via VAHP integrated Analytic Network Process methodology. Hadi-Vencheh and Niazi-Motlagh (2011) select an appropriate supplier via VAHP. Tang and Sun (2018) develop a multiobjective model to minimize the emergency rescue dispatch time and the number of emergency rescue bases. VAHP methodology is employed to solve this multi-objective model. Pishchulov et al. (2019) use VAHP to solve the sustainable supplier selection problem. Manu et al. (2019) determine key attributes for organizational capability through VAHP.

TOPSIS, one of the most commonly used MCDM methods, is introduced to the literature by Yoon and Hwang (1981). One of the essential features of the TOPSIS method, which is a linear weighting technique, is the determination of the most suitable solution that is the closest to the positive ideal solution and the furthest to the negative ideal solution. Since these distances are bilateral, the most appropriate selection is made by considering the situations that need to be maximized and the situations that need to be minimized (Özdemir & Seçme, 2009). The method can be used as an alternative method that can be applied to rank the factors. However, numerical (crisp) values may be insufficient when evaluating many real-life situations because human thoughts and judgments especially preferences often contain uncertainty and fuzziness (Ayyildiz & Taskin Gumus, 2020). For this reason, the TOPSIS method is applied under the Pythagorean fuzzy environment to avoid these negativities. Pythagorean Fuzzy sets are presented by Yager and applied to many real-life problems (Yager, 2013). These sets are developed based on intuitionistic fuzzy sets. Pythagorean fuzzy sets are flexible tools to handle uncertainty and fuzziness in MCDM problems (Zhu & Li, 2018). Especially in decision-making problems where expert
opinions are obtained in linguistic terms, pythagorean fuzzy sets provide more space for experts to express their views on uncertainty (Gul, 2018). Pythagorean fuzzy sets provide decision-makers with greater autonomy for evaluating uncertainty in the problem handled (Yucesan & Gul, 2020). PF-TOPSIS is utilized in many studies to handle different problems. Cevik Onar et al. (2018) evaluate four different cloud service providers across 21 criteria through PF-TOPSIS. Su et al. (2019) select the best project delivery system using PF-TOPSIS. Also, three similarity measures are developed to determine the best alternative. Oz et al. (2019) develop a PF-TOPSIS based risk assessment methodology for the natural gas pipeline project. Yildiz et al. (2020) determine the best location for an automated teller machine via PF-AHP integrated PF-TOPSIS methodology. Rani et al. (2020) present a PF-TOPSIS based decision-making methodology for sustainable recycling partner selection.

The use of OSHA checklists to evaluate different ergonomic factors is one of the issues addressed in the current literature, as shown in the literature review above. However, there is no study that uses OSHA checklists to evaluate distance learning ergonomic factors. Furthermore, a very limited number of studies deal with the distance learning ergonomic factors as an integrated MCDM problem. Unlike all other studies, a comprehensive set of ergonomic factors is defined and weighted in this study. In addition, there is no study determining the importance of distance learning ergonomics factors to the best of our knowledge. This study includes the first integration of VAHP and PF-TOPSIS for evaluation of the distance learning ergonomic factors.

3 | THE METHODOLOGY

In this paper, a novel MCDM approach is proposed to prioritize anthropometric, environmental, and psychosocial factors for students’ distance learning process during the COVID-19 pandemic. For this purpose, firstly, OSHA checklists are analyzed and modified to determine distance learning factors during the pandemic. Then, the novel hybrid methodology including VAHP and PF-TOPSIS integration is proposed to evaluate the determined

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**FIGURE 1** The proposed hybrid methodology
factors. The proposed methodology is discussed and explained in this section. The flow of the proposed hybrid methodology is given in Figure 1.

### 3.1 Voting AHP

AHP is one of the most used multicriteria ranking methods in decision making problems (Erensal & Albayrak, 2004; Ocampo & Seva, 2016). The method is proposed to deal with decision-making environments in which subjective judgments exist (Elleuch et al., 2014; Yilmaz Kaya & Dağdeviren, 2016). AHP can be used to carry out an integrated analysis of explicit objectives (Beauchamp-Akatova, 2009). AHP is one of the MCDM methods based on pairwise comparisons of predetermined criteria (Çavdur et al., 2019). AHP enables the analytical evaluation of criteria that are not expressed numerically by pairwise comparisons. AHP finds an answer to the question of "Which criterion is the most important one?" by performing pairwise comparisons. Decision-makers use the scale given in Table 1 (Saaty, 1977) to evaluate pairwise comparisons.

For example, a decision-maker who thinks about buying a new car wants to determine the most important criteria in the decision making process. Three criteria affect the decision: price, fuel consumption, and appearance. For this purpose, pairwise comparisons of these criteria are performed using the values given in Table 1. First, the importance levels of price and fuel consumption for decision-maker are compared. Then the importance levels of the price and appearance of the vehicle for decision-maker are compared. Finally, the importance levels of fuel consumption and appearance are compared, and thus a pairwise comparison matrix is constructed. Then, the most important criterion is determined by applying the steps of the AHP method.

One of the methods for determining the weights of criteria for AHP is the voting method. VAHP method uses the ranking of votes instead of constructing the pairwise comparison matrix to determine weights and measure inconsistency. Using pairwise comparisons to determine factor weights in AHP is much more time-consuming than voting in VAHP (Taskin Gumus & Yilmaz, 2010).

Sometimes, it is difficult to decide the appropriate weight of each criterion. Cook and Kress (1990) list candidate criteria for preferential elimination and put forward a procedure for using DEA application. For example, all voters may evaluate the subset of criteria and place them in their preferred order. A matrix is created, and then each candidate criterion is placed in the ranking (first, second, ..., last). Green et al. (1996) develop another procedure for setting specific restrictions for weights. The procedure is called "Green's Method" in the following process. The following two assumptions have been made to create constraints in this method. The weight difference between the criteria placed in jth and (j+1)th orders can be zero for any j, and the above difference of weight must be positive (Liu & Hai, 2005).

Green's Method is sometimes insufficient due to the effect of minimum differences in the total order of the objects and the insufficient application for the concrete sample. The minimum differences can be analyzed by considering the feasible region of the weight solutions obtained through linear programming, which is affected by the number of votes given to the objects. Noguchi et al. (2002) study the implementation of Green's Method and show the differences between high-weight objects for different ranking results. Besides, "Noguchi's strong rule" is applied not only to single-objective problems but also to multi-objective problems such as supplier selection for a giant company. When trying to obtain the weight of a particular constraint in the total ranking method using DEA, "Noguchi's strong rule" is adopted, which is characterized by the following constraints (Liu & Hai, 2005). In this proposed MCDM application, "Noguchi's strong rule" is defined by the following mathematical model:

\[
Q_{tr} = \max \sum_{i=1}^{S} u_{is}x_{rs} \quad (2.1)
\]

\[
Q_{tr} = \sum_{i=1}^{S} u_{is}x_{rs} \leq 1 (p = 1, 2, ..., R) \quad (2.2)
\]

\[
u_{t1} \geq 2u_{t2} \geq 3u_{t3} \geq \cdots \geq Su_{ts} \quad (2.3)
\]

\[
u_{rs} \geq \epsilon = \frac{1}{(1 + 2 + \cdots + S)} = \frac{2}{nS(S + 1)} \quad (2.4)
\]

There are multiple ranking criteria while evaluating an MCDM problem. The number of criteria is expressed as "R". "n" is the number of voters, and "S" is the number of places. "u_{is}" defines the weight of criterion "r" with respect to the place "s". All candidates for each "u_{is}" can be preferred such that the maximum weight is obtained by voting for criterion "r". Thus, the value of "Q_{tr}" becomes the largest.

"Noguchi's strong rule" is applied separately to calculate the weight of each criterion. Then, initial criteria weights are normalized to determine the final weights.

### 3.2 PF-TOPSIS

While people evaluate the criteria and alternatives in the decision process, they can use fuzzy numbers better to reflect uncertainty (Ayyildiz et al., 2020). In this study, we apply Pythagorean fuzzy sets to deal with vagueness better.

**Table 1** Index scale for AHP proposed by Saaty

| Intensity of Importance | Definition          |
|-------------------------|---------------------|
| 1                       | Equal importance    |
| 3                       | Moderate importance |
| 5                       | Strong importance   |
| 7                       | Very strong importance |
| 9                       | Extreme importance  |
| 2,4,6,8                 | Intermediate values |

Abbreviation: AHP, Analytic Hierarchy Process.
Pythagorean fuzzy sets are proposed by Yager (2013) derived from intuitionistic fuzzy sets, which were initially presented by Atanassov (1999). Unlike intuitionistic fuzzy sets, the sum of membership and nonmembership degrees can exceed 1, but the sum of their squares cannot in Pythagorean fuzzy sets (Ilbahar et al., 2018; Karasan et al., 2018), as explained in Definition 1.

**Definition 1.** Let X be a fixed set. A pythagorean fuzzy set is shown as \( \tilde{P} \) (Ilbahar et al., 2018; Karasan et al., 2018):

\[
\tilde{P} \approx (x, \mu_x(x), \nu_x(x); x \in X)
\]

where \( \mu_x(x) : X \rightarrow [0, 1] \) and \( \nu_x(x) : X \rightarrow [0, 1] \) show the degree of membership and nonmembership of the element \( x \in X \) to \( \tilde{P} \) respectively and for every \( x \in X \), it holds:

\[
0 \leq \mu_x(x)^2 + \nu_x(x)^2 \leq 1
\]

The indeterminacy value is:

\[
\eta_x(x) = \sqrt{1 - \mu_x(x)^2 - \nu_x(x)^2}
\]

**Definition 2.** Some of the basic operations on two pythagorean fuzzy numbers \( \tilde{P}_1 = P(\mu_{\tilde{P}_1}, \nu_{\tilde{P}_1}) \) and \( \tilde{P}_2 = P(\mu_{\tilde{P}_2}, \nu_{\tilde{P}_2}) \) are given as follows (Yildiz et al., 2020).

\[
\begin{align*}
\tilde{P}_1 \oplus \tilde{P}_2 &= P \left( \mu_{\tilde{P}_1}^2 + \mu_{\tilde{P}_2}^2 - \mu_{\tilde{P}_1} \mu_{\tilde{P}_2}, \nu_{\tilde{P}_1} \nu_{\tilde{P}_2} \right) \\
\tilde{P}_1 \otimes \tilde{P}_2 &= P \left( \mu_{\tilde{P}_1} \mu_{\tilde{P}_2}, \nu_{\tilde{P}_1} \nu_{\tilde{P}_2} - \nu_{\tilde{P}_1} \nu_{\tilde{P}_2} \right) \\
\tilde{P}_1 \ominus \tilde{P}_2 &= P \left( \frac{\mu_{\tilde{P}_1}^2 - \mu_{\tilde{P}_2}^2}{1 - \mu_{\tilde{P}_2}^2}, \nu_{\tilde{P}_1} \nu_{\tilde{P}_2} \right)
\end{align*}
\]

The indeterminacy value is:

\[
\eta_{\tilde{P}_1}(x) = \sqrt{1 - \mu_{\tilde{P}_1}(x)^2 - \nu_{\tilde{P}_1}(x)^2}
\]

**Definition 3.** Quasi-ordering on the Pythagorean fuzzy numbers is shown in Equation 2.14.

\[
\beta_1 \preceq \beta_2 \text{if and only if } \mu_{\beta_1} \geq \mu_{\beta_2} \text{ and } v_{\beta_1} \leq v_{\beta_2}
\]

In this study, a hybrid decision-making application is proposed using fuzzy logic and MCDM approaches to determine the most important distance learning factors during the COVID-19 pandemic. Therefore, we focus on prioritizing anthropometric, environmental, and psychosocial factors in the distance learning process during the COVID-19 pandemic. For this purpose, a checklist is prepared to determine and prioritize these factors. The checklist proposed as a novel distance learning ergonomics checklist is structured as a two-level hierarchical structure, considering ergonomic factors.

### 4.1 The novel distance learning checklist

OSHA is responsible for the rules and laws required to set and enforce occupational health and safety standards in the United States and operates under the Ministry of Labor. OSHA aims to provide healthy and safe working conditions for people by setting and defining standards and by providing training, education, and assistance for organizations (OSHA, 2020a). For this reason, different checklists
to be followed for different jobs and processes are prepared by OSHA.

In this study, "Office Safety and Health Checklist (OSHA, 2020a)* and "Computer Workstations Checklist (OSHA, 2020b)" were analyzed considering psychosocial factors on distance learning during the pandemic. Different anthropometric and environmental factors were evaluated, and these checklists were modified to create a new checklist for the distance learning process.

Fifty-eight different subfactors are evaluated under eleven different main factors in Computer Workstations Checklist proposed by OSHA. This checklist aims to answer the following questions: (1) How to sit properly at a computer workstation? (2) How to set up the workstation? (3) How to arrange the workstation equipment? (4) How to place the documents?

Firstly, this checklist was analyzed, and the most relevant factors for distance learning ergonomics during the pandemic were determined by consulting experts. The experts were determined based on their experiences in distance learning systems. We consulted one from the private education sector, two from public schools, and three academicians to determine the main and sub-factors. Eighteen different sub-factors were classified under the main factors of "Computer/Workstation (C), "Seating (S)," and "Equipment (E)," to be used in the distance learning ergonomics checklist. Some of these factors were modified to construct a comprehensive assessment checklist.

After that, the Office Safety and Health Checklist that consists of forty different factors and focuses specifically on office workers was analyzed. It was recognized that most of the factors in the Office Safety and Health Checklist were not related to distance learning. According to the literature review and expert opinions, only seven factors from Office Safety and Health Checklist were selected to evaluate distance learning ergonomics. These seven subfactors were collected under the main factor of "General Room/Office Condition (G)."

Finally, the main factor of "Psychosocial Health and Satisfaction" is added to represent the psychosocial difficulties students experience during the pandemic. "Psychosocial Health and Satisfaction" consists of fourteen different subfactors. In this way, a novel distance learning ergonomics checklist was created. The main factors and their subfactors establishing distance learning ergonomics checklist are given in Table 2.

Students from the Industrial Engineering Department of Yildiz Technical University, Istanbul participated in the research. The data were collected from 100 undergraduate students participating in the Ergonomics course. This course was being processed online due to the pandemic. Evaluations of the students were obtained using the proposed distance learning ergonomics checklist. An online questionnaire is utilized to collect their opinions on the main and sub-factors. Firstly, they ranked five main factors in order of their importance. Students determined the importance level of each sub-factor by choosing one of the linguistic terms shown in Table 3. Based on these evaluations, the factors were prioritized using the proposed methodology. The main factors used in the evaluation process were weighted by applying VAHP. Then the importance

### Table 2 Distance learning checklist

| Computer/Workstation (C) |  |
|-------------------------|--|
| C1-Head and neck are balanced and in-line with the torso. |  |
| C2-Head, neck, and trunk facing forward (not twisted to view monitor/work/documents). |  |
| C3-Back is fully supported by chair lumbar support. |  |
| C4-Thighs are approximately parallel to the floor. |  |
| C5-There should be sufficient room under the work surface. |  |
| C6-Legs and feet have sufficient forward clearance under the work surface. |  |
| C7-Sharp or square edges that contact hands, wrists, or forearms are padded or rounded. |  |

| Seating (S) |  |
|-------------|--|
| S1-Backrest has height adjustability so support is provided for the lower back (lumbar area). |  |
| S2-Seat width and depth should accommodate the specific user. |  |
| S3-Seat is cushioned and rounded with a "waterfall" front (no sharp edge). |  |
| S4-Seat height is adjustable and allows for proper alignment with the work surface. |  |
| S5-Adjustments are straight forward and easy to perform while seated in the chair. |  |

| Equipment (E) |  |
|---------------|---|
| E1-Keyboard/input device platform(s) is stable and large enough to hold a keyboard and an input device. |  |
| E2-Input device (mouse) is located right next to the keyboard so it can be operated without reaching. |  |
| E3-Input device is easy to activate and the shape/size fits hand (not too big/small). |  |
| E4-There is sufficient room so the monitor can be placed at a distance. |  |
| E5-Monitor position is directly in front of the user so they do not have to twist head or neck. |  |
| E6-Tablets and smartphones should be used with the shoulders relaxed, arms positioned near the torso. |  |

| General Room/Office Condition (G) |  |
|----------------------------------|--|
| G1-Computer and equipment have sufficient adjustability. |  |
| G2-Computer workstation and components are maintained in serviceable condition and function properly. |  |
| G3-Items that must be accessed frequently are within easy reach, generally with the elbows close the body. |  |
| G4-User has the ability to alternate between sitting and standing postures. |  |
| G5-Lighting levels are adjustable for differing tasks. |  |
| G6-The ventilation system delivers quality indoor air. |  |
| G7-Noise levels within acceptable levels. |  |

(Continues)
weights of subfactors were evaluated via PF-TOPSIS methodology. PF-TOPSIS was employed to evaluate sub-factors since each main factor consists of a different number of sub-factors. Then, PF-TOPSIS scores of subfactors were multiplied by the weights of the relevant main factors gained by VAHP to make a fair assessment among the subfactors. Subsequently, the results were analyzed and interpreted.

4.2 Determination of main factor weights by VAHP

First, the weights of each main factor of the distance learning ergonomics checklist were obtained using the VAHP method. For this purpose, a questionnaire was prepared to get the opinions of the students. It was asked to rank the main factors according to their importance from the most to the least (1, 2, 3, 4, 5). Multiple factors in the same ranking were allowed in the questionnaire prepared (e.g., if two were tied for 1, the next possible rank was 3). A total of 100 students participating in Ergonomics classes conducted the questionnaire. Then, the responses were analyzed and summarized in Table 4. Table 4 reflects the priority orders of students. There was no contradiction among the students.

For example, the main factor of "Seating" was evaluated as the most important factor by 60 students, and 10 students considered this main factor as the 5th important (the least important) one. After that, the mathematical models were structured using "Naguchi’s strong ordering" method. For example, the mathematical model was structured to determine the weight of the main factor "Computer/Workstation (C)" as follows:

\[
\text{maximize } 60U_{11} + 11U_{12} + 10U_{13} + 9U_{14} + 10U_{15} \quad (2.20)
\]

subject to:

\[
60U_{11} + 11U_{12} + 10U_{13} + 9U_{14} + 10U_{15} \leq 1 \quad (2.21)
\]
\[
43U_{11} + 16U_{12} + 11U_{13} + 17U_{14} + 13U_{15} \leq 1 \quad (2.22)
\]
\[
43U_{11} + 9U_{12} + 13U_{13} + 17U_{14} + 18U_{15} \leq 1 \quad (2.23)
\]
\[
44U_{11} + 12U_{12} + 20U_{13} + 14U_{14} + 10U_{15} \leq 1 \quad (2.24)
\]
\[
73U_{11} + 7U_{12} + 7U_{13} + 5U_{14} + 8U_{15} \leq 1 \quad (2.25)
\]
\[
U_{11} \geq 2U_{12} \quad (2.26)
\]
\[
2U_{12} \geq 3U_{13} \quad (2.27)
\]
\[
3U_{13} \geq 4U_{14} \quad (2.28)
\]
\[
4U_{14} \geq 5U_{15} \quad (2.29)
\]
\[
U_{11}, U_{12}, U_{13}, U_{14}, U_{15} \geq 0.0002083 \quad (2.30)
\]

The mathematical model was solved by IBM ILOG Cplex OPL Optimization Studio 12.8 on a PC with a 1.8 GHz Intel i5 CPU and 8 G memory. The objective value of this mathematical model was obtained as 0.8947. Thus, the unnormalized weight of the criterion "Computer/Workstation (C)" was determined as 0.8947. Four more mathematical models were then structured to determine the weights of the other four main factors and objective functions were
obtained. Last, the weights of the factors were normalized, as given in Table 5.

The importance weights of the five main factors, "Computer/Work Station (C)," "Seating," "Equipment," "General Room/Office Condition" and "Psychosocial Health and Satisfaction" were calculated as 0.2161, 0.1819, 0.1765, 0.1839, and 0.2416, respectively. The most significant main factor for distance learning ergonomics during Covid-19 was specified as "Psychosocial Health and Satisfaction," with an importance weight of 0.2416. In other words, it was determined that the most critical factor when evaluating anthropometric, environmental, and psychosocial factors for students in the distance learning process during the Covid-19 pandemic is "Psychological Health and Satisfaction." Also, "Work Station/Computer" is the factor that should be evaluated as a priority. The least important criterion is found to be "Equipment." Considering the difficulties experienced by students, equipment such as a keyboard, mouse, tablet, smartphone, etc., appears to be considered at the end of the list.

4.3 Ranking of subfactors by PF-TOPSIS

After determining the weights of the main factors, the same students were consulted and asked to express their opinions in weighting the subfactors through the questionnaire. For this purpose, they used the linguistic variables (shown in Table 3) to assess the importance of the subfactors (as shown in Table 6), and thus, decision matrices for subfactors were constructed.

At this step of the study, the evaluations of sub-factors were performed for relevant main factors, specifically. For example, the decision matrix was structured by Student-1 for "Computer/Work Station," as shown in Table 6.

When Table 6 is examined in detail, it can be seen that "C1-Head and neck are balanced and in-line with torso" is extremely highly important, while "C2-Head, neck, and trunk facing forward (not twisted to view monitor/work/documents)" is highly important according to Student-1. Student-1 filled out a questionnaire for each subfactor in this way. The opinions of 100 students were taken to make a comprehensive evaluation. After all decision matrices were structured by students’ evaluations, PF-TOPSIS steps were applied for each main factor and the weights of sub-factors were calculated.

PF-TOPSIS scores of subfactors were multiplied by the importance weights of the relevant main factors to determine the subfactors’ final importances. Table 7 shows the weights of main and subfactor and rankings of subfactors calculated by VAHP integrated PF-TOPSIS by considering all students’ opinions.

5 DISCUSSION

We present the results of ergonomics risk checklist evaluation and the importance of each risk for the distance learning process during the COVID-19 pandemic. As a result, the ergonomics risk evaluation data in the questionnaire reveals a few interesting points regarding the views on distance learning ergonomic factors in the pandemic. The findings reflect that "Psychosocial Health and Satisfaction" is the most important main factor in distance learning. Experts felt that these factors significantly affected distance learning ergonomics during the pandemic, according to the questionnaire responses. Calisir et al. (2014) also show that anxiety is an important factor affecting learning performance in e-learning systems.

When the weights of distance learning ergonomics factors are examined, it can be seen that "Psychosocial Health and Satisfaction" takes first place with the weight of 0.2416. "Computer/Work Station," "General Room/Office Condition," "Seating," and "Equipment" are then determined as the second, third, fourth, and fifth important main factors in terms of distance learning ergonomics. The strengths and weaknesses of ergonomic factors for educational institution administrators are frequently evaluated comprehensively by the students in distance learning activities. Understanding and developing these factors will affect student performance. In addition to the high importance of "Psychosocial Health and Satisfaction," other four main dimensions should be considered to evaluate distance learning ergonomics.

If the sub-factors given in Table 7 are focused on, "P10-Feelings of deprivation, boredom, pressure, irritation, worry, sadness, pessimism, hopeless view of future" is the most important sub-factor with the highest importance level of 0.041. It can be said that "P10-Feelings of deprivation, boredom, pressure, irritation, worry, sadness, pessimism, hopeless view of future" has more impact on students than the other subfactors. Therefore, students should be supported by professionals in difficult times like the COVID-19 outbreak. Then, "C3-Back is fully supported by chair lumbar support" is determined as the second most important subfactor with an importance level of 0.35. Šagat et al. (2020) show that low back pain intensity increases significantly during COVID-19 quarantine. Increased sitting time

### Table 5

| Main Factor                                | Unnormalized weight | Normalized weight |
|--------------------------------------------|---------------------|-------------------|
| Computer/Work Station (C)                  | 0.8947              | 0.2161            |
| Seating (S)                                | 0.7531              | 0.1819            |
| Equipment (E)                              | 0.7307              | 0.1765            |
| General Room/Office Condition (G)          | 0.7611              | 0.1839            |
| Psychosocial Health and Satisfaction (P)   | 1                   | 0.2416            |
causes an increase in the severity of low back pain. Furthermore, Edwar et al. (2020) use structural equation modeling to evaluate the working style model with work posture factors and musculoskeletal pain. They indicate that several distance learning factors contribute to the musculoskeletal disorders of students during the pandemic. Therefore, students should consider ergonomic factors when choosing a chair. And “P11-Apathy (The course/subject/task should be interesting)” must be considered, with the importance level of 0.033. It can be said that while students listen to the lectures at home for long hours, they experience physiological difficulties due to their limited facilities at home. Additionally, the instructors should assist students in this process by preparing interesting content. The least important subfactors are determined as “E4-There is sufficient room so the monitor can be placed at a distance,” “G1-Computer and equipment have sufficient adjustability,”, and “G4-User has the ability to alternate between sitting and standing postures,” with importance levels less than 0.018. It can be said that these factors are not very crucial for students on distance education during the pandemic.

In this study, an integrated MCDM model is applied that evaluates distance learning ergonomics through the effects of predetermined factors during the Covid-19 outbreak. In the light of this model, the opinions of six different experts and 100 students are collected in Turkey. The results showed that distance learning decision makers need a greater focus on “Psychosocial Health and Satisfaction” to provide better conditions for students. However, this result needs to be analyzed carefully. Some possible explanations for this result can be considered. First of all, the VAHP methodology is constructed with experts’ opinions to measure the weights of the main factors. Obviously, in such difficult situations, students especially need psychological support, according to VAHP application results. Then PF-TOPSIS is applied to determine the weights of the subfactors. The findings of this study provide valuable information to decision makers about dimensions that reflect students’ needs. By addressing individual factors, administrators will improve the conditions to provide better education service to students.

Different institutions have prepared ergonomics-based checklists. These checklists usually focus on specific topics such as; office safety, computer usage, etc. The scholars apply the checklists to evaluate different ergonomic factors. Lin et al. (2013) investigate the suitability of the OSHA musculoskeletal diseases checklist for manufacturing industries. Six different companies sign up for the study. They show that a checklist is a surveillance tool that helps identify musculoskeletal conditions and is easily applied to evaluate risks. Keyserling et al. (1993) present a checklist to evaluate ergonomic risk factors related to upper extremity cumulative trauma disorders. Norman et al. (2004) use an ergonomic checklist to assess workstation design for call center workers. Nag et al. (2012) apply an ergonomic checklist on general health and psychosocial issues to female workers to examine the prevalence of musculoskeletal pain and discomfort. Brooks (1998) proposes an ergonomic checklist outlining some issues to organize office layout. Engkvist et al. (1995) design an ergonomics checklist for nursing staff to plan patient rooms, corridors, toilets, and treatment rooms. Lindegård et al. (2012) examine whether perceived effort, perceived comfort, and working technique among professional computer users are associated with the frequency of neck and upper extremity symptoms using an ergonomic checklist. Basu and Dasgupta (2020) use different ergonomics checklists to find out the rate of ocular problem types among video display terminal users. As can be seen, ergonomics checklists are used to evaluate different ergonomics-related problems. However, there are very few checklists that can be used to assess the distance learning environment. Unlike other studies, this study focuses on distance learning and identifies both main and subfactors from different aspects to evaluate ergonomics conditions.

The proposed novel distance learning ergonomics checklist includes an extended version of the checklists currently used. In this context, the proposed checklist stands out as the most detailed checklist in which distance learning ergonomics factors are defined and evaluated comprehensively, considering the pandemic conditions.

Various management implications can be presented in this study. Such findings emphasize the importance of recognizing students’ changing conditions for distance learning. We propose, albeit temporarily, some potentially important implications of distance learning ergonomics for future pandemics. First of all, psychosocial service should be encouraged. Psychologists should support students to reduce the negative impact of the pandemic on students’ learning.

### Table 6: Evaluation of the subfactors of Computer/Workstation by Student-1

| Computer/Workstation (C) | Linguistic variable |
|-------------------------|--------------------|
| C1-Head and neck are balanced and in-line with the torso. | EH |
| C2-Head, neck, and trunk facing forward (not twisted to view monitor/ work/documents). | H |
| C3-Back is fully supported by chair lumbar support. | EH |
| C4-Thighs are approximately parallel to the floor. | EH |
| C5-There should be sufficient room under the work surface. | VH |
| C6-Legs and feet have sufficient forward clearance under the work surface. | MH |
| C7-Sharp or square edges that contact hands, wrists, or forearms are padded or rounded. | H |
| Main factor                  | Weight | Subfactor | Score | Inner ranking | Final importance | Final ranking |
|-----------------------------|--------|-----------|-------|---------------|------------------|--------------|
| Computer/Work Station       | 0.2161 | C1        | 0.632 | 2             | 0.032            | 5            |
|                             |        | C2        | 0.519 | 3             | 0.026            | 18           |
|                             |        | C3        | 0.694 | 1             | 0.035            | 2            |
|                             |        | C4        | 0.442 | 5             | 0.022            | 26           |
|                             |        | C5        | 0.501 | 4             | 0.025            | 19           |
|                             |        | C6        | 0.375 | 7             | 0.019            | 34           |
|                             |        | C7        | 0.402 | 6             | 0.020            | 31           |
| Seating                     | 0.1819 | S1        | 0.496 | 3             | 0.021            | 29           |
|                             |        | S2        | 0.590 | 1             | 0.025            | 20           |
|                             |        | S3        | 0.472 | 4             | 0.020            | 32           |
|                             |        | S4        | 0.556 | 2             | 0.024            | 25           |
|                             |        | S5        | 0.458 | 5             | 0.020            | 33           |
| Equipment                   | 0.1765 | E1        | 0.532 | 4             | 0.022            | 27           |
|                             |        | E2        | 0.591 | 2             | 0.024            | 23           |
|                             |        | E3        | 0.646 | 1             | 0.027            | 17           |
|                             |        | E4        | 0.336 | 6             | 0.014            | 39           |
|                             |        | E5        | 0.456 | 5             | 0.019            | 36           |
|                             |        | E6        | 0.588 | 3             | 0.024            | 24           |
| General Room/Office Condition | 0.1839 | G1        | 0.374 | 7             | 0.016            | 38           |
|                             |        | G2        | 0.583 | 3             | 0.025            | 21           |
|                             |        | G3        | 0.439 | 5             | 0.019            | 35           |
|                             |        | G4        | 0.420 | 6             | 0.018            | 37           |
|                             |        | G5        | 0.501 | 4             | 0.022            | 28           |
|                             |        | G6        | 0.621 | 2             | 0.027            | 16           |
|                             |        | G7        | 0.699 | 1             | 0.030            | 10           |
| Psychosocial Health and Satisfaction | 0.2416 | P1        | 0.503 | 11            | 0.029            | 14           |
|                             |        | P2        | 0.547 | 7             | 0.031            | 9            |
|                             |        | P3        | 0.526 | 9             | 0.030            | 12           |
|                             |        | P4        | 0.530 | 8             | 0.030            | 11           |
|                             |        | P5        | 0.573 | 3             | 0.032            | 4            |
|                             |        | P6        | 0.516 | 10            | 0.029            | 13           |
|                             |        | P7        | 0.553 | 6             | 0.031            | 8            |
|                             |        | P8        | 0.477 | 12            | 0.027            | 15           |
|                             |        | P9        | 0.554 | 5             | 0.031            | 7            |
|                             |        | P10       | 0.727 | 1             | 0.041            | 1            |
|                             |        | P11       | 0.581 | 2             | 0.033            | 3            |
|                             |        | P12       | 0.437 | 13            | 0.025            | 22           |
|                             |        | P13       | 0.372 | 14            | 0.021            | 30           |
|                             |        | P14       | 0.559 | 4             | 0.032            | 6            |

Note: The bold values emphasize the most important factors.
performances. This also helps students focus on their courses. In addition to meeting the needs of students, it is necessary to respond quickly as soon as possible. Second, governments should provide a study environment in students’ homes that meet their minimum ergonomic requirements. Especially the computers used by students are crucial. Computers and general room conditions are critical in enhancing students’ learning performances and improving their attitudes and intentions.

In this study, we integrate VAHP with PF-TOPSIS for the first time in the literature. Moreover, we apply this integrated decision-making methodology to evaluate distance learning ergonomics factors from a Turkey-based perspective. Although methodological studies are presented in the MCDM literature, those pertaining to distance learning ergonomics are still critically lacking. So there is a lot to be done, but we think the study will produce important findings in the field of distance learning ergonomics. Also, a novel checklist is presented in this study to evaluate ergonomic factors. We apply this checklist to 100 university students in Turkey, and VAHP integrated PF-TOPSIS is used to measure the weights of distance learning ergonomics factors for the first time.

Student sampling in the survey was a potential limitation of the study. It was difficult to reach and consult students’ opinions due to the pandemic. Instead of making face-to-face interviews, student opinions were taken through an online questionnaire. Therefore, student views could be evaluated using VAHP and PF-TOPSIS.

6 | CONCLUSIONS

With the rapid spread of COVID-19, there have been very sudden changes all over the world. One of these changes is that universities have switched to distance learning with a sudden decision because of pandemic conditions. Probably many students did not expect to have to join distance learning in such a short time, compared to students who had previously considered using it. Therefore, it is inevitable for students to encounter some difficulties in distance learning. Identifying these difficulties that affect the learning level of students will be a guide in determining the right strategies to increase the quality of education.

In this paper, determining and prioritizing anthropometric, environmental, and psychosocial factors related to the distance learning process during the COVID-19 pandemic are discussed. To identify the main and sub-factors for evaluation, the OSHA checklists are analyzed, and the relevant literature is reviewed. At the end of this process, 39 different ergonomic factors are determined under five different main factors. Then, 100 students are asked to evaluate the ergonomic factors encountered during the Covid-19 outbreak. The decision-making model is structured as a two-level hierarchical structure to evaluate the ergonomic factors on distance learning. Subsequently, a novel VAHP integrated PF-TOPSIS methodology is structured to determine the importance level of each factor.

The contributions of the paper to the literature can be specified as follows: (1) The anthropometric, environmental and psychosocial factors on distance learning process during COVID-19 pandemic are determined; (2) The most important factors on distance learning ergonomics during a pandemic are defined and classified; (3) A novel distance learning ergonomics checklist is created; (4) The main factors are evaluated by VAHP and their importance levels are determined; (5) The sub-factors (inner levels) are evaluated by PF-TOPSIS method and the importance weights of them are obtained; (6) To the best of our knowledge it is the first study to address anthropometric, environmental and psychosocial factors on distance learning process during Covid-19 pandemic, as an MCDM problem; (7) To the best of our knowledge, this is the first study proposing the integration of VAHP and TOPSIS methods; (8) The proposed method is aimed to be used by public and private organizations to improve their distance learning strategies.

As future suggestions, more students can be consulted for opinions by interviewing students from different universities. Factors can be evaluated by providing equal conditions for each student caused by their studying environment. Other MCDM methods or heuristics can be included in the methodology to ensure a more comparative and integrated study as a future direction. This study can be expanded by discussing with more experts.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

Author elects to not share data.

The data that supports the results of this study and all the tables in this study are available upon reasonable request from the corresponding author.

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