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Determining Awareness on the Protection of Employees and Service Users from Gamma Rays in Places Where Gamma Ray is Used

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Makalenin Alanı: Fizik ve Fizik Mühendisliği

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Öz

İyonlaştırıcı radyasyon sınıfına giren ve maruz kalan kişiler için tehlike oluşturan gama ışınları hakkında çalışanların ve hizmet alanların bilgi sahibi olması son derece önemlidir. Bu çalışma gama ışınlarından korunma konusunda farkındalığın belirlenerek yükseltilmesi amacıyla gama ışınlarıyla çalışma yapan Türkiye Atom Enerjisi Kurumu, GAMMAPAK sterilizasyon A.Ş ve gamma knife radyocerrahisini kullanan hastane çalışanları ve buradan hizmet alanlar (hastalar ve diğerleri) üzerinde online anket uygulaması kullanılarak yapılmıştır. Çalışma nicel araştırma yöntemlerinden genel tarama modeline uygun şekilde tasarlanmıştır. 153 katılımcının 20 sorudan oluşan anketi cevaplandırması sonucunda elde edilen bulgular çalışmaya aktarılmıştır. Çalışma; farklı cinsiyet, pozisyon (hizmet alan veya çalışan), gelir düzeyi, yaş ve eğitim düzeyindeki kişilere ankette yer alan 20 soru sorularak gerçekleştirilmiştir. Elde edilen veriler Açımlayıcı Faktör Analizi (EFA) uygulanarak analiz edilmiştir. Sırasıyla Doğrulayıcı Faktör Analizi (DFA), normallik testi, tanımlayıcı istatistikler, bağımsız gruplar t-testi tek yönlü ANOVA, Kruskal Wallis-H Testi yapılmıştır. Anket verileri incelendiğinde, gama ışınlarına yönelik farkındalığın katılımcıların cinsiyet, gelir düzeyi, yaş ve eğitim düzeyine göre farklılaştığı belirlenmiştir.

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Abstract

It is extremely important that workers and service recipients have information about gamma rays which are in the class of ionizing radiation and pose a danger to people who are exposed to it. This study was conducted by using an online questionnaire on the Turkish Atomic Energy Agency, GAMMAPAK sterilization INC, which work with gamma rays and hospital employees who use gamma knife radiosurgery and service recipients from it (patients and others) in order to raise awareness about protection from gamma rays. The study was designed in accordance with the general survey model, one of the quantitative research methods. The findings obtained as a result of 153 participants answering the questionnaire consisting of 20 questions were transferred to the study. The study was carried out by asking 20 questions in the survey to people of different gender, position (service recipient or worker), income level, age and education level. The data obtained were analyzed by applying Exploratory Factor Analysis (EFA). Confirmatory Factor Analysis (CFA), normality test, descriptive statistics, independent groups t-test one-way ANOVA, Kruskal Wallis-H Test were carried out, respectively. When the survey data were analyzed it was determined that awareness of gamma rays differed according to the gender income level age and education level of the participants.

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INTRODUCTION

Radiation in the most basic sense is the phenomenon that occurs in the form of quantized energy which is the spread of the energy of high-speed particles and electromagnetic waves in the form of particles and waves (Coşkun, 2011; Erdoğan et al., 2017).

Another definition of radiation; It is the energy emitted by unstable atoms that can easily pass-through matter and space (URL1). The phenomenon known as radiation is not only rays such as alpha, beta, gamma but also electromagnetic waves in the electromagnetic spectrum when they are ordered according to their wavelengths and from the longest to the shortest; radio waves, microwaves, infrared region, light (visible region), ultraviolet region. X-ray region and γ-rays region. It even includes particles such as neutrons, protons and other subatomic particles depending on their speed (Öztürk, 2007, p 490). Radiation is also classified according to its energy type and source. It can be considered: (i) in term of energy; with low and high energy. (ii) in terms of type; particle and electromagnetic radiations and (iii) in term of source; as natural and artificial radiation. (Çubuk, 2010, s.2) Small and high energy radiation groups include ionizing radiation and non-ionizing radiation. Respectively, since non-ionizing radiation is low in energy it cannot ionize the atoms of the material it interacts with, but only excites it. Radio waves, visible light, microwaves, infrared light, ultraviolet light are examples of non-ionizing radiations. The energies of all of the electromagnetic radiations in the electromagnetic spectrum are carried by photons which have no charge, no mass and are known as quantized (Erdoğan et al., 2017). In this study ionizing radiation will be discussed and as it is known X- and γ-rays are included in this class. German physicist Wilhelm Conrad Roentgen was the first scientist to perform imaging using X-rays. The invention of X-rays in 1895 which are defining with his name was a beginning concept of ionizing radiation. In the year following the discovery of x-ray in 1896.French scientist Antoine Henri Becquerel discovered that Uranium salts also showed similar properties to X-rays and emitted penetrating rays into some matter and called it as radioactivity (Daşdağ, 2010).With the discovery of different radioactive elements (such as radium) by Marie and Pierre Curie, ionizing radiation has been used in many areas such as medicine, industry, agriculture and research (Aral,2019,s.18). As it is known X- and γ-rays with particles called radioactive form the class of ionizing radiation. Ionizing radiations can cause to the increasing or decreasing of electrons in the atom or group of atoms with which they interact. As a result of this situation positively or negatively charged ions are formed. Ionizing radiations are also evaluated in two groups according to their wave and particle characteristics (Daşdağ, 2010). X-rays and γ-rays are examples of wave-like radiation while alpha(α), beta(β) and neutrons are examples of particle-like radiation (Daşdağ, 2010).

A large number of studies have been conducted on X-rays to date and X-rays are more common in daily life than γ-rays. In addition the use of gamma rays in technological and health fields is increasing. As a member of the ionizing radiation family γ-rays are electromagnetic in nature although they are likened to α or β particles in that they can ionize atoms and are emitted in packets (quanta) of energy called photons. Considering the ability to be stopped it is seen that only a part of it is stopped with a few centimeters of lead bricks (Oyar, 1998,s.13). In this study it is aimed to examine and evaluate the awareness of both employees and service users about γ-rays in places where γ-rays are used.

MATERIAL AND METHOD

This study was designed in accordance with the general survey model which is one of the quantitative research methods. Survey models are a type of research based on describing a situation that has existed in the past or that has already existed. In this type of research situations are tried to be defined as they are (Karasar, 2007, s.77). Since the aim of this study is to determine the level of awareness of employees and service users about protection from Gamma rays it was deemed appropriate to use the general screening model as the research model of the study.

Research had done at Turkish Atomic Energy Authority (TAEA), GAMMAPAK Sterilization Inc. and Gamma Knife Radiosurgery with the staff and service recipients in the hospital in 2020-2021. As of 2021 the number of personnel working in these institutions is 120 and the number of service recipients is 115. In a different way the target population of the study consists of a total of 225 people. The sample of the study consists of 153 people selected through simple random sampling.

The distribution of various demographic variables of the participants is given in Table 1.

Table 1. Distribution of Some Demographic Variables of Research Participants

Demographic variables	Explanation	N	%
Gender	Male	81	52.9
	Female	72	47.1
	Total	153	100.0
Age range	19-29 Age range	40	26.1
	30-39 Age range	79	51.6
	40+ Age	34	22.2
	Total	153	100.00
Position	Service provider	101	66.0
	service recipient	52	34.0
	Total	153	100.0
Education Level	Less than Bachelor's	24	15.7
	Undergraduate	78	51.0
	Graduate	51	33.3
	Total	153	100.0
Perception of income status by minimum wage	Low	12	7.8
	Middle	83	54.2
	High	58	37.9
	Total	153	100.00

Data Collection Tools. Data Collection. Validity and Reliability

In order to measure the sub-problems of this research the γ-ray protection awareness scale was developed by the researchers. During the scale development process an item pool was created by first examining the relevant literature and looking at case studies. There are 20 Likert type judgments in total in the item pool created. After the items were created they were checked by 2 field experts to check the validity and comprehensibility of the Turkish language and after various feedbacks and corrections from them, they were made ready for the pre-implementation phase.

After the item pool was ready the scale items were first piloted with 20 people, and it was desired to determine whether there were any negativities in the pilot application. Since no problems were encountered in this application the actual application was started later. The data collection process which is another stage of scale development was obtained online by the researcher among 25.12.2020 and 20.03.2021 dates. Since there are 20 items in the scale at first it is aimed to reach at least five times (100 people) the number of items.

After the data were collected exploratory factor analysis (EFA) was carried out to see how many factors the items were clustered under as a first step. At this stage items with a load value below 0.30 or with more than one factor were removed. At this stage 18 items had remained. It was observed that the remaining items were clustered under two factors. In the next step confirmatory factor analysis (CFA) was performed to confirm the inclusion of the items in two factors. In the CFA analysis it was seen that the item load values were in the desired range. In this way it was seen that the construct validity of the relevant measurement tool was ensured. Cronbach's alpha coefficient was used for the reliability of the measurement tool used in the research. The Cronbach's coefficient was calculated in the SPSS program, and the acceptable value of Cronbach's alpha coefficient is 0.60 and above. Above 0.70 means it is strong and reliable. In this study the Cronbach's alpha coefficient of the first sub-factor was 0.65; Cronbach's coefficient of the second sub-factor was 0.96; the overall Cronbach's coefficient of the scale was calculated as 0.93. Depending on the obtained scales it is concluded that the scale is reliable. It is seen that both the sub-factors and the general scale of the scale developed with a different expression was within certain and desired ranges.

Analysis of the Data

After the data of the research were collected the forms that did not comply with the instructions specified in the data collection tool were excluded from the data set and the data were first transferred to the Excel program and then to SPSS 25. In SPSS firstly, outlier data were extracted. After this stage the data were done ready for analysis. The analyzes were carried out as follows, respectively: (i) Exploratory Factor Analysis (EFA), (ii) Confirmatory Factor Analysis (CFA), (iii) Normality Test, (iv) Descriptive Statistics, (v) Independent Groups t-test, (vi) One direction ANOVA and (vii) Kruskal Wallis-H Test.

Results and Discussion

In this part of the study the results of exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) related to the scale development stages, respectively the normality distribution indicators related to the dependent variable the distributions of the demographic characteristics of the participants obtained from the personal information form and the findings related to the identified sub-problems were included.

Results of Exploratory Factor Analysis (EFA)

For the validity processes factor analysis was performed to determine the groupings (factors) between the items. During the factor analysis Kaiser-Meyer-Olkin (KMO) and Bartlett values were determined; principal components analysis was carried out and finally varimax rotation operations were performed. The Kaiser-Meyer-Olkin (KMO) and Bartlett Test values of the scale are given in Table 2.

Table 2. KMO and Barlett Test Results of the scale

Kaiser-Meyer-Olkin Sampling Adequacy	**0.925**	
Barlett Test of Sphericity	Ki-Square Value	2365.502
	Degrees of Freedom	171
	p	0.000

As seen from the Table 2. the KMO value was found to be 0.925 in Principal Components Analysis. This means that factor analysis can be interpreted perfectly.

The load value provided in the Exploratory Factor Analysis is an important criterion used to determine whether the relevant item belongs to the sub-factors to be defined. Indicators regarding the total variance values explained by the two sub-factors are presented in Table 3.

Table 3. Total amount of variance explained by the scale

Factors	**Initial Eigenvalues**			**Total Factor Loads**			**Transformed Sums of Factor Loads**		
	Total	**Variance %**	**Cumulative %**	**Total %**	**Variance %**	**Cumulative %**	**Total %**	**Variance %**	**Cumulative %**
1	9.967	55.733	55.373	9.967	55.373	55.373	9.950	55.279	55.279
2	1.921	10.672	66.045	1.921	10.672	10.672	1.938	10.766	663.045
3	0.843	4.684	70.729						
4	0.757	4.204	74.933						

The total amount of variance explained by the two factors is quite high. The load values of each item and the distribution of the factors it belongs to them are presented in Table 4.

Table 4. Matrix of transformed components after factor analysis

Samples		**Factors**	
		γ-ray Information	**γ-ray Awareness**
M1	I have a good knowledge about radiation.	0.711	
M2	I have a good knowledge about γ-ray radiation.	0.896	
M3	I know how many doses of γ radiation my body/organ was exposed to while serving/receiving.	0.810	
M4	I know about the units of γ radiation.	0.909	
M5	I take adequate precautions when being exposed to γ-rays.	0.849	
M6	I was sufficiently informed before I was exposed to γ-rays.	0.800	
M7	I act knowing that even though it is the same type of radiation, it will have different effects on different parts of my body.	0.782	
M8	I have a good knowledge of radiation units	0.878	
M9	I am aware of where γ radiation occupies in the electromagnetic spectrum in terms of energy.	0.842	
M10	Areas containing gamma radiation should be insulated with lead sheet.	0.575	
M11	I have a good knowledge of the physical properties of γ radiation.	0.930	
M12	γ radiation should be used not only for medical treatment but also in many industries and R&D fields.	0.709	
M13	I have a good knowledge of γ radiation sources.	0.905	
M14	I have knowledge that γ radiation can be obtained naturally and artificially.	0.735	
M15	I have a good knowledge of where γ radiation is used in industry.	0.741	
M16	γ radiation is visible to the naked eye.		0.786
M17	I think that γ radiation does not harm the human body because it propagates at the speed of light.		0.846
M18	I take as little air travel as possible to avoid exposure to γ radiation.		0.645

The Cronbach's Alpha value, which is calculated as the reliability coefficient over both the overall total of the scale and the item in each sub-dimension is given in Table 5.

Table 5. General of γ-Ray Protection Awareness Scale and Reliability Coefficients of Sub-Dimensions Revealed by Factor Analysis

Factor	**Cronbach's Alpha Value**
γ-Information	0.652
γ-Awareness	0.962
Total	0.936

Results of Confirmatory Factor Analysis (CFA)

The main purpose of confirmatory factor analysis is to test whether the items really belong to the relevant factors with the distribution that emerges in the exploratory factor analysis.

The fit index values, which are considered as criteria for the model emerging in the Confirmatory Factor Analysis are given in Table 6.

Table 6. Goodness of Fit Index Values for the DFA Model

Factors	Samples	Standardized Factor Loads (λi)	R^2	Standard error	t value	p value
γ-Information (Factor 1)	F1-M1	0.72	0.52	0.14	4.645	0.000
	F1-M2	0.89	0.79	0.15	11.252	0.000
	F1-M3	0.79	0.62	0.15	9.840	0.000
	F1-M4	0.91	0.83	0.16	11.423	0.000
	F1-M5	0.80	0.64	0.14	9.992	0.000
	F1-M6	0.75	0.56	0.16	9.336	0.000
	F1-M7	0.77	0.59	0.14	9.513	0.000
	F1-M8	0.87	0.76	0.14	10.882	0.000
	F1-M9	0.84	0.71	0.14	10.589	0.000
	F1-M10	0.54	0.29	0.11	6.675	0.000
	F1-M11	0.94	0.88	0.13	11.821	0.000
	F1-M12	0.66	0.44	0.13	8.190	0.000
	F1-M13	0.88	0.77	0.13	11.126	0.000
	F1-M14	0.70	0.49	0.13	8.652	0.000
	F1-M15	0.68	0.46	0.13	8.444	0.000
γ-Awareness (Factor 2)	F2-M1	0.62	0.38	0.24	3.415	0.000
	F2-M2	0.91	0.83	0.36	3.892	0.000
	F2-M3	0.38	0.14	0.16	4.132	0.000

Table 6 shows the standardized regression and t values of the Gamma Ray Protection Awareness Scale. It is seen that the load values of the items that make up the two-factor and 18-item structure vary between 0.35 and 0.58. It is seen that the item load value of each item is in the acceptable range and the p values are significant.

The p value expresses the statistical significance level and if it is below 0.05, it indicates that the value is statistically significant. The t value is also the critical ratio C.r value. C.R value has no upper and lower limit.The parameter estimates including the non-standardized and standardized regression coefficients and C.R (t) values obtained for the structural model are given in Table 7.

Table 7. Standardized regression and t values of the scale for awareness of γ-Ray protection

Fit indices	Perfect fit	Acceptable fit	Model Results	Situation
χ^2/df	$0 \leq \chi^2 \leq 3sd$	$4 \leq \chi^2 \leq 5sd$	1.982	Perfect fit
RMSEA	RMSEA ≤ 0.05	0.06 ≤ RMSEA ≤ .08	0.80	Acceptable fit
CFI	0.95 ≤ CFI ≤ 1.00	0.90 ≤ CFI ≤ 0.95	0.94	Acceptable fit
GFI	0.95 ≤ GFI	0.85 ≤ GFI ≤ 0.89	0.85	Acceptable fit
AGFI	0.90 ≤ AGFI	0.85 ≤ AGFI ≤ 0.89	0.85	Acceptable fit
IFI	0.95 ≤ IFI	0.90 ≤ IFI ≤ 0.94	0.94	Acceptable fit
SRMR	SRMR ≤ 0.05	0.05 ≤ SRMR ≤ 010	0.78	Acceptable fit

Results Related to the Normality Test

The dependent variable of the research is γ-Ray Protection Awareness. In normality assumptions, if n>50 and Kolmogorov Smirnov test p>0.05, the distribution is assumed to be normal and parametric tests are applied. Similarly, if the value obtained from dividing the kurtosis and skewness values into their error coefficients is within the range of ±1.96, parametric tests are continued. In addition, the linearity of the distribution is checked in the Q-Q plot histogram. If the normality assumptions are not met, non-parametric tests are used to analyze the data. The normality test results of the study according to the dependent variable are given in Table 8.

Table 8. Normality test results regarding the dependent variable of the study

Variables	Kolmogorov-Smirnov[a]			Shapiro-Wilk				
	Statistics	sd	p	Statistics	sd	p	Skewness-standard deviation error	Kurtosis-standard deviation error
γ-Ray Protection Awareness	0.072	153	**0.053**	0.983	153	0.062	-0.217 0.196	-0.579 0.390

a. Lilliefors Significance Correction

The arithmetic mean and standard deviation levels of the γ-Ray protection awareness scale according to various demographic variables of the participants are given in Table 9.

Table 9. Various demographic variables and γ-Ray protection scale arithmetic mean and standard deviation values of participants

Demographic Variable	γ-Information (Factor 1)			γ-Awareness (Factor 2)		Scale grand total	
	Category	X̄	SS	X̄	SS	X̄	SS
Gender	Male	49.68	16.32	6.15	2.65	55.83	16.37
	Female	50.58	12.34	6.36	2.10	56.94	12.52
Age range	19-29 Age	48.60	13.46	6.28	2.63	54.88	14.00
	30-39 Age	48.25	13.62	6.52	2.31	54.77	13.59
	40+ Age	56.18	16.52	5.59	2.24	61.76	16.79
Position	Service provider	51.52	15.80	5.90	2.37	57.43	15.75
	Service receiver	47.35	11.36	6.92	2.33	54.27	12.11
Educational Status	less than undergraduate	48.92	13.76	5.88	2.19	54.79	12.66
	Undergraduate	44.63	13.81	6.60	2.41	53.23	14.57
	Graduate	55.98	14.40	5.88	2.44	61.86	14.31
Perceived Income level	Lower	49.58	11.88	7.92	3.40	57.50	14.61
	Middle	49.11	13.02	6.33	2.01	55.43	13.03
	Upper	51.64	17.00	5.79	2.55	57.43	16.86

The arithmetic mean and standard deviation values of the participants related to the γ-Ray Protection Awareness levels are presented in Table 10.

Table 10. Arithmetic mean and standard deviation values obtained from Participants related to γ-Ray protection awareness scale

Variables	X̄	ss
γ-Information	50.10	14.54
γ-Awareness	6.24	2.39
γ-Ray Protection Awareness (Scale General)	56.35	14.65

Table 10 shows the arithmetic mean and standard deviation values for the sub-dimensions and general of the γ-rays protection awareness scale of the participants. The first sub-dimension, gamma information, has a total of 15 items and according to 5-point Likert scoring, participants can score between 0-75 in this sub-dimension. According to the table, γ-knowledge, which is the first sub-dimension of the participants, was calculated as $\bar{X}$=50.10 (SD=14.54) and was determined at a high level. The second sub-dimension, γ-awareness, has 3 items, and participants can score between 0-15 from this sub-dimension according to 5-point Likert-type scoring. The γ-awareness levels of the participants were calculated as $\bar{X}$=6.24 (SD=0.2.39), below the median. There are 18 items in the scale, and participants can score between 0-90. The level of awareness of protection from γ-rays was calculated as $\bar{X}$=56.35

(SD=14.65) for the participants. This value was above the medium level. In other words, the level of awareness of protection from γ-rays of the participants was above the medium level of 45.00.

In Table 11, the arithmetic mean and standard deviation values calculated for each item of the scale are presented.

Table 11. Arithmetic mean and standard deviation values of γ-Ray protection awareness scale items

Samples		Values	
		$\bar{X}$	SS
M1	I have a good knowledge of radiation.	**3.72**	**0.96**
M2	I have a good knowledge of γ-Ray radiation.	3.35	1.17
M3	I know how many doses of γ radiation my body/organ is exposed to while serving/receiving.	2.99	1.36
M4	I know about the units of gamma radiation.	3.13	1.32
M5	I take adequate precautions when being exposed to gamma rays.	3.24	1.31
M6	I was sufficiently informed before I was exposed to gamma rays.	3.19	1.36
M7	I act knowing that even if it is the same type of radiation, it will have different effects on different parts of my body.	3.66	1.25
M8	I have a good knowledge of radiation units.	3.26	1.22
M9	I am aware of where γ radiation occupies in the electromagnetic spectrum in terms of energy.	3.15	1.25
M10	Areas containing γ radiation should be insulated with lead sheet.	**3.77**	**0.99**
M11	I have a good knowledge of the physical properties of γ radiation.	3.24	1.18
M12	γ radiation should be used not only for medical treatment but also in many industries and R&D fields.	**3.67**	**1.11**
M13	I have a good knowledge of γ radiation sources.	3.31	1.12
M14	I have knowledge that γ radiation can be obtained naturally and artificially.	3.28	1.11
M15	I have a good knowledge of where γ radiation is used in industry.	3.07	1.15
M16	γ radiation is visible to the naked eye.	*1.94*	*1.00*
M17	I think that γ radiation does not harm the human body because it spreads at the speed of light.	*1.92*	*0.97*
M18	I travel as little as possible to avoid exposure to γ radiation.	*2.37*	*1.13*

Results Related to the Differences Between the Sub-Dimensions of the γ-Ray Protection Awareness Scale and Various Demographic Variables of the Participants of the Study

Here, the results of the Independent Groups t-test, which show the differences between the sub-dimensions of the γ-Ray protection awareness scale and some demographic variables of the participants, one-way ANOVA and Kruskal Wallis-H test are included.

Difference by Gender Variable

Table 12 shows the independent groups t-test results showing the difference between the γ-Ray protection awareness scale sub-dimensions and genders of the participants.

Table 12. t-test results showing the differences of the sub-dimensions of the γ-Ray protection awareness scale in terms of the gender of the participants.

Variables	Gender	N	$\bar{X}$	S	Sd	t	p
γ-Information (Factor 1)	Male	81	49.67	16.32	151	-0.383	0.702
	Female	72	50.58	12.33			
γ-Awareness (Factor 2)	Male	81	6.14	2.64	151	-0.547	0.585
	Female	72	6.36	2.09			
Scale Grand Total	Male	81	55.82	16.37	151	-0.470	0.639
	Female	72	56.94	12.52			

In Table 12, the items of the γ-rays protection awareness scale have arithmetic mean and standard deviation values. Accordingly, the regions containing gamma radiation of the first three items with the highest arithmetic mean over a 5-point Likert type scoring should be isolated with a lead plate ($\bar{X}$= 3.77). I have a good knowledge of radiation ($\bar{X}$= 3.72) and it is seen that γ radiation should be used not only for medical treatment but also in many industries and R&D fields ($\bar{X}$= 3.67). I think that the substances with the lowest average do not harm the human body, since γ radiation is emitted at the speed of light, respectively ($\bar{X}$= 1.92). γ radiation is visible to the naked eye ($\bar{X}$= 1.94). I travel as little as possible to avoid exposure to γ radiation ($\bar{X}$= 2.37). These results show that the participants are more knowledgeable than just general information.

Table 12 shows the results of the independent groups t-test to determine whether the sub-dimensions of the γ-Ray protection awareness scale show a significant difference in terms of the gender of the participants. According to the table, the γ Information sub-dimension does not make a statistically significant difference in terms of the gender of the participants [t (151) =-0.383. p>.05]. When the arithmetic averages are examined, it is seen that the average of male ($\bar{X}_{male}$=49.67) participants is slightly below the average of female participants ($\bar{X}_{female}$=50.58).

Gamma Awareness sub-dimension does not make a statistically significant difference in terms of gender of the participants [*t* (151) = -0.547; *p*>.05]. When the arithmetic averages are examined, it is seen that the average of male ($\bar{X}_{male}$=6.14) participants is slightly below the average of female participants ($\bar{X}_{female}$=6.36).

Considering the general total of the scale, there was no statistically significant difference in terms of gender of the participants [t (151) = -0.470; p>.05] is seen. When the arithmetic averages are examined, it is seen that the average of male ($\bar{X}_{male}$=55.82) participants is slightly below the average of female participants ($\bar{X}_{female}$=12.52).

Difference by Position Variable

Table 13 shows the t-test results of independent groups showing the difference between the γ-Ray protection awareness scale sub-dimensions and positions of the participants.

Table 13. t-test results showing the differences of the sub-dimensions of the γ-Ray protection awareness scale in terms of the positions of the participants.

Variables	**Position**	**N**	**X̄**	**S**	**Sd**	**t**	**p**	**Cohen's d**
γ-Information (Factor 1)	Service provider	101	51.52	15.80	151	1.694	0.09	-
	Service receiver	52	47.34	11.36				
γ-Awareness (Factor 2)	Service provider	101	5.90	2.37	151	-2.541	**0.01**	**0.43**
	Service receiver	52	6.92	2.32				
Scale Grand Total	Service provider	101	57.42	15.75	151	1.265	0.20	-
	Service receiver	52	54.26	12.11				

Table 13 shows the results of the independent groups t-test to determine whether the sub-dimensions of the γ-rays protection awareness scale show a significant difference in terms of the positions of the participants. According to the table, the γ information sub-dimension does not make a statistically significant difference in terms of the positions of the participants. [*t* (151) = 1.694. *p*>.05]. When the arithmetic averages are examined, it is seen that the average of the participants who provide service ($\bar{X}_{\text{service provider}}$=51.52) is above the average of the participants who receive service ($\bar{X}_{\text{receive service}}$ =47.34).

There is a statistically significant difference in terms of the positions of the participants in the γ awareness sub-dimension. [*t* (151) = -2.541; *p*<.05]. When the arithmetic averages are examined, it is seen that the average of the participants who provide service ($\bar{X}_{\text{service provider}}$ = 5.90) is below the average of the participants who receive service ($\bar{X}_{\text{receive service}}$ = 6.92). In a different way, the significant difference was in favor of the participants who received the service. According to the Cohen's d coefficient calculated for the effect size of the significant difference (0.43), there is a moderate effect size.

Considering the Grand Total of the scale, it was not found that there was a statistically significant difference in terms of the positions of the participants [t (151) = 1.265; p>.05] is seen. When the arithmetic averages are examined, it is seen that the average of the participants who provide service ($\bar{X}_{\text{service provider}}$ = 57.42) is above the average of the participants who receive service ($\bar{X}_{\text{receive service}}$ = 12.11).

Difference by Age Variable

Table 14 shows the t-test results of independent groups showing the difference between the γ-Ray protection awareness scale sub-dimensions and age ranges of the participants.

Table 14. One-Way Analysis of Variance (ANOVA) results between class levels of participants and γ-Ray protection awareness scale

Variable	Age range	*n*	X̄	SS	Sum of squares	df	Mean of squares	F	*p*	*Difference*
γ-Information (Factor 1)	19-29 Age	40	48.60	13.46	1614.84	2 150 152	807.42	3.967	**0.02**	2<3
	29-39 Age	79	48.25	13.61						
	40+ Age	34	56.17	16.51						
	Total	153	50.10	14.54						
γ-Awareness (Factor 2)	19-29 Age	40	6.27	2.63	20.630	2 150 152	10.315	1.812	0.16	-
	29-39 Age	79	6.51	2.31						
	40+ Age	34	5.58	2.24						
	Total	153	6.24	2.39						
Scale Grand Total	19-29 Age	40	54.87	14.00	1280.55	2 150 152	640.27	3.063	0.06	-
	29-39 Age	79	54.77	13.58						
	40+ Age	34	61.76	16.79						
	Total	153	56.35	14.65						

Table 14 shows the results of the one-way analysis of variance (ANOVA) showing whether there is a significant difference between the age ranges of the participants, the sub-dimensions of the awareness of γ-rays protection scale and the overall total. According to the table, there is a statistically significant difference between the first sub-dimension, γ-information, and the age ranges of the participants [*F* (2. 150) = 3.967; *p*<.05]. According to the post-hoc tests conducted regarding the source of the difference, there is a difference between the participants whose age range is 29-39 and 40+, and it is in favor of the participants who are 40+ years old. In other words, the γ knowledge level of the participants whose age range is 40+ is significantly at the highest level and it differs statistically significantly from the participants in the other age range.

According to the table, there is no statistically significant difference between the second sub-dimension, γ information, and the age ranges of the participants. [*F* (2. 150) = 1.812; *p*>.05]. Looking at the arithmetic averages, γ awareness is highest in the age range of 29-39, in the second place in the age range of 19-29 and in the third place in the age range of 40+.

According to the table, there is no statistically significant difference between the general sum of the γ- Ray protection awareness scale and the age ranges of the participants. [*F* (2. 150) = 3.063; *p*>.05]. Looking at the arithmetic averages, Gamma Awareness is highest in the age range of 40+, in the second place in the age range of 19-29 and in the third in the age range of 40+.

Difference According to Perception of Income Level

Table 15 shows the results of the Kruskal Wallis test, which shows the difference between the γ-Ray protection awareness sub-dimensions and the income level perception ranges of the participants.

Table 15. Kruskal Wallis Test results showing the difference between the sub-dimensions of γ-Ray protection awareness and income level ranges of the participants.

Variable	Income Range	*n*	*Rank Average*	sd	χ^2	*p*
γ-Information	Low	12	74.13	2	1.428	0.490
	Middle	83	73.59			
	High	58	82.47			
	Total	153				
γ-Awareness	Low	12	95.92	2	5.062	0.080
	Middle	83	80.40			
	High	58	68.22			
	Total	153				
Scale Total	Low	12	76.21	2	1.026	0.599
	Middle	83	73.92			
	High	58	81.58			
	Total	153				

Table 15 shows the results of Kruskal Wallis (KW), which indicates whether there is a significant difference between the participants' γ-Ray protection awareness scale sub-dimensions and their income level perception. According to the results of the analysis, no statistically significant difference was found between the γ-information levels of the participants and their income level perception [χ^2 (sd=2. n=153) = 1.428. p>0.05]. According to the mean rank, the participants who see themselves in the high-income group (Avg. =82.47), the participants who see themselves in the low-income group (Avg. =103.22) and the participants who see themselves in the middle-income group (Avg. =73.59) take the third place. According to the results of the analysis in Table 15, no statistically significant difference was found between the γ awareness sub-dimension and the income level perception of the participants [χ^2 (sd=2. n=153) =5.062. p>0.05]. According to the mean rank, the participants who see themselves in the low income group (Avg. =95.92), the participants who see themselves in the middle income group (Avg. =80.40) and the participants who see themselves in the high income group (Avg. = 68.22) take the third place.

According to the analysis results in Table 15, there was no statistically significant difference in the income level perception of the participants in the general total of the γ-Ray protection awareness scale. [χ^2 (sd=2. n=153) =1.026. p>0.05]. According to the mean rank, the participants who see themselves in the high-income group (Avg. =81.58), the participants who see themselves in the low-income group (Avg. =76.21) and the participants who see themselves in the middle-income group (Avg. =73.92) take the third place.

Difference by Education Level

Table 16 shows the results of the Kruskal Wallis test, which shows the difference between the γ-Ray protection awareness sub-dimensions and the educational level ranges of the participants.

Table 16. Kruskal Wallis Test results showing the difference between the sub-dimensions of γ-Ray protection awareness and income level ranges of the participants.

Variable	Education Level	*n*	*Rank Average*	sd	χ^2	*p*
γ-Information	Low than undergraduate	24	73.73	2	12.695	**0.002**
	Undergraduate	78	66.44			
	Graduate	51	94.69			
	Total	153				
γ-Awareness	Low than undergraduate	24	72.58	2	4.544	0.103
	Undergraduate	78	84.26			
	Graduate	51	67.98			
	Total	153				
Scale Total	Low than undergraduate	24	71.75	2	12.154	**0.002**
	Undergraduate	78	67.17			
	Graduate	51	94.51			
	Total	153				

Table 16 shows the results of Kruskal Wallis (KW), which indicates whether there is a significant difference between the γ-Ray protection awareness scale sub-dimensions and education level of the participants. According to the results of the analysis, a statistically significant difference was found between the γ information levels of the participants and their education level. [χ^2 (sd=2. n=153) = 12.695. p<0.05].

According to the analysis results in Table 16, no statistically significant difference was found between the education level of the participants in the γ awareness sub-dimension. [χ^2 (sd=2. n=153) =4.544. p>0.05]. According to the mean rank, the participants with a bachelor's degree (Avg. =84.26) are in the first place, the participants with a lower education level than a bachelor's degree (Avg. =72.28) and the participants with a graduate degree (Avg. =67.98) are in the third place.

Table 17 shows the results of all pairwise comparison tests performed after Bonferroni correction for which groups the difference occurred.

According to the adjusted p value (adjusted sigma) after Bonferroni correction in Table 17, a significant difference was found between the undergraduate and graduate participants, and the significant difference was in favor of the graduate graduates. In other words, the γ-Ray protection awareness of graduate graduates is significantly higher and different from the other participants.

Table 17. The results of pairwise comparison of the education level of the participants with the γ-information sub-dimension

Group1-Group2	Test Statistics	Standard Deviation	Standard Test	p	Corrected p
Undergraduate-Low than Undergraduate	7.827	10.339	0.705	0.481	1.00
Undergraduate-Graduate	-28.244	7.976	-3.541	0.000	0.001
Low than Undergraduate-	-20.957	10.964	-1.912	0.056	0.168

According to Table 17, a statistically significant difference was found between the γ-Ray protection awareness scale general total and the education level of the participants [χ^2 (sd=2. n=153) = 12.154. p<0.05]. Table 18 shows the results of all pairwise comparison tests performed after Bonferroni correction for which groups the difference occurred.

Table 18. The results of pairwise comparison of the education level of the participants with the γ-Ray protection awareness

Group1-Group2	Test Statistics	Standard Deviation	Standard Test	p	Corrected p
Undergraduate-Low than Undergraduate	4.583	10.338	0.443	0.658	1.00
Undergraduate-Graduate	-27.343	7.975	-3.428	0.001	0.002
Low than Undergraduate-	-22.760	10.963	-2.076	0.038	0.114

Considering the genders of the participants participating in the research, it is understood that the arithmetic mean value ($\overline{X}$=49.68; SD=16.32) of the male participants in the γ-information sub-dimension is partially lower than the arithmetic mean value ($\overline{X}$=50.58; SD=12.34) of the female participants. Looking at the γ- awareness sub-dimension, it is seen that the arithmetic mean value ($\overline{X}$=6.15; SD=2.65) of male participants is partially lower than the arithmetic mean value ($\overline{X}$= 6.36; SD=2.10) of female participants. According to the general total of the scale, it is understood that the arithmetic mean value of male participants ($\overline{X}$=55.83; SD=16.37) is lower than the arithmetic mean of female participants ($\overline{X}$=56.94; SD=12.52).

When the arithmetic mean and standard deviation values according to the age range in the γ-information sub-dimension are examined, the participants in the 40+ age range and participating in the research have the highest mean score ($\overline{X}$=56.18; SD=16.52). This is an indication that the knowledge about this technology increases with the age of the employees and service recipients in the workplaces where γ-technology is used. In the second place is the 19-29 age group. It is due to the fact that the participants of the research ($\overline{X}$=48.60; SD=13.46) were included in the study and that this group was newly graduated from universities and had fresh knowledge. In the third place, there are participants between the ages of 30-39 ($\overline{X}$=48.25; SD=13.62) and it is evaluated that this age group may generally originate from the segment that service receivers. When the γ-awareness values are examined, the participants in the 30-39 age range and participating in the research ($\overline{X}$=6.52; SD=2.31) have the highest average score. In the second place are those aged between 19-29 ($\overline{X}$=6.28; SD=2.63). it is seen that the participants in the 40+ age range are in the third place ($\overline{X}$=5.59; SD=2.24). When the average scores of γ-information and γ-awareness depending on age ranges are examined, it is seen that the opposite results are obtained. In other words, a result emerges that means that the age group with more knowledge has less awareness. From this situation, it can be concluded that in parallel with the increase in knowledge, indifference also increases. It is seen that the arithmetic mean ($\overline{X}$=51.52; SD=15.80) of the participants serving in the γ-information sub-dimension is higher than the average of the participants receiving service ($\overline{X}$=47.35; SD=11.36). It is seen that the average of the participants serving in the γ-awareness sub-dimension ($\overline{X}$=5.90; SD=2.37) is lower than the average of the participants receiving the service ($\overline{X}$=6.92; SD=2.33). When the general total of the scale is examined, it is understood that the average of the participants who provided service ($\overline{X}$=57.43; SD=15.75) is higher than the average of the participants who received service ($\overline{X}$=54.27; SD=12.11) as expected. Because while the service providers receive this information in a more comprehensive education process, the service recipients gain only by own researching the information and awareness about the service or within the limits of the information provided by the service providers.

According to the educational status variable, the highest score in the γ-information sub-dimension was among the graduates, as expected ($\bar{X}$=55.98; SD=14.40). The second rank is among the participants with less than undergraduate education ($\bar{X}$=48.92; SD=13.76). The third rank consists of undergraduate education ($\bar{X}$=44.63; SD= 13.81). This is due to the fact that most of those who receive radiology education in our country are associate undergraduate degree rather than graduates. In the γ-awareness sub-dimension, the highest score was composed of the participants with a bachelor's degree ($\bar{X}$=6.60, SD=2.41). Participants with a graduate degree take the second place ($\bar{X}$=5.88; SD=2.44). The third rank is composed of participants with less than undergraduate education ($\bar{X}$=5.88; SD= 2.19). When we look at the general total of the scale, it is seen that the highest score is composed of graduate education ($\bar{X}$=61.86; SD=14.31), the second is the participants with less than undergraduate education ($\bar{X}$=54.79; SD=12.66) and the third is undergraduate education ($\bar{X}$=53.23 ; SD = 14.57).

According to the perceived income level variable, the highest score in the γ-information sub-dimension consists of the participants who see themselves in the upper income group ($\bar{X}$=51.64; SD=17.00). In the second place, it consists of the participants who see themselves in the lower income group ($\bar{X}$=49.58; SD=11.88). The third rank is composed of participants who consider themselves to be in the middle income group ($\bar{X}$=13.02; SD=6.33). In the γ-awareness sub-dimension, the highest score consists of the participants who see themselves in the lower income group ($\bar{X}$=7.92; SD=3.40). Participants who see themselves in the middle income group take the second place ($\bar{X}$=2.01; SD=11.88). In the third rank, there are participants who see themselves in the upper income group ($\bar{X}$=5.79; SD= 2.55). In the general total sub-dimension of the scale, the highest score is consisting of the participants who see themselves from the low income group ($\bar{X}$==57.50; SD=14.61), the second consisting of the participants who see themselves in the high income group ($\bar{X}$==57.43; SD=16.86) and the third from the participants who see themselves in the middle income group ($\bar{X}$==55.43; SD= 13.003). From this, it is concluded that the participants with the perception of middle-income level are unfortunately slightly less aware of this issue.

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