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Effect of Educational Intervention based on Health Belief Model toward the Awareness Regarding Endocrine Disrupting Chemicals among Female Nursing Students

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Abstract
Background: Exposure to Endocrine Disrupting Chemicals (EDCs) poses a serious global health concern. **Aim:** This study aimed to evaluate the effect of an educational intervention based on the Health Belief Model (HBM) toward awareness of EDCs among female nursing students. **Methods:** A quasi-experimental design with pre/post-tests was used to assess the intervention's effectiveness. A stratified random sampling technique was used to select 116 female students from the Faculty of Nursing, at Minia University. Data were collected using two tools. The first tool assessed sociodemographic characteristics and knowledge regarding EDCs; the second tool assessed the health beliefs regarding EDCs. **Results:** The study showed a statistically significant difference in participants' knowledge of EDCs post-intervention. While pre-intervention, 81.9% of the participants demonstrated an unsatisfactory level of knowledge, post-intervention, 92.2% had a satisfactory level of knowledge. Furthermore, the mean scores for all HBM constructs excluding perceived barriers showed a statistically significant increase post-intervention, with a P-value of 0.000**, establishing the intervention's effectiveness. **Conclusion:** The educational intervention based on the HBM notably boosted participants' awareness of EDCs and positively affected their health beliefs. These results highlight the importance of educational approaches based on theory in improving health awareness and reforming beliefs regarding health risks in the environment. **Recommendations:** Incorporating EDCs-related educational materials into the nursing curriculum at the undergraduate level. This integration will help ensure that future healthcare professionals maintain a strong awareness and are well-prepared to handle related health challenges.

Keywords: Awareness, Educational Intervention, Endocrine Disrupting Chemicals, Female Nursing Students & Health Belief Model.

Introduction
Endocrine Disrupting Chemicals (EDCs) represent a category of external substances that can profoundly affect the hormonal systems of both animals and humans. They do this by mimicking or obstructing the action of natural hormones in the body. The Endocrine Disruption Exchange (TEDX) reports that there are over 1,400 possible EDCs present in our environment and food supply **(Kelly et al., 2020).**

Some familiar examples of these chemicals include bisphenol A (BPA) and phthalates, commonly found in plastic products and food containers; Dichlorodiphenyltrichloroethane (DDT) used in pesticides; parabens, which are prevalent in personal care and cosmetic items; triclosan, an antimicrobial agent used in various cosmetics and antiperspirants; as well as phytoestrogens and mycotoxins that occur naturally in foods. Other EDCs include lead and other heavy metals and certain chemicals utilized in flame retardants for furniture and flooring **(Kelly et al., 2020).**

Endocrine-disrupting chemicals influence the hormonal system. Given that the endocrine system operates on extremely low hormone levels, even minimal concentrations of certain substances can disrupt its functioning. Furthermore, phytoestrogens, which can exhibit either pro- or antiestrogenic effects, challenge traditional toxicology principles. Substances that individually may not cause noticeable endocrine disruption can still lead to significant impacts when combined, a phenomenon often referred to as the cocktail effect **(Denois et al., 2024).**

Endocrine Disrupting Chemicals are known to have a significant impact on both physical and mental health. Their mechanisms of action involve disrupting receptor binding, hormone production, and metabolism. Research has linked EDCs to various health issues, including certain types of cancer like prostate cancer, diabetes, thyroid disorders, and mental health issues such as anxiety, depression, and aggression **(Park et al., 2022)**. Endocrine Disrupting Chemicals particularly affect women's health, targeting female reproductive organs that contain estrogen receptors. This can lead to serious reproductive health concerns, including premenstrual syndrome, breast cancer, endometrial cancer, and infertility **(Mallozzi et al., 2017).**

Diet plays a crucial role in exposure to EDCs, with ingestion being the primary source of exposure worldwide. There are also reports of dermal

absorption and inhalation as routes of exposure to these chemicals. Additionally, many building materials and industrial products, such as flame retardants and polyvinyl chloride (PVC)—a common synthetic plastic—also contain EDCs. Cosmetics, personal care items, antimicrobial products, cleaning supplies, and both household and industrial pesticides are all sources of EDCs **(Corbett et al., 2022).**

Even though many EDCs have been banned or limited, they tend to persist in the environment, posing long-term risks **(Sharma et al., 2014).** While EDCs might be found in low concentrations, they can slowly build up in ecosystems and within the tissues of living organisms. This accumulation can lead to increased dangers, especially when these chemicals interact with one another, resulting in what is known as the "cocktail effect" **(Kelly et al., 2020).**

Providers have a few effective strategies they can share with individuals to help decrease their exposure to EDCs. These strategies include: (1) reducing BPA exposure, (2) minimizing contact with pesticides in the home, and (3) steering clear of phthalates found in many personal-care items **(HOPP & PREGLER, 2016).** To ensure high-quality care, it is essential for healthcare professionals to receive specialized training on EDCs risks connected to everyday life, making this knowledge both necessary and ethically important **(Genco et al., 2020).**

Environmental nursing practices focus on assessing, managing, and educating communities about environmental health risks. These practices are essential for preventing and mitigating the negative health effects that can arise from environmental hazards **(Smith et al., 2023).** Nurses have a crucial role in identifying potential dangers, such as chemical exposures from household products, pesticides, and industrial waste. These exposures have been associated with serious health issues like endocrine disruption, cancer, and neurodevelopmental disorders, highlighting the necessity for careful monitoring and effective preventive strategies **(Nurhadijah et al., 2025).**

Theoretical framework

The impact of health education interventions largely hinges on the effective application of relevant theories and models. Health-related behaviors, adherence to healthy practices, and awareness of the factors that contribute to negative conditions all play a role in influencing health outcomes. Merely having knowledge isn't enough to change behavior; there must be a motivation to do so **(Bazargani et al., 2022).**

One theoretical framework utilized in developing of many training programs is the Health Belief Model (HBM), which examines behaviors in the context of health education. This model encompasses several key components: perceived sensitivity (an individual's awareness of their vulnerability to a specific disease), perceived severity (personal beliefs regarding the seriousness of the disease), perceived benefits (understanding the advantages of engaging in preventive behaviors), perceived barriers (recognizing the challenges that may hinder health actions), cues to action (triggers that encourage decision-making and prompt behavior change), and self-efficacy (the confidence in one's ability to successfully engage in a behavior) **(Tehrani et al., 2014).**

Significance of the research

In numerous countries, while agencies like the Ministry of Environment share information about EDCs on their websites, the resources available are often insufficient. Most individuals report learning about EDCs mainly through news stories related to incidents involving these chemicals. The scarcity of detailed guidance on how to minimize exposure to EDCs leaves many individuals vulnerable to these hazardous substances without proper safeguards **(Yoon & Kim, 2022).** Furthermore, the intricate and pervasive nature of EDCs complicates efforts to effectively communicate their risks to the broader public **(WHO, 2014).**

Females are particularly vulnerable to the impacts of EDCs, which can negatively affect their reproductive health. This vulnerability is supported by a noticeable rise in reproductive health issues, such as endometriosis, uterine fibroids, polycystic ovary syndrome, premature ovarian failure, irregular menstrual cycles, menarche changes, and infertility **(Hassan et al., 2024)**.

A systematic review was conducted to investigate the association between exposure to BPA and PCOS, included 22 studies with 1,682 PCOS diagnosed women from various countries. The BPA levels of 82.7% of these women were elevated. Serum; urine, plasma, and follicular fluid were among the biologicalmaterials used in the investigations, consistently demonstrated favorable connections between BPA exposure and PCOS especially with regard to hyperandrogenism **(Urbanetz et al., 2024).**

Young women, especially those of childbearing age, face heightened risks, as EDCs exposure during pregnancy or through breast milk can influence the brain development and behavior of fetuses and newborns **(Yuan et al., 2015).** Notably, studies have indicated that pregnant women exposed to parabens, such as methylparaben and propylparaben, may see a correlation with certain growth metrics in their fetuses, including reduced head circumference **(Hajizadeh et al., 2021).**

Health initiatives aimed at enhancing the well-being of women and children should begin in the

pre/periconceptional phase, as these are critical times for raising awareness about exposure and promoting environmental health. There are various guidelines and strategies designed to boost maternal and infant health, focusing on areas such as nutrition, iron supplementation, physical activity, management of hypertensive conditions, oral health, and minimizing exposure to environmental tobacco smoke. Nevertheless, only a limited number specifically address exposure to EDCs **(Ouazzani et al., 2021).**

Given the significant effects of EDCs on human health, especially concerning the well-being of women and children, it is crucial to implement preventive measures. These interventions should focus on increasing awareness about EDCs and effectively minimizing exposure **(Park et al., 2022)**. So, the current research aimed to evaluate the effect of an educational intervention based on the HBM toward the awareness regarding EDCs among female nursing students.

Aim of The research

The current research aimed to evaluate the effect of an educational intervention based on the HBM toward the awareness regarding EDCs among female nursing students

Research Hypothesis

An educational intervention based on the HBM will increase the awareness and positively influence health beliefs regarding EDCs among female nursing students.

Material and Methods

Research design: A quasi– experimental design with pre/ posttest was used to measure the effectiveness of the educational intervention.

Setting: the study conducted at faculty of nursing at Minia University**.** The researchers selected this setting as nursing students are future healthcare professionals so they can have an important role in individual, family and community education regarding EDCs, which can mitigate its associated health risk.

Sample Size Calculation

Sample size was calculated by using G Power 3.1. since the main objective was to compare the difference in parameters between two dependent groups, T test was set to calculate sample size. Theoretical effect size of 0.3 was used, α was set at 0.05. The total sample size of 97 was required to achieve power of 0.9. Adding 20% drop-out rate, the total sample size was 116 students**.**

Sampling Technique

A Stratified random sample was used to fulfill the sample size. The number of female students that was selected from each grade was calculated by dividing the number of female students in each grade by the total number of female students at all grades (1909) then multiplied by the estimated sample size (106). A simple random sampling technique was used to select the female students in each grade using their attendance record.

Grade level	Total Number of female students	Sample Taken
1st grade	255	14
2nd grade	548	30
3rd grade	538	30
4th grade	568	32

Data collection tools:

To fulfill the aim of the current research, two data collection tools were developed by the researcher after reviewing the following literature **(Kelly et al., 2020; El Ouazzani et al., 2021; Corbett et al., 2022; Yoon& Kim, 2022)**.

Tool No (1): A self-administered questionnaire based on HBM, in Arabic to assess students' knowledge regarding EDCs. This tool included two parts, as follows:

Part I: **To assess the sociodemographic data of the students** such as age, study grade, residence, mother education, marital status, and perceived family socioeconomic status. Three questions were added to this part to assess personal and family history of chronic diseases and prior education about EDCs

Part II: To assess knowledge regarding EDCs among the students. This part included 36 questions in the form of yes or no or I don't know to assess the definition of EDCs (2 questions), sources of EDCs (14 questions), ways of exposure (3 questions), knowledge of plastic resin identification code (5 questions), effect of EDCs on pregnancy (4 questions), its effect on child health (3 questions) and its effect on adult health (3 questions). Two open questions were included at the end of this part to assess knowledge of the studied subjects about examples of EDCs and how to reduce the exposure.

Scoring system

The scores for the knowledge section of the questionnaire were determined by assigning one point (1) for a correct answer and zero points (0) for either an incorrect answer or a response of "don't know." As a result, participants were classified as having a satisfactory level of knowledge if their total score was greater than or equal to 60%, and as having an unsatisfactory level of knowledge if their total score was less than 60%.

Tool No (2): A five-point Likert scale based on the HBM was developed to assess students' health beliefs regarding EDCs. This scale included six subscales: perceived susceptibility (three questions), perceived severity (five questions), perceived barriers (nine questions), perceived benefits (five questions),

cues to action (ten questions), and perceived self-efficacy (five questions).

Scoring system

Responses to this section were rated on a five-point Likert-type scale with the following values: strongly disagree (1), disagree (2), neutral (3), agree (4), and strongly agree (5). The total score for each subscale was determined by adding together all responses for that subscale. A total score of 60% or higher signifies a greater level of the HBM subscale/construct, while a total score below 60% indicates a lower level for each subscale or construct.

Reliability of the tools:

The reliability of the study's data collection tools was assessed using Cronbach's alpha. The analysis revealed an alpha value of 0.80 for the knowledge questionnaire, while the reliability of HBM subscales regarding EDCs was 0.78 for perceived susceptibility, 0.75 for perceived severity, 0.89 for perceived benefits, 0.70 for perceived barriers, 0.90 for self-efficacy, and 0.92 for cues to action. Additionally, the overall reliability of the research tools was found to be 0.88.

Validity of the tools:

The content validity of the study tools was evaluated by three specialists in community health nursing. They examined the tools for factors including content comprehensiveness, order of items, clarity, relevance, practicality, word length, format, and overall presentation. Changes were implemented according to the feedback and recommendations from the experts.

Development of the Educational intervention

Administrative phase:

Prior to initiating the study, formal approval was obtained from the dean of the Faculty of Nursing. The study was carried out in four distinct phases: the assessment phase, the planning phase, the intervention or implementation phase, and the post-intervention (evaluation) phase, which was conducted immediately following the implementation of the intervention.

Pilot study:

It was conducted with 10% of the sample size, involving 11 students. The primary focus of this study was to evaluate the validity of the questionnaire and gauge the students' acceptance of the research topic. The findings from the pilot study were incorporated into the final results, as no significant modifications were made to the study tools.

Assessment phase:

The goal was to gather baseline data from the students and evaluate their knowledge and health beliefs EDCs. This process helped in developing the educational intervention and served as a pretest for future comparisons before the intervention was launched. The researchers first introduced themselves to the students, briefly outlining the study's objectives and securing verbal consent for participation. The students completed the study tools on their own, taking approximately 10 to 15 minutes to fill out the questionnaire.

Planning phase: It focused on the educational content, the number of sessions, teaching methods, media to be utilized, and the location along with the facilities for the intervention. Drawing on assessment data and relevant literature, we crafted the content of the educational intervention using HBM constructs to enhance students' knowledge and beliefs about EDCs.

Implementation phase:

The intervention consisted of six sessions, each lasting between 45 and 60 minutes. Students were grouped into four categories according to their grade levels to ensure that everyone could grasp the educational content effectively. At the start of every session, the objectives were clearly outlined, and a summary of the key points was provided at the end. This phase took place from the beginning of November 2024 to the end of January 2025.

Teaching place and time:

The sessions for each grade are held at their respective faculty classes after completing the daily study routine. These take place every Sunday and Monday for 3rd and 4th grades, every Tuesday and Wednesday for 1st grade, and every Wednesday and Thursday for 2nd grade.

Teaching Methods and Strategies:

The educational sessions employed a variety of instructional approaches, including lectures, small group discussions, and interactive question-and-answer segments. To enhance engagement and comprehension, diverse educational materials were utilized, such as data show presentations, newspaper articles, statistical information, brochures and videos on what are EDCs, what is its impact on health, and how to reduce the exposure, Additionally, a structured, illustrated, and colored booklet prepared in Arabic and supplemented with visual aids was distributed to students at the conclusion of the sessions. The educational sessions implied the following:

- **The first session (Introduction to EDCs):** This session aimed to provide a clear and engaging introduction to what EDCs are, common sources (plastics, pesticides, personal care products, etc and examples of chemicals (BPA, phthalates, parabens).
- **The second session (Perceived susceptibility):** This session aimed to make participants understand that they are vulnerable to the effects of EDCs through the following: Providing statistics on how common exposure to EDCs is in everyday life (e.g., through food, plastic containers, personal care products, etc.), sharing case studies showing the

impact of EDCs exposure on human health, and discussing how various groups, such as pregnant women, children, and individuals with certain medical conditions, are more susceptible to the harmful effects of EDCs.

- **The third session (Perceived severity):** This session aimed to emphasize the potential serious health consequences of exposure to EDCs offering the following: Highlighting research linking EDCs to various health issues like infertility, developmental issues, hormone-related cancers (e.g., breast and prostate cancer), obesity, diabetes, and cognitive disorders. Explaining how the severity of these health issues can affect not just individual health but also public health (e.g., the long-term societal burden of disease)**.**
- **The fourth session (Perceived barriers):** This session aimed to identify and address barriers that may prevent participants from taking action to reduce EDCs exposure through the following: Discussion of common barriers such, as cost, convenience, and lack of knowledge about safer alternatives while Providing practical solutions to overcome these barriers, like recommending affordable non-toxic products or easy-to-implement strategies (e.g., using glass containers instead of plastic, choosing EDCs-free cosmetics). Help the participants acknowledge the challenges of fully avoiding EDCs, but emphasize that even small changes can make a difference in reducing exposure.
- **The fifth session (Cues to action):** This session aimed to motivate the participants to take steps to reduce exposure to EDCs through the following: Offering a checklist or action plan that individuals can follow to reduce EDCs exposure (e.g., steps to reduce plastic use, options for choosing non-toxic cleaning supplies, etc.) in addition to providing reminders through emails, or social media posts to encourage action and encouraging the participants to spread awareness about EDCs and encourage individuals to take action together.
- **The sixth session(Perceived self-Efficacy):** This session aimed to boost participants' confidence in their ability to reduce exposure to EDCs and make healthier choices: This session included the following: Encouraging participants to attend hands-on workshops where they can learn to make their non-toxic cleaning products or understand how to read product labels for EDCs-free items, in addition to offering testimonials from people who have successfully reduced their EDCs exposure and improved their health, showing that these changes are achievable. Providing educational resources, including guides, websites, and community groups, to support ongoing behavior change.

Evaluation phase:

It involved assessing the impact of the educational intervention by conducting a post-test immediately after finishing the implementation phase, utilizing the same data collection forms that were used during the pre-test.

Ethical issues

A written endorsement, identified by code number (REC202476), was secured from the ethics and research committee of the Nursing Faculty at Minia University. Informed oral consent was acquired from students who were given a clear explanation of the study's nature and objectives to encourage their participation. To maintain privacy and confidentiality, each assessment sheet was assigned a unique code. Participants were also given the option to withdraw from the study at any time.

Statistical analysis

Statistical analysis and data entry were performed using SPSS version 24.0. The results are summarized through descriptive statistics, which include means and standard deviations for quantitative variables, along with frequencies and percentages for qualitative variables. To evaluate the differences in qualitative data from the pre- and post-tests, both Fisher's exact test and the Chi-square test were utilized. For the quantitative data, the Wilcoxon Signed Ranks Test was used to determine mean score differences between the pre- and post-tests. Furthermore, the Spearman correlation test was applied to investigate relationships between quantitative variables. A significance threshold of less than 5% ($p < 0.05$) was established to assess statistical significance for all findings.

Result

Table (1): Distribution of the studied subjects according to their sociodemographic characteristics (n=116)

Item	No.	Percent%
Age (yrs.)		
18-21yrs.	77	66.4
22-24 yrs.	39	33.6
Mean ± SD 20.58±1.74		
Faculty grade		
1st year	14	12.1
2nd year	30	25.9
3rd year	30	25.9
4th year	42	36.2
Residence		
Rural	80	69.0
Urban	36	31.0
Father education		
Illiterate	15	12.9
Read and write	16	13.8
Primary	1	0.9
Preparatory	6	5.2
Secondary	46	39.7
University or Post graduate studies	32	27.6
Mother education		
Illiterate	21	18.1
Read and write	19	16.4
Primary	3	2.6
Preparatory	5	4.3
Secondary	40	34.5
University or Post graduate studies	28	24.1
Marital status		
Single	102	87.9
Married	14	12.1
Perceived family Socioeconomic Status		
Low	10	8.6
Middle	102	87.9
High	4	3.4
Personal history of chronic diseases		
Yes	6	6.2
No	110	94.8
Family history of chronic diseases		
Yes	44	37.9
No	72	62.1
Prior education about EDCs		
Yes	33	28.4
No	83	71.6

Table (2): Comparison of the studied subjects' Knowledge regarding EDCs definition, sources, and ways of exposure pre and after the educational intervention (n=116)

Item	Pre (n=116)						Post (n=116)					
	Yes		No		I do not know		Yes		No		I do not know	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Definition												
Correct answer	94	81.0	6	5.2	16	13.8	112	96.6	4	3.4	0	0.0
Incorrect answer	29	25.0	52	44.8	35	30.2	30	25.9	78	67.2	8	6.9
Sources of EDCs												
Cosmetics.	61	52.6	14	12.1	41	35.3	94	81.0	10	8.6	12	10.3
Packaging. of food	60	51.7	24	20.7	32	27.6	105	90.5	2	1.7	9	7.8
toys of babies	28	24.1	40	34.5	48	41.4	92	79.3	11	9.5	13	11.2
Pesticides.	80	69.0	5	4.3	31	26.7	110	94.8	2	1.7	4	3.4
Personal care products.	39	33.6	24	20.7	53	45.7	98	84.5	7	6.0	11	9.5
Tap water.	30	25.9	38	32.8	48	41.4	42	36.2	54	46.6	20	17.2
Canned food.	42	36.2	22	19.0	52	44.8	104	89.7	5	4.3	7	6.0
Untreated vegetables.	55	47.4	12	10.3	49	42.2	99	85.3	8	6.9	9	7.8
Plastic containers.	52	44.8	15	12.9	49	42.2	106	91.4	4	3.4	6	5.2
Nonstick cookware.	40	34.5	27	23.3	49	42.2	90	77.6	16	13.8	10	8.6
Aluminum foil.	40	34.5	27	23.3	49	42.2	87	75.0	18	15.5	11	9.5
Paper receipt.	27	23.3	38	32.8	51	44.0	84	72.4	21	18.1	11	9.5
Flame retardant.	43	37.1	24	20.7	49	42.2	82	70.7	15	12.9	19	16.4
Ways of exposure												
Ingestion	67	57.8	12	10.3	37	31.9	108	93.1	2	1.7	6	5.2
Inhalation	74	63.8	11	9.5	31	26.7	102	87.9	4	3.4	10	8.6
Drinking water	61	52.6	21	18.1	34	29.3	91	78.4	9	7.8	16	13.8

Table (3): Comparison of the studied subjects' Knowledge regarding effect of EDCs on pregnancy, child and adult health pre and after the educational intervention (n=116)

Item	Pre (n=116)						Post (n=116)					
	Yes		No		I do not know		Yes		No		I do not know	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Effect of EDCs on pregnancy												
Preeclampsia.	67	57.8	16	13.8	33	28.4	103	88.8	5	4.3	8	6.9
Gestational diabetes	59	50.9	15	12.9	42	36.2	95	81.9	11	9.5	10	8.6
Fetal growth restriction.	66	56.9	19	16.4	31	26.7	105	90.5	4	3.4	7	6.0
LBW or prematurity	56	48.3	18	15.5	42	36.2	101	87.1	5	4.3	10	8.6
Effect of EDCs on child health												
Autism, ADHD	49	42.2	34	29.3	33	28.4	98	84.5	14	12.1	4	3.4
Asthma	57	49.1	19	16.4	40	34.5	108	93.1	6	5.2	2	1.7
Obesity	60	51.7	17	14.7	39	33.6	94	81.0	14	12.1	8	6.9
Effect of EDCs on adult health												
Reproductive problems	34	29.3	26	22.4	56	48.3	89	76.7	13	11.2	14	12.1
Cancer.	68	58.6	17	14.7	31	26.7	100	86.2	10	8.6	6	5.2
Diabetes.	58	50.0	12	10.3	44	37.9	98	84.5	11	9.5	7	6.0

***LBW** (Low Birth Weight), **ADHD** (Attention Deficit Hyperactivity Disorder)*

Table (4): Comparison of the studied subjects' Knowledge regarding examples of EDCs and ways to reduce its exposure pre and after the educational intervention (n=116)

Item	Pre (n=116)		Post (n=116)	
	No.	%	No.	%
Examples of EDCs*				
BPA	5	4.3	79	68.1
DDT	6	5.2	73	62.9
Perfluorinated compound	0	0.0	47	40.5
Paraben	2	1.7	44	37.9
Perchlorate	0	0.0	34	29.3
Triclosan	0	0.0	30	25.9
sodium lauryl sulfate	1	0.9	33	28.4
Industrial dyes for food	2	1.7	28	24.1
I do not know	101	87.1	10	8.6
Ways to reduce exposure*				
reduce pesticide use	18	15.5	71	61.2
reduce plastic use	30	25.9	89	76.7
Eat organic food	6	5.2	59	50.9
Parben free cosmetics	9	7.8	67	57.8
Prevent dust buildup.	11	9.5	33	28.4
Triclosan free personal product	5	4.3	30	25.9
I do not know	71	61.2	9	7.8

**mutual exclusive more than one answer*

Table (5): Distribution of the studied subjects' total level of Knowledge regarding EDCs pre and after the educational intervention (n=116)

Items	Pre		Post		Test of significance	
	No.	%	No.	%	X^2	P – value
Total knowledge about EDCs						
Satisfactory	21	18.1	107	92.2	47.207	0.000**
Unsatisfactory	95	81.9	9	7.8		

Chi square test *** High Significance P ≤ 0.001*

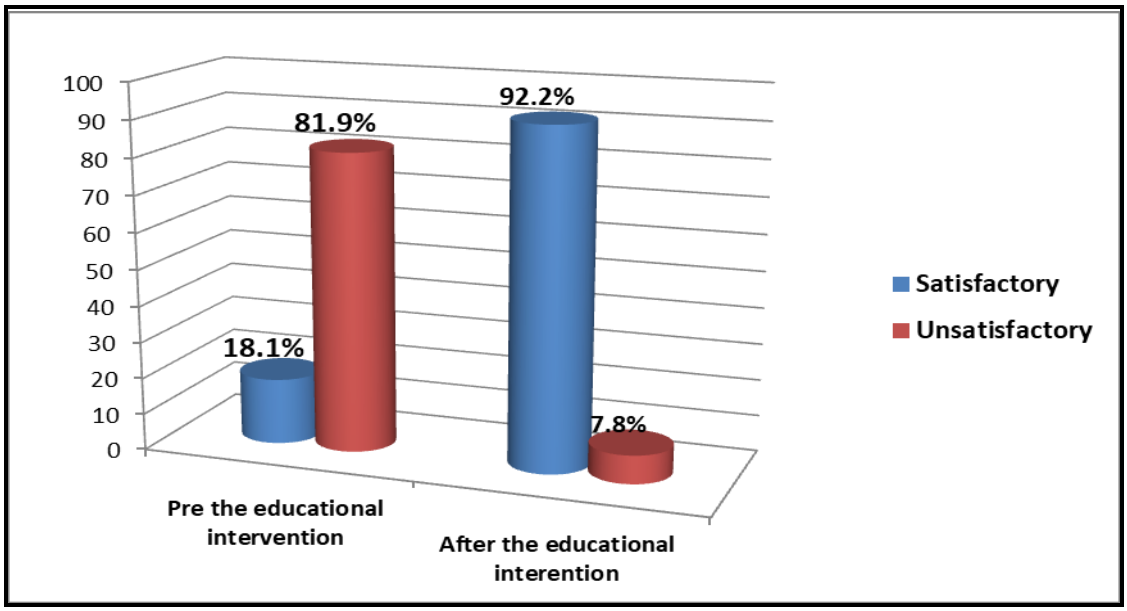

Figure (1): Comparison of the studied subjects' level of Knowledge regarding EDCs in pre and after the educational intervention (n=116)

Table (6): Distribution of the studied subjects according to their level of health beliefs toward EDCs pre and after the educational intervention (n=116)

Item	Pre-the educational intervention (n=116)				Post the educational intervention (n=116)				Test of significance	
	High		Low		High		Low		X^2	P-value
	No.	%	No.	%	No.	%	No.	%		
Perceived susceptibility	62	53.4	54	46.6	104	89.7	12	10.3	0.552	0.000**
Perceived severity	66	56.9	50	43.1	99	85.3	17	14.7	2.207	0.000**
Perceived barriers	106	91.4	10	8.6	95	81.9	21	18.1	79.448	0.000**
Perceived benefits	36	31.0	80	69.0	105	90.5	11	9.5	16.690	0.000**
Cues to action	69	59.5	47	40.5	108	93.1	8	6.9	4.172	0.000**
Perceived self-efficacy	52	44.8	64	55.2	91	78.4	25	21.6	1.241	0.000**

Chi square test *** High Significance P ≤ 0.001*

Table (7): Comparison of the studied subjects' mean score of the total knowledge and the Structures of the HBM model regarding EDC pre and after the educational intervention (N=116)

Items	Pre	Post	Test of significance	
	Mean ± SD	Mean ± SD	Wilcoxon Signed Ranks Test	P – value
Total EDCs knowledge	15.75 ± 8.03	32.57 ± 5.93	9.193	0.000**
Perceived susceptibility	10.99±2.66	13.36±1.67	7.201	0.000**
Perceived severity	16.78±4.08	19.83±3.24	5.776	0.000**
Perceived barriers	32.52±4.96	31.91±6.99	0.089	0.929
Perceived benefits	19.42±4.18	22.66±4.18	6.115	0.000**
Cues to action	36.56±8.03	43.92±6.48	7.009	0.000**
Perceived self-efficacy	17.18±4.93	21.18±2.65	6.755	0.000**

Wilcoxon Signed Ranks Test *** High Significance P ≤ 0.001*

Table (8): Relation between demographic data of the studied sample and total knowledge levels regarding EDCs pre and after the educational intervention (n= 116)

Items	Total knowledge levels pre the educational intervention				Total knowledge levels post the educational intervention			
	Satisfactory (n = 21)		Unsatisfactory (n = 95)		Satisfactory (n = 107)		Unsatisfactory (n = 9)	
	No.	%	No.	%	No.	%	No.	%
Age (yr.s)								
18-21 yrs	17	81.0	60	63.2	72	67.3	5	55.6
22-24 yrs	4	19.0	35	36.8	35	32.7	4	44.4
X 2 /Fisher (P – Value)	**2.440 (0.118)**				**4.733 (0.181)**			
Faculty grade								
1st grade	5	23.8	9	9.5	14	13.1	0	0.0
2nd grade	3	14.3	27	28.4	28	26.2	2	22.2
3rd grade	4	19.0	26	27.4	27	25.2	3	33.3
4th grade	9	42.9	33	34.7	38	35.5	4	44.4
X 2 /Fisher (P – Value)	**5.031 (0.170)**				**1.277 (0.861)**			
Residence								
Rural	7	33.0	73	76.8	74	69.2	6	66.7
Urban	14	66.7	22	32.2	33	30.8	3	33.3
X2 /Fisher (P – Value)	**15.211 (0.000) ******				**Fisher (1.000))**			
Father education								
Illiterate	0	0.0	15	15.8	13	12.1	2	22.2
Read and write	1	4.8	15	15.8	15	14.0	1	11.1
Primary	0	0.0	1	1.1	1	0.9	0	0.0
Preparatory	1	4.8	5	5.3	4	3.7	2	22.2
Secondary	9	42.9	37	38.9	44	41.4	2	22.2
University or post graduate	10	47.6	22	23.2	30	28.0	2	22.2
X 2/Fisher (P – Value)	**Fisher (0.091)**				**Fisher (0.189)**			

Items	Total knowledge levels pre the educational intervention				Total knowledge levels post the educational intervention			
	Satisfactory (n = 21)		Unsatisfactory (n = 95)		Satisfactory (n = 107)		Unsatisfactory (n = 9)	
	No.	%	No.	%	No.	%	No.	%
Mother education								
Illiterate	2	9.5	19	20.0	18	16.8	3	33.3
Read and write	2	9.5	17	17.9	19	17.8	0	0.0
Primary	1	4.8	2	2.1	3	2.8	0	0.0
Preparatory	1	4.8	4	4.2	3	2.8	2	22.2
Secondary	7	33.3	33	34.7	38	35.5	2	22.2
University or post graduate	8	38.1	20	21.1	26	24.3	2	22.2
X 2/Fisher (P– Value)	**Fisher (0.418)**				**Fisher (0.090)**			
Marital status								
Single	17	81.0	85	89.5	94	87.9	8	88.9
Married	4	19.0	10	10.5	13	12.1	1	11.1
X 2/Fisher (P – Value)	**Fisher (0.279)**					**Fisher (1.000)**		
Perceived Socioeconomic Status								
Low	2	9.5	8	8.4	9	8.4	1	11.1
Middle	18	85.7	84	88.4	95	88.8	7	77.8
High	1	4.8	3	3.2	3	2.8	1	11.1
X 2/Fisher (P– Value)	**Fisher(0.730)**				**2.706 (0.188)**			
Personal history of chronic diseases								
Yes	4	19.0	2	2.1	6	5.6	0	0.0
No	17	81.0	93	97.9	101	94.4	9	100.0
X^2/Fisher (P – Value)	**Fisher (0.010) ***				**Fisher (1.000)**			
Family history of chronic diseases								
Yes	14	66.7	30	31.6	40	37.4	4	44.4
No	7	33.3	65	68.4	67	62.6	5	55.6
X^2 /Fisher (P – Value)	**0.003****				**Fisher (0.729)**			
Prior EDCs Education								
Yes	17	81.0	16	16.8	31	29.0	2	22.2
No	4	19.0	79	83.2	76	71.0	7	77.8
X2 /Fisher (P – Value)	**34.726 (0.000) ****				**Fisher (1.000)**			

*Column percentage table X^2/Fisher, * statistically significant at P – value ≤ .05,*
*** statistically significant at P– value ≤ .01*

Table (9): Correlations between knowledge and HBM constructs related to EDCs among the participants before the educational intervention (n = 116).

Items		Pre the educational intervention						
		Knowledge about EDCs	Perceived susceptibility	Perceived severity	Perceived barriers	Perceived benefits	Perceived cues to action	Perceived self-efficacy
Knowledge about EDCs	**R**	1.000	0.220	0.261	0.008	0.316	0.340	0.322
	P-value	.	0.018*	0.005**	0.932	0.001**	0.000**	0.000**

Table (10): Correlations between knowledge and HBM constructs related to EDCs among the participants after the educational intervention (n = 116).

Items		Post the educational intervention						
		Knowledge about EDCs	Perceived susceptibility	Perceived severity	Perceived barriers	Perceived benefits	Perceived cues to action	Perceived self-efficacy
Knowledge about EDCs	**R**	1.000	0.105	0.040	0.065	0.224	0.253	0.227
	P-value	.	0.263	0.667	0.491	0.016*	0.006**	0.014*

Table (1): Displays the sociodemographic characteristics of the participants in the study. The majority (66.4%) was aged between 18 and 21 years, and 69% resided in rural areas. Regarding parental education, 39.7% of participants reported that their fathers had completed secondary education, while 34.5% stated the same for their mothers. Most participants (87.9%) were single, and an equal proportion (87.9%) perceived their family's socioeconomic status as middle level. Additionally, 37% had a family history of chronic diseases, and 71.6% had not received prior education about EDCs.

Table (2): Illustrates that 81% of the studied subjects correctly identified the definition of EDCs pre-intervention compared to 96.6 % post-intervention, 69%, 52.6%, and 51.7%, respectively mentioned pesticides, cosmetics, packing of food and pesticides as sources of EDCs pre -intervention compared to 94.8 ,81 %, and 90.5%, following the intervention. Moreover, 57.8% and 63.8% stated that ingestion and inhalation as ways of exposure to EDCs pre-intervention compared to 93.1% and 87.9 % respectively post-intervention.

Table (3): Shows that among the studied subjects, 48.3% did not know that EDCs is associated with reproductive problems pre-intervention compared to 76.7% reported these associations post-intervention. Furthermore, 57.8% and 56.9% respectively mentioned preeclampsia and fetal growth restriction as possible effects of EDCs on pregnancy pre-intervention compared to 88.8% and 90.5% post–intervention, while 58.6% reported cancer as a possible effect of EDCs on adult health pre-intervention compared to 86.2 % post-intervention.

Table (4): Shows 87.1% of the studied subjects didn't know any examples of EDCs pre-intervention while post-intervention, 68.1% mentioned BPA, 62.9% mentioned DDT, 40.5% mentioned PFCs, and 37.9% mentioned Paraben. Regarding the ways to reduce exposure to EDCs, 61.2% did not know to reduce exposure to EDCs pre-intervention while post-intervention 76.7% mentioned reducing plastic use, followed by 61.2% mentioned reducing pesticide use, followed by 57.8% mentioned using Paraben free cosmetics.

Table (5): Illustrates there are statistically significant differences between the studied subject's level of knowledge regarding EDCs pre- and post-intervention while the p value is 0.000**

Figure (1): Shows that 18.1% of the studied subjects had satisfactory knowledge regarding EDCs pre-intervention compared to 92.2% post- intervention.

Table (6): Indicates statistically significant differences in the levels of all HBM constructs related to EDCs pre- and post- intervention, with a P-value of 0.000**. The table shows that the most remarkable improvement was in the participants' perceived benefits regarding EDCs while 31.0% had high perceived benefits pre-intervention compared to 90.5% post-intervention. Moreover, the lowest improvement was in the participants' perceived barriers while 8.6% of the participants had low perceived barriers pre-intervention compared to 18.1% post-intervention.

Table (7): Indicates that, following the educational intervention, there was an increase in the mean scores of all HBM constructs related to EDCs among the participants, except for perceived barriers. Statistically significant differences were observed between pre- and post-intervention scores, with a P-value of 0.000**.

Table (8): Shows that pre-intervention, there is a statistically significant relation between total knowledge level about EDCs and residence, personal history of chronic diseases, and Prior education about EDCs while the p-value is (0.000,0.000, 0.000) respectively. Moreover, there is no statistically significant relation between the total knowledge level of the studied subjects about EDCs and their (age, faculty grade, parents' education, marital status, perceived socioeconomic status, family history of chronic diseases). The same table shows that there is no significant relation between the total knowledge level about EDCs and any of their sociodemographic data post-intervention.

Table (9): Presents the Pearson correlation coefficients (R) between knowledge about EDCs and various HBM constructs pre-intervention. Knowledge about EDCs shows statistically significant positive correlations with perceived susceptibility ($R = 0.220$, $p = 0.018$), perceived severity ($R = 0.261$, $p = 0.005$), perceived benefits ($R = 0.316$, $p = 0.001$), cues to action ($R = 0.340$, $p < 0.001$), and perceived self-efficacy ($R = 0.322$, $p < 0.001$). However, there is no significant correlation between knowledge and perceived barriers ($R = 0.008$, $p = 0.932$).

Table (10): Shows that post-intervention; the correlation between knowledge about EDCs and HBM constructs indicates a shift in relationships. Statistically significant positive correlations were found between knowledge and perceived benefits ($R = 0.224$, $p = 0.016$), cues to action ($R = 0.253$, $p = 0.006$), and perceived self-efficacy ($R = 0.227$, $p = 0.014$). However, no significant associations were observed with perceived susceptibility ($R = 0.105$, $p = 0.263$), perceived severity ($R = 0.040$, $p = 0.667$), or perceived barriers ($R = 0.065$, $p = 0.491$).

Discussion

According to the Environmental Protection Agency (EPA), EDCs are defined as exogenous substances that disrupt the synthesis, secretion, transport,

metabolism, binding, or elimination of endogenous hormones that regulate critical physiological functions such as homeostasis, reproduction, and development. Human exposure to EDCs has been associated with a range of adverse health effects, including abnormal growth patterns, reproductive dysfunction, and neurological disorders. Alarmingly, these detrimental effects can extend across generations, raising significant public health concerns. In response, the WHO has emphasized the importance of implementing stringent regulatory measures to limit human exposure to EDCs **(Hassan et al., 2024).**

The impact of EDCs is particularly pronounced in women's reproductive health, with documented associations to delayed puberty, early-onset breast cancer, infertility, menstrual irregularities, uterine fibroids, challenges in conception, and obstetric complications **(Hassan et al., 2024).** So the current study aimed to evaluate the effect of an educational intervention based on the HBM toward the awareness regarding EDCs among female nursing students.

Regarding the participants' level of knowledge about EDCs, the current study revealed statistically significant differences between the studied subjects' level of knowledge regarding EDCs before and after the educational intervention. While the majority had unsatisfactory knowledge pre-intervention, however, the majority had a satisfactory level of knowledge post-intervention. These findings suggest that the educational intervention was highly effective in enhancing participants' awareness and understanding of EDCs. The significant shift from unsatisfactory to satisfactory knowledge underscores the importance and impact of structured health education programs in promoting environmental health literacy.

The current study results are consistent with a study done by **Ouazzani et al., (2021),** to investigate "The Effect of Perinatal Environmental Health Education on Exposure to EDCs among Pregnant Women In France", while it was concluded that significant improvements in participants' knowledge and behaviors related to EDCs were achieved following workshops focusing on environmental health and EDCs exposure.

Further study supported the finding of the current study revealed by **Park et al., (2022)**, in their study "A Scoping Review of Interventions for Reducing Exposure to EDCs in Humans" .The review found that educational programs, counseling, and behavior change strategies effectively increased awareness and promoted practices to minimize EDCs exposure.

Additional findings are congruent with the current finding reported by **Jang et al., (2020)** to assess knowledge of EDCs and actions to lower its exposure among cooking staff at a Gyeonggi province while indicating improved EDCs awareness after providing related information.

Concerning the relation between demographic data of the studied sample and knowledge levels regarding EDCs, the current study revealed that pre-intervention, there is a statistically significant relation between total knowledge level about EDCs, residence, personal history of chronic diseases, and prior education about EDCs. The relation between knowledge level about EDCs and residence is congruent with the finding reported by **Trasande et al., (2015),** who studied "EDCs Exposure in The USA: A population-Based Disease Burden and Cost Analysis" showing that urban vs. rural differences in exposure and awareness of EDCs were noted, with urban populations more likely to have both higher exposure and more awareness due to environmental and educational access differences.

The relation between level of knowledge about EDCs and personal history of chronic diseases found in the current study is similar to the finding reported by **Kelly et al., (2020),** who investigated "Public Awareness and Risk Perceptions of Endocrine Disrupting Chemicals" while participants who were affected by a hormone-related disorder were more aware of EDCs. Moreover, the relation between knowledge level about EDCs and prior education is in the same line with **Zhang et al., (2020),** who investigated " Public Awareness and Knowledge about EDCs: A cross-sectional Study in China" revealing that individuals who had previous educational exposure (e.g., workshops, health campaigns) showed significantly higher knowledge scores related to EDCs.

Concerning the participants' health beliefs regarding EDCs, the present study revealed statistically significant differences in the levels of all HBM constructs related to EDCs among the participants pre-and post-intervention. While the greatest improvement was in the participants' perceived benefits, and the lowest improvement was in the participants' perceived barriers. The current study results are in line with a Korean study done by **Kim & Choi, (2021)** to evaluate the effect of a behavioral program to reduce EDCs exposure among unmarried females, while it was shown that the educational intervention could improve the perceived benefits and self-efficacy of reducing one's exposure to EDCs. It also decreases the perceived barriers.

The limited change in perceived barriers regarding EDCs among the participants of the current study, even post-interventions, can be attributed to factors like limited access to safer alternatives (e.g., organic foods, BPA-free containers), the high cost of non-toxic products, and lack of EDC-free labeling, making it hard to identify harmful products.

Regarding the correlations between knowledge and health beliefs regarding EDCs, the present study revealed that pre-intervention, knowledge about EDCs shows statistically significant positive correlations with perceived susceptibility, perceived severity, perceived benefits, cues to action, and perceived self-efficacy. These findings are in the same line with a Korean study conducted by **Yoon& Kim (2022)** to assess the factors affect actions to reduce EDCs exposure and indicating the need for related education, while there was a significant positive correlation between knowledge about EDCs perceived benefits, and behavior for reducing exposure to EDCs.

These results indicate that participants, who know more about EDCs are more likely to realize themselves as vulnerable to EDCs-related health risks, perceive the health outcomes as serious, realize the benefits of prevention, and feel confident to take action.

The current study revealed that there is no significant correlation between EDCs knowledge and perceived barriers to reduce the exposure. This indicates that increased knowledge alone may not be enough to reduce perceived barriers. A possible explanation for this may be that perceived barriers are more influenced by structural or personal factors – cost, convenience, habits – rather than informational awareness alone. This points to the need for educational interventions that not only increase knowledge but also address and reduce perceived barriers, possibly through practical demonstrations, behavioral support or policy changes.

Conclusion:

This study shows that the HBM based educational intervention was effective in increasing awareness about EDCs as evidenced by increased knowledge and positively influenced health beliefs among female nursing students. These results support the use of theory based educational programs in promoting health awareness and health beliefs related to environmental health risks. Scaling up such interventions can help in developing health conscious health professionals.

Recommendations:

1. Including EDCs and environmental health content in undergraduate nursing curricula to keep future healthcare professionals aware and prepared.
2. Conducting regular workshops and seminars based on the HBM to reinforce knowledge and promote positive health beliefs about EDCs.
3. Using various educational tools, digital media and interactive sessions to engage students and retain information about EDCs.
4. Conducting longitudinal studies to evaluate the long term impact of HBM-based educational interventions on behavioral change and actual EDCs exposure reduction.

Limitations of the study:

1. The study assessed knowledge and health beliefs regarding EDCs, but did not measure actual behaviors related to exposure, as EDCs are present in a wide range of products (plastics, cosmetics, food packaging, etc.) and have varied exposure routes (ingestion, inhalation, skin contact), making avoidance behaviors difficult to isolate and measure.
2. Data were collected using a self-administered questionnaire, which may introduce inaccuracies in self-assessment.

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