

Effect of Virtual Reality-Based Hand Hygiene Training on Nursing Students' Knowledge and Behavior: A Quasi-Experimental Study

Sanal Gerçeklik Tabanlı El Hijyeni Eğitiminin Hemşirelik Öğrencilerinin Bilgi ve Davranışları Üzerindeki Etkisi: Yarı DeneySEL Bir Çalışma

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ABSTRACT

Objective: This study aimed to evaluate the effect of virtual reality-based hand hygiene training on nursing students' knowledge, attitudes, beliefs, and behaviors regarding hand hygiene.

Method: A quasi-experimental study using a single-group pretest-posttest design was conducted with 102 nursing students. Data were collected using the Demographic Information Form, the Social Handwashing Knowledge Scale, the Social Handwashing Attitude Scale, the Hand Hygiene Belief Scale, and the Hand Hygiene Practice Inventory. The Cronbach's alpha coefficients of the scales were found to be at an acceptable level of reliability. Students received training via virtual reality devices using the "Tork VR Clean Hands Training" application, which included interactive scenarios and educational videos covering routine and clinical hand hygiene practices.

Results: Statistically significant differences were found between the pre-test and post-test scores on the Social Handwashing Attitude Scale, the Hand Hygiene Practice Inventory, the Hand Hygiene Belief Scale, and the "importance of hand hygiene" subscale ($p<0.05$). Strong, positive correlations were identified between the pretest scores of the Social Handwashing Attitude Scale and the Hand Hygiene Practice Inventory, as well as between the Hand Hygiene Belief Scale and its subdimensional score ($p<0.001$).

Conclusion: It was concluded that virtual reality-based hand hygiene education positively influences students' knowledge, attitudes, beliefs, and practices regarding hand hygiene and may serve as an effective, innovative, and practical educational method that supports the learning process in nursing education. The findings support the use of virtual reality in hand hygiene education.

Keywords: Hand Hygiene, Nursing Education, Nursing Students, Virtual Reality

ÖZ

Amaç: Bu çalışma, sanal gerçeklik temelli el hijyeni eğitiminin hemşirelik öğrencilerinin el hijyenine ilişkin bilgi, tutum, inanç ve davranışları üzerindeki etkisini değerlendirmeyi amaçlamıştır.

Yöntem: Tek grup ön test-son test tasarımıyla yarı deneysel çalışma, 102 hemşirelik öğrencisiyle yürütülmüştür. Veriler; Tanımlayıcı Bilgi Formu, Sosyal El Yıkama Bilgi Ölçeği, Sosyal El Yıkama Tutum Ölçeği, El Hijyeni İnanç Ölçeği ve El Hijyeni Uygulama Envanteri ile toplanmıştır. Ölçeklerin Cronbach alfa katsayılarının kabul edilebilir güvenirlik düzeyinde olduğu belirlenmiştir. Öğrencilere, rutin ve klinik el hijyeni uygulamalarını kapsayan etkileşimli senaryolar ve eğitici videolar içeren "Tork VR Clean Hands Training" uygulaması kullanılarak sanal gerçeklik cihazları aracılığıyla eğitim verilmiştir.

Bulgular: Sosyal El Yıkama Tutum Ölçeği, El Hijyeni Uygulama Envanteri, El Hijyeni İnanç Ölçeği ve "el hijyeninin önemi" alt boyutunun ön test-son test puanları arasında istatistiksel olarak anlamlı farklılıklar bulunmuştur ($p<0,05$). Sosyal El Yıkama Tutum Ölçeği ile El Hijyeni Uygulama Envanteri ön test puanları arasında ve El Hijyeni İnanç Ölçeği ile alt boyutu arasında güçlü, pozitif korelasyonlar belirlenmiştir ($p<0,001$).

Sonuç: Sanal gerçeklik temelli el hijyeni eğitiminin öğrencilerin el hijyenine ilişkin bilgi, tutum, inanç ve uygulamalarını olumlu etkilediği ve hemşirelik eğitiminde öğrenme sürecini destekleyen etkili, yenilikçi ve uygulanabilir bir eğitim yöntemi olabileceği sonucuna ulaşılmıştır. Bulgular, sanal gerçekliğin el hijyeni eğitiminde kullanımını desteklemektedir.

Anahtar Kelimeler: El Hijyeni, Hemşirelik Eğitimi, Hemşirelik Öğrencileri, Sanal Gerçeklik

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INTRODUCTION

Hand hygiene is a globally important infection prevention and control method. It is also the most important and least expensive strategy for reducing harm from healthcare-associated infections (Centers for Disease Control and Prevention [CDC], 2021). Nurses, as one of the main actors in healthcare, assume significant responsibility for hand hygiene practices. However, research shows that nurses and nursing students lack sufficient knowledge and skills in hand hygiene (Abate & Salih, 2024; Fernandes et al., 2024). Preventing hand hygiene-related infections should be a priority for health care organizations. The World Health Organization (WHO) reports that seven out of 100 patients will acquire at least one healthcare-associated infection, with the risk doubling and increasing 20-fold in low- and middle-income countries (World Health Organization [WHO], 2022). Infection prevention and control interventions can reduce infections by 70%. Therefore, health costs are also reduced (Tomczyk et al., 2022). All healthcare personnel involved in patient care, including nursing students, should clean their hands properly (Fernandes et al., 2024; Martos-Cabrera et al., 2019). Proper hand hygiene is ensured when each step outlined in the WHO's 2009 "Five Moments for Hand Hygiene" document is correctly implemented (WHO, 2009).

Clinical skills are an important part of nursing education and nursing practice. Traditional education methods are effective for teaching theoretical knowledge and basic principles of hand hygiene; however, they have limitations in developing practical skills. In recent years, virtual reality (VR) technology has come to the fore as an innovative approach in health education (Fernandes et al., 2024).

VR is a simulation tool that allows the individual to feel as if they are really in the virtual environment and interact with it using three-dimensional computer technology (Parsons et al., 2017). In a computer-generated artificial world, users experience a kind of real life through imaging equipment worn on their bodies or by entering various devices (Plotzky et al., 2023). VR systems allow the creation of virtual scenarios that are very close to the real world and thus enable control of many sensory cues, such as vision, hearing, motor coordination, and balance. The individual can interact with other objects in this virtual environment. In the last decade, VR applications have gained importance in nursing education and research (Chen et al., 2020; Efendi et al., 2023; Liu et al., 2023; Ma et al., 2024; Mäkinen et al., 2023; Plotzky et al., 2023; Saab et al., 2021; Shorey & Ng, 2021).

VR technology is recognized as a new and effective learning tool in health education. For nursing students, VR simulations offer practical applications that are closest to real-world experience. This gives students real-world experience while at the same time providing the freedom to make mistakes and the opportunity to learn safely from these mistakes (Bodur et al., 2024; Chen et al., 2020; Efendi et al., 2023; Liu et al., 2023; Ma et al., 2024; Mäkinen et al., 2023; Plotzky et al., 2023; Saab et al., 2021; Shorey & Ng, 2021).

VR simulations also offer students the opportunity to integrate theoretical knowledge with practical skills. The use of VR in hand hygiene education allows students to practice in different scenarios while learning hygiene protocols interactively (Fernandes et al., 2024; Gasteiger et al., 2024; Plotzky et al., 2023). Students apply their theoretical knowledge of hand hygiene through VR simulations, thereby improving their understanding and application of this knowledge. This

makes the learning process more effective and helps students remember the information long-term (Bodur et al., 2024; Chen et al., 2020; Fernandes et al., 2024; Gasteiger et al., 2024; Liu et al., 2023; Plotzky et al., 2023; Saab et al., 2021; Shorey & Ng, 2021). It is important for nurses, who are the most numerous among health professionals and who most often encounter or care for patients and healthy individuals, to adopt handwashing attitudes and behaviors. Nursing students, who are the nurses of the future, should acquire handwashing skills in the cognitive, affective, and psychomotor domains (Bayram et al., 2019). A study concluded that knowledge, attitude, and practice regarding hand hygiene are insufficient in healthcare settings (Demiray et al., 2022). The acquisition of this skill and its transformation into an attitude should be ensured at the student stage. Students' understanding of the importance of handwashing during nursing education and its transfer to the working environment is a key step in preventing nosocomial infections. Therefore, it is necessary to monitor nursing students' behavior to ensure compliance with hand hygiene. Many factors affect compliance with hand hygiene (lack of knowledge, motivation, and experience in hand hygiene; negative attitudes towards hand hygiene; insufficient personnel; excessive workload; inadequate equipment and materials for hand hygiene; hand irritation and allergies, etc.). In addition to these environmental factors, many of them are individual factors, such as knowledge, beliefs, attitudes, and perceptions. Determining these factors is important for increasing compliance with hand hygiene. In addition, assessing nursing students' attitudes toward handwashing will help identify factors that affect nurses' handwashing practices and those who will provide future care. For this reason, it is very important to raise awareness of proper handwashing and reinforce their knowledge to instill handwashing behaviors among students who are open to learning and development, thereby fostering positive attitudes (Bayram et al., 2019; Demiray et al., 2022).

When the national and international literature was reviewed, no studies were found that reported hand hygiene training using VR simulations with nursing students. However, there are studies in which VR hand hygiene training was performed on different samples. In Japan, VR clips with patient views were developed to encourage compliance with hand hygiene in health care settings. In a pilot study of 20 nurses and 5 nurse assistants, all participants reported that the VR experience increased awareness of the 5 Moments for Hand Hygiene (Hagiya et al., 2024). In another cross-sectional study conducted in South Korea, university students (n=150) were included in a 2-week, 5-minute VR handwashing program. The study found that VR applications increased handwashing intentions (Choi & Noh, 2020). In this context, the aim of the study was to evaluate the effect of virtual reality-based hand hygiene training on nursing students' knowledge, attitudes, beliefs, and behaviors related to hand hygiene.

Research Questions

1. Does hand hygiene training with virtual realite increase nursing students' hand hygiene knowledge test scores?
2. Does hand hygiene training with virtual realite increase nursing students' hand hygiene attitude test scores?
3. Does hand hygiene training with virtual realite increase nursing students' hand hygiene belief test scores?
4. Does hand hygiene training with virtual realite increase nursing students' hand hygiene practice test scores?

METHODS

Research Design

The research is a one-group pretest-posttest educational intervention study.

Setting

The study was conducted at the Ege University Faculty of Nursing between January 2023 and December 2023. The data were collected between January and March 2023.

Population and Sample

The population of the study consisted of a total of 936 students studying at Ege University Faculty of Nursing in the 2022-2023 academic year (2nd grade (n=346), 3rd grade (n=306), and 4th grade (n=284)). The sample of the study was calculated by power analysis using the G*Power 3.1.9.7 program. As a result of the power analysis based on a similar study conducted previously for the research to be designed as an experimental group, the number of samples determined for power was calculated as 102 when the power of 0.95 was taken as bidirectional, effect size 0.5, and Standard deviation 0.05. Considering the voluntary participation of the students in the study and the possibility of dropping out of the study, it was decided to include at least 110 students for each group in the study. During the research process, eight students left the study. The study was completed with 102 students who met the inclusion criteria.

Inclusion Criteria

- To be a 2nd, 3rd, or 4th year student at Ege University Faculty of Nursing
- To have participated in applied courses.
- To have practiced in hospital and public health fields
- Not having a previously known psychological disorder
- No visual or hearing loss
- To be open to communication and cooperation
- Not having a mental problem
- To volunteer to participate in the study
- Participating in the entire training
- Signing the informed consent form

Exclusion Criteria

- Being a 1st year student at Ege University Faculty of Nursing (1st year students of Ege University Faculty of Nursing were not included in the study because they did not take practical courses).
- Students who did not meet the inclusion criteria and students who did not give written consent for participation in the study were excluded from the study.

Data Collection Tools

In the study, data were collected using a 3-question descriptive information form including age, gender, and class, the Social Hand washing Knowledge Scale (SHWKS), the Social Hand washing Attitude Scale (SHWAS), the Hand Hygiene Belief Scale (HHBI), and the Hand Hygiene Practice Inventory (HHPI).

Descriptive Information Form: It is a 3-question form including age, gender, and class variables (Kayar et al., 2020; Şensoy, 2021).

Social Hand washing Knowledge Scale (SHSWK): The scale developed by Üner et al. (2009), which includes a total of 8 questions evaluating the participant's knowledge on "social hand washing," has a 3-point Likert (agree, disagree, no opinion) structure. The answers that are accepted as correct for the SHSWK are "disagree" for 1, 3, 4, 6, and "agree" for 2, 7, 5, and 8. Participants were given 1 point for each correct answer, and the scale scores were found by dividing the total points they received by the number of questions and calculating the results out of 100. The minimum score that can be obtained from this scale is 0, and the maximum score is 16. The Cronbach Alpha reliability coefficient value of the scale is 0.639. In this study, the Cronbach Alpha reliability coefficient value is 0.62 (Üner et al., 2009).

Social Hand washing Attitude Scale (SHWAS): The 21-question scale developed by Üner et al. (2009), which evaluates the attitudes of the participants, has a 3-point Likert (always, sometimes, never) structure. The answers accepted as correct for SHWAS; "always" for propositions 1, 2, 4, 5, 7, 9, 10, 12, 13, 15, 16, 17, 18, 20, 21; and "never" for propositions 3, 6, 8, 11, 14, and 19 were evaluated as positive attitudes (1 point). Participants were given 1 point for each correct answer they gave to the attitude questions, and the scale scores were calculated by dividing the total points they received by the number of questions and evaluating the results out of 100 points. The minimum score that can be obtained from this scale is 0, and the maximum score is 44 (Üner et al., 2009).

Hand Hygiene Practice Inventory (HHPI): The HHPI developed by Van de Mortel (2009) was adapted into Turkish by Karadağ et al. (2016), and a validity and reliability study was conducted. It is a 5-point Likert-type scale consisting of 14 items and scored as never=1, sometimes=2, often=3, most of the time=4, always=5. The total score of HHPI is between 14 and 70, and a high scale score indicates that the personal ways performs hand hygiene practices. The Cronbach alpha internal consistency coefficient of the scale is 0.80. The validity study of the scale was carried out by Karadağ with 340 university students, and the internal consistency reliability coefficient of the scale was 0.85 and the test-retest reliability was 0.60. The factor structure obtained from the HHPI was similar to the factor structure of the original inventory. The minimum score that can be obtained from the inventory is 14, and the maximum score is 70 (Karadağ et al., 2016; Van de Mortel, 2009).

Hand Hygiene Belief Scale (HHBS): Van de Mortel's (2009) EHI was adapted into Turkish by Karadağ et al. (2016), followed by a validity and reliability study. The original scale consists of a total of 23 items, including hand hygiene beliefs (20 items) and perceptions of the importance of hand hygiene (3 items). It is a 5-point Likert-type scale scored as strongly disagree=1, disagree=2, not sure=3, agree=4, strongly agree=5. The Cronbach alpha internal consistency coefficient of the scale is 0.80. The total score of the HHBS varies between 22 and 110, and a high score indicates that the person has a positive belief about hand hygiene. Karadağ conducted the validity study of the scale with 340 university students, yielding an internal consistency reliability coefficient of 0.76 and a test-retest reliability of 0.66. In the evaluation, it was determined that the number of factor items did not overlap with the original scale. After analyzing the fit indices obtained from the confirmatory factor analysis, it was concluded that the two-factor structure of the EHI is not appropriate for the Turkish scale, thus resulting in the Turkish version of the EHI being considered a single-factor. As a result, the Hand Hygiene Belief Scale, consisting of 22 items and 2 subscales, was obtained. These subscales are Hand Hygiene Importance (items 1, 2, 3, 4, 6, 7, 7, 9, 11, 12, 13, 14, 15, 21, and 22), consisting of 14 items, and Belief (items 5, 8, 10, 16, 17, 18, 19, and 20), consisting of 8 items (Karadağ et al., 2016; Van de Mortel, 2009).

The internal consistency of the measurement tools used in the study was assessed using Cronbach's alpha. Reliability analyses were conducted by including all scale items, and the SPSS program was used for the analyses.

In this study, Cronbach's alpha for the SHSWK was found to be 0.448. This value indicates that the scale has low internal consistency. Upon examining item-total correlations, it was determined that some items showed a weak relationship with the scale, for the SHWAS was calculated as 0.874, indicating that the scale possesses high internal consistency, for the HHBS was found to be 0.916, and it was determined that the scale possesses excellent internal consistency, for the HHPI was calculated as 0.948, and this result indicates that the scale is highly reliable. Cronbach's alpha coefficients of 0.70 or higher are considered acceptable, 0.80 or higher are considered good, and 0.90 or higher are considered excellent indicators of internal consistency. Accordingly, it was determined that the majority of the scales used in the study are highly reliable, but the internal consistency of the knowledge scale is low.

VR Devices: In this study, a VR device (Samsung Gear VR BOX 3.0-South Korea) was used for nursing students during the hand hygiene training process. The device is compatible with 4-6-inch-screen smart mobile phones. The device, which is activated with the application installed on smart mobile phones, divides the image in to two equal Windows and offers the visor range required for panoramic vision. It contains air outlets capable of dissipating the heat emitted by mobile phones. During use, there is no need for any power or connection unit other than the mobile phone. The distance between the mobile phone and the lens can be adjusted. A VR device consists of a headset, a smart mobile phone compatible with the headset, and a remote control. After the headset is attached to the individual, it can be adjusted according to the individual. In order to use the VR device, the Tork VR Clean Hands Training application available in the AppStore and Google Play Store must be downloaded to the smart mobile phone (<https://play.google.com/store/apps/details?id=com.essity.FusionVR&gl=TR>) (Eichel et al., 2022). After the application is downloaded, each time the smart mobile phone is placed on the VR device, the 360-degree image appears on the screen spontaneously. Since watching videos with VR glasses requires an internet connection, the internet connection should not be interrupted during use. The following steps were followed to open the video show into the students:

1. The smart mobile phone was placed on the VR device.
2. The VR device is stuck in the head.
3. The Tork VR Clean Hands Training application was selected from the menu.
4. The video was started by clicking "Play".

Data Collection

Application of Question Forms (Pretest)

The data were collected from the students who met the research criteria by using the face-to-face question naire technique and in the form of questions and answers. Firstly, the purpose of the study was explained, and written informed consent was obtained. Descriptive information form was applied to all students in the intervention and control groups. The students who agreed to participate in the study were administered SHWKS to evaluate the level of knowledge, SHWAS to evaluate attitude and behavior, HHBS and HHPI.

Education Initiative

The training is based on the Tork VR Clean Hands Training application in the AppStore and Google Play Store developed by Essity, which is used with the VR device and offers practical training for health care personnel to improve hand hygiene

compliance according to WHO's 5 hand hygiene are a and CDC (Centers for Disease Control and Prevention) guidelines. The training focuses on gamified, correct hand hygiene techniques. In the game, one can choose to be a nurse or a physician (Figure 1). Nursing students chose the nurse part.

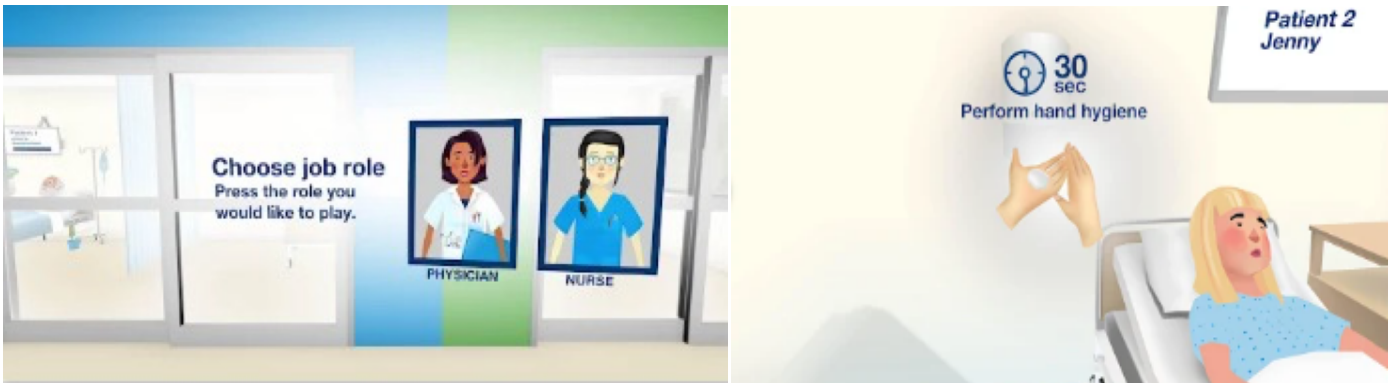


Figure 1. Images of Tork VR Clean Hands Training Application

In the scenario, a brief description of the correct technique of hand hygiene and the five indications for hand hygiene after WHO were presented to the participants. After choosing the profession (physician or nurse), the three virtual patient rooms were entered. In a variety of clinical-practical situations, the participant had to identify the correct indication and sequence of hand hygiene and use of protective gloves. An immediate warning appeared, if a measure was forgotten. After completion of the scenarios, the application directly evaluated the situations and gave feedback by creating an adherence score in percent. Although taking place in a virtual world, a series of real-life situations are encountered, and hand hygiene is practiced using hands. Before the training, a presentation on how to use the VR application was made. Firstly, information about hand hygiene and an explanation about the use of VR devices and training applications were presented, and then the video was watched. In the training: the normal skin flora, hand hygiene, indications for hand hygiene, types of hand hygiene (social handwashing and technique, hygienic handwashing and technique, hand disinfection and technique, surgical handwashing and technique), factors that hinder hand hygiene, and nurses' adherence to hand hygiene and strategies to improve adherence. A hand hygiene brochure was given to students after the training. Virtual reality-based hand hygiene training took place in a total of 3 sessions between January and March 2023, with each participant attending once. The training took place one full day between 09.30 and 17.00. There were a total of 6-10 students in each session. The students were contacted by telephone the day before the training day and invited to the Ege University Faculty of Nursing Meeting Hall, where the training would be held. Before the training, the hall was made suitable (seat arrangement, appropriate lighting, ambient temperature, sound, preparation of training materials, computer, and other audio visual training tools). The training was completed in a single session lasting a total of 90 minutes. The topics in the training program were given in order, and the questions of the participants were answered and their feedback was received. The research implementation scheme is shown in Figure 2.

Students studying in the 2nd, 3rd, 4th grades at
Ege University Faculty of Nursing at



Figure 2. Research Implementation Scheme

Application of Question Forms (Post Test)

In order to evaluate the effectiveness of the training, the post-test was administered to the students three weeks after the training. The students who would participate in the training were reminded of the place and time of the training by telephone one day before the post-test. In the post-test, the students in the intervention group were administered the SHWKS, SHWAS, HHBS, and HHPI measurement tools again.

Dependent and Independent Variables

The dependent variables of the study were nursing students' hand washing knowledge, attitude, belief, and behavior scores, and the independent variable was VR-based hand washing training.

Data Analysis

The IBM SPSS 22 program was used for statistical analyses while evaluating the findings obtained from the study. While evaluating the study data, the suitability of the parameters for a normal distribution was evaluated by the Shapiro-Wilks test. In addition to descriptive statistical methods (mean, Standard deviation, and frequency), a one-way ANOVA test was used in the evaluation of quantitative data showing a normal distribution between more than two groups, and Bonferroni correction was used to determine the group causing the difference. The Kruskal-Wallis test was used in the evaluation of quantitative

data that did not show a normal distribution between more than two groups, and the Mann-Whitney U test was used to determine the group causing the difference. Significance was evaluated at the $p < 0.05$ level.

Ethical Considerations

Before starting the study, ethical permission was obtained from the Scientific Research and Publication Ethics Committee of Ege University with the number E-27344949-100-1066931. Written permission was obtained from the dean of the Faculty of Nursing at Ege University for data collection. For the conduct of the study, the participants were explained in detail about the research, and voluntariness and confidentiality were taken as the basis for participation in the study. Participants were informed about ensuring the security of the information obtained, and their written permission was obtained. Training and data collection procedures were carried out at the time when the students were available. Data were collected anonymously. The students in the intervention group were asked to assign a pseudonym in order to apply the post-test, and they were instructed to perform the post-test by indicating the same pseudonym. For the scales used in the study, written permission was obtained from the authors who tested the validity and reliability of the scales.

RESULTS

The mean age of the participants was 22.14 ± 1.542 (min:20, max:32). It was seen that 70.6% of the participants were female ($n=72$) and 28.4% were male ($n=29$). Of the participants, 32.4% were in the second grade ($n=33$), 33.3% were in the third grade ($n=34$), and 34.3% were in the fourth grade ($n=35$) (Table 1).

Table 1. Distribution of Scale Scores According to Descriptive Characteristics of Nursing Students (N=102)

Descriptive Features	n	%	Test and p value											
			SHWKS		HHPI		SHWAS		HHBS		HHBS HandHygiene Importance subdimension		HHBS Belief subdimension	
			Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Age														
20	7	6.9												
21	28	27.5	KW=	KW=	KW=	KW=		KW=		KW=	KW=	KW=	KW=	KW=
22	37	36.3	6.175	4.402	5.121	14.334	F=1.920	16.837	F= 3.839	5.748	16.995	5.760	3.868	6.189
23	15	14.7	df= 6	df=6	df=6	df= 6	p=0.085	df= 6	p= 0.002	df= 6	df=6	df=5	df=6	df=6
24	11	10.8	p= 0.404	p= 0.622	p=0.528	p= 0.026		p= 0.010		p= 0.452	p=0.009	p=0.451	p=0.695	p=0.402
25	3	2.9												
32	1	1.0												
Gender			U=	U=	U=	U=	U=	U=	U=	U=	U=	U=	U=	U=
Female	72	70.6	1027.500	1028.500	989.000	1042.500	780.000	995.000	1029.000	968.500	980.500	954.000	807.000	763.000
Male	29	28.4	p=0.900	p=0.902	p=0.672	p=0.990	p= 0.047	p=0.711	p=0.910	p=0.570	p=0.633	p=0.497	p=0.074	p=0.035
Class			KW=	KW=4.280	KW=	KW=	KW=		KW=	KW=			KW=	
2nd	33	32.4	0.525	df= 2	4.560	12.119	12.998	F= 7.345	F= 3.728	5.073	22.355	F=2.858	0.642	F=0.592
3th	34	33.3	df= 2	p= 0.118	df= 2	df= 2	df= 2	p= 0.001	p= 0.027	df= 2	df=2	p=0.648	df=2	p=0.724
4th*	35	34.3	p= 0.769		p= 0.102	p= 0.002	p= 0.002			p= 0.079	p=0.000		p=0.726	

$p < 0.05$, *Bonferroni test, KW:Kruskal Wallis Testi, U: Mann-Whitney U Testi, F:Anova Testi

According to the age variable of nursing students, there was a significant difference in the HHBS pre-test ($p=0.002$), the importance of the hand hygiene sub-dimension of the HHBS pre-test ($p=0.009$), the HHPI post-test ($p=0.026$), and the SHWAS post-test ($p=0.010$) ($p < 0.05$). In addition, according to the gender variable of nursing students, there was a significant difference ($p < 0.05$) in SHWAS pre-test ($p=0.047$) and the HHBS belief sub-dimension post-test ($p=0.035$). However, a significant difference was found in the HHPI post-test ($p=0.002$), SHWAS pre-test ($p=0.002$), SHWAS post-test ($p=0.001$), HHBS pre-test ($p=0.027$), and HHBS hand hygiene importance sub-dimension pre-test ($p=0.000$) according to the class

variable ($p < 0.05$). The Bonferroni correction for the grade variable showed that the difference originated from the 4th grade students (Table 1).

The mean scores of the participants on the scales are shown in Figure 3, and the test and p values are shown in Table 2. When the mean scores of nursing students before and after VR-based hand hygiene training were compared, an increase was observed in all scale scores (Figure 3).

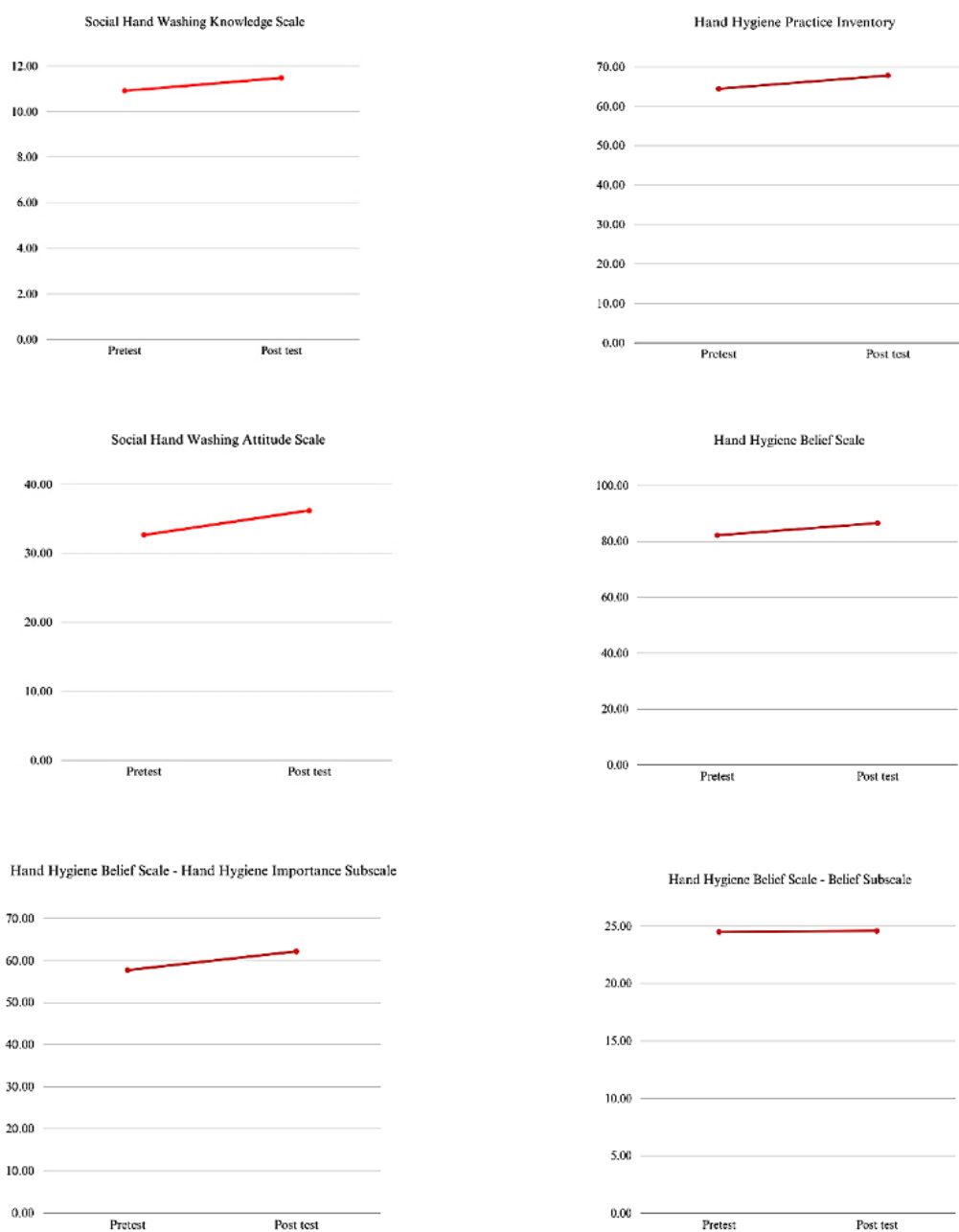


Figure 3. Comparison of Pre-test and Post-test Mean Scores of Nursing Students on the Scales

When the difference between the mean scores of the nursing students before and after the education was evaluated, it was determined that there was a significant difference in SHWAS ($p = 0.000$), HHPI ($p = 0.000$), HHBS ($p = 0.007$), and the HHBS hand hygiene importance sub-dimension ($p = 0.000$) ($p < 0.05$) (Table 2).

Table 2. Mean Scores of Nursing Students From the Scales (N=102)

Scales	Original scale values		Pre-test			Post-test		
	Min	Max	X±SD	Min	Max	X±SD	Min	Max
SHWKS	0.0	16.0	10.91±2.58 <i>test and p value</i> =-1.837	0.0	15.0	11.48±1.62 df=101 p=0.069	0.0	16.0
SHWAS	0.0	44.0	32.67±6.01 <i>test and p value</i> =-5.425	20.0	42.0	36.19±5.38 df=101 p=0.000	21.0	42.0
HHPI	14.0	70.0	64.41±11.30 <i>test and p value</i> =-4.555	42.0	70.0	67.80±4.52 df=101 p=0.000	42.0	70.0
HHBS	22.0	110.0	82.17±11.30 <i>test and p value</i> =-2.768	22.0	110.0	86.50±13.06 df=101 p=0.007	22.0	110.0
HHBS Hand Hygiene Importance subdimension	14.0	70.0	57.69±9.18 <i>test and p value</i> =-3.933	14.0	70.0	62.12±8.38 df=101 p=0.000	14.0	70.0
HHBS Belief subdimension	8.0	40.0	24.48±5.58 <i>test and p value</i> =0.126	8.0	40.0	24.57±7.34 df=101 p=0.900	8.0	40.0

In this study, the relationship between the mean scores of the scales applied before and after the education of nursing students is shown in Table 3.

Table 3. The Relationship Between the Mean Scores of the Scales Applied in the Pre-test and Post-test in the Study

Scales	SHWKS		SHWAS		HHPI		HHBS		HHBS Hand Hygiene Importance subdimension		HHBS Belief subdimension	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
SHWAS	Pre test	- r=-0.051 p=0.138	r=0.020 p=0.844	r=0.148 p=0.138	r=0.004 p=0.791	r=0.234 p=0.018 *	r=0.027 p=0.791	r=0.154 p=0.122	r=0.086 p=0.388	r=0.100 p=0.318	r=0.088 p=0.378	r=0.160 p=0.108
	Post test	-	r=0.023 p=0.818	r=0.292 p=0.003 *	r=0.022 p=0.830	r=0.060 p=0.549	r=0.426 p=0.000 0*	r=0.257 p=0.009 *	r=0.455 p=0.000 0*	r=0.321 p=0.001 *	r=0.115 p=0.250	r=0.090 p=0.366
SEYTÖ	Pre test	-	r=0.343 p=0.000	r=0.706 p=0.000 0*	r=0.314 p=0.001 *	r=0.258 p=0.000 9*	r=0.051 p=0.608	r=0.461 p=0.000 0*	r=0.034 p=0.731	r=0.236 p=0.017 *	r=0.052 p=0.603	
	Post test	-	-	r=0.247 p=0.012 2*	r=0.536 p=0.000 *	r=0.204 p=0.040 0*	r=0.211 p=0.033 *	r=0.280 p=0.000 4*	r=0.244 p=0.013 *	r=0.048 p=0.630	r=0.097 p=0.334	
HHPI	Pre test	-	r=0.359 p=0.000 *	r=0.365 p=0.000 0*	r=0.132 p=0.186	r=0.511 p=0.000 0*	r=0.142 p=0.154	r=0.102 p=0.308	r=0.073 p=0.467			
	Post test	-	r=0.039 p=0.700	r=0.146 p=0.143	r=0.137 p=0.170	r=0.218 p=0.028	r=0.147 p=0.141	r=0.011 p=0.911				
HHBS	Pre test	-	r=0.168 p=0.092	r=0.872 p=0.000 0*	r=0.220 p=0.027 *	r=0.591 p=0.000 *	r=0.048 p=0.631					
	Post test	-	r=0.094 p=0.349	r=0.854 p=0.000 *	r=0.186 p=0.061	r=0.804 p=0.000 *						
HHBS Hand Hygiene Importance subdimension	Pre test	-	r=0.163 p=0.101	r=0.120 p=0.232	r=0.020 p=0.844							
	Post test	-	r=0.176 p=0.077	r=0.377 p=0.000 *								
HHBS Belief subdimension	Pre test	-	r=0.130 p=0.193									
	Post test	-										

*p<0.05

When Table 3 was analyzed, a negative, weak, and significant relationship ($r=-0.234$, $p=0.018$) was determined between the mean scores of nursing students' pre-test scores of SHWKS and post-test scores of HHBS. There was a positive and significant correlation between the mean posttest scores of SHWKS and the mean posttest scores of SHWAS ($r=0.292$, $p=0.003$), HHBS pre-test ($r=0.426$, $p=0.000$), HHBS hand hygiene importance sub-dimension pre-test ($r=0.455$, $p=0.000$), and a negative, weak and significant relationship was observed between the mean scores of HHBS post-test ($r=-0.257$, $p=0.009$), HHBS hand hygiene importance sub-dimension post-test ($r=-0.321$, $p=0.001$). There is a positive, strong, and significant relationship between the mean scores of SHWAS pre-test and HHPI pre-test ($r=0.706$, $p=0.000$), a negative, weak, and significant relationship between the mean scores of HHPI post-test ($r=0.314$, $p=0.001$), HHBS pre-test ($r=0.258$, $p=0.009$), HHBS hand hygiene importance sub-dimension pre-test ($r=0.461$, $p=0.000$), and a negative, weak, and significant correlation was found between the mean scores of the pre-test ($r=-0.236$, $p=0.017$) and the belief sub-dimension pre-test ($r=-0.236$, $p=0.017$). SHWAS post-test mean scores were correlated with HHPI pretest ($r=0.247$, $p=0.012$), HHPI post-test ($r=0.536$, $p=0.000$), HHBS pre-test ($r=0.204$, $p=0.040$), HHBS post-test ($r=0.211$, $p=0.033$), HHBS hand hygiene importance sub-dimension pre-test ($r=0.280$, $p=0.004$), and HHBS hand hygiene importance sub-dimension post-test ($r=0.244$, $p=0.013$). A positive, weak, and significant relationship was determined between the mean scores. A positive, weak, and significant correlation was found between the mean scores of the HHPI pre-test and HHPI post-test ($r=0.359$, $p=0.000$), HHBS pre-test ($r=0.365$, $p=0.000$), and the HHBS hand hygiene importance sub-dimension pre-test ($r=0.511$, $p=0.000$). A positive, strong, and significant relationship was determined between the mean scores of the pre-test scores of the HHBS and the pre-test scores of the hand hygiene importance sub-dimension of the HHBS ($r=0.872$, $p=0.000$); a positive, weak, and significant relationship was determined between the post-test scores of the hand hygiene importance sub-dimension of the HHBS ($r=0.220$, $p=0.027$) and the post-test scores of the belief sub-dimension of the HHBS ($r=0.804$, $p=0.000$). Finally, there was a positive, weak, and significant relationship between the pre-test mean scores of the importance sub-dimension of the hand hygiene sub-dimension of the HHBS and the post-test mean scores of the importance sub-dimension of the hand hygiene sub-dimension of the HHBS ($r=0.377$, $p=0.000$).

DISCUSSION

Compared to YouTube or web-based environments, training videos watched with VR-based experiences may cause the individual to focus more on the training because they isolate the individual more from the external environment and reduce the effect of other stimuli. In addition, the fact that the viewer perceives himself as very close to the environment causes him to feel himself in the environment and thus shows a higher learning effect (Jung & Park, 2022; Peden et al., 2016; Tsai et al., 2008).

In this study, it was observed that virtual reality-based hand hygiene training positively affected nursing students' knowledge, attitudes, and behaviors related to hand hygiene. Similarly, Sen et al. (2022) reported that the mobile VR method performed better in their study investigating the effect of mobile VR training on surgical hand washing and sterile dressing skills in nursing students ($n=40$) (Sen et al., 2022). In the study of Chang et al. (2022), it was determined that the learning performance of the spherical video (360-degree video)-based VR group in the education of nursing students ($n=64$) was more effective than the traditional teaching group (Chang et al., 2022). Similarly, in other studies investigating the effectiveness of technology-based education methods, it was reported that students made fewer mistakes (Samadbeik et al., 2018), their skill development was better (Kang et al., 2020; Kim et al., 2021), and their nursing diagnosis knowledge and skills were higher (Ordu & Çalışkan, 2023) in groups where methods such as VR, video education, and VR simulation were used.

In this study, it is thought that VR-based hand hygiene education contributes to making the subject more understandable and memorable by activating multiple senses, such as vision and hearing, in nursing students. There are few studies on VR-based hand hygiene education. Evidence on the effectiveness of these studies is also limited (Clack et al., 2021; Kanazawa et al., 2014). In a study conducted by Shimada et al. (2017) in preschool children, a data glove was used instead of hand controllers to obtain the posture of the user's hand as a VR device. In the study, leap motion was used to obtain the posture of the hand. It was reported that VR systems were more effective than traditional hand hygiene training in a group of children ($n=12$) (Shimada et al., 2017).

In this study, it was observed that the mean scores of all scales increased in the post-test after VR-based hand hygiene training. As shown in Table 2, there was a significant difference ($p<0.05$) in the pre-training and post-training SHWAS ($p=0.000$), HHPI ($p=0.000$), HHBS ($p=0.007$), and HHBS hand hygiene importance sub-dimension ($p=0.000$) of nursing students. Similar to the results of this study, the literature shows that VR improves the knowledge and skill outcomes of nursing students compared to traditional approaches; technology-based teaching models are effective in increasing knowledge, self-confidence, and satisfaction in nursing education (Aygin & Yilmaz, 2022; Ulupinar & Toygar, 2020). It was reported that the VR simulation training program contributed positively to the level of knowledge in nursing care of respiratory-transmitted diseases with the COVID-19 scenario (Jeong et al., 2022), and in another study, it was reported to increase the level of knowledge of nursing students about chemotherapy port placement surgery procedures (Jung & Park, 2022). In another study, the learning effect of VR simulation on nursing students caring for asthmatic children was examined, and it was reported that the VR group received the highest knowledge scores when compared to different teaching methods (Kang et al., 2020). Although the use of VR has many advantages, some studies emphasize that VR is not more effective than other traditional methods for some outcomes, such as knowledge and performance scores (Bryant et al., 2015; Farra et al., 2015). However, it is seen that there are differences between the studies in which VR technology is used, the years in which the studies were conducted, the study methodologies, the number of skills, and the measurement techniques.

In the present study, a statistically significant difference was observed between groups in the pre-test scores of the HHBS. This finding may be attributed to individual differences among participants, such as prior exposure to hand hygiene education, variability in clinical experience, and differing levels of awareness regarding infection prevention and control practices. Recent studies have emphasized that nursing students often demonstrate heterogeneous baseline levels in hand hygiene beliefs due to differences in previous training and clinical exposure (Bakare & Bayraktar, 2025).

Furthermore, the absence of randomization and the use of a single-group pre-test-post-test design may have contributed to these initial differences. Despite this, the significant improvement observed in post-test scores indicates that virtual reality-based training effectively enhanced hand hygiene beliefs. Consistent with current literature, simulation-based and virtual reality-supported educational interventions have been shown to improve knowledge, attitudes, and behavioral intentions related to infection control, regardless of baseline differences (Padilha et al., 2019; Foronda et al., 2020; Plotzky et al., 2021). Therefore, although baseline differences existed, the findings support the effectiveness of virtual reality as an innovative and impactful teaching method in nursing education.

In this study, it was observed that there was a positive, strong, and significant relationship between the mean scores of the pre-test scores of the nursing students on the SHWAS and the mean scores of the pre-test scores of the HHPI ($r=0.706$, $p=0.000$) and between the mean scores of the pre-test scores of the HHBS and the mean scores of the pre-test scores of the importance of the hand hygiene sub-dimension of the HHBS ($r=0.872$, $p=0.000$) (Table 3). When these

results are evaluated, it is seen that hand hygiene beliefs are also important in increasing the handwashing attitudes of nursing students. The results of studies examining the effects of research methods such as meta-analysis, meta-synthesis, and systematic review, which are preferred at the highest levels of scientific evidence, on the effects of VR technologies on increasing knowledge and skills in education indicate that the use of VR goggles and scenario-based education methods together has positive results, and it is recommended that these methods be used in nursing education. As a matter of fact, in the meta-analysis study of Chen et al. (2020), in which the effectiveness of virtual reality in nursing education was evaluated, it was reported that VR education was more effective than traditional education or other simulation education methods in students' knowledge acquisition (Chen et al., 2020). In the systematic review conducted by Woon et al. (2021), it was reported that the virtual reality method is appropriate to increase the knowledge levels of nursing students and to strengthen and support traditional teaching methods. In the same study, it was also stated that VR can complement the inadequacy of clinical practice areas, but well-designed randomized controlled studies with larger samples are needed to strengthen the evidence on the effectiveness of nursing education with VR (Woon et al., 2021).

Limitations

Firstly, the study was conducted using a single-group pre-test–post-test design without a control group, which limits the ability to establish causal relationships. Additionally, the fact that some students had previously received hand hygiene training may have influenced the outcomes. The number of participants was limited, and therefore, the generalisability of the results may be limited. Furthermore, the study focused on short-term results, and further research is required to evaluate the long-term effects of VR-based hand hygiene training. However, given the potential advantages provided by virtual reality technology, the importance of future research in this area is clear.

CONCLUSION

In this study, it was observed that VR-based hand hygiene training positively affected the knowledge, attitudes, and behaviors of nursing students regarding hand hygiene, and the mean scores of all scales increased in the post-test applied after the training. VR is an innovative tool that is being used more and more widely in nursing education. This technology offers potential benefits, especially in areas such as teaching and practicing practical skills. The results of the study show that VR-based training has the potential to improve hand hygiene skills. VR encourages the active engagement of learners through its ability to simulate the real-world experience of participants. This allows students to learn more in-depth hand hygiene practices more effectively. VR can help students improve their practical skills and better prepare for clinical practice. However, it can be argued that more research and training are needed for wider acceptance and integration of VR-based hand hygiene education.

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