Original Article

Effectiveness of a Virtual Reality-based Infection Control Education Program

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Purpose: This study evaluated the effect of virtual reality (VR)-based infection control (IC) education program on IC knowledge, awareness, performance confidence, and self-efficacy in nursing students. Methods: A single-group pretest-posttest design was employed. The study participants consisted of 86 nursing students. The VR-based IC education program was developed by applying the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model. The subject of the VR-based IC education program was isolation precautions. The effects of the VR-based educational program were measured via a questionnaire. Results: There were no significant differences in IC knowledge before and after the VR-based IC education program. However, IC awareness (t=2.31, p=0.023), IC performance confidence (t=2.19, p=0.031), and self-efficacy (t=3.43, p=0.001) exhibited statistically significant increases after the VR-based IC education program. Satisfaction with the VR-based IC education program was relatively high, at 4.71 ± 0.59 points. Conclusion: IC education using VR effectively strengthened IC competency by improving IC awareness, performance confidence, and self-efficacy. Therefore, it is necessary to develop and utilize various VR-based IC education content for nursing students.

Key Words: Infection control; Students; Virtual reality

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INTRODUCTION

The importance of healthcare-associated infections (HAIs) has recently become more prominent due to infections caused by emerging infectious diseases and multidrug-resistant organisms. To effectively prevent infections in clinical practice settings, competence through clinical practice and theoretical knowledge in the curriculum is necessary.

Clinical practice is essential in the nursing curriculum. Nursing students must meet patients in the clinical field through clinical practice and cultivate nursing theory and skills. Still, the opportunity to apply nursing techniques directly to subjects has reduced been due to the recent emphasis on human rights and the safety of patients [1]. Nursing students may become carriers for HAIs by directly contacting patients during clinical practice or by risking exposure to infections. In a study by Cho [2], which surveyed the necessity of infection control (IC) education for nursing students, 94.1% of students answered that IC education is necessary. However, not much time is spent on IC education in the nursing curriculum. Additionally, due to safety issues, there is little opportunity to practice the application of IC directly for isolated patients due to infectious diseases. Therefore, Virtual Reality (VR) IC education based on simulation scenarios could be an alternative in this educational environment.

VR simulation is three-dimensional VR implemented based on simulation scenarios [3]. It is used as an adequate education and training method to acquire competencies necessary for practice as a complementary or alternative method to existing mannequin-based simulations [4,5]. VR simulation has the advantage of designing a wide range of scenarios, enabling a high level of interaction and realistic situations [6]. VR and AR (Augmented Reality) technologies are rapidly being applied to medical fields such as medical education, neurorehabilitation therapy, psychotherapy, and telemedicine. These technologies, especially in medical education, attract attention as a cost-effective next-generation education that induces learners’ interest, increases immersion, and ultimately expects to gradually improve the quality of medical care [7]. In a study of Korean nursing students, most of whom are in their 20s, 83.7% of students experienced VR or AR and positively perceived content and education using VR and AR technology [1]. In a systematic review of research using VR for nursing education, some positive results were confirmed for students’ knowledge and performance. Positive results were also confirmed for efficacy in the application of educational intervention programs and nursing education programs. Programs such as these maximize the advantages of VR technology and can be expected to improve the overall quality of nursing by expanding students’ learning opportunities.

It has been reported that traditionally, IC education programs in nursing education in Korea are reported to consist of one-day lectures or 2~3 short lectures of 2~4 hours each [8]. Although this short-term training has an immediate effect on improving knowledge, it is difficult to improve performance skills and confidence related to IC [8]. To improve IC performance, systematic and repetitive training should be provided rather than applying a one-time, short-term training program [8]. In IC-related education, Yu and Mann [9] have developed neonatal IC VR simulations for new nurses and nursing students with limited NICU experience. Additionally, Masson et al. [10] have developed VR education to help medical students learn appropriate behaviors, such as preventing infection at surgical sites or restricting movement in the operating room. These medical students were then compared with students who received education through slides and videos. Despite this, overall research using VR education programs related to IC for students is insufficient. Therefore, this study attempted to evaluate the educational effectiveness and satisfaction after developing an IC scenario and applying the VR-based IC education program developed based on it to nursing students.

METHODS

1. Study Design

This is a one-group pretest-posttest study to evaluate the effectiveness of developing and applying a scenario-based VR-based IC education program based on the ADDIE (Analysis, Design, Development, Implementation, Evaluation) instructional design model (Figure 1).

2. Participants and Data Collection

Data were collected from December 1 to 2, 2021. Among the second-year nursing students attending a university, 86 students understood and voluntarily agreed to the purpose and content of the study. Participants were selected from individuals who had completed IC in fundamental nursing and had no clinical practice experience; based on previous studies [11], the minimum sample size required was 75 people when set to a .3 effect size, .85 power, and .05 significance level in the t-test using the G*Power 3.1.0 program. Considering the dropout rate of 15%, 86 people
were selected. There were, however, no dropouts. To recruit research subjects, the researcher explained the research purpose, period, and participation conditions to potential participants in the classroom. As subjects, the students are categorized as a vulnerable group. Consequently, they were targeted at times when they had no interest, such as when not being evaluated or giving credit to researchers for ethical protection. This study was conducted by receiving written consent along with voluntary participation. In addition, it was explained to the subjects that they could feel cybersickness during VR-based virtual simulation training. The subjects were notified that they could stop participating in the study if nausea or dizziness appeared and would not be disadvantaged.

3. Development of the VR-based IC Program

The VR-based IC education program was developed using the ADDIE instructional design model. In the analysis stage, a literature review and focus group interviews with six nursing professors were conducted to investigate IC education needs. Focus group interviews were conducted once with five nursing students in each group in the sophomore, junior, and senior years to analyze users’ IC education needs. As a result of the focus group interview, both professors and student groups had demands for education on isolation precautions.

In the design stage, based on the content derived from the focus group interview, the application of airborne attention to patients hospitalized with tuberculosis in negative pressure isolation rooms was set as the topic of VR-based IC scenarios. In the development stage, scenarios were developed with topics determined in the design stage, and VR IC contents were developed based on these scenarios (Figures 2, 3). Seven experts were involved in verifying the content validity of the scenario and VR IC contents. This group of experts consisted of three professors of infectious disease, two nursing professors with an IC nurse specialist certification, one IC nurse, and one VR content development expert. In the implementation stage, 37 students (10 nursing and 27 medical students) were applied to the developed VR-based IC education program. In the evaluation stage, students who had experienced the developed VR education program were asked to evaluate the quality of the VR system and information, design, and use of VR content. The researcher then revised the VR content to reflect these evaluations.

4. Application of the VR-based IC Program

The revised final VR-based IC education program was applied to 86 nursing students to identify its effect. Before conducting the research, participants were administered a pre-survey through a questionnaire to measure general characteristics, IC knowledge, IC awareness, IC performance confidence, and self-efficacy in performing IC. The VR-based IC education content was implemented in the VR practice room on campus. Eight sets of VR equipment were set up in the VR practice room, and participants entered in order and participated in the training. The VR-based IC education content lasted 10~15 minutes per student. After VR completion, all participants participated in a post-survey.

5. Study Tools

1) VR device

The head mount display (HMD) Oculus Quest was a VR device in the VR-based IC education program.

2) IC knowledge

IC knowledge was measured using a questionnaire developed by researchers based on healthcare-related standard prevention guidelines [12]. The questionnaire consists of 42 items, covering hand hygiene, personal personal protective equipments (PPEs), respiratory hygiene/cough etiquette, injection safety, linen, environment management, transmission-based isolations, personal hygiene, and
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vaccination. The correct answer was scored 1 point, and incorrect or "I don’t know" responses were scored 0 point. A higher score indicates a higher level of IC knowledge. Content validity was obtained from one professor of infectious disease and four nursing professors with an IC nurse specialist certification and CVI=0.96. The reliability of the IC knowledge tool was the Kuder-Richardson (KR) formula 20=.82.

**Figure 2.** Virtual reality-based infection control education program algorithm.

**Figure 3.** Screenshot of the virtual reality-based infection control education program.
3) IC awareness

IC awareness was measured using a questionnaire developed by researchers based on healthcare-related standard prevention guidelines [12] and the tool by Choi et al. [13]. The questionnaire was developed based on the VR simulation scenario. The questionnaire consists of a total of 43 items and a 5-point Likert scale (1 point is ‘not important at all’ and 5 point is ‘very important’). The IC awareness tool included hand hygiene, respiratory hygiene/cough etiquette, injection safety, linen, environmental management, transmission-based isolations, personal hygiene, and vaccination. A higher score indicates higher IC awareness. Content validity was obtained from one professor of infectious disease and four nursing professors with an IC nurse specialist certification and CVI=0.96. The reliability of the IC awareness tool was Cronbach’s α = .99.

4) IC performance confidence

IC performance confidence was measured using a questionnaire based on the VR content. Researchers developed the questionnaire based on healthcare-related standard prevention guidelines [12] and the tool by Choi et al.[13]. The questionnaire was developed based on the VR content. The questionnaire consists of a total of 43 items, covering hand hygiene, PPEs, respiratory hygiene/cough etiquette, injection safety, linen, environmental management, transmission-based isolations, personal hygiene, and vaccination. The IC performance confidence was a 5-point Likert scale (1 point is ‘I have no confidence at all in performing it’, 5 point is ‘I am always confident in performing it’). A higher score indicates higher performance confidence in performing IC measures. Content validity was obtained from one professor of infectious disease and four nursing professors with an IC nurse specialist certification and CVI=0.96. The reliability of the IC performance confidence tool was Cronbach’s α = .99.

5) Self-efficacy of IC performance

The self-efficacy of IC performance was modified in this study by Jung [14] and Kim [15], who modified and supplemented the self-efficacy tool developed by Sherer et al.[16] for nurses and nursing students, respectively. The questionnaire consists of a total of 22 items and a 5-point Likert scale (1 point is ‘strongly disagree’, 5 point is ‘strongly agree’). A higher score indicates higher self-efficacy of IC performance. CVI=1.00 of the self-efficacy, and Cronbach’s α = .99 of the IC self-efficacy tool.

6) VR IC education satisfaction

The VR IC education satisfaction tool consisted of four questions (overall satisfaction, intention to participate in VR IC education in other topics, recommendation of education to other students, and degree of help in understanding IC) on a five-point Likert scale (1 point is ‘strongly disagree’, 5 point is ’strongly agree’). In this study, the reliability of the educational satisfaction tool was Cronbach’s α = .94.

6. Ethical Consideration

This study was conducted after deliberation by the researcher’s bioethics committee (IRB No. CBNU-202110-HR-0174). The participation of the subjects was voluntary. There was no disadvantage to not participating in the study, and written consent was provided. The study was conducted after fully explaining that participation could be withdrawn at any time when subjects no longer wanted to participate.

7. Analysis

The data collected were analyzed using the SPSS WIN 18.0 program (IBM Corp., NY, USA). According to the Kolmogorov-Smirnov test, the main variables were normally distributed. The general characteristics of the subjects were analyzed as numbers and percentages. Differences in IC knowledge, perception, performance confidence, and self-efficacy before and after IC education were analyzed by both mean and standard deviation and paired t-tests. In addition, VR IC education satisfaction was analyzed by mean and standard deviation.

RESULTS

1. Characteristics of the Subjects

The subjects were 86 nursing students. Sixty-three were women (73.3%) and twenty-three (26.7%) were men in the second year of the nursing department.

2. Differences in IC knowledge before and after VR-based IC Education

IC knowledge was 0.76±0.19 points before VR-based IC education and 0.78±0.11 points after training, but the difference between before and after education was not statistically significant (t=1.07, p=.288). Regarding differences in knowledge by items, injection safety (t=2.50, p=.015)
and waste management (t=2.23, p=.029) were significantly higher after education. Standard precaution, hand hygiene, donning and doffing PPEs, aseptic technique, and environmental management were not statistically significant (Table 1).

3. Differences in IC awareness before and after VR-based IC Education

According to the difference in IC awareness before and after VR-based IC education, the level of perception after education was significantly higher, with 4.66±0.93 points before education but 4.91±0.31 points after education (t=2.31, p=.023). According to the difference in awareness before and after education by items, there were statistically significant differences in respiratory/cough etiquette (t=2.31, p=.029), linens and environment management (t=2.44, p=.017), transmission-based precaution (t=2.35, p=.021), personal hygiene (t=2.91, p=.005), and vaccination (t=2.20, p=.031). However, there were no statistically significant differences in hand hygiene, donning and doffing PPEs, and injection safety (Table 1).

4. Difference in IC Performance Confidence before and after VR-based IC Education

Scores on IC performance confidence were significantly higher after VR-based IC education than before training, with 4.62±0.86 points before and 4.84±0.44 points after training (t=2.19, p=.031). According to the difference in performance confidence by items, there was a statistically significant difference in hand hygiene (t=2.10, p=.039), linens and environment management (t=2.49, p=.015), transmission-based precaution (t=2.05, p=.043), and personal hygiene (t=3.14, p=.002). However, there were no differences in donning and doffing PPEs, respiratory/cough etiquette, injection safety, and vaccination (Table 1).

5. Differences in Self-efficacy of IC Performance before and after VR-based IC Education

<table>
<thead>
<tr>
<th>Variables</th>
<th>Before education</th>
<th>After education</th>
<th>t (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge of infection control</td>
<td>0.76±0.19</td>
<td>0.78±0.11</td>
<td>1.07 (.288)</td>
</tr>
<tr>
<td>Standard precautions</td>
<td>0.79±0.25</td>
<td>0.85±0.17</td>
<td>1.71 (.091)</td>
</tr>
<tr>
<td>Hand hygiene</td>
<td>0.73±0.26</td>
<td>0.77±0.25</td>
<td>1.09 (.281)</td>
</tr>
<tr>
<td>Donning &amp; doffing PPEs</td>
<td>0.79±0.20</td>
<td>0.75±0.14</td>
<td>-1.47 (.146)</td>
</tr>
<tr>
<td>Injection safety</td>
<td>0.81±0.23</td>
<td>0.87±0.14</td>
<td>2.50 (.015)</td>
</tr>
<tr>
<td>Aseptic technique</td>
<td>0.81±0.27</td>
<td>0.81±0.24</td>
<td>0.00 (.100)</td>
</tr>
<tr>
<td>Environmental management</td>
<td>0.60±0.37</td>
<td>0.66±0.37</td>
<td>1.37 (.175)</td>
</tr>
<tr>
<td>Waste management</td>
<td>0.49±0.22</td>
<td>0.55±0.21</td>
<td>2.23 (.029)</td>
</tr>
<tr>
<td>Awareness of infection control</td>
<td>4.66±0.93</td>
<td>4.91±0.31</td>
<td>2.31 (.023)</td>
</tr>
<tr>
<td>Hand hygiene</td>
<td>4.67±0.94</td>
<td>4.88±0.36</td>
<td>1.98 (.051)</td>
</tr>
<tr>
<td>Donning &amp; doffing PPE*</td>
<td>4.70±0.94</td>
<td>4.91±0.34</td>
<td>1.94 (.055)</td>
</tr>
<tr>
<td>Respiratory/cough etiquette</td>
<td>4.66±0.94</td>
<td>4.90±0.35</td>
<td>2.50 (.024)</td>
</tr>
<tr>
<td>Injection safety</td>
<td>4.67±0.95</td>
<td>4.88±0.37</td>
<td>1.91 (.060)</td>
</tr>
<tr>
<td>Linens and environment management</td>
<td>4.62±0.97</td>
<td>4.90±0.36</td>
<td>2.44 (.017)</td>
</tr>
<tr>
<td>Transmission-based precautions</td>
<td>4.67±0.95</td>
<td>4.92±0.29</td>
<td>2.35 (.021)</td>
</tr>
<tr>
<td>Personal hygiene</td>
<td>4.57±0.97</td>
<td>4.90±0.32</td>
<td>2.91 (.005)</td>
</tr>
<tr>
<td>Vaccination</td>
<td>4.70±0.95</td>
<td>4.94±0.28</td>
<td>2.20 (.031)</td>
</tr>
<tr>
<td>Confidence in the practice of infection control</td>
<td>4.62±0.86</td>
<td>4.84±0.44</td>
<td>2.19 (.031)</td>
</tr>
<tr>
<td>Hand hygiene</td>
<td>4.63±0.88</td>
<td>4.85±0.45</td>
<td>2.10 (.039)</td>
</tr>
<tr>
<td>Donning &amp; doffing PPE</td>
<td>4.68±0.87</td>
<td>4.85±0.44</td>
<td>1.63 (.107)</td>
</tr>
<tr>
<td>Respiratory/cough etiquette</td>
<td>4.65±0.87</td>
<td>4.85±0.46</td>
<td>1.95 (.054)</td>
</tr>
<tr>
<td>Injection safety</td>
<td>4.67±0.89</td>
<td>4.85±0.44</td>
<td>1.67 (.098)</td>
</tr>
<tr>
<td>Linens and environment management</td>
<td>4.57±0.90</td>
<td>4.84±0.45</td>
<td>2.49 (.015)</td>
</tr>
<tr>
<td>Transmission-based precautions</td>
<td>4.60±0.88</td>
<td>4.81±0.47</td>
<td>2.05 (.043)</td>
</tr>
<tr>
<td>Personal hygiene</td>
<td>4.50±0.94</td>
<td>4.84±0.44</td>
<td>3.14 (.002)</td>
</tr>
<tr>
<td>Vaccination</td>
<td>4.67±0.90</td>
<td>4.86±0.45</td>
<td>1.89 (.062)</td>
</tr>
</tbody>
</table>

Self-efficacy                                      4.38±0.97       4.73±0.49       3.43 (.001)

PPEs=Personal protective equipments.
Differences in self-efficacy of performing IC before and after VR-based IC education were significantly higher from 4.38±0.97 points before education to 4.73±0.49 points after education (t=3.43, p=.001) (Table 1).

6. VR-based IC Education Satisfaction

The overall satisfaction with VR-based IC education was 4.71±0.59 points (94.2 points for 100 points), and the items that VR-based IC education was more helpful in understanding IC than the other education methods (e.g., lectures, practice) were 4.66±0.64 points (93.2 points for 100 points). The intention to participate in VR-based IC education on other topics in the future was 4.66±0.63 points (93.2 points for 100 points), and the intention to recommend VR-based IC education to other students was 4.70±0.63 points (94.0 points for 100 points) (Table 2).

<table>
<thead>
<tr>
<th>Items</th>
<th>M±SD</th>
<th>Convert to 100 points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Overall satisfaction with VR IC education</td>
<td>4.71±0.59</td>
<td>94.2</td>
</tr>
<tr>
<td>2. VR-based IC education is more helpful for understanding IC than other education methods (e.g., lecture, practice, etc.)</td>
<td>4.66±0.64</td>
<td>93.2</td>
</tr>
<tr>
<td>3. Intention to recommend VR-based IC education to other students</td>
<td>4.70±0.63</td>
<td>94.0</td>
</tr>
<tr>
<td>4. Intention to participate in VR-based IC education on other topics in the future</td>
<td>4.66±0.63</td>
<td>93.2</td>
</tr>
<tr>
<td>Total mean</td>
<td>4.68±0.57</td>
<td>93.6</td>
</tr>
</tbody>
</table>

VR=virtual reality; IC=infection control.

DISCUSSION

Nursing students who stay in medical institutions for a long time for clinical practice participate directly or indirectly in patient care. Therefore, they need the proper ability to perform IC to prevent the spread of HAIs. Nursing students acquire knowledge and skills in IC before clinical practice through the curriculum, but most of the education is conducted through theoretical lectures or lab practice. Hence, there is relatively little reality of the clinical field. In order to solve these limitations of education, VR-based IC education using a virtual environment similar to a medical institution has been partially attempted for medical students and nursing students [9,10]. For example, Yu and Mann [9] developed a VR-based IC education program for neonatal IC for nursing students, and Masson et al. [10] developed a VR program for preventing infection at the surgical site for medical students. This study [10] evaluated the effectiveness of VR education programs and education for medical students.

In this study, the knowledge of IC increased after VR-based IC education. However, the difference in knowledge before and after education was not statistically significant. In previous studies on the effectiveness of VR simulation education, there were different reports, such as VR simulation education being effective in enhancing knowledge [17] or that it is not [18,19]. The reason why there was no difference between before and after education in this study is believed to be because the educational program consists of performance-oriented content that is experienced in VR rather than through knowledge acquisition. In addition, standard precaution, hand hygiene, donning and doffing PPEs, and aseptic techniques were learned in fundamental nursing. Hence, there was no statistically significant difference between before and after education because the subjects already had prior knowledge before VR-based IC education, and injection safety was focused on learning by participating in this VR education.

The awareness of IC among nursing students who participated in this study was “relatively high” even before VR IC education. However, it increased significantly after VR simulation education and then rose to a “very high level.” This is consistent with the results of previous studies [20] that VR simulation education positively affects perception change. As such, it was found that VR simulation education positively affected the change in perception of IC, so it is necessary to develop and operate VR simulation-based education programs in various healthcare majors.

In a prior study of nursing students and nurses [21-23], VR IC education improved performance confidence and self-efficacy. Confidence in performing IC significantly increased in the experimental group through VR-based education on high-risk newborn care [24]. In addition, in VR-based training for nursing students related to PPEs for pe-
diabetic isolation patients with COVID-19, IC performance and self-efficacy for personal protective equipment in the experimental group were statistically significantly increased compared to the control group [25]. In this study, as in previous studies, VR simulation IC education increased students’ performance confidence and self-efficacy. In particular, the confidence in performance was high, focusing on the educational contents learned in in-school practice, such as hand hygiene and personal hygiene. It can be interpreted that repeated learning through VR-based IC education, similar to the clinical environment, strengthened performance confidence and self-efficacy. Confidence and self-efficacy in performing IC are acquired not only by simple knowledge but also by directly carrying out IC practice. In order to improve IC performance, systematic and repetitive training should be provided rather than applying a one-time, short-term training program [8]. VR-based education can be viewed as an effective educational method for acquiring practical IC capabilities that are difficult to experience in clinical practice because it allows hands-on experience representing actual clinical settings [26]. Therefore, even if it is covered in the curriculum, it is necessary to increase the self-efficacy and performance confidence that students believe can solve IC problems through repeated education using VR simulations similar to clinical practice environments.

Satisfaction with VR IC education in this study was high at 94.2 points, and satisfaction was high in a previous study [27], as it was in this study. In particular, the subjects who participated in this study showed positive intentions not only to participate in VR-based IC education on other topics in the future but also to recommend this education to other students. In addition, nursing students suggested that VR-based IC education is fun and helpful for understanding clinical practice. This is believed to be because students felt the educational content was lively and friendly. After all, education is conducted through a realistic virtual working environment, which is the advantage of VR-based IC education. However, disadvantages such as difficulty in operation or motion sickness due to unfamiliar equipment are considered challenges to overcome through continuous technology development and repeated education.

**CONCLUSION**

This study found that IC education using VR is efficacious in improving awareness, performance confidence, and self-efficacy when it is difficult to experience infected patient care in a limited clinical practice environment. Therefore, efforts are needed to improve nursing students’ IC capabilities by developing and applying various VR-based education content.

**CONFLICTS OF INTEREST**

The authors declared no conflict of interest.

**AUTHORSHIP**

Study conception and design acquisition - Choi JH, Kim TH and Kim KM; Data collection - Cha KS; Data analysis & Interpretation - Cha KS and Kim KM; Drafting & Revision of the manuscript - Cha KS and Kim KM.

**DATA AVAILABILITY**

Please contact the corresponding author for data availability.

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