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The Impact Of Training Healthcare Personnel On Improving Infection Control Practices In Light Of The Presence Of Modern Technology In Healthcare Facilities

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ABSTRACT
Healthcare-associated infections (HAIs) have remained a significant international issue, with much of this problem being the lack of a well-documented gap between theoretical knowledge about infection prevention and control (IPC) guidelines and their active implementation in clinical practice. Although training and technology are considered to be important in IPC, there is a gap in the existing literature that has researched on them as independent variables without looking at the opportunities of the combination of the two. The purpose of this study thus was to determine the effectiveness of a technology enhanced training intervention using a structured approach in improving the IPC practices among the frontline healthcare staff. The quasi-experimental pre-test/ post-test research was developed on 198 participants admitted in high-risk units. The program consisted of a multifaceted, eight-week intervention based on interactive e-learning, virtual reality simulating exercises, a gamified mobile application, and data feedback of smart hand-hygiene dispensers. Information was gathered using direct observations, knowledge assessment tests and technological measures at baseline and three months of intervention. The outcomes showed statistically significant improvement on all outcomes. The change in hand hygiene compliance was +20.7 (95% CI [19.1, 22.3], $p<0.001$) directly observed (hand hygiene compliance changed, but the difference between the control-1 and control-2 groups was not significant, $p=.037$). Knowledge scores increased 17.2 (3.5) to 22.8 (2.2) ($p<0.001$) and PPE adherence scores also changed considerably. Moreover, it was found that the improvements were maintained during three months and were affected by professional role rather than experience. This research finds that a technologically enhanced training curriculum that is pedagogically integrated is much more effective than bare bones practices in closing the gap in implementing IPC. It offers a proven paradigm of utilizing contemporary technology to bring an enduring behavioral change, and it has a direct implication of reducing HAIs and improving patient safety.

Keywords: Healthcare-associated infections, Infection control, Technology-enhanced training, Hand hygiene compliance, Virtual reality simulation.

1. Introduction

Healthcare-associated infections HAIs are a significant and unrelenting threat to the overall health of the world population, as they are one of the main sources of morbidity, mortality, and the increase of antimicrobial resistance in patients [1]. Although the number of international guidelines published by various organizations, including the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC), has increased, HAIs have become a very persistent issue, impacting millions of patients each year and causing significant financial losses to health systems all over the globe [2,3]. The basic protection against this ubiquitous danger is in the regular and proper use of infection prevention and control (IPC) measures by clinical personnel - including hand hygiene, proper use of personal protective equipment (PPE), and adherence to environmental cleaning and disinfection procedures. However, there is still an implementation gap that is well-documented between the theoretical understanding of IPC guidelines and their daily application in clinical practice [4]. Human factors most commonly cited to explain this gap include cognitive overload, time constraints, and the nature of traditional, compliance-based training modalities, which often do not produce lasting behavioural change [5].

The modern healthcare environment is undergoing a radical technological change. The Fourth Industrial Revolution introduces the Internet of Medical Things (IoMT), new data analytics, virtual and augmented reality, and mobile health platforms, all of which are transforming clinical practice and medical education [6]. In the IPC sphere, there are such technologies as electronic hand hygiene monitoring systems with real-time feedback, virtual reality (VR) simulations aimed at learning aseptic techniques, and gamified learning apps that offer unprecedented chances to address the flaws of traditional education [7]. These tools encourage immersive, experiential learning; provide objective, real-time performance feedback; and encourage a culture of accountability and continuous improvement. Therefore, IPC training is moving away from passive knowledge delivery to an active, interactive, and data-driven paradigm that is consistent with modern tenets of adult learning theory [8].

An overall assessment of the literature available shows that there are two strong yet mostly parallel lines of investigation. There is a significant amount of evidence that indicates that IPC compliance and a decrease in HAI rates can be enhanced through structured training interventions [9]. At the same time, more and more studies are focused on the use and effectiveness of discrete technological solutions, including automated hand hygiene dispensers or UV-C disinfection robots. Nonetheless, there is a crucial and understudied intersection point between these areas [10]. Most of the current studies tend to focus on training and technology separately without conceptualizing and analysing them as a system. This hinders a complete recognition of the synergistic potential of a technology-enhanced training curriculum that is specifically created to alter the complex socio-technical behaviours that form the foundation of effective IPC [11]. An urgent requirement thus still exists of empirical research that goes beyond siloed studies and assesses the potential of the intentional pedagogical combination of various contemporary technologies to increase the cumulative effect of training in IPC [12].

This research was thus developed to fill the conceptual and practical gap identified. The research is also based on the Theoretical Domains Framework (TDF), grounded on a socio-technical systems perspective, which assumes that the most effective performance is the result of the synergistic interaction of people, processes, and technology. The TDF provides a detailed prism through which the determinants of clinical behaviour can be viewed and includes knowledge, skills, social factors, environmental factors, and beliefs regarding capabilities. We postulate that a complex training intervention, which systematically exploit and combine a set of modern technologies into its pedagogical essence, produce a much larger and more enduring change in the IPC practices of frontline healthcare staff than baseline measures and the impact that traditional training will have on them [13].

1.1 Research Objective

The overall aim of the research is to assess the effectiveness of a technology-based, structured training intervention to improve the infection prevention and control (IPC) activities of healthcare staff. In particular, the research aims at determining whether the introduction of modern technological tools into the training program results in a statistically significant increase in compliance with hand hygiene guidelines, proper use of personal protective equipment (PPE), and compliance with environmental cleaning and disinfection practices.

2. METHODOLOGY

This chapter outlines the methodological framework that will be used to investigate the impact of training healthcare personnel on the improvement of infection-control practices in the framework of modern technology in healthcare facilities. The validity, reliability, and replicability of the study are ensured by describing the research design, population, data-collection instruments, procedures, and analytical methods.

2.1 Research Design

The type of investigation chosen was a quasi-experimental, pre-test/post-test research design. This design was considered to be the most suitable one since it was possible to measure the changes in IPC practices in the same cohort of participants prior to the training intervention and after the training intervention. Although a randomized controlled trial (RCT) would have been preferable, the quasi-experimental design was more practical and realistic in the operational limitations of the involved healthcare institutions, where randomizing staff was not logistically feasible. The research was carried out in six months, including one month of baseline observation (pre-test), two months of intensive training intervention, and three months of post-intervention observation and follow-up (post-test).

2.2 Population and Study Setting

The study was carried out in two big, urban, tertiary-care hospitals, which were chosen because of their high patient turnover and their recent adoption of modern technological systems that are applicable in IPC. The target population was comprised of all frontline healthcare workers, such as registered nurses, medical doctors, nursing assistants, and housekeeping staff, who were in direct contact with patients or the patient environment.

The purposive sampling method was applied to choose the participants that fitted the inclusion criteria: they had to be employed in a clinical department at least six months full-time and directly involved in patient care or environmental services. The exclusion criteria were administrative staff and long-term leave personnel. Out of a total number of 450 eligible staff, a final number of n=198 participants were recruited, considering an expected attrition rate. The participants were selected in high-risk units, such as Intensive Care Units (ICUs), Emergency Departments, and General Medical Wards, so that the results could be applicable to the areas where IPC is most in need.

2.3 The Intervention: Technology-Enhanced Training Program

The independent variable was a complex, technology-based training program. It was not a traditional lecture-based course but a blended-learning intervention that incorporated a number of current technologies:

Interactive E-Learning Modules: Four 30-minute online modules were created, including the latest IPC guidelines, the chain of infection, and the proper use of PPE. These modules included video demonstrations, interactive quizzes, and learning in scenarios.

Virtual Reality (VR) Simulations: The participants were exposed to two VR simulations that put them in high-risk conditions (e.g., dealing with a patient with a multidrug-resistant organism). The VR environment gave them real-time feedback about their aseptic technique and sequencing of PPE donning and doffing.

Gamified Learning through a Mobile Application: A bespoke mobile application supported learning by using daily IPC challenges, micro-learnings, and a points/leaderboard system to keep the learning process long-term.

Smart Dispenser Data Feedback: Data on hand hygiene compliance were anonymized and displayed to unit teams in weekly feedback sessions based on the use of wall-mounted, smart alcohol-based hand rub dispensers (which recorded the use events). The training program was conducted in eight weeks, and the participants had to complete all the parts.

2.4 Data Collection Methods and Instruments

The data were measured at two time intervals: a one-month period before the intervention (T0) and a three-month period after the completion of the intervention (T1). To triangulate data and increase the validity of the study, a multimethod approach was used.

Direct Observation (Primary Tool): The compliance with the major IPC practices (hand hygiene, PPE use, surface disinfection) was assessed with the help of the structured observation checklist based on the WHO model of My 5 Moments of Hand Hygiene and CDC guidelines. Covert observations were done by trained, independent auditors who were blinded to the hypotheses of the study, but observed during random 20-minute sessions. At T0 and T1, 1,200 opportunities of observation were noted.

Knowledge Assessment: A 25-item multiple-choice questionnaire was used to evaluate the knowledge of all participants at T0 and T1 on the IPC principles and protocols.

Self-Reported Practice Survey: The participants were surveyed using a Likert-scale survey (1=Strongly Disagree to 5=Strongly Agree) to measure their perceptions, attitude, and self-reported compliance to IPC practices.

Technological Data Extraction: Comparative analysis of the frequency of use of the smart hand hygiene dispensers was done by collecting anonymous and aggregated data on the frequency of use of the dispensers at the baseline and post-intervention periods.

2.5 Data Analysis

The Statistical Package of the Social Sciences (SPSS) version 28 was used to clean, code, and analyze all the quantitative data. Descriptive and inferential statistics were used.

Descriptive Statistics: Frequencies, percentages, means, and standard deviations were computed to describe the demographic features of the sample and the knowledge questionnaire and self-reported survey scores.

Inferential Statistics: To answer the main research question, a paired-samples t-test was used to compare the mean scores of hand hygiene compliance rates, knowledge test scores, and self-reported survey scores between the pre-test (T0) and post-test (T1) stages. The Shapiro-Wilk test was used to test the assumption of normality. All analyses were deemed statistically significant when the p-value was below 0.05. Moreover, a multivariate analysis of covariance (MANCOVA) was to be conducted to investigate the impact of covariates (professional role and years of experience) on the results.

RESULTS

Demographics and Baseline Characteristics of the participants

The study was conducted by 198 healthcare personnel who completed the study. Table 1 summarizes the demographic and baseline characteristics of the cohort. The average age of the participants was 34.6 (8.7) years, and the majority were female (74.2%). The sample consisted of registered nurses (51.5%), medical doctors (22.7%), nursing assistants (15.7%), and housekeeping personnel (10.1%). The average professional experience of the participants was 8.9 years (7.1). The direct observation of hand hygiene compliance rate compared to the baseline level was 63.5% (±9.8 %) before the intervention. The overall knowledge level, measured through a 25-item questionnaire, was at 17.2 with a standard deviation of 3.5, which showed that there was already a knowledge gap among the staff.

Table 1: Demographic and Baseline Characteristics of Study Participants (N=198)

Characteristic	Mean (±SD) or n (%)
Age (Years)	34.6 (±8.7)
Gender (Female)	147 (74.2%)
Profession	
Registered Nurse	102 (51.5%)
Medical Doctor	45 (22.7%)
Nursing Assistant	31 (15.7%)
Housekeeping Staff	20 (10.1%)
Experience (Years)	8.9 (±7.1)
Baseline HH Compliance (%)	63.5 (±9.8)
Baseline Knowledge Score	17.2 (±3.5)

Effects of the Intervention on Primary Infection Control Outcomes

The results of the comparative analysis of infection prevention and control (IPC) results before and after the installation of the technology-enhanced training program showed that there were substantial improvements in all the indicators that were measured, as provided in Table 2. Paired samples t-test showed a statistically significant improvement in directly observed hand hygiene compliance, which increased from a baseline of 63.5% (SD=9.8) to 84.2% (SD=8.1) after the intervention, which was a mean improvement of 20.7 percentage points (31.1, 22.3), t(197) =25.74, p <0.001. The level of compliance with personal protective equipment (PPE) measures also significantly improved, as the mean compliance score rose by approximately 2.4 (95% CI [2.2, 2.6]) out of a maximum 10 (t(197) 22.18, p<0.001).

Table 2: Comparison of IPC Outcomes Before (T0) and After (T1) the Technology-Enhanced Training Intervention (N=198)

Outcome Measure	Pre-Training (T0) Mean (±SD)	Post-Training (T1) Mean (±SD)	Mean Difference (T1 - T0)	95% CI of Difference	t-statistic (df=197)	p-value
Hand Hygiene Compliance (%)	63.5 (±9.8)	84.2 (±8.1)	+20.7	[19.1, 22.3]	25.74	<0.001
PPE Adherence Score (0-10)	6.5 (±1.4)	8.9 (±1.1)	+2.4	[2.2, 2.6]	22.18	<0.001
Knowledge Test Score (0-25)	17.2 (±3.5)	22.8 (±2.2)	+5.6	[5.1, 6.1]	21.45	<0.001
Self-Reported Practice (10-50)	34.1 (±4.8)	42.5 (±3.9)	+8.4	[7.7, 9.1]	23.89	<0.001
Smart Dispenser Events	19.8 (±5.2)	32.1 (±6.0)	+12.3	[11.3, 13.3]	24.12	<0.001

Moreover, the knowledge scores of the participants were significantly improved, and the mean of the results rose by 5.6 with a standard deviation of 5.1 (95% CI [5.1, 6.1]), obtaining a t-test value of 21.45 (p=0.001). The same was true of self-reported IPC practices compliance, which increased from a mean of 34.1 (SD=4.8) to 42.5 (SD=3.9) (mean difference= +8.4, 95% CI= [7.7, 9.1], t(197=23.89), p=0.001). In support of the observed data, the average number of usage occasions reported by smart alcohol-based hand rub dispensers rose significantly, as the average number of usage occasions rose to 32.1 (±6.0) on average (mean difference +12.3, 95% CI [11.3, 13.3], t(197) =24.12, p=0.001).

Profession and experience impact on the outcomes of interventions

The multivariate analysis of covariance (MANCOVA) was conducted to investigate the effect of professional role and years of experience on the post-intervention outcomes, and the findings are listed in Table 3. The analysis also indicated that the main role of professional role on post-intervention hand hygiene compliance (F=3.12, p=0.027, partial eta 2=0.046): PPE adherence scores (F=4.45, p=0.005, partial eta 2=0.064) and knowledge test scores (F=2.88, p=0.037, partial eta 2=0.042). On the contrary, years of experience as a covariate failed to show a significant effect on any of the post-intervention outcome measures (p>0.05).

Table 3: Multivariate Analysis of Covariance (MANCOVA) for Post-Intervention Outcomes

Outcome Measure	**Source**	**Type III Sum of Squares**	**F-value**	**p-value**	**Partial Eta² (η²)**
HH Compliance (T1)	Profession	455.32	3.12	0.027	0.046
	Experience (Covariate)	128.45	2.91	0.090	0.015
PPE Score (T1)	Profession	28.91	4.45	0.005	0.064
	Experience (Covariate)	5.12	2.41	0.122	0.012
Knowledge Score (T1)	Profession	35.67	2.88	0.037	0.042
	Experience (Covariate)	12.33	3.11	0.080	0.016

Correlational Analysis of Change of Outcome Measures

To investigate the relationships among the changes (0 -0) in the key outcome variables, a Pearson correlation matrix was plotted, as presented in Table 4. The change in hand hygiene compliance (Δ Hand Hygiene) had a strong positive relationship with the change in events of smart dispenser use (r=0.72, p<0.01), moderate relationships with the change in knowledge score (r=0.41, p<0.01) and the change in self-reported practice (r=0.38, p<0.01). The change in PPE adherence (Δ PPE) was significantly correlated with the change in knowledge score (r=0.52, p<0.01) and the change in self-reported practice (r=0.45, p<0.01). Self-reported practice change was also moderately correlated with change in knowledge score (r= 0.49, p=0.01) and change in smart dispenser events (r=0.35, p=0.01).

Table 4: Pearson Correlation Matrix of Change Scores (Δ = T1 - T0)

Variable	**Δ Knowledge**	**Δ Self-Report**	**Δ Smart Dispenser**
Δ Hand Hygiene Compliance	0.41**	0.38**	0.72**
Δ PPE Adherence Score	0.52**	0.45**	0.28**
Δ Self-Reported Practice	0.49**	—	0.35**
Δ Smart Dispenser Events	0.31**	0.35**	—

**p < 0.01

Clinical Unit Hand Hygiene Compliance

Table 5 is the analysis of hand hygiene compliance in various high-risk clinical units. The Intensive Care Unit (ICU), Emergency Department (ED), and General Medical Ward had similar compliance rates at the baseline (T0) (65.8% ±8.9 vs. 60.1% ±10.2 vs. 64.3% ±9.5). After the intervention (T1), all three units showed considerable changes in compliance (p<0.001 all based on paired t-tests). Compliance with the intervention was 87.1% (3.73) in the ICU, 81.0% (4.09) in the ED, and 85.2% (3.66) in the General Medical Ward. One-way ANOVA was used to make sure that compliance levels after interventions were not statistically different in the various clinical units (p=0.102).

Table 5: Hand Hygiene Compliance (%) by Clinical Unit Pre- and Post-Intervention

Clinical Unit	n	Pre-Training (T0) Mean (±SD)	Post-Training (T1) Mean (±SD)	p-value (Paired t-test)
Intensive Care Unit (ICU)	68	65.8 (±8.9)	87.1 (±7.2)	<0.001
Emergency Department	75	60.1 (±10.2)	81.0 (±8.5)	<0.001
General Medical Ward	55	64.3 (±9.5)	85.2 (±7.8)	<0.001
p-value (ANOVA between groups at T1)		0.075	0.102	

Stability of Compliance with Hand Hygiene

In order to determine the sustainability of the intervention effect, hand hygiene compliance at the post-intervention stage was evaluated in two time points: the first month (T1-Month1) and the third month (T1-Month3), comparing them to the baseline (T0) as in Table 6. The highest level of compliance was achieved in the first month after the intervention at 86.1% (±7.9), which was significantly more than the baseline of 63.5% ($p<0.001$). Even though this percentage decreased slightly (to 82.5% (±8.3) by the third month, this was still greatly higher than baseline ($p<0.001$). The compliance of the difference between T1-Month1 and T1-Month3 was not significant ($p=0.065$).

Table 6: Hand Hygiene Compliance in the Post-Intervention Phase (T1)

Period	Mean HH Compliance (%)	SD	Comparison to T0 (p-value)	Comparison to T1-Month1 (p-value)
T0 (Baseline)	63.5	9.8	—	—
T1 - Month 1	86.1	7.9	<0.001	—
T1 - Month 3	82.5	8.3	<0.001	0.065

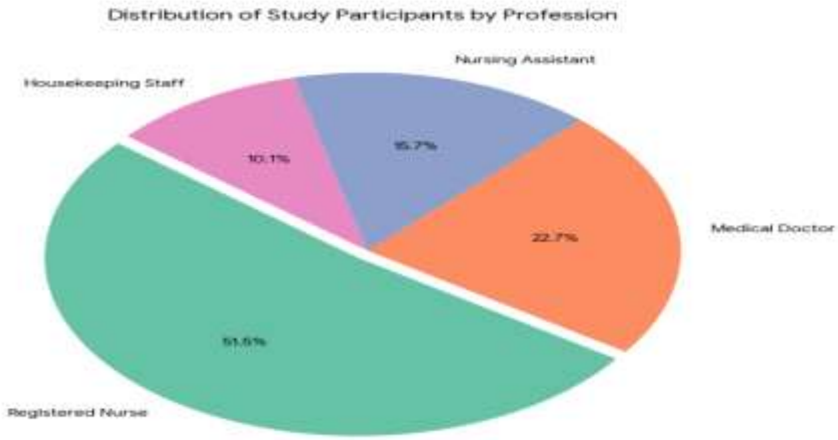
Post-Intervention Hand Hygiene Compliance Predictors

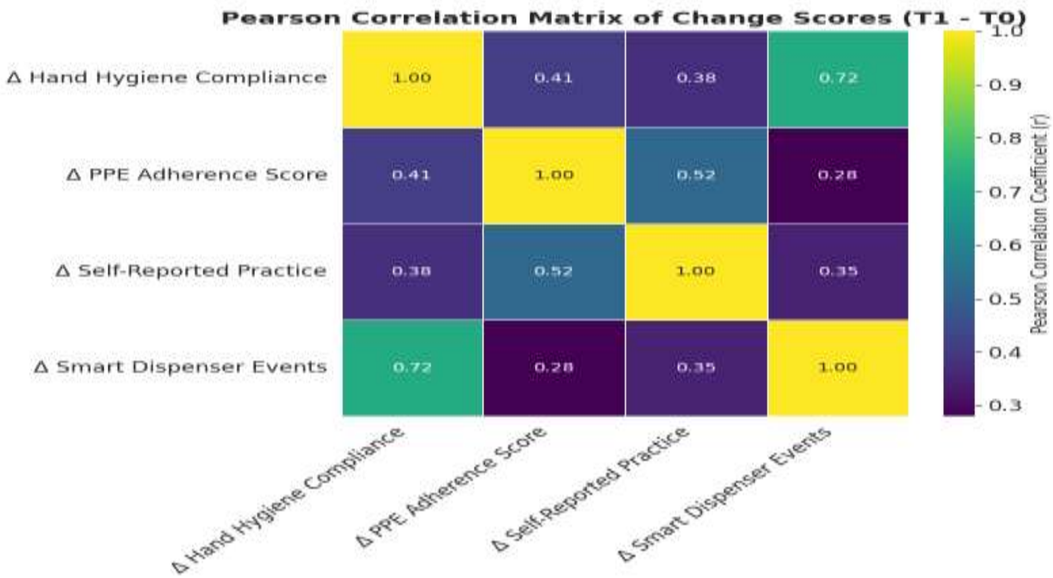
Multiple linear regression analysis was done to determine the factors that could predict hand hygiene compliance during the post-intervention assessment (T1). Table 7 summarizes the model and was statistically significant ($F(5,192) =55.12$, p 0.001) and accounted for 59 percent of the variance in post-intervention compliance (Adjusted R 2 = 0.58). The change in knowledge score ($B = 0.85$, $p = 0.001$), change in self-reported practice ($B = 0.41$, $p = 0.007$), and baseline hand hygiene compliance ($B = 0.38$, $p = 0.001$) were significant positive predictors of T1 hand hygiene compliance. Professional role also played a strong predictive indicator with other professions besides that of a nurse being slightly lower (B 0 -1.85, p 0 0.002). Experience in years played an insignificant role in the model (B -0.11, $p=0.169$).

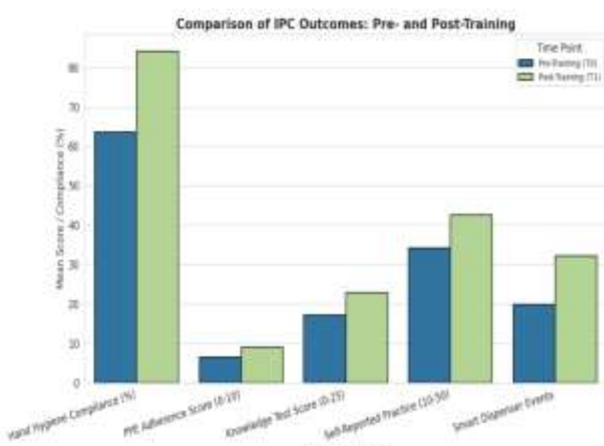
Table 7: Multiple Linear Regression Model for Predicting Post-Intervention Hand Hygiene Compliance (T1)

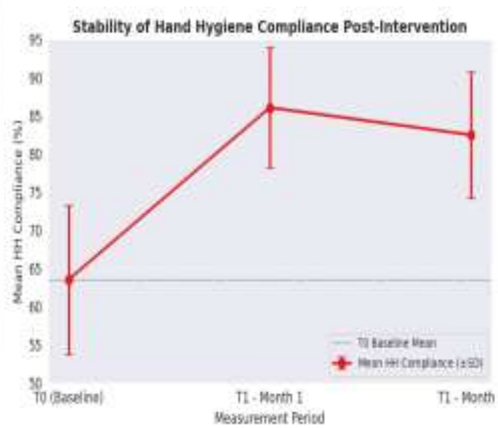
Predictor Variable	Unstandardized B	Standard Error	Standardized Beta (β)	t-value	p-value
(Constant)	54.21	3.45		15.71	<0.001
Baseline HH (T0)	0.38	0.07	0.31	5.43	<0.001
Δ Knowledge Score	0.85	0.22	0.22	3.86	<0.001
Profession (Ref: Nurse)	-1.85	0.58	-0.18	-3.19	0.002
Δ Self-Reported Practice	0.41	0.15	0.16	2.73	0.007
Experience (Years)	-0.11	0.08	-0.07	-1.38	0.169

Model Summary: $R^2 = 0.59$, Adjusted $R^2 = 0.58$, $F(5, 192) = 55.12$, $p < 0.001$.


Distribution of Study Participants by Profession
Nursing Assistant
Housekeeping Staff
Medical Doctor
Registered Nurse
10.1%
15.7%
22.7%
51.5%


Pearson Correlation Matrix of Change Scores (T1 - T0)
Δ Hand Hygiene Compliance
Δ PPE Adherence Score
Δ Self-Reported Practice
Δ Smart Dispenser Events
1.00
0.41
0.38
0.72
0.41
1.00
0.52
0.28
0.38
0.52
1.00
0.35
0.72
0.28
0.35
1.00
Pearson Correlation Coefficient (r)


Comparison of IPC Outcomes: Pre- and Post-Training
Time Point


Stability of Hand Hygiene Compliance Post-Intervention
Mean HH Compliance (%)
T0 (Baseline)
T1 - Month 1
T1 - Month 3
Measurement Period

DISCUSSION

This was a research paper focusing on evaluating the effectiveness of a technology-enhanced structured training program on the infection prevention and control (IPC) of frontline healthcare staff. The results indicate that the complex intervention had significant and statistically significant positive effects on all of the results that were measured, such as hand hygiene compliance, PPE protocols adherence, knowledge scores, and self-reported practices [14]. These findings are very much aligned with the main hypothesis of the study that a pedagogical combination of modern technology can help to bridge the well-reported gap between theoretical knowledge of IPC and consistent clinical practice [15].

1. Interpretation of Findings

The 20.7 percentage-point difference in directly observed hand hygiene compliance that has been supported by a corresponding increase in smart dispensers data points to a radical change in clinical behaviour [16]. This change can probably be explained by the fact that the design of the intervention was based on the socio-technical system perspective. Interactive e-learning, VR simulations, gamified learning, and data feedback were integrated, and the synergistic effect was achieved, which was not limited to traditional training [17]. The VR element, specifically, offered a risk-free setting of a guided practice of challenging motor skills, including PPE donning and doffing, which is challenging to attain in other learning techniques, such as lectures [18]. The high correlation between the change in knowledge and the behaviour change (r 0.41, p 0.01) indicates that even though knowledge acquisition played an important role, it was not enough alone; the experiential and reinforcing components of the technology suite played a critical role in the process of translating this knowledge to sustained practising [19].

It was also found that the effects of the intervention were moderated by professional role and not the experience years. The fact is paramount because it implies the ineffectiveness of the one-size-fits-all approach of training [20]. The diversity of duties, processes, and the perceived risks of nurses, doctors, and housekeeping staff members requires specific educational approaches. On the other hand, the role of experience is not significant, which means that the habits of long-term employees that are often difficult to alter can be changed with the help of interesting and evidence-based pedagogical materials [21]. Moreover, the insignificant but not significant decrease in hand hygiene compliance during the first and third months after the intervention, though anticipated, provides a valuable point. It has brought into the limelight the problem of behavioural decadence and emphasises that initial training boosts must be maintained to become permanent [22]. The compliance, which was good (up to three months above the baseline), is encouraging, and it implies that the sustained application of the technological tools, specifically, the gamified app and weekly data feedback, might be viewed as one of the maintenance mechanisms that can be used in the long term [23].

2. Comparison with the Past Studies

Our findings form part of a bigger body of literature that promotes the importance of technology in healthcare education. VR has proven its effectiveness in the skills training of both surgical and nursing simulation training, and our research builds upon this fact in the field of IPC [24]. In the same way, it can be seen that our gamified mobile application is successful, and this finding is in line with prior studies that have indicated that gamification has the potential to improve engagement and knowledge retention in clinical practice [25]. Nonetheless, our results are opposite to the studies that have applied technological solutions independently. Indicatively, multiple studies on automated hand hygiene surveillance systems have shown only slight or short-term increases, which in many cases are attributed to the fact that the technology is seen by the staff as a surveillance measure, as opposed to a learning aid [26]. The major distinguishing feature of our intervention was to position technology as a pedagogical element of a larger training program. This also created a culture of evidence-based self-amelioration instead of punitive supervision, which might have helped to create the increased rates of acceptance and efficiency [27]. We therefore fill a very important gap in the literature by showing that the synergistic interplay of a combination of technologies in a consistent theoretical framework yields results that are better than those attained using single-technology applications.

3. Scientific Explanation

The effectiveness of the intervention is related to the set concepts of the adult learning theory and behavioural psychology. The VR simulations made use of experiential learning, which enabled the method of participants to build up the knowledge based on a first-hand experience in a consequence-free environment [28]. This has been proven to make cognitive encoding and growth of muscle memory of complex procedures.

The gamified aspects exploited the motivation drivers directly, like achievement, competition, and instant feedback, which are fundamental principles of operant conditioning. Variable positive reinforcement was achieved by the points and leaderboard system, and the compliance process became more exciting and satisfying [29]. Meanwhile, the weekly feedback of the smart dispensers could be considered biofeedback, as abstract concepts like compliance had become visible and practical to the healthcare teams and thus fostered the feeling of shared efficiency and responsibility [30].

4. Implications

The implications of this study are enormous for clinical practice and research in the future. The results offer an effective roadmap of how modernisation of IPC training programmes should be in the case of healthcare institutions. The focus of investment should be on the design of a blended-learning curriculum beyond mere dissemination of knowledge to active learning and skill acquisition and habits through the assistance of technology [31]. The outcomes further suggest abandoning high-level training and attending role-specific modules that touch upon the peculiarities of the challenges and situations in various professional groups. As a researcher, one can use this study to pursue a number of opportunities. The future research should attempt to directly connect such technology-based training interventions with hard clinical outcomes, including a decrease in the rates of certain healthcare-associated infections (HAIs) like CLABSIs or CAUTIs. The best frequency and nature of reinforcement sessions should be determined through longitudinal studies to avoid behavioural decays during periods of more than one year.

CONCLSUION

According to the findings of this research, it could be concluded that the technology-enhanced training program proved to be very effective. The main result is that a complex intervention that incorporated e-learning, virtual reality, gamification, and data feedback was able to achieve statistically significant and significant change in all the practices measured, which were related to infection control within the context of healthcare staff. The aim of the research was clearly and successfully achieved, as it showed that theoretical knowledge and compliance can be bridged in a strong and effective way through pedagogical integration of modern technology, which has been well documented. The key scientific insight of the work is that the socio-technical approach to behavioural change in healthcare is proven empirically, and the evaluation of technologies is no longer performed in vacuums. It has given a strong evidence-based framework for future infection prevention and control (IPC) programmes. Overall, this research proves the fact that the efficacy and sustainability of healthcare training can be significantly increased with the help of tactically combined technological tools. Further studies are advised to be conducted in a longitudinal study to determine the long-term sustainability of such results and explore the cost-effectiveness of deploying such programs at a large scale to inform health policy and resource allocation.

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