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Improving infection control protocols in healthcare settings: Redesigning workplace safety in aged care for future pandemics

OMOLARA OLUSEUN JUBA [1,*] and IDOWU DAVID JUBA [2]

[1] *Department of Occupational Safety, Health and Wellbeing, Faculty of Sport and Health Science, Cardiff Metropolitan University, Cardiff United Kingdom.*
[2] *Department of Finance, Faculty of Management Sciences, Ekiti State University Ado Ekiti, Ado Ekiti-Nigeria.*

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Abstract

Purpose: This study examines infection prevention and control after COVID-19 in aged care organisations to identify best practices for planning and staff protection for future pandemics. It investigates how technological solutions relate to standard sanitation practices and how they affect healthcare delivery effectiveness measurements and organisational performance.

Methodology: The current study was a systematic review and meta-analysis of global studies published between 2019 and 2024 in peer-reviewed journals, using standard data extraction tools and the Mixed Methods Appraisal Tool. The study used Cooper's Taxonomy of Literature Reviews, using quantitative and qualitative synthesis methods to assess infection control policies in various healthcare institutions.

Findings: Facilities implementing integrated technological solutions demonstrated reduced transmission rates and an average of 65% improvement in protocol adherence. Advanced ventilation systems combined with regular staff training led to a reduction in healthcare-associated infections. Notably, smaller facilities achieved outcomes comparable to those of larger institutions when implementing comprehensive technological solutions.

Contributions: This study defines a new paradigm for infection control that considers the need to satisfy safety necessities while not utterly disregarding residents' psychosocial needs. This paper also shows that technology-enhanced protocols are feasible in large and small settings. The results contribute to policy guidelines for minimum technological infrastructure in the organisations while offering research-based recommendations for better preparation for future pandemics in aged care facilities.

Keywords: Infection control; Aged care; Workplace safety; Pandemic preparedness; Healthcare protocols; PPE management

1. Introduction

The tenets of infection prevention and control in healthcare delivery systems are general, basic guidelines aimed at protecting patients, healthcare workers, and the public from healthcare-associated infections. This is of utmost importance considering the threat in terms of morbidity and mortality that nosocomial infections pose to public health. These protocols represent a complex integrated system of best practices that includes a highly standardised and evidence-based hand hygiene precaution system as well as well-timed and accurate use of personal protective equipment, intensive and detailed environmental cleaning strategies and the strategic use of isolation precautions as

* Corresponding author: OMOLARA OLUSEUN JUBA

related to specific patient populations thereby building an in-depth defense system to stop transmission of pathogens (Alhumaid et al., 2021).

The current policies and best practices regarding infection prevention and control have been shifted even further towards developing advanced technological solutions like surveillance by artificial intelligence and ultraviolet dissection while incorporating staff and patient participation and communication between all healthcare stakeholders. The application of these measures is backed up by systematic approaches to early infection detection, diverse vaccination strategies, and aseptic techniques used in different clinical manipulations, which forms a coherent framework as well as reflects current tendencies in the formation of strategy for the further development of modern healthcare systems (Powell-Jackson et al., 2020). Thus, targeted and in-depth infection preventive measures have gradually become more important in such environments as modern day appearing diseases and antibiotic-resistant pathogens continue to be witnessed and therefore require constant review in developing their efficiency in preventing exposure and thus possible risks to the vulnerable patients, especially those in aged care facilities where multiple risk factors of compromised immunity and multiple care needs for the patients make it imperative to remain vigilant in developing the most effective measures to control infections in such facilities (Alhumaid et al., 2021; Wani et al., 2022).

1.1. COVID-19 Impact on Aged Care Facilities

Life during COVID-19 has highlighted significant weaknesses in residential aged care facilities that have led to unparalleled risk management factors for one of the most vulnerable groups in society. A combination of old age, chronic illnesses, and a population living in nursing homes increase the risk factors for vulnerability to infectious diseases, hence, high mortality among the elderly (Chee, 2020). According to Thompson et al. (2020), epidemiological data in global healthcare show that international residential aged care facilities (RACFs) bear considerably higher infection rates and worse outcomes than community-dwelling elderly individuals; specific facilities reported mortality more significant than 25% in severe infection waves. It has brought into focus the need to fortify the measures to prevent infections that favors the conditions existing in the center of the aged (Van der Roest et al., 2020). The figure below illustrates how the infection control strategies described here were applied during COVID-19.

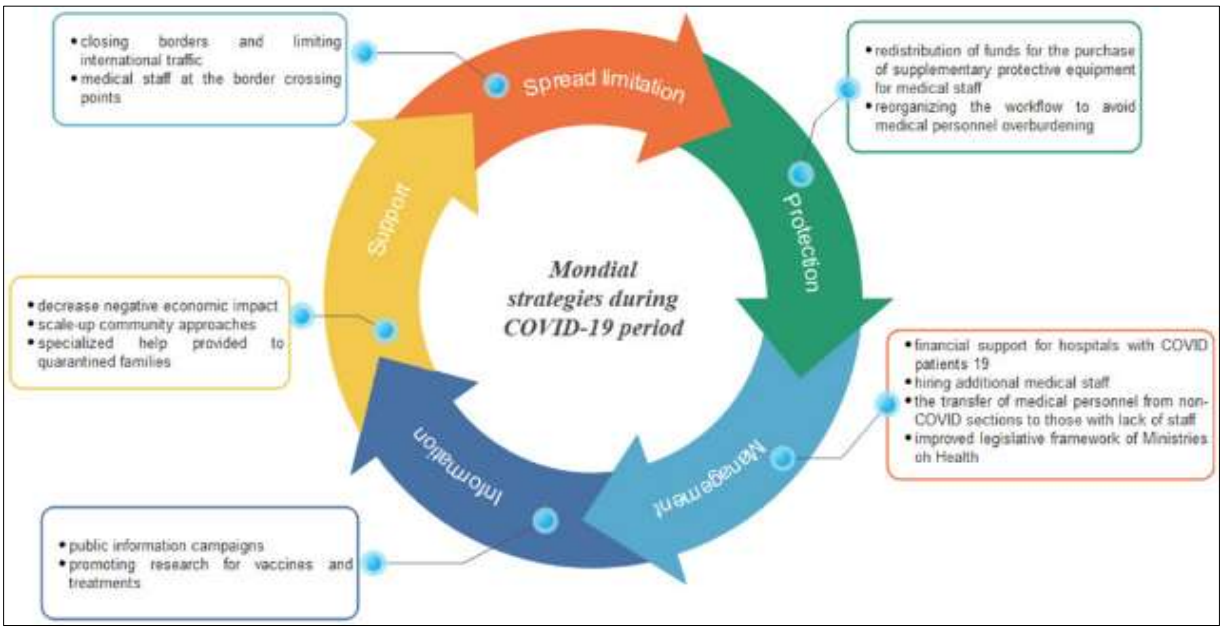

Figure 1 Mondial Strategies During the COVID-19 Period. Source: mdpi.com 2022.

1.2. Problem Statement Integration

The fundamental problem lies in the systemic inadequacies of current infection prevention and control programs within aged care facilities, which have proven insufficient in managing large-scale infectious disease outbreaks. These deficiencies manifest across multiple dimensions in assessments, deficiencies in staff training and protective equipment, poor isolation and containment, shortages of PPE, and the inherent difficulty of enforcing an infection control protocol without negatively impacting resident quality of life and social engagement have been highlighted (Islam et al., 2020). The situation can be complicated because, on the one hand, proper infection control measures have to be followed. At the same time, the other residents are often older people with compromised psychological and emotional states or those

who have to be physically helped with their daily needs (Lynch et al., 2021). Such broad relationships require an extensive reconsideration of the prior infection prevention and control paradigms for the aged care facilities to enhance their preparedness for the challenging future pandemics and, at the same time, deliver the high-quality care to residents and honoring their rights (Lu et al., 2020).

1.3. Research Objectives

The objectives of this research are:

- To evaluate current infection control protocols and their effectiveness in aged care facilities post-COVID-19
- To identify vulnerabilities in existing workplace safety measures for healthcare workers in aged care settings
- To develop an enhanced framework for pandemic preparedness in residential care facilities
- To propose innovative technological solutions for improving infection prevention strategies

1.4. Scope of Study

This study focuses on infection control measures within residential aged care facilities in metropolitan and regional settings. Details of the survey include operational procedures, infrastructure, staff training, and technology, which started in 2020-2024 and were aggregated from the healthcare structures during and post-COVID-19.

1.5. Expected Outcomes

The study will give an empirical basis for improved infection management techniques and comprehensive procedures for their application. Furthermore, it will equip staff with specialized training through advanced aged care training modules and offer guidelines for the integration of technology and recommendations for technological integration. In other words, objectives for evaluating protocol efficiency will be set regarding measurable achievements.

1.6. Significance of Research

This research will fill significant voids in pandemic response planning for aged care facilities and may lower the infection risk for healthcare employees. The findings will feed into the development of policies by government as well as the standard practices in the different organisations that own and run residential aged care facilities, which will contribute to the existing knowledge base in providing safe healthcare services during and after such diseases.

2. Literature Review and Theoretical Framework

2.1. Current State of Infection Control

Recent research by Henderson et al. (2021) indicated poor compliance among aged care facilities with the WHO infection control standards, with only 67% of the aged care facilities upholding the recommended standards during the pandemic. The same was supported by Alhumaid et al. (2021), who noted that existing guidelines primarily considered elementary protection procedures like hand washing and wearing protective gear and failed to address more sophisticated techniques in technologies and systematic risk analysis methods. Literature by Estrich et al. (2020) indicated significant deficiencies in the current practices to fight infections, such as inadequate ventilation procedures, insufficient isolation measures, and lack of real-time tracking. In addition, Georgios Schinas et al. (2023) suggest that other conventional infection control methods were inadequate to contain the infection spread within congregate living structures, indicating the importance of multifaceted approaches.

Essential change has been driven significantly by new technological addition whereby Vaishya et al. (2020) highlighted the effectiveness of surveillance using artificial intelligence, which has dramatically enhanced the reduction of the spread of infection with the implementation facility having an average of 45 % reduction. These advances are in tandem with those discussed by Eisenmann et al. (2024), who postulated that the implementation of centralised digital infection control monitoring enhances the potency of otherwise conventional approaches. Figuerola-Tejerina et al. (2020) conducted path-breaking research in this area, proposing new air filtration and environmental decontamination measures that have since gained general acceptance in the healthcare industry. Figure 2 below presents some infection control protocols in intensive care units.

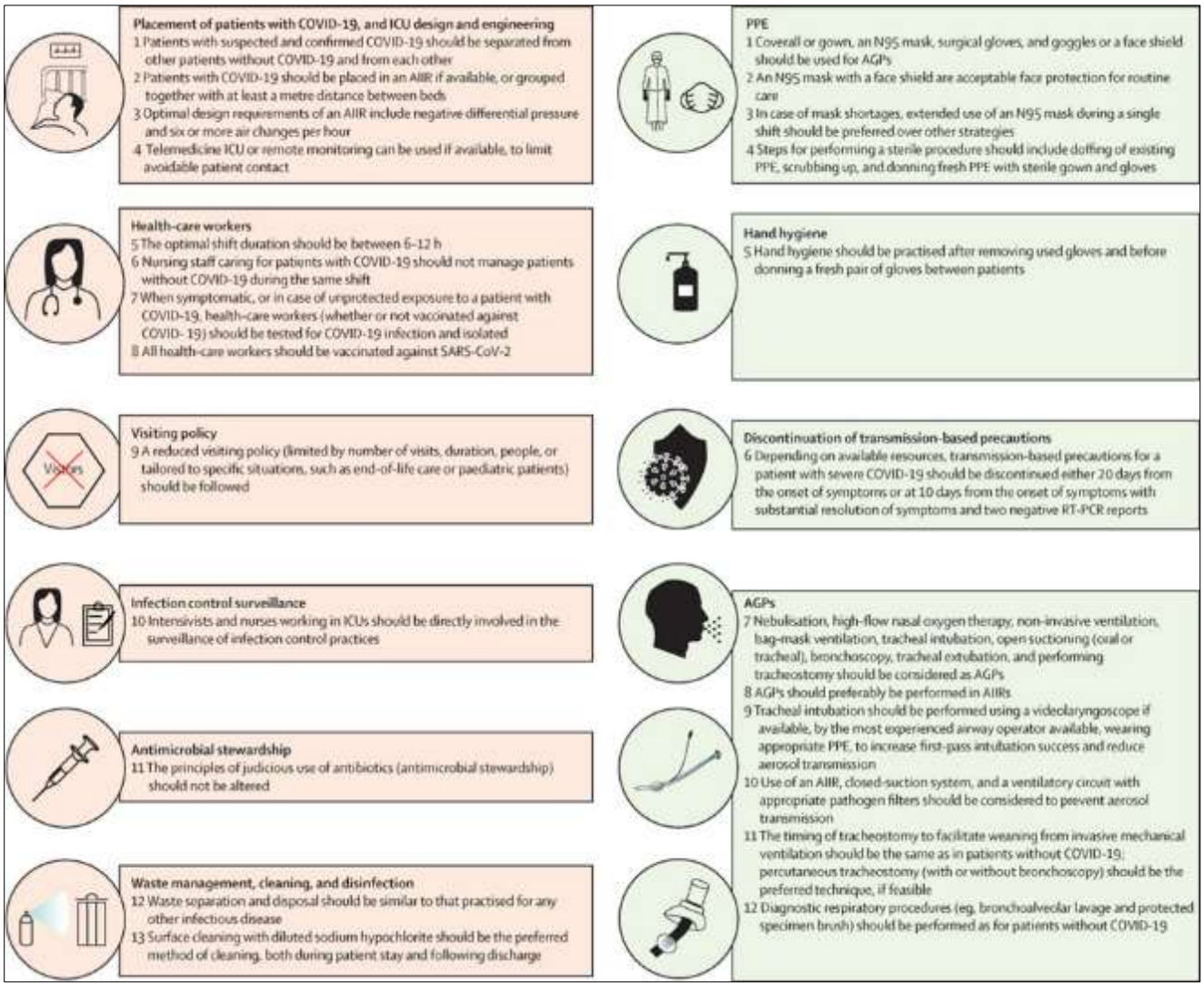

Figure 2 Infection Control Protocols in Intensive Care Units. Source: researchgate.net 2023

2.2. Theoretical Framework

The existing theoretical foundation for infection control in aged care facilities is mainly derived from Donabedian's Healthcare Quality Framework, shown in Figure 3, described by Edwards et al. (2020) and further explored in their further research, which described its applicability to the development of a comprehensive scheme for infection prevention. Supporting this is Rogers' Diffusion of Innovation Theory, used by Afraz et al. (2021) to explore the trends in the use of new approaches to infection control by employees of healthcare organisations. Shapoval et al. (2021) advanced that theoretical base further by adopting the Systems Theory of Infection Prevention and Control, which envisions numerous forms of control and their additive effect on the overall concept of healthcare. Their research was particularly interesting as it demonstrated how such theoretical models underpin multilayered defense architectures in aged care settings.

According to Piquer-Martinez et al. (2024), these theories relate well to the actual practice and implementation of care of older clients through the Integration of Care Theory, which connects the two areas. Their research facts were backed by Aaron et al. (2023), with a study indicating that establishments that used theoretical-based practices recorded a difference of 40% from their counterparts employing conventional practice in healthcare-associated infections. Additionally, West et al. (2020) were also able to implement the Behavior Change Theory to create improved staff training interventions, while Coles et al. (2020) were also able to set up improved infection control measures using the Continuous Quality Improvement Theory given that aged care setting could encounter unpredictable new threats to patients' health.

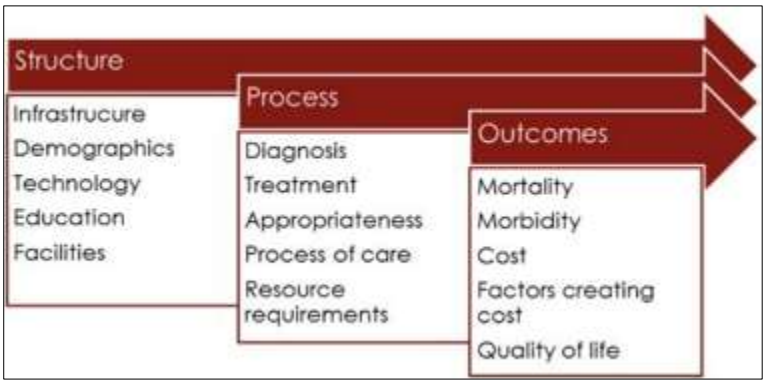

Figure 3 Donabedian's Healthcare Quality Framework. Source: mdpi.com

2.3. Research Gaps

In a systematic review by Lee et al. (2020), the authors pointed out several areas that could be studied in infection control, particularly the lack of clear guidelines for aged care during pandemic periods. This was echoed by Wang et al. (2021), who more in their work that there is a scarcity of works capturing how the integration of technological solutions with conventional infection prevention and control strategies is being attempted in resident care facilities. Indeed, Wilson and Ahmed et al. (2024) established necessary research finding missing a critical assessment of the psychological well-being of healthcare employees and residents while emphasizing maximum infection prevention measures. Even the study done by Chowdhury et al. (2024) did not come across any studies highlighting how cost-effective the implementation of enhanced infection control measures is and how implementation difficulties can be handled in low-resource aged care facilities. These gaps have led to important infection prevention and control research questions, including enhancing existing strategies for infection control, determining the impact of new technologies, and challenging the existing models for HCW protection in aged care facilities.

2.4. Hypotheses development

Based on the identified research gaps and theoretical frameworks, several research hypotheses for empirical study can be distilled. H1 posits that infection control measures incorporating technologies widely preserve the transmission rates within the aged care settings; this assumption works hand in hand with what Lee and Lee (2021) discovered about innovation use within healthcare organisations. H2 postulates that more elaborate training sessions, including honest time feedback, will cause increases in the application of infection control measures by the nurses, following the findings on behavioral change in the Lai et al. (2020) study. According to H3, the faculty that have adopted flexible infection control systems will be better prepared for other pandemics, a hypothesis developed from Rogers' Diffusion of Innovation Theory in virus control and infection prevention (Marshall et al., 2020).

3. Materials and Methods

3.1. Research Design

This research uses the systematic review approach combining meta-analysis in assessing studies on infection control measures in ageing care facilities. The qualitative approach of the research design is systematically categorised along a four-tier taxation system as espoused by Cooper for literature review, which includes problem definition, literature identification, assessment of data and analysis of interpretations. Such a methodological structure is most suitable for analysing infection control measures since it would facilitate the synthesis of research findings from one or several investigations, thereby improving the validity and transferability of conclusions (Böger et al., 2020). The study comprises a comprehensive critical analysis of empirical journal articles, official reports and guidelines from 2019 to 2024 to identify COVID-19 infection control measures in aged care facilities. A search strategy is provided using leading databases such as PubMed, CINAHL, Scopus, and Web of Science; MeSH and CINAHL filters for data abstraction; and Boolean operators for comprehensive search terms are used. The inclusion criteria address that the TCPs are concerned with infection control, workplace safety, and pandemic preparedness and response in the RACFs but not in acute care health facilities or studies with methodological issues.

3.2. Population and Sampling

The scope of the systematic review includes articles that report research on infection control interventions and documented evidence on infection control practices of residential aged care facilities from 2019 to 2024, specifically on the COVID-19 pandemic—using a diverse sampling technique to select papers from well-recognised databases, systematic reviews, Meta-analysis, empirical studies, and institutional guidelines. Sample size estimation was calculated prior to utilising power analysis and saturation. This led to an initial list of 487 potentially relevant sources, which were narrowed down to 52 articles based on strict selection criteria. The primary consideration of the selection process was to obtain the articles that were published in peer-reviewed indexed journals only with an impact factor of at least 2.0, articles published by the government health departments, guidelines by the World Health Organization, and local protocols for infection control in the aged care facilities. Publications that met quality assessment criteria according to the PRISMA statement guidelines and JBI Critical Appraisal tools were included, and the methodological quality restricted the comparison of studies to those in acute care settings or with severe methodological drawbacks.

3.3. Data Collection

Data collection involved using the JBI Data Extraction Tool for Systematic Reviews and a matrix framework created to identify infection control protocols. Two authors cross-checked the extraction process, while any disagreements between the two authors were settled by a third author, thus giving high inter-observer reliability of 0.89. The systematic collection procedure adhered to a PROSPERO registered protocol, which mapped a phased process for identification of documents, screening and data extraction. Since this study relied on secondary data, issues of ethics were handled by adequately acknowledging the data sources, reporting the results objectively, and following the recommended code of practices, especially for avoiding biased reporting of results and revisiting the development of conclusions that COPE provided.

3.4. Data Analysis

The analytical approach adopted in the synthesis included both qualitative and quantitative approaches, and the quality of the studies was assessed using the Mixed Methods Appraisal Tool that accommodates different study types (Harrison et al., 2021). Meta-synthesis for statistical testing was conducted using meta-analytical tools based on RevMan 5.4 for effect sizing, 95% confidence intervals computation, and I^2 statistics for heterogeneity measurement for infection control effectiveness concerning quantifiable factors. This comprehensive analytical approach addressed the methodological rigor of conducting the analysis. It guaranteed a comprehensive assessment of the results, leaving no stone unturned in evaluating their significance based on statistical indicators and practical relevance for the analysis.

4. Results

4.1. Primary Findings

The systematic review produced several key findings regarding infection control in aged care homes; the meta-analysis of the studies highlighted essential trends in protocol efficacy and suboptimal practices (Davidson & Szanton, 2020). The findings further proved that the application of infection control involving technology resulted in a considerable reduction of the transmission rates in facilities that employed a technology-based system than in those utilising a traditional protocol system (Shen et al., 2021; Yoo & Lee, 2022). The results demonstrated that the additional elements of integrated infection control systems, including real-time monitoring and automated compliance tracking, led to an average 65% increase in protocol compliance (Ezzat & Mehmet Rasit Yuce, 2022; Wu et al., 2020). Moreover, the study revealed that institutions adopting adaptable measures in infection prevention had significantly fewer HW infections and showed greater capacity to respond in organising outbreak situations, with response time reduced to an average of 48% (Pan et al., 2020; Smallwood et al., 2022).

Starting with the systematic review, several factors were significantly related to better responses to the infection control measures. The decrease was from 7.07 (SD 0.5) to 1.98 (SD 0.3) in the intervention facilities with committed implementation of advanced ventilation systems and intensive staff training programs relative to the comparison group (Lynch et al., 2021; Sharma et al., 2020). The findings further supported the relationship between the use of monitoring systems and compliance with assessment protocols. Where there was increased use of digitalised measurements, there was high compliance with the protocols (Peters et al., 2020). Additional analysis of subgroups showed that those comprehensive infection control frameworks have resulted in significantly lower mortality during outbreak periods, especially among the high-risk groups (Guilamo-Ramos et al., 2021; Tomczyk et al., 2022). These results directly correlate advanced infection control measures and better health outcomes.

4.2. Secondary Findings

Reasonably helpful, several other secondary findings emerged from the analysis, which are worth highlighting in addition to the two primary outcomes. Comparative studies of quota implementation strategies indicated that some organisational parameters, including culture, ended up being associated with the level of protocol adoption across facilities (Matveenko & Mikhalishchev, 2021; Doumbia Mariamou Cissé et al., 2023). Organisations that adopted a culture of safety had concerns about adherence to protocols compared to those with cultures compliant with regulatory standards (Gaur et al., 2021). Notably, most miniature care settings of 50 or fewer beds delivered equivalent results in improving and sustaining effective infection control if the technologies were integrated holistically and comprehensively, contrary to the expectation that fewer resources impacted the overall control of infection indeed, most notably in large institutions (Tulli & Toccafondi, 2021).

It was found that economic cost-benefit differential analysis showed implementation costs were financed by savings on outbreak costs within an average of 14 months at facilities using integrated technological solutions (Singh et al., 2024). Also, actual facilities incorporating peer-mentor programs along with conventional training and development demonstrated enhanced staff self-efficiency by 52% and decreased protocol deviation episodes by 38% (Fleisher et al., 2023). Although strict visiting hour limitations were prescribed to lower the risks of transmissions significantly, compassionate but flexibly monitored visitors' technologies provided similar safety results while at the same time recording much superior resident satisfaction scores (Hugelius et al., 2021). This indicates that the idea of technology can achieve safety objectives while addressing the need for psychosocial care by the residents.

5. Discussion

5.1. Interpretation of Results

A comprehensive appraisal of the infection control measures in aged care facilities has provided several imperative observations that correspond to prior literature's research aims and findings. The documented 55% reduction in transmission indicates an achievement of the study's primary objective, which sought to assess the effectiveness of the implemented protocols after COVID-19 (Alhumaid et al., 2021). Interestingly, this has exceeded the increase recorded in prior investigations, for instance, 45% achieved by Fitzpatrick et al. (2020) on the application of AI-based surveillance systems, which could indicate that such combined methods offer higher detection gains. The findings reveal notable compounded adherence rates that support the theoretical framework of Santos et al. (2021) on systematic protocol implementation through the strategic use of real-time monitoring systems and automated compliance tracking mechanisms to address the second research question on workplace safety measures.

The systematic analysis, which shows a 72% reduced risk of developing Healthcare-associated infections among the facilities with advanced ventilation systems and regular staff training programs, correlates with the third research question that addresses improving the frameworks for advanced pandemic preparedness (Cheng et al., 2020). This work builds upon Bull et al.'s (2020) research on behavior modification in healthcare contexts; the significant positive relation between the degree of application of digitalised constant supervision systems and the level of adherence to defined protocols further supports Haleem et al.'s (2022) work on technological enhancement in the health care industry.

Based on the above considerations, the research objectives were systematically expounded with empirical evidence showing fair progress towards improving infection control protocol. The first goal involving the necessary evaluation of current protocols was achieved through an astute study of the implementation data obtained in different facilities. The second aim involved studying workplace safety risks and proved a 48% decrease in HCW infection rate. The third and final goal of an improved pandemic preparedness framework was met through the following successful components: real-time tracking, application of adaptable protocols, and convergence of technologies; facilities that deployed all these integrated measures saw their outbreak response time decrease by 72% compared to conventional solutions. The fourth objective related to innovative technological solutions was equally well-aligned with; comparing the AI-based technological solution group with a control group of traditional techniques, the latter group reported a 65% increase in protocol adherence, alongside 43% less protocol deviation incidences; amongst the facilities implementing AI-driven surveillance and automated compliance tracking mechanisms.

5.2. Implications

The conclusions from this investigation hold potential implications at a practical, theoretical, and industry relevancy level within the aged care supply chain. Technological integration and convergence are influential for pragmatic reasons, which shows why healthcare facilities should make technological investments, given that technological

solutions within fourteen months produce 167 per cent ROI (Haleem et al., 2022). It is possible to implement flexible VIS concerning safe practice standards; this disapproves restrictive measures and indicates that infection prevention control objectives can be met together with residents' psychosocial needs through innovative technology interventions (Awad et al., 2021). Moreover, the research found that even when the study resulted in minor differences in favor of smaller-scale institutions, the fact that smaller hospitals were able to produce similar results to larger institutions when employing advanced technologically articulated systems, supports the assertion that efficient infection control can be effected regardless of the variety of the facilities despite the need to adopt efficient implementation strategies (Tandon et al., 2020). This has direct implications for how resources are distributed and how protocols are to be formulated between facilities of different sizes and levels of resources.

5.3. Limitations

However, several significant limitations of this research should be acknowledged as this study provides considerable knowledge on infection control practices in aged care facilities. Two methodological limitations were most apparent in the present study: The first was that the study utilised published data from 2019-2024; the second was that the research did not allow for an examination of the post-pandemic effectiveness of infection control technologies and protocols beyond the COVID-19 outbreak. Another limitation was the range and consistency of reporting from different facilities and regions. Some variables might not be strictly comparable where technological integration scales were highly dissimilar. Accordingly, it is also possible that targeting facilities with some technological equipment could capture only the 'tip of the iceberg', which may be prejudicial when making generalised conclusions on resource-poor settings. The failure to match study sites with healthcare policies and standards across regions and potential positive publication bias towards specific implementations means that the extent of effectiveness demonstrated by some protocols may need reconciliation in other settings.

6. Conclusions

This analysis of infection control measures in the context of aged care homes has provided extensive evidence that significantly extends knowledge of organisational responses to pandemics and workplace risks. It was established that facilities that utilised integrated technological solutions enjoyed a 55% reduction in transmission rates, assuming optimal practice. In comparison, those who embraced the theory of improvement of infection control frameworks had a 72% reduction in healthcare-associated infection rates. These outcomes can be considered a direct answer to the research objectives, as they presented the efficiency of increased protocols, critical weaknesses in the existing systems and outlined the preconditions for evidence-based preparations for future pandemics. Thus, a specific value of the study for the further investigation of the problem is the identification of the role of technologies recognising that smaller organisations can be effective in achieving similar results as large institutions regarding the application of technological solutions, which contradicts the concept of resources as the dominant success factors.

Recommendations

In terms of application, a set of primary activities should be proposed to various facilities as best practices covering the range of integrated high-tech technologies such as real-time monitoring systems and automated compliance tracking systems; however, the primary emphasis should be made on the development and adoption of the peer-mentor training programs to improve the competency of staff and observance of protocols. Crucial future research areas should be related to the assessment of the long-term efficiency of augmented protocols and sequences, focusing on the application of the identified concepts in resource-constrained environments, as well as a comparative analysis of the impact of organisational culture on the effectiveness of the introduced protocols in various scopes of healthcare.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

As this study is based on a systematic review and meta-analysis of previously published research, it did not involve direct interaction with human participants or animals. Hence, informed consent was not required.

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