ORIGINAL RESEARCH

Impact of antimicrobial copper surfaces on microbial load and healthcare-acquired infection rates in long-term care settings: A comparative study in British Columbia, Canada

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ABSTRACT

Background: Healthcare-acquired infections (HAIs) pose significant challenges in healthcare facilities. Although antimicrobial copper surfaces have shown promise in reducing environmental microbial contamination, their effectiveness specifically in long-term care (LTC) homes remains insufficiently explored. This study aims to evaluate the impact of antimicrobial copper surfaces on microbial load and HAI rates in the LTC home setting.
Methods: A prospective study was conducted across units of three LTC homes over six months. Antimicrobial copper was installed on designated common surfaces in intervention units, while control units retained existing surfaces. Microbial load was assessed weekly using Hygiena® SuperSnap® ATP bioluminescence assay and 3M™ Petrifilm™ Aerobic Count culture plates. HAI rates were monitored in two facilities over the same period.
Results: The study revealed a substantial reduction in microbial load on copper surfaces compared to conventional surfaces, with reductions of 79.3% and 34.1% using ATP bioluminescence and aerobic microbial culture methods, respectively. HAI rates did not significantly differ between intervention and control units. Of the 30 recorded cases of HAI during the study period, 70% occurred during respiratory infection outbreaks, with 12 cases in intervention units and nine in control units.
Conclusion: Antimicrobial copper surfaces show potential for reducing microbial contamination in LTC homes. However, further research is needed to comprehensively assess their impact on HAI rates in this setting.

KEYWORDS
Antimicrobial copper, infection prevention and control, healthcare acquired infections, long-term care homes

INTRODUCTION

Healthcare-acquired infections (HAIs) cause a high burden of disease and have garnered increased attention in recent years (Efstathiou, 2011). They are caused by bacteria, viruses, and fungi acquired while receiving care in a healthcare environment (Boyce, 2007). Their clinical manifestations include surgical site infections, urinary tract infections, and bloodstream infections. They disproportionately affect vulnerable populations, such as the elderly and the immunocompromised. In the Canadian acute care setting, it is estimated that one in nine adults has an HAI at any given time and more than 8,000 die each year as a result (PICNET, 2021).

The burden of HAIs is likely higher in long-term care (LTC) homes than in acute care facilities (Smith *et al,* 2008). Also of note is that residents in LTC facilities were disproportionately affected during the COVID-19 pandemic, accounting for 33.7-56% of COVID-19 mortality in high-income countries (Thompson *et al*, 2020). The risk of HAIs increases linearly with age and elderly populations over 65 years are at a higher risk of acquiring severe disease following infection than any other age group (Strausbaugh, 2001). Residents in LTC homes are especially at risk of acquiring HAIs due to their multiple comorbidities, dependence on care, exposure to other residents, and living in spaces with poor ventilation (Koch, Eriksen, Elstrøm, Aavitsland, & Harthug, 2009). As such, there is a need for infection control measures to prevent HAIs in this setting.

Antimicrobial copper serves as a structural measure for infection control, proven effective in reducing HAIs

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(Salgado *et al*, 2013). A systematic review of 14 articles demonstrated that antimicrobial copper surfaces in high-touch areas reduced the incidence of HAIs by around 25% (Pineda, Hubbard, & Rodríguez, 2017), and numerous studies have highlighted its efficacy in eradicating bacteria and viruses (Michels, Keevil, Salgado, & Schmidt, 2015; Schmidt *et al*, 2013; Schmidt *et al*, 2012). Copper's inherent broad-spectrum antimicrobial properties persist throughout the product's lifespan without diminishing (Michels *et al,* 2015). Its versatility allows incorporation into various surfaces to protect patients, staff, and visitors against exposure to microorganisms (Bryce *et al*, 2020). Copper is also notable for its safety, simplicity (requires no specialized training or maintenance beyond routine cleaning), and effectiveness around the clock. Moreover, it operates independently of electricity, protocol adherence, or human behaviour (Borkow, 2012).

Studies have shown that antimicrobial copper surfaces can eliminate 99.9% of bacteria within two hours of contact and decrease the microbial burden on adjacent non-copper surfaces (Michels *et al*, 2015; Rai *et al*, 2012). Copper demonstrates effectiveness against various pathogens, including methicillin-resistant *Staphylococcus aureus* (MRSA), Vancomycin-resistant *Enterococcus* (VRE)*, Legionella pneumophila*, *Acinetobacter baumannii* complex, *Mycobacterium tuberculosis*, *Candida albicans, Clostridioides difficile, Escherichia coli*, and *Enterococcus faecium* (Vincent *et al,* 2018). One study has also demonstrated the rapid inactivation of human coronavirus on a range of copper alloys (Warnes *et al*, 2015).

Although there is considerable research on the use of antimicrobial copper surfaces in healthcare settings, there is a paucity of data for its use in LTC homes. As such, the primary objective of this study was to assess the impact of antimicrobial copper surfaces on microbial load and HAI rates compared to existing surfaces over a six-month period.

METHODS

Study design

This was a prospective comparative study conducted in three LTC facilities in British Columbia, Canada. Two commercially available copper products approved by Health Canada were installed on high-touch common surfaces in one unit (intervention unit) in each of the three LTC homes. These intervention units had matching control units with existing non-antimicrobial surfaces within the same facility. The two copper products were: 1) Thermally fabricated copper alloy applied to originally installed products; and, 2) Integral copper alloy. The selection of suitable surfaces for the intervention units was based on careful consideration of factors such as maximum impact, minimum disruption, and feasibility of installation. Common surfaces included door handles/push plates, cupboard handles, faucet handles, washroom support bars, and staff desk blotters.

Surface testing for microbial load determination

Surface testing was conducted weekly from April to October 2023 to assess microbial load on intervention versus control surfaces at three LTC facilities. Two methods were used: aerobic bacterial culture enumeration in colony-forming units (CFUs) per plate, and adenosine triphosphate (ATP) bioluminescence assay for measurement of organic load in relative light units (RLUs) (Williams *et al*, 2023). Each week, five copper surfaces from the intervention unit and five equivalent control surfaces were tested within each LTC facility by trained research staff. A 30 cm² surface area (SA) was sampled using a disinfected silicon template, which was adapted for irregularly shaped surfaces. Samples were taken at consistent times weekly, before or at least one hour after cleaning. Where there was sufficient SA, tests for both methods were conducted adjacent to one another. For small SAs, such as door handles, small cupboards, and faucet handles, two identical sites were often required for testing.

Aerobic culture colony counts

Aerobic culture colony counts were completed using 3M™ Quick Swabs (QSs) and Petrifilm plates (PFs) as described previously (Williams *et al*, 2023). PFs were processed according to the manufacturer's instructions and incubated at 30°C for 48 hours, and CFUs were enumerated using the Petrifilm Plate Reader Advanced imager and the 3M™ Petrifilm Plate Manager Software v2.0.1 (3M, Ontario, Canada). Ten percent of PF plates were counted manually to confirm CFU numbers. Counts were estimated on plates with greater than 300 CFU per plate by counting four or more representative squares on the 20 cm² growth area grid to calculate the average number of colonies per square, then multiplying by 20 to get the estimated CFU per plate. In cases where an organism caused the gel media to liquefy and obscure the presence of other colonies, an estimated count was made by counting unaffected areas and converting to determine CFU/plate.

Adenosine Triphosphate Bioluminescence Assay

Adenosine triphosphate (ATP) bioluminescence measured in RLUs was completed using Hygiena® SuperSnaps® (Ontario, Canada) as described previously (Williams *et al*, 2023).

Healthcare-associated infections

Assessment of antimicrobial efficacy of copper surfaces was also determined through monitoring of HAIs in two of three LTC homes during the study period. As such, HAI was defined as a case of MRSA infection, *C. difficile* infection (CDI), and COVID-19 infection. MRSA infection was defined as a new positive MRSA culture from a clinical sample in a patient residing at the LTC facility for at least 48 hours prior to sample collection date during the study period. CDI was defined as a new positive *C. difficile* PCR from a stool sample in a patient residing at the LTC facility for at least 72 hours prior to sample collection date during the study period. COVID-19 infection was defined as a new positive SARS-CoV-2 PCR from a respiratory sample in a patient residing at the LTC facility for at least 72 hours prior to sample collection date during the study period. Review of recent resident admission to acute care facilities for all positive cases was also completed.

Data analysis

Data analysis was conducted using IBM® SPSS® Statistics 2024. Frequency tabulations and proportions were calculated for type and number of surfaces included in the copper and control groups. Independent sample t-tests were used to compare microbial load means between the intervention and control groups, and an alpha value of 0.05 was used to determine statistical significance. Confidence intervals (95%) were computed around the difference in means between the copper and control groups. The percentage change in microbial load was calculated as the difference between the microbial load in the copper and control groups divided by the microbial load in the control group, multiplied by 100.

RESULTS

Microbial load

A total of 863 surfaces were sampled during the study period, of which 424 were copper and 439 were control surfaces (Table 1). Within the copper group, thermally fabricated copper surfaces were swabbed 320 times, and integral copper surfaces were swabbed 104 times. Door handles/push plates constituted the largest proportion (36.7%) of samples taken compared to other surface types (Table 1). There was a 34.1% overall reduction in microbial load on antimicrobial copper surfaces compared to existing surfaces as assessed by aerobic microbial cultures, over the study period ($p<0.001$) (Figure 1). There was a 79.3% overall reduction in microbial load on antimicrobial copper surfaces compared to existing surfaces as assessed by the ATP bioluminescence assay, over the study period ($p<0.001$) (Figure 2). The greatest microbial reduction using both assessment methods occurred on shower and toilet bars, followed by faucet handles (Figures 3 and 4). There was no statistically significant microbial reduction on door handles/push plates, desk surfaces, and cabinet handles as assessed by aerobic microbial culture (Figure 4). When stratified by study site, there was a reduction of microbial load using the ATP bioluminescence testing method across all three study sites (Figure 5). There was also a reduction in microbial load using the aerobic microbial culture method, except for in study site B (Figure 6).

Microbial load reduction also differed by study site (Figures 5 and 6) but was not statistically different between copper surfaces and control surfaces in study sites B and C as assessed by the aerobic culture, though there was a trend towards statistical significance in study site C. There was a net reduction of microbial load as measured by the ATP bioluminescence method in all study sites, with the least reduction seen in study site B.

Table 1: Total samples taken, broken down by surface type and study group

	Copper n (%)	Control n (%)
Total surfaces swabbed	424 (49.1)	439 (50.9)
Copper type:		
Thermal fabrication	320 (75.5)	-
Integral surface	104 (24.5)	-
Surface Type:		
Door handle/push plate	156 (36.8)	161 (36.7)
Toilet bar	38 (9.0)	43 (9.8)
Shower bar	29 (6.8)	32 (7.3)
Faucet handle	84 (19.8)	87 (19.8)
Desk surface	58 (13.7)	53 (12.1)
Cabinet drawer handle	59 (13.9)	63 (14.4)

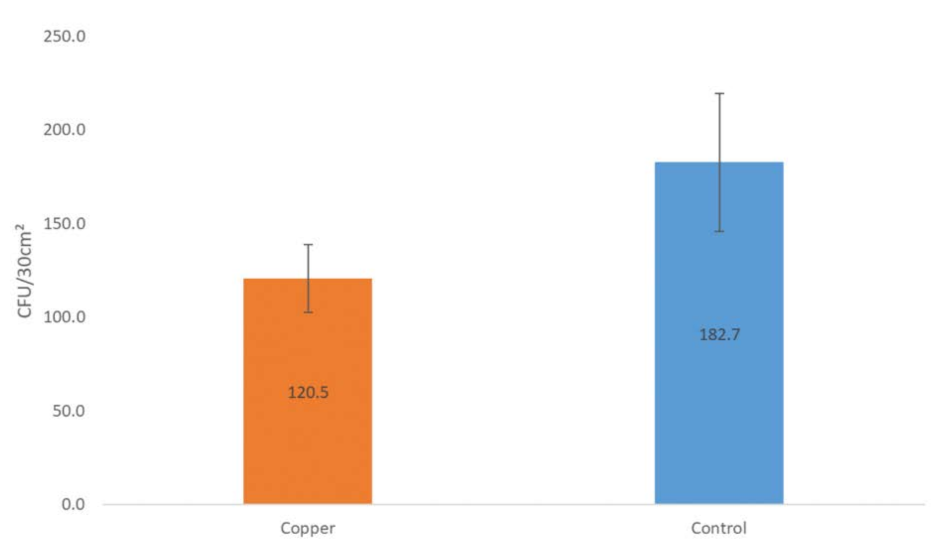

Figure 1: Microbial load testing using aerobic culture method measured in colony forming units (CFU) in the copper compared to the control group ($p<0.001$).

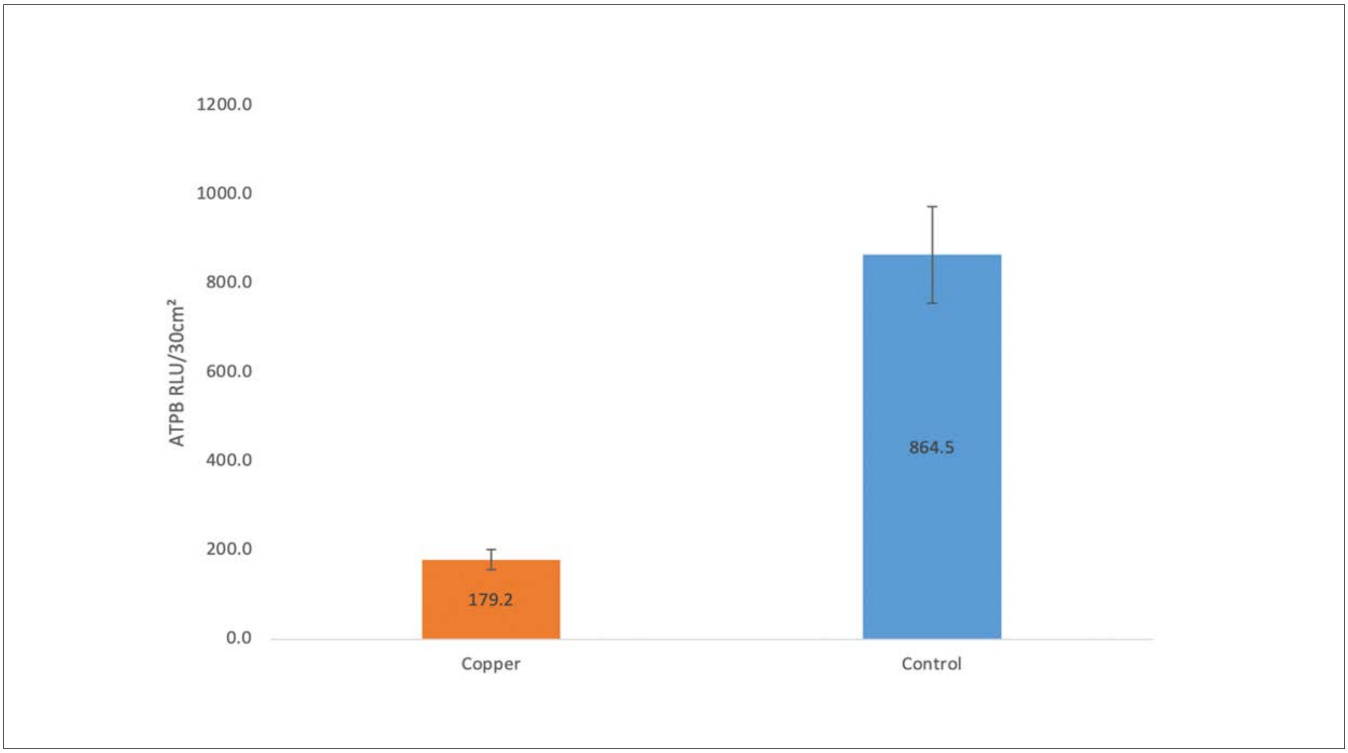

Figure 2: Microbial load testing using ATP bioluminescence method measured in relative light units (RLU) in the copper compared to the control group ($p<0.001$).

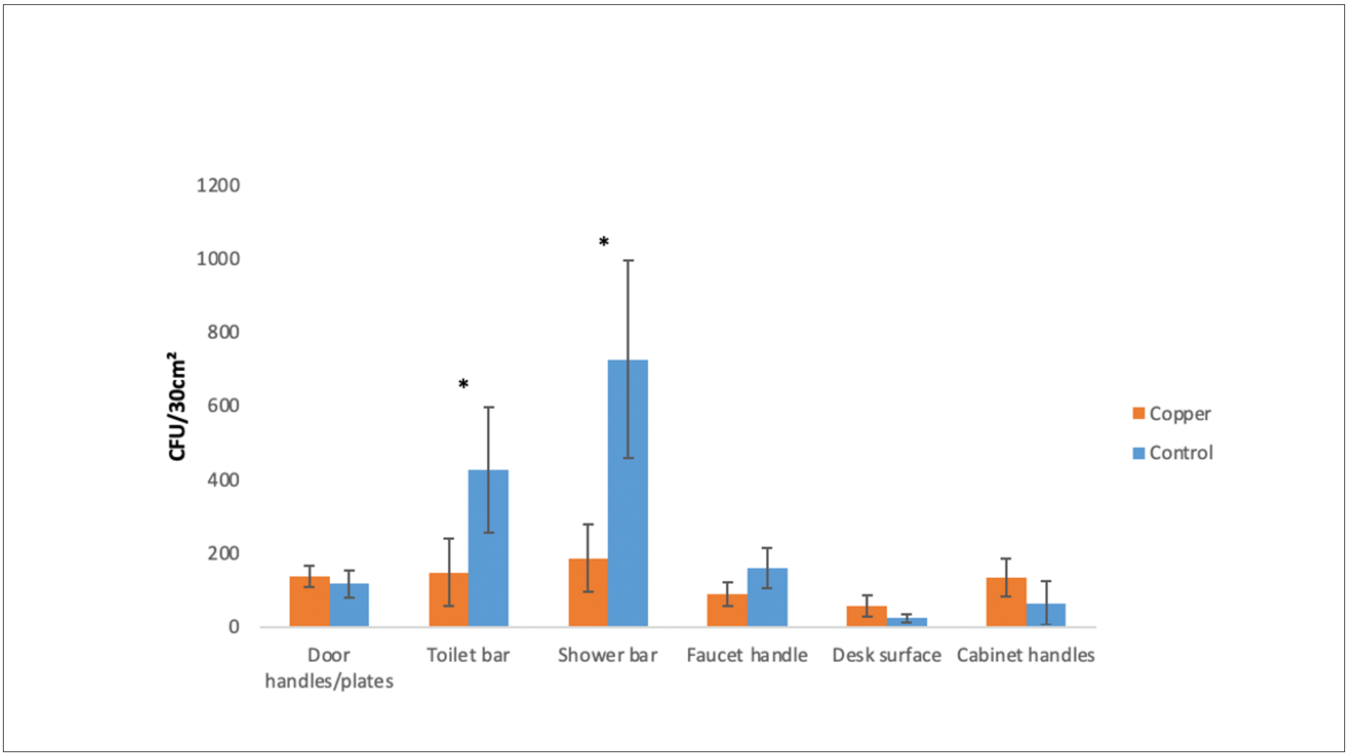

Figure 3: Microbial load testing using aerobic culture method measured in colony forming units (CFU) in the copper compared to the control group, by surface type.
*Denotes statistically significant comparisons.

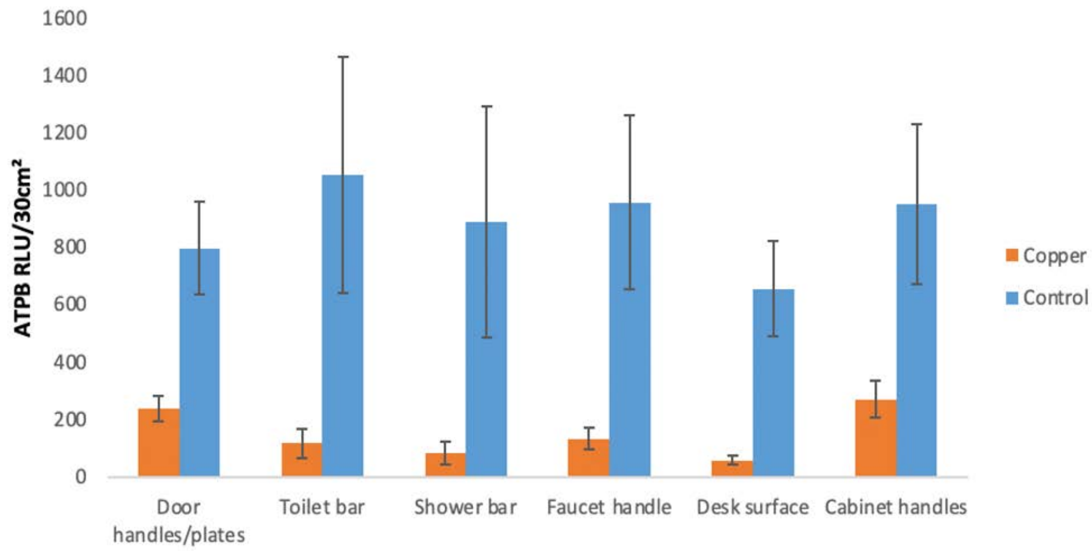

Figure 4: Microbial load testing using ATP bioluminescence method measured in relative light units (RLU) in the copper compared to the control group, by surface type ($p<0.001$).

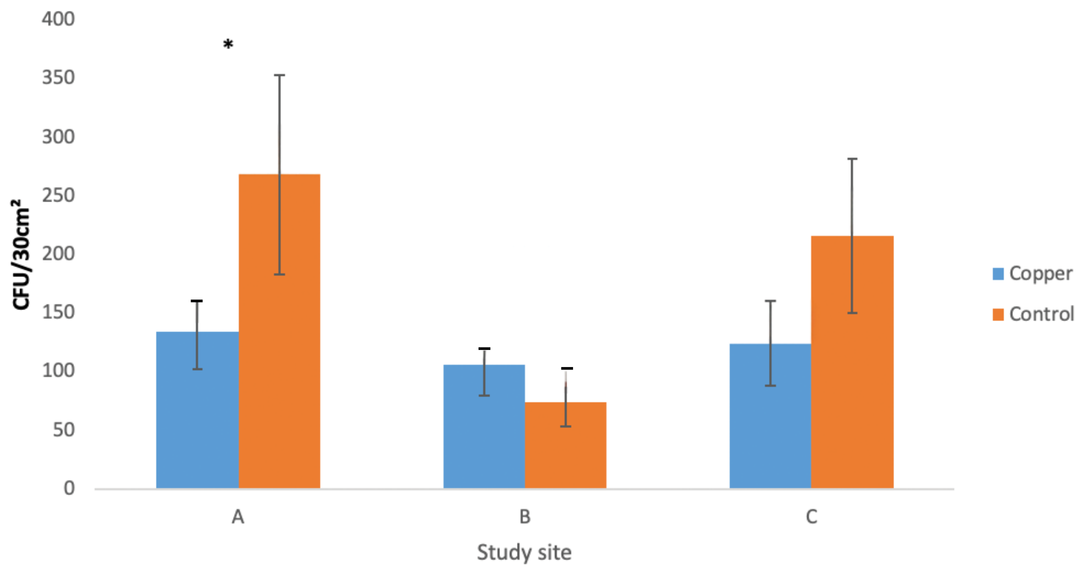

Figure 5: Microbial load testing using aerobic culture method measured in colony forming units (CFU) in the copper compared to the control group, by study site. *Denotes statistically significant comparisons.

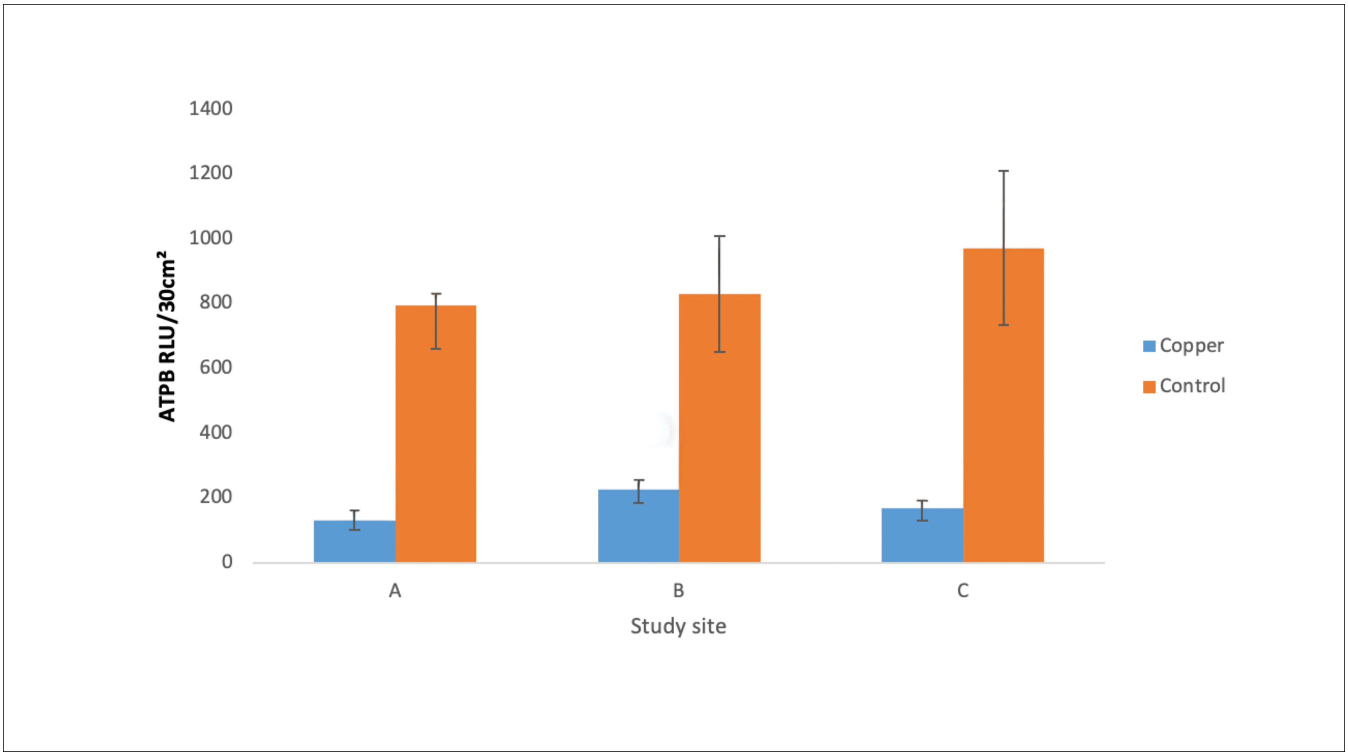

Figure 6: Microbial load testing using ATP bioluminescence method measured in relative light units (RLU) in the copper compared to the control group, by study site (p<0.001).

Healthcare-associated infections

HAIs were measured in two of the study sites (B and C), as one study site was excluded given that laboratory samples were analyzed at a private laboratory for which data was not accessible. Altogether, there were a total of 30 cases of HAIs over the study period, 19 of which occurred in the copper group (14 in study site B, five in study site C), and 11 in the control group (two in study site B, nine in study site C). There were 26 COVID-19 cases, one case of CDI, and three cases of new MRSA infection. Of the 26 COVID-19 cases, 21 (70%) occurred during an outbreak in the copper unit of one study site, and the control unit of the other study site (12 and 9 respectively). Overall, HAI rates did not differ significantly between the copper and control units (p=0.2).

DISCUSSION

Despite the importance of handwashing in preventing pathogen spread in LTC settings, inanimate surfaces still play a crucial role in harbouring microbes (Colin *et al*, 2018; Neely, 2000; Otter, Yezli, Salkeld, & French, 2013). Pathogens can be transmitted to residents, patients, staff, and visitors through fomites in a rapid manner. As such, the use of antimicrobial copper surfaces offers a promising approach for continuous and inherent disinfection. This study examined the impact of two different types of antimicrobial copper surfaces on microbial load and HAI rates in LTC homes.

The results demonstrated a 79.3% and 34.1% overall reduction in microbial load on antimicrobial copper surfaces compared to existing surfaces using the ATP bioluminescence and aerobic microbial culture methods, respectively. The most significant reductions occurred on bathroom and shower bars, followed by faucet handles.

Compared to similar studies in healthcare settings, the magnitude of change was not as large, particularly when measured in CFU/cm² (Aillón-García, Parga-Landa, & Guillén-Grima, 2023). However, this study was conducted in an LTC setting, which differs in terms of population, cleaning frequency, and environmental factors compared to previous studies, which were mostly done in hospitals. These differences can influence microbial load on surfaces (Colin *et al*, 2018). For example, frequent cleaning and disinfection protocols, combined with targeted placement in high-risk areas like intensive care units and operating rooms, enhance the effectiveness of copper surfaces through synergistic microbial load reduction in hospitals. In contrast, LTC facilities have communal living spaces, shared equipment, and undergo less frequent cleaning, which lead to widespread microbial dissemination, limiting the impact of copper surfaces in isolated areas due to continuous recontamination. Additionally, variations in sampling methods such as using rayon-tipped swabs with neutralizing broth in this study compared to wipes or agar plates in others can affect bacterial recovery (Hinsa-Leasure *et al*, 2017). Also, this study used a smaller sampling area (30 cm²) compared to some previous studies that sampled up to 100 cm² (Hinsa-Leasure *et al*, 2016; Ibrahim *et al,* 2018). Finally, differences in copper alloy composition across studies may impact antimicrobial effectiveness, even when a similar copper percentage is used (Aillón-García *et al*, 2023; Warnes *et al*, 2015).

To the best of our knowledge, only one other study from France has examined microbial load on copper surfaces in the LTC setting (Colin *et al*, 2018). In that study, moistened cotton swabs were used to sample 10 cm^2 areas on copper door handles and handrails compared to similar control surfaces in five LTC homes. The estimated average bacterial burden reduction was 59% on copper door handles and 33% on copper handrails (Colin *et al*, 2018). In this study, there was no statistically significant difference between copper door handles/push bars and control door handles/push bars as assessed by aerobic microbial culture. However, there was a 70.1% reduction of microbial load using the ATP bioluminescence method on copper door handles/push bars compared to control door handles/push bars. There were also an average 70.9% and 89.7% reductions in microbial load on copper shower/toilet bars compared to control shower/toilet bars using the aerobic microbial culture and ATP bioluminescence methods, respectively.

The discrepancy between microbial load measured by aerobic culture counts and ATP bioluminescence methods is documented in previous studies (Huang *et al*, 2015). Aerobic culture counts account for common aerobic bacteria that can be grown within a microbiology laboratory setting under controlled conditions and then enumerated, whereas ATP bioluminescence assesses organic material from all matter. Additionally, sample transport conditions may affect the isolation and enumeration of bacteria using the aerobic culture count method, while ATP bioluminescence testing, and enumeration occurred at point of testing. As such, ATP bioluminescence testing provides important secondary data to aerobic culture count measurements for organisms that are fastidious, anaerobic, or that cannot be cultured.

In this study, all sites used accelerated hydrogen peroxide disinfectant and there were no changes to the cleaning protocols after copper surfaces implementation and for the duration of the study. All surfaces were cleaned in the same frequency. However, cleaning audit protocols differed: Study sites A and C conducted fluorescent marker audits monthly, while site B did them weekly, resulting in a higher standard of cleaning at site B, where environmental services also provided staff incentives. This may account for the differences seen in microbial load reduction in study site B compared to A and C. Additionally, while effort was made to collect microbial load samples at the same time of day across different sites, this was not always synchronized with cleaning times. As such, some microbial load sampling occurred before cleaning, and some occurred after cleaning. Finally, COVID-19 outbreaks on units in study sites B and C likely resulted in increased frequency of routine and terminal cleaning procedures compared to units that did not have outbreaks.

This study assessed HAI rates (COVID-19, CDI, MRSA) as it relates to the effect of antimicrobial copper surfaces. While previous studies have shown decreased HAI and MRSA/VRE colonization (Lazary *et al*, 2014; Salgado *et al*, 2013), we did not observe any statistically significant differences in HAI rates between intervention and control units in this study. This may be explained by a few factors. Firstly, there was an overall low number of HAI during the study period, both in the intervention and control units. Secondly, while transmission of CDI and MRSA infection can occur through fomites (Derqui *et al*, 2023), it is not a significant mode of transmission for COVID-19 infection (Cheng *et al*, 2022; Rocha *et al*, 2021). As such, copper surfaces are not expected to cause large reductions in transmission of SARS-CoV-2. Indeed, COVID-19 infections accounted for the largest number of HAIs during this study, in both the intervention and control units. There were two COVID-19 outbreaks during the study period, one occurring in the intervention and one occurring in the control units at separate time intervals.

This study had several limitations. The lack of standardized cleaning frequency and timing between study sites may have introduced variability, potentially skewing comparisons of microbial loads on copper versus control surfaces. HAI rates were only available for two of the three study sites, reducing the statistical power to draw conclusions about the impact of copper on HAI rates. Additionally, COVID-19 outbreaks at two of the sites led to a disproportionate increase in HAI cases, affecting both intervention and control units, which limits the interpretation of HAI rates in relation to antimicrobial copper. The study also focused on only two types of HAIs (CDI and MRSA), which are primarily transmitted through fomites, limiting the ability to generalize findings to other types of HAIs. In the LTC setting, urinary tract infection (UTI) and respiratory infections are the most common HAI (Noleen *et al*, 2024). However, the microbiological diagnosis of UTI and pneumonia are challenging to verify without clear documentation given the high prevalence of bacteriuria in the elderly, and the difficulty in identifying an organism in cases of pneumonia. Additionally, no determination was made on whether the clinical samples testing positive for MRSA or *C. difficile* were representative of infection versus colonization. Furthermore, while data on resident movement between units was minimal, staff movement was not tracked, which could have influenced HAI rates in the intervention and control units.

CONCLUSION

HAIs are a major cause of morbidity and mortality worldwide, especially among elderly and immunocompromised patients. High-touch surfaces contribute to pathogen transmission in LTC settings, increasing infection rates. Studies have shown that antimicrobial copper can reduce microbial load and HAIs. This study found that copper use was associated with decreased microbial load in the LTC setting over six months. Further research is needed to evaluate the impact of antimicrobial copper on HAI rates and its cost-effectiveness in LTC settings.

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