A case study of food handler hand hygiene compliance in high-care and high-risk food manufacturing environments using covert-observation

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Abstract:

Observation of behaviour is superior to cognitive data, which does not equate to behaviour. Covert-observation is seldom used in food manufacturing to assess behaviour. In this case study, closed-circuit-television footage (15h) in a business were reviewed to assess hand hygiene compliance using an electronic-checklist. Hand hygiene attempts were observed prior to entering high-risk (cake/pie)(*n*=47) and high-care (sandwich/salad)(*n*=153) production areas. Business hand hygiene protocol required handwashing durations ≥20s. Observed durations ranged 1–71s, <96% of attempts were <20s. Significantly longer durations were observed when food handlers were in the presence of others (12s) than when alone (9s). Although <99% utilised soap, only 56–69% wetted hands first. Failure to rub all parts of hands was commonplace (<87%) and 24–35% failed to apply sanitiser after drying. Consequently, >98% of observed attempts before entering production areas did not comply with the protocol. Observed non-compliant practices may have implications for food safety in manufacturing.

Keywords:

Observation, behaviour, food handler, food industry, ready-to-eat, hand hygiene,

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Main introduction.

Hand washing is one of the simplest – and yet, most effective methods to reduce the risk of food related illness (Griffith 2013; Health Protection Agency 2013). Indeed, the hand hygiene practices of the food handler is often recognised as an important contributory factor that causes foodborne illness (Gould et al. 2013). For food manufacturing, where numerous products are handled and prepared; poor hand hygiene among food handlers can cause contamination, through the spread of pathogens between hands and surfaces and to food products (Lambrechts et al. 2014). Therefore, to reduce the risk of contamination and prevent the spread of pathogens, ensuring effective hand hygiene is critical in food manufacturing environments. Consequently, in food manufacturing sites that have high-care and/or high-risk production facilities, clause 8.4.1 of the British Retail Consortium Global Standard (BRCGS) Global Standard for Food Safety (Issue 8) requires provision and use of hand washing and disinfection facilities prior to entry (BRCGS 2018).

In the UK, food industry hand washing guidance suggests adequate hand washing procedures should utilise non-hand operated taps to wet hands before applying soap. The procedure should include warm water (~40°C) and liquid soap (3–5 ml) containing a biocide. Hands (including both sides, the wrists, thumbs, fingers and nails) should be rubbed vigorously for 15-30 seconds, rinsed under clean running water, dried thoroughly followed by application of hand sanitiser (Smith 2009). Food manufacturing businesses have specific hand hygiene protocols based upon such guidelines, but must also ensure suitable and sufficient facilities at access to production areas for food handlers to implement hand hygiene practices are available (BRCGS 2018).

Food manufacturing businesses must provide training and instruction for food handlers regarding hand hygiene, as well as supervise or monitor behaviour periodically (European Parliament 2004). As training often relates to the acquisition of knowledge, as opposed to a change in behaviour (Lelieveld et al. 2016; Zanin et al. 2017), food safety

knowledge does not always result in improved safe food practices, despite employees often indicating awareness (Brannon et al. 2009; Rossi et al. 2016).

As the provision of hand hygiene facilities and the delivery of training does not always ensure that food handlers will implement sufficient hand washing practices, there is a need to assess hand hygiene behaviour in food manufacturing environments. However, data detailing hand hygiene compliance in food manufacturing environments are limited (Taylor et al. 2000), as many published hand hygiene studies relate to healthcare environments (Taylor and Holah 2000).

The majority of published research detailing food handler food safety data incorporate food safety knowledge (75%), self-reported practices (48%) and attitudinal data (39%) while inclusion of observational food handler behaviour is less frequent (29%) (Wallis and Evans 2020). Although insightful, assessing food safety cognition such as knowledge, attitudes and self-reported practices have limitations and can be subject to biases (Evans and Redmond 2014). For example, self-reported practices can be subject to social desirability bias, whereby practices perceived to be favourable by research participants are over reported and undesirable practices are underreported (Hebert et al. 1995; Barker et al. 2002; Dharod et al. 2007). As a result, discrepancies have been determined between data detailing self-reported practices and observed behavioural data (Clayton et al. 2002; Clayton et al. 2003; Redmond and Griffith 2003). Thus, behavioural observations can indicate a superior method of assessment over the determination of cognition, because observed actions are a reflection of actual behaviour rather than an intermediary measure (Evans and Redmond 2018). Behavioural data may be utilised to inform policy, training and audits to improve practices.

Research studies utilising methods to observe food handler behaviour have been based in retail (Lubran et al. 2010) and foodservice settings (Worsfold and Griffith 2003; Clayton and Griffith 2004; Green et al. 2006b; Chapman et al. 2013; Rajagopal and Strohbehn 2013; Arendt et al. 2015). Indeed, the majority of published food handler studies focus on food

handlers in establishments that provide prepared food directly to the consumer, such as in catering settings (25%) or institutional/high-risk food service (e.g. schools, hospitals, nursing homes) (24%). Data that are specific to food handlers in food manufacturing environments are particularly lacking (13%) (Wallis and Evans 2020).

Although Smigic *et al.* (2016) suggest that food safety knowledge is significantly better among food handlers in food manufacturing environments compared to retail outlets, however, such cognitive data is not an indicator of actual behaviour. Given the volume of food produced by food manufacturing businesses and distribution of coverage, understanding food safety behaviours, such as the hand hygiene practices of food handlers is critical. As cognitive data can provide insights into food handler hand hygiene awareness, but is not indicative of actual behaviour, there is a need to observe practices to evaluate hand hygiene compliance in food manufacturing environments. Consequently, this case study aimed to address the lack of data by conducting a covert-observational study of food handler hand hygiene practices and compare compliance to company protocol in two production areas of a ready-to-eat (RTE) food manufacturing business.

Material and methods.

Sample and recruitment of a food manufacturing business.

A UK based food manufacturing business that produces RTE and ready-to-heat food products for retail and food service outlets, was selected for participation in the study due to having separate high-risk and high-care production areas;

- High-risk production is defined as a physically segregated area designed to a high-hygiene standard where practices aim to prevent contamination by pathogenic microorganisms, all components receive a full cook process to a minimum of 70°C for 2 minutes or equivalent prior to entry into the area (BRCGS 2018).

- High-care production is defined a physically segregated area designed to a high-hygiene standard where practices aim to minimise product contamination by pathogenic microorganisms, microbiologically susceptible components receive a process to reduce microbiological contamination to acceptable levels (typically 1-2 log reduction of microorganisms) (BRCGS 2018).

At this food manufacturing business, the high-care area produces cakes and ready-to-eat pies and the high-care area produces sandwiches and salads. Both production areas require hand contact with RTE food products thus hand hygiene is of paramount importance. During a briefing visit with senior management at the business (prior to commencement of the study), it was determined that close-circuit television (CCTV) recording cameras were used throughout the production site, but were not utilised to observe hand hygiene practices, such as in the pre-production hand hygiene facilities. The aims and objectives of the project were discussed with the technical manager prior to obtaining CCTV footage for observation of hand hygiene practices. The business gave consent for researchers to access pre-recorded CCTV video footage of the pre-production hand hygiene facilities by completing a consent form. Consent was not sought from each individual food handler as individuals were not identified as part of the research. Food handlers were informed during pre-employment induction that cameras may be utilised to monitor hygiene practices. Footage recorded prior to the briefing visit was utilised for this study to reduce the potential of reactivity bias.

Development of a hand hygiene observation checklist.

The company hand hygiene protocol required staff to implement handwashing prior to entering production in the pre-production hand hygiene facilities, with soap and water, based upon the World Health Organization technique (World Health Organization n.d.). For a hand hygiene attempt to be classed as 'compliant' with the company protocol, the necessary steps to be implemented by food handlers prior to proceeding into the production areas include:

- Push sleeves up 3 inches above the wrist.
- Put tap on by pushing lever with your knee and place hands under tap and wet thoroughly.
- Take soap from dispenser labelled ‘Hand Soap’ and rub soap all over hands, palms, wrists and between fingers.
- Ensure that hands are thoroughly lathered for 20 seconds.
- Rinse hands with warm water until the water runs clear and all soap is removed.
- Dry hands with blue paper towels or use the hand dryer.
- Take liquid from dispenser labelled ‘hand sanitiser’ and rub evenly over hands.

As previously described by Evans and Redmond (2018), an observation checklist was developed based upon the hand hygiene protocol of the business using a Qualtrics database (Qualtrics 2017, Provo, Utah, USA). This allowed for a researcher to manually review the CCTV footage and record the observed behaviours in the specifically designed electronic checklist, saved on a cloud infrastructure, which could be exported as an electronic database for analysis. Inclusion of each element of hand hygiene protocol enabled determination of hand hygiene attempts that were ‘compliant’. In the event of non-compliant practices, the electronic checklist allowed for details of such data to be captured. The electronic checklist was piloted using CCTV footage from the business (n=100 observations), which resulted in amendments to the flow of the checklist, and the addition of variables to capture the implementation of additional non-compliant practices. The finalised checklist captured every occasion a food handler passed through the pre-production hand hygiene facilities prior to entering the food production areas; it recorded which area was being observed (high-care or high-risk), if a hand hygiene attempt was implemented, the start time and end time of the attempt (to calculate duration), adequacy and compliance of hand hygiene attempts with the company protocol. The presence of other food handlers during hand hygiene attempts were also noted.

Involvement of the food manufacturing business in the study.

To minimise the potential Hawthorne Effect (whereby people modify their behaviour because they know they are being studied, and potentially distort the research findings (Payne and Payne 2004)), in this case study, food handlers in the participating business were not informed of the project as the researcher reviewed retrospective footage. CCTV cameras in the pre-production hand hygiene facilities of the business, had been in-situ for a number of years and were located throughout the business facility. Food handlers were routinely informed during pre-employment induction that cameras may be utilised to monitor hygiene practices and senior management indicated they were more commonly used for security purposes.

Data collection, storage and analysis.

Observation of hand hygiene footage from the pre-production hand hygiene facilities were undertaken over one production day. This incorporated a specified day of the week that the business reported had a high food production volume and a full workforce. Observation commenced from the first entry of a food handler into production at 05:39:56 through to final exit from production at 20:35:11. The CCTV software only recorded periods of activity in the pre-production hand hygiene facilities. A total of 446 individual clips were downloaded for the designated observation period and clip durations varied from 10 seconds to 11 minutes. All footage could be viewed at a regular and a reduced speed and the electronic checklist was used to compile a database of all recorded observations.

Following completion, the entire database was checked and assessed to ensure no missing values. A 10% sample of the entries were randomly checked by the researcher to ensure intra-operator reliability. A 20% sample of the entries were randomly selected by a second researcher, the footage for each selected entry was viewed and coded to ensure inter-operator reliability. Intraclass correlation coefficient was utilised to determine consistency between the repeated observations to determine intra-operator and inter-operator reliability.

All kappa values were determined to be ≥0.80, thus indicating the data to be highly reliable (Bowling, 2009). Descriptive analysis was conducted using an Excel spreadsheet (Excel 2016, Microsoft Office; Redmond, WA) and inferential statistics, such as Pearson's chi-squared test ($\chi 2$) were conducted using SPSS Statistics package 25 (IBM Software Group, Chicago, IL) to determined significant differences in observed behaviours according to the specific pre-production hand hygiene facility (high-risk or high-care), gender and the presence of other food handlers. Mann–Whitney (*U* test) was utilised to determine significant differences in hand washing duration according to facility and presence of others

Ethical approval.

Ethical approval for this case study was granted by the Research and Ethics Committee of the Cardiff School of Sport and Health Sciences at Cardiff Metropolitan University (project reference number: 8152).

Results.

A total of 200 occurrences of food handlers entering the two pre-production hand hygiene facilities were observed during the observation period for this case study. As indicated in Figure 1, 47 instances were of food handlers entering the high-risk production area (where cakes and ready-to-eat pies are manufactured) and 153 instances were of food handlers entering the high-care production area (where sandwiches and ready-to-eat salads are produced). On 13 occasions food handlers were observed failing to attempt implementation of any hand hygiene practices prior to entering the production areas. No significant differences ($p>0.05$) in failed attempts at hand hygiene practices were determined between high-risk (9%) and high-care (6%) pre-production hand hygiene facilities.

[Figure 1 near here]

Observed hand hygiene practices when entering production areas.

Of the 187 attempts to implement hand hygiene practices prior to entering the two production areas, the majority of food handlers (76–91%) neglected to push-up sleeves prior to commencing handwashing (Table 1). The practice of pushing sleeves up above the wrist prior to commencing handwashing (as described in the company protocol) was observed to be implemented significantly more frequently (p <0.005) in the high-care hand hygiene facility (24%) compared to the high-risk hand hygiene facility (9%) (X^2 (1, n = 187) = 4.516, p <0.05, phi = 0.155). No further statistically significant differences were determined in observed hand hygiene attempts or compliance (p>0.05) between the two pre-production hand hygiene facilities of the RTE food manufacturing business.

As indicated in Table 1, of the 187 attempts to implement hand hygiene practices prior to entering production; while 98% in high-risk and 99% in high-care utilised soap, only 56–69% wetted hands prior to soap application. Failure to rub all parts of the hands, palms, fingers and wrists was commonplace (<87%); with only 23% of food handlers in high-risk observed implementing this practice and only 13% in high-care, however, no significant difference was determined (p >0.05).

[Table 1 near here]

Duration of hand washing practices.

Observed hand washing duration ranged from 1–71 seconds. However, 93–96% of hand washing attempts in both high-risk and high-care pre-production hand hygiene facilities had durations shorter than the specified 20 seconds. Shorter hand washing durations were more frequently observed in the pre-production hand hygiene facility of high-risk than high-care (Figure 2). Hand washing attempts in neither area were significantly more likely (p >0.05) to have durations that complied with company protocol. However, significantly longer hand washing durations (Mean=11 seconds, n=144) were observed in high-care than in high-risk

(Mean=9 seconds, n=43) (U = 2214.0, z = -3.373, p <0.001, r = 0.25). Furthermore, significantly longer hand washing durations were observed when food handlers were in the presence of others (Mean=12 seconds, n=106) than when the food handler attempting hand washing was alone (Mean=9 seconds, n=81) (U = 2912.0, z = -4.896, p <0.001, r = 0.35); no other observed hand hygiene practices were found to be significantly different as a result of the presence of others.

[Figure 2 near here]

Hand drying and sanitising practices.

All food handlers were observed drying hands after implementing hand washing attempts. The most utilised method (89%) was the hand drier (high-risk: 72%, high-care: 94%) as opposed to disposable paper towel. On four occasions, food handlers entering high-care, were observed drying hands using the hand dryer for a short period and completing the drying action by drying hands on personal protection equipment (PPE).

To complete the hand hygiene practice, after hand washing and drying, the company protocol required food handlers to apply sanitiser. Although no significant differences were determined between the two pre-production hand hygiene facilities; of those entering high-risk, 24% failed to apply sanitiser after completing hand washing and drying, and 35% of those entering high-care failed to do so after completing hand washing and drying.

Comparison of observed hand hygiene practices according to gender.

Statistical analyses were conducted to explore potential differences in observed practices according to gender. Female food handlers (74%) were observed wetting hands before applying soap more frequently than male food handlers (56%) (X^2 (1, n = 187) = 6.334, p <0.05, phi = -0.184). Male food handlers (24%), however, rubbed all parts of hands, palms, fingers and wrists while washing hands (X^2 (1, n = 187) = 8.456, p <0.05, phi = 0.213) more frequently than female food handlers (8%). Male food handlers (13%) more frequently used

paper towels to dry hands than female food handlers (2%) (X^2 (1, n = 187) = 8.615, p <0.005, phi = 0.215) (Table 2).

No significant differences (p>0.05) were determined in compliance of hand hygiene attempts with company protocol according to gender and no significant difference (p>0.05) in the duration of hand washing practices were determined according to gender (males: Mean = 11.3 seconds, n = 80 and females: Mean = 10.8 seconds, n = 107). No significant gender differences were determined in relation to the use of hand sanitiser (p>0.05).

[Table 2 near here].

Compliance to company hand hygiene protocol.

The majority of hand hygiene attempts were not compliant with company protocol. No significant differences were determined between the two production areas (p >0.05). No compliant attempts were observed among food handlers entering the high-risk production area, and only 3% of food handlers implemented compliant hand hygiene attempts prior to entering high-care (4 attempts). Consequently, 98% of observed hand hygiene attempts prior to entering the two production areas in the RTE food manufacturing company were not compliant with company protocol. Although not determined to be significant (p>0.05), all compliant hand hygiene attempts were in the presence of others.

Discussion

Attempts to implement hand hygiene practices.

The vast majority attempted to implement hand hygiene practices in the pre-production hand hygiene facilities of high-risk (91%) and high-care (94%). This is comparable with previous research that determined attempts were observed prior to entering production (89.6%) suggesting food handlers are aware of the need to implement hand hygiene practices for the purposes of product safety and illustrates attempts to comply with company protocol (Evans and Redmond 2018).

Use of soap for hand hygiene practice.

For the removal of bacteria from hands, washing hands with soap and water is more effective than rinsing with water alone (Burton et al. 2011). In this present study, 99% of food handlers were observed using soap, however, only 56–69% were observed wetting their hands prior to applying soap as described in the company protocol. Failure to use soap, or failing to use soap appropriately when washing hands, may have potential implications for the safety of food products produced in an RTE food manufacturing business.

Cognitive research suggests that in catering settings, the majority of foodhandlers, chefs and catering managers report washing hands with soap (Bolton et al. 2008; Parry-Hanson Kunadu et al. 2016; Jones et al. 2017), however, discrepancies can exist between cognitive measures (knowledge, attitudes and self-reported practices) and observed behaviours (Tan et al. 2013). Indeed, in observational studies, it has been determined that soap was only used in 28% of activities, indicating that when workers omit a component of hand washing, it is usually soap (Green et al. 2006a). Observational data of food handlers in food environments serving the consumer directly indicate between 8% of food handlers in foodservice establishments (Clayton and Griffith 2004) and 15% of food handlers in grocery stores (Robertson et al. 2013) fail to use soap when washing hands. From industry based behavioural research, it has previously been reported between 8% (Schroeder et al. 2016) and 22% (Evans and Redmond 2018) of food handlers fail to use soap when implementing hand hygiene practices.

Hand washing durations.

The time taken to wash hands is an important factor for the removal of microorganisms (Todd et al. 2010). Food handlers who wash their hands for <10 seconds have been found to have higher counts of aerobic mesophiles and *Staphylococci* than food handlers who wash their hands for >10 seconds (Fawzi et al. 2009). In this study, 93–96% of hand washing attempts

had durations shorter than the specified 20 seconds.

One of the most frequently occurring issues with handwashing attempts, is the failure to continue washing durations to 20 seconds or more (Allwood et al. 2005). In previous observational studies, failure to execute hand washing for the recommended duration has been determined in 29% of attempts by grocery store food handlers (Robertson et al. 2013) and 44% of attempts by food service employees (York et al. 2009). By comparison, industry based observational research established that 93.7% of handwashing attempts by food handlers in a manufacturing business were not compliant with the specified duration (Evans and Redmond 2018), such data correspond with the findings of this study, (93–96% of attempts shorter than 20 seconds). Failing to wash hands for the recommended duration reduces the effectiveness of the hand washing attempt, a 20 second hand wash reportedly results in ~1.5 log CFU/hand greater reduction than a 5 second hand wash (Jensen et al. 2012).

Rubbing hands, palms and fingers during hand hygiene practices.

The degree of friction generated during lathering is regarded as more important than water temperature for removing soil and microorganisms (Todd et al. 2010), and thus, hands should be vigorously scrubbed for at least 20 seconds (York et al. 2009). In this study, vigorous and various actions, rubbing all parts of the hands, palms, fingers and wrists when lathering, were only observed in 23% of attempts in high-risk and in 13% of attempts in high-care pre-production hand hygiene facilities. Previous observational research with food handlers in manufacturing environments indicate that despite 73.7% rubbing hands palm to palm, the majority fail to rub other parts of hands such as between fingers and the back of hands, (observed in <10% of handwashing attempts) (Evans and Redmond 2018). The friction caused by rubbing hands together during hand washing, has the most influence on hand decontamination and significantly enhances the level of decontamination on hands (Miller et al. 2011). Consequently, failing to rub hands together during hand washing may result in an

ineffective hand wash whereby microorganisms remain on the hands, which may cause microbiological contamination in the food manufacturing environment.

Drying hands.

Hand drying is an essential step in the handwashing process to maintain high hand hygiene standards. Hands that remain damp have been found to transfer microorganisms to food and food contact surfaces more readily (Taylor et al. 2000), it is suggested that effective hand drying with paper towels may reduce transient flora populations by up to 90% (Gangar et al. 2000). Effective hand hygiene is a dual process, as much attention should be paid to the hand drying as to the hand washing (Miller et al. 2011).In previous food service establishment research, food handlers demonstrating ineffective hand drying using paper towel contributed to 93% of all observed incorrect hand hygiene events (Chapman et al. 2010). In recent industry-based research, 83.4% of hand hygiene attempts were concluded by drying hands with single use paper towel (Evans and Redmond 2018), however, in this present study, all food handlers were observed drying hands after hand washing attempts, and 94% opted to use the hand drier as opposed to disposable paper towel prior to entering the high-care production area.

Previously observed hand drying malpractices relate to failing to dry hands before entering production (1.8%) or drying hands on PPE (3.6%) (Evans and Redmond 2018). Such malpractices can have implications for food safety, as damp hands can readily transfer microorganisms in food environments (Taylor et al. 2000). Likewise, in this study non-compliant hand drying practices were observed on 2% of occasions, whereby food handlers were observed entering production areas without drying hands at all or drying hands on PPE.

Use of hand sanitiser.

Handwashing with water and soap has been found to be more effective than using a sanitiser alone (Charbonneau et al. 2000), however, given that alcohol-based products achieve rapid

and effective inactivation of various bacteria (Foddai et al. 2016); when combined with handwashing, the use of sanitiser significantly enhances the hygiene process (Michaels et al. 2003), consequently, the addition of a sanitiser to a hand washing regimen results in a greater reduction of microorganisms (Edmonds et al. 2012). There is a lack of data detailing the awareness, attitudes, self-reported use or observed utilisation of hand sanitiser among food handlers in food manufacturing research to allow comparison. In this study, 24% (high-risk) and 35% (high-care) of food handlers failed to apply sanitiser after completing hand washing and drying, prior to entering the production areas. This is in comparison to 63.2% of attempts by food handlers who failed to include the use of sanitiser prior to entering production areas (Evans and Redmond 2018).

Differences in hand hygiene practices between genders.

Differences in food safety behaviours are commonly reported between genders in consumer focused food safety research (Altekruse et al. 1999; Shiferaw et al. 2000; Zorba and Kaptan 2011). However, previous industry based observational research indicated no significant differences in the hand hygiene practices of individuals according to gender (Evans and Redmond 2018). In this study, although it was found that female food handlers were more frequently observed wetting hands prior to applying soap, and that male food handlers were observed vigorously rubbing all parts of the hands (i.e. palms, fingers and wrists) more frequently than food handler females, no statistically significant differences ($p>0.05$) were determined in compliant handwashing attempts or duration according to gender.

Differences in hand hygiene practices in the presence of others

A novel finding from this case study is that food handlers in the presence of others implemented significantly longer hand hygiene practices, than those implementing hand hygiene practices alone. Findings suggest presence of others may influence behaviour.

405 The Reasoned Action Approach (Fishbein and Ajzen 2011) considers how subjective
406 norms (the belief that others will approve or disapprove a certain behaviour) encourages or
407 discourages behaviour (Ajzen 2012). In terms of food safety – attitudes, subjective norms,
408 perceived behavioural control and work habits, may influence food safety behaviours (Hinsz
409 et al. 2007). Indeed, social norms are said to have greater influence on food safety behaviour
410 than perceived risk (Veflen et al. 2020). However, conflicts may exist between norms for safe
411 food handling and norms for maintaining social relationships (Scholderer and Veflen 2019).
412 Peer-pressure may promote or discourage compliant behaviour (Sigler and Murphy 1988).
413 Healthcare research has determined presence and proximity of others is associated with higher
414 hand hygiene rates (Monsalve et al. 2014). Presence of an audience has been found to
415 improve behaviours in certain settings (Baxter et al. 1990), consequently, the presence of
416 others reportedly improves food safety practices in food environments (Egan et al. 2007).
417 Despite increased interest in food safety culture (Yiannas 2008; Griffith Christopher J.
418 et al. 2010; Griffith C. J. et al. 2010; Powell et al. 2011), which consider the impact of shared
419 values, beliefs and norms upon food safety behaviour (Global Food Safety 2018); few studies
420 have investigated the effect of social norms in the context of food safety (Veflen et al. 2020).
421 There is a lack of research exploring the potential impact of peer-pressure, subjective norms
422 and audience presence on hand hygiene practices in food manufacturing environments.

423 ***Compliance to company protocol.***

424 Cognitive research suggests that food handlers are aware of recommended hand hygiene
425 protocols. Jianu and Goleţ (2014) reported that 81% of food handlers in Romanian meat
426 processing units were knowledgeable in correct handwashing procedures, whilst Gizaw et al.
427 (2014) reported that 46% of food handlers in Ethiopia knew how to wash their hands
428 correctly. Observation of foodservice employees has determined hand hygiene compliance of
429 in 47 – 75% of employees at the beginning of their shift or when returning to their work area
430 following a break (York et al. 2009). In this current case study, only 2% of hand hygiene

attempts were observed to be compliant with the company hand hygiene protocol. This is comparable to previous research in food manufacturing which found that the vast majority of attempts (97.8%) were not compliant with company protocol (Evans and Redmond 2018).

Limitations.

This study provides a novel snapshot of hand hygiene practices in two pre-production hand hygiene facilities in one company, at a specific point in time. The method is extremely time-consuming to conduct frequent and structured observation; when outcomes are presented to manufacturers, data are outdated and may not be indicative of current performance. Industry, requires real-time information regarding handwashing compliance, consequently there is a need to explore if the process can be automated through the utilisation of artificial intelligence or machine learning.

Although the study presents insights into the pre-production hand hygiene practices of food handlers, data detailing hand hygiene practices during production are not captured. Consequently, there is a need for research detailing the occasions when hand hygiene practices are implemented during production, together with an indication of compliance of practices at such times. There is a need for linking observed behaviours with cognitive influences, increasing understanding of organizational food safety culture associated with hand hygiene practices, and determining microbiological contamination of hand hygiene facilities within production and hand hygiene areas.

Conclusions.

This study has facilitated a covert assessment of hand hygiene practices in a RTE food manufacturing business, and has enabled a unique comparison of practices entering a high-risk food production area and a high-care food production area. Even though CCTV cameras were installed throughout the food manufacturing areas, the manufacturer did not routinely conduct structured observations of footage to monitor food handler hand hygiene practices

prior to entering production areas. Utilising pre-recorded footage from the company to enable covert-observation may have reduced potential reactivity bias. This novel method can be utilised to inform company policy and training.

Completion of the study indicates that despite different food handlers working in the two separate food production areas extensive non-compliant practices were observed in both; the majority of observed hand hygiene practices were contrary to company hand hygiene protocol, which may compromise food safety during food manufacturing. Findings suggest the hand hygiene issues were company-wide and were not contained to one pre-production hand hygiene facility. Considerable differences in the two areas were not observed, and non-compliant practices were observed in both areas; indicating a need for bespoke training interventions to inform food handlers of identified site-specific issues with a view to improving hand hygiene practices throughout the business.

As determined in similar research conducted in a food manufacturing business (Evans and Redmond 2018), observed hand hygiene practices did not meet the duration specified in company protocol. In this study, only 2% of observed hand hygiene attempts prior to entering production were compliant with protocol. A novel finding from this study is the determination of significant differences in hand hygiene practices in the presence of others, thus indicating the potential impact of social desirability or reactivity bias in the workplace.

This study highlights the potential discrepancy between hand hygiene training, company protocol and actual hand washing behaviour in practice. Investing time and resources in food handler training programmes that are ineffective limits progress towards building positive, proactive, food safety cultures and confident employees who are empowered to undertake correct hand hygiene action at key moments to ensure food safety is never compromised.

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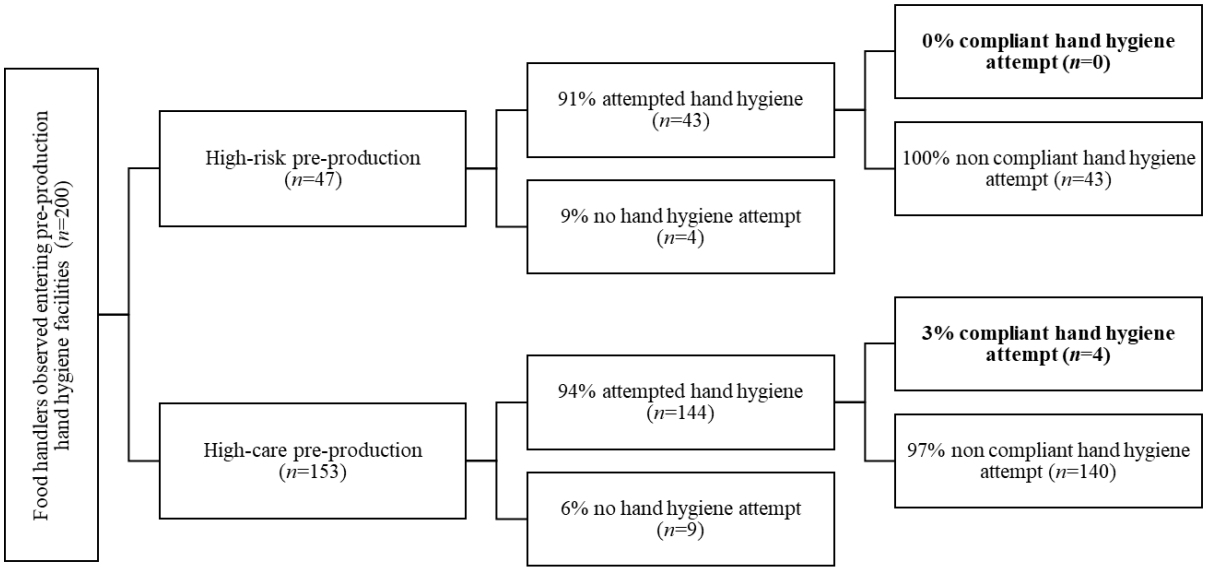
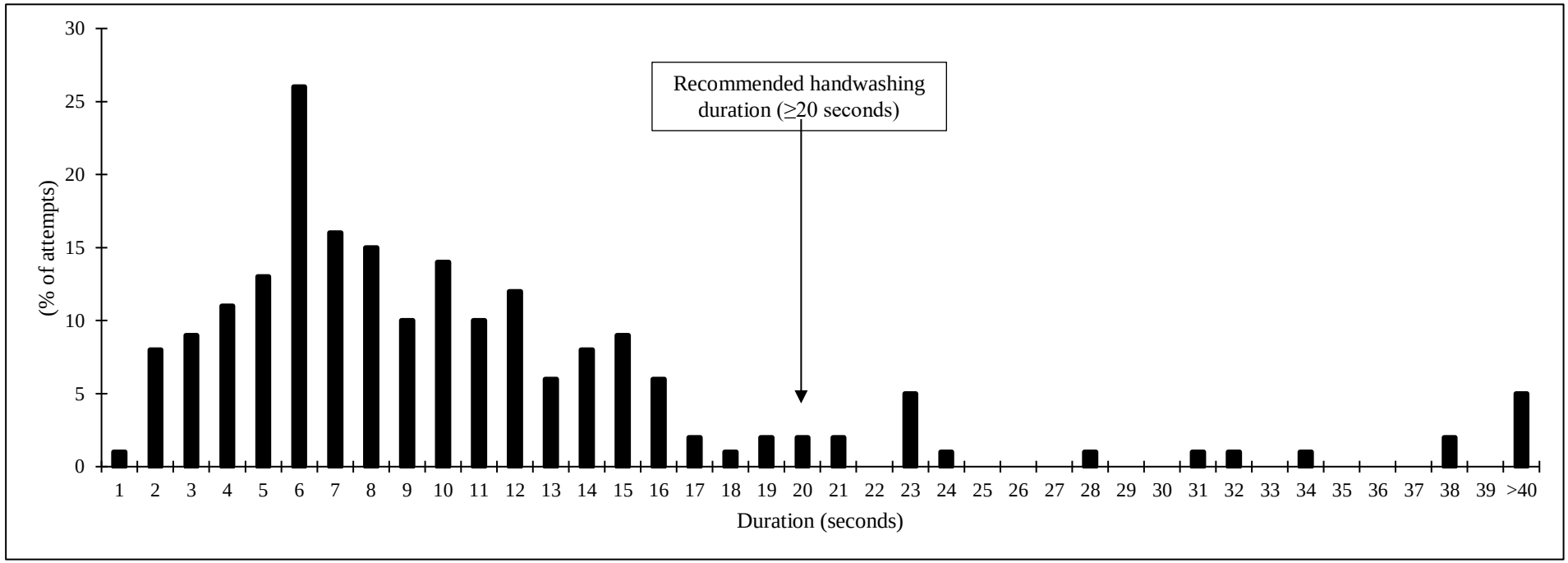
Figures

Figure 1 Observed food handler hand hygiene attempts according to pre-production location and compliance to company protocol (*n*=200)



491 Figure 2 Hand washing duration prior to entering production areas (*n*=187).



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493 # Tables

494 Table 1. Significant differences in observed hand hygiene practices prior to entering the two
495 production areas (*n*=187)

Observed hand hygiene practices	**High-risk production (*n*=43)**	**High-care production (*n*=144)**	**Statistical analysis (X^2 test)**
Push sleeves up 3 inches above the wrist	9%	24%	X^2 (1, n = 187) = 4.516, p <0.023, phi = 0.155
Wet hands with water first before applying soap	56%	69%	p>0.05
Apply soap	98%	99%	p>0.05
Vigorous and various actions when lathering – rubbing all parts of hands, palms, fingers and wrists	23%	13%	p>0.05
Duration of hand washing >20 seconds	7%	4%	p>0.05
Dry hands with paper towel, hand drier or both	100%	100%	p>0.05
Use of hand sanitiser	65%	76%	p>0.05
Attempts compliant with protocol*	0%	3%	p>0.05

***** For a hand hygiene attempt to be classed as 'compliant' with the company protocol, the necessary steps to be implemented by food handlers included; pushing sleeves up 3 inches above the wrist; wetting hands thoroughly; applying soap and rubbing all parts of hands, palms, fingers and wrists for 20 seconds, rinse hands to remove all soap, dry hands with paper towel or hand drier, apply hand sanitiser.

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Table 2. Significant differences in observed hand hygiene practices according to gender (*n*=187)

Observed hand hygiene practices	**Male (*n*=80)**	**Female (*n*=107)**	**Statistical analysis (X^2 test)**
Push sleeves up 3 inches above the wrist	18%	23%	$p > 0.05$
Wet hands with water first before applying soap	56%	74%	$X^2 = 6.334$, $p < 0.05$
Apply soap	99%	99%	$p > 0.05$
Vigorous and various actions when lathering – rubbing all parts of hands, palms, fingers and wrists	24%	8%	$X^2 = 8.456$, $p < 0.05$
Duration of hand washing ≥20 seconds	15%	7.5%	$p > 0.05$
Dry hands with paper towel, hand drier or both	100%	100%	$p > 0.05$
Use of hand sanitiser	75%	72%	$p > 0.05$
Attempts compliant with protocol*	3%	2%	$p > 0.05$

***** For a hand hygiene attempt to be classed as 'compliant' with the company protocol, the necessary steps to be implemented by food handlers included; pushing sleeves up 3 inches above the wrist; wetting hands thoroughly; applying soap and rubbing all parts of hands, palms, fingers and wrists for 20 seconds, rinse hands to remove all soap, dry hands with paper towel or hand drier, apply hand sanitiser.

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