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Risk behaviours and practices of food handlers in norovirus transmission

Abstract

Purpose – Food handlers are often a major source of norovirus transmission in the UK. Considering key behaviours of food handlers that lead to norovirus transmission would help prevent the spread. The purpose of this paper is to examine the key risk behaviours of food handlers that lead to norovirus transmission, and to recognise important prevention strategies.

Design/methodology/approach – A narrative review of the literature summarising the main risk behaviours of food handlers that lead to norovirus transmission.

Findings - Suboptimal personal hygiene such as poor hand washing compliance, working while ill or returning to work too early, and not adhering to cleaning and disinfecting protocols were the main risk behaviours of food handlers identified. To prevent the transmission of norovirus within UK food establishments, environmental barriers such as limited access to cleaning products and facilities, workload and pay concerns should be resolved, and a theory-based approach should be used when developing training programmes to improve food handlers' knowledge and behaviour. Systematic monitoring to ensure food safety protocols are adhered to should be regularly carried out.

Research limitations/implications – A limited number of qualitative studies assessing food handlers' attitudes and beliefs concerning norovirus transmission are available. Gaining more detailed and in depth information on what food handlers perceive are the main barriers when it comes to adhering to food safety guidelines, would aid in the development of effective norovirus mitigation strategies.

Originality/value – This review discusses the main risk behaviours of food handlers associated with norovirus transmission. It highlights the need for more qualitative research on exploring the attitudes and beliefs of food handlers with regards to norovirus transmission.

Keywords – Norovirus, food handler, transmission, barriers, prevention

Introduction

Noroviruses, a group of highly contagious single-stranded RNA viruses belonging to the *Caliciviridae* family, are recognised as a common cause of viral gastroenteritis and foodborne illness in the UK (Adak *et al*., 2002; Tam *et al*., 2012). Symptoms, including vomiting, diarrhoea, abdominal cramps, headaches and nausea, which encompass an incubation period between 10 and 50 hours following exposure, can last between 12 and 48 hours (ACMSF, 2015) and typically resolve exclusive of treatment. Dehydration is the main complication related to the norovirus infection, and can lead to hospitalisation, especially of vulnerable population groups such as very young children under the age of five, the elderly and immunocompromised patients.

Characterised by its low infectious dose, ~10 virus particles (ACMSF, 2015), alongside its high level of viral shedding that can persist for more than 3 weeks (Atmar *et al*., 2008; Murata *et al*., 2007; Rockx *et al*., 2002), norovirus is considered a highly contagious pathogen. Within the UK, between the years 2008-2009, the rate of norovirus in the community was estimated as 47 cases per 1000 person-years, this equated to ~3 million cases out of a population of ~62 million (Tam *et al*., 2012). Furthermore, only 4% (1 in every 23) of infected people consulted a General Practitioner, most of which were severe cases (Tam *et al*., 2012). Large outbreaks are typically observed during the winter months (Matthews *et al*., 2012), especially within health and social care institutions, schools, cruise ships, restaurants, and other closely confined densely populated settings (Hall *et al*., 2011).

Detecting human norovirus (HuNoV) can be challenging as it does not replicate in tissue culture. This makes it difficult to accurately quantify the risk to human health, as well as determine the efficacy of control measures. A number of surrogate markers, however, have been developed, namely feline calicivirus (FCV) and murine norovirus 1 (MNV-1), and more recently tulane virus (TV). Owing to its high sensitivity and specificity, real-time quantitative reverse transcription-polymerase chain reaction (RT-qPCR) is considered the gold standard assay used in public health and research laboratories to detect norovirus in stool, vomitus, serum, water and food samples (Vinje, 2015).

Norovirus is a huge economic burden for the health service. For instance, in the UK between the years 2008-2009, it was estimated that norovirus costed patients (i.e. medication, transport to health clinics, childcare etc.) and the health service (face-to-face and telephone consultations and visits to Accident and Emergency departments) £81 million (95% CI: 63m-£106m) (Tam and O'Brien, 2016). Furthermore, compared with other infectious intestinal diseases, norovirus presented a greater economic burden, as during the same period it was estimated that *Campylobacter* costs were £50m (95% CI: £33m, £75m) and rotavirus costs were £25m (95% CI: 18m, 35m) (Tam and O'Brien, 2016). Furthermore, a study that investigated the costs of norovirus outbreaks within NHS Lothian, Scotland, over two norovirus seasons, found that lost-bed days and staff absence due to norovirus resulted in costs of £1.2 million (Danial *et al*., 2011).

Norovirus is predominantly transmitted from person-to-person via body contact, e.g. shaking hands with an infected individual who had faecal or vomitus particles on their hand, who subsequently may touch ready-to-eat (RTE) food with their bare hands, or touch their own mouth (faecal-oral route or vomit-oral route), or via inhalation of aerosolised vomitus particles (Marks *et al*., 2000 and 2003). A reasonable proportion of norovirus cases are also a result of indirect transmission through the consumption of contaminated food or water. According to the UK Food Standards Agency (FSA), in 2011 there were approximately 314,000 norovirus cases out of a population of ~63 million where contaminated food was implicated (FSA, 2014). Furthermore, between 2013 and 2015, 186 norovirus outbreaks associated with a food outlet or registered food caterer occurred in London and South East England (Rumble *et al*., 2017). On a global scale it is estimated that the proportion of norovirus infections attributable to food is ~14% (Verhoef *et al*., 2015).

Norovirus does not replicate on food; instead it is a suitable transmission vehicle for the virus. Ready-to-eat fresh produce such as fruit and vegetables are considered high-risk foods as they are typically consumed raw with little or no processing, or no heat treatment to inactivate the virus. These foods can come into contact with faecal contaminated water during irrigation, through the application of fungicides, or during processing if contaminated water is used for washing (EFSA, 2014a and 2014b).

The role of contaminated water in norovirus foodborne transmission is typically via the overflow of untreated sewage into rivers and coastal waters, resulting in shellfish and bivalves coming into contact with the virus (Campos *et al*., 2014). Furthermore, as molluscs are filter-feeding organisms, they can bioaccumulate and concentrate norovirus (Campos *et al*., 2014). Without adequate heat treatment to inactivate norovirus before consumption, the risk of becoming infected is high. Shellfish and bivalves are considered high-risk foods for these aforementioned reasons, and have been implicated in many norovirus outbreaks worldwide (Hall *et al*., 2012; Smith *et al*., 2012; Webby *et al*., 2007). Between January and March 2010, there were 334 norovirus cases in 65 clusters, linked to the consumption of raw oysters in five European countries, including the UK, France, Denmark, Sweden and Norway (Westrell *et al*., 2010).

In addition to water-based contamination, food handlers involved in the processing, preparing or serving of food, typically ready-to-eat, are often a major source of foodborne transmission and subsequent outbreaks (Hall *et al*., 2012 and 2014). Attendance at work while infected along with inadequate personal hygiene, such as failure to wash and dry hands after attending the toilet, or not washing hands thoroughly with soap and running water can result in faecal particles remaining on the hand, which subsequently could be transferred to food or food preparing surfaces, leading to norovirus contamination. Between 2009 and 2012, food handlers were identified as the main source of norovirus outbreaks (70% of 520 outbreaks) in the US (Hall *et al*., 2014). Understanding the key practices and risk behaviours of food handlers that lead to norovirus transmission, hence, would help prevent the spread of this highly contagious virus in food establishments. The aim of this review is therefore to identify key practices and behaviours of food handlers and circumstances, which lead to norovirus transmission, as well as to identify potential norovirus mitigation strategies.

Risk behaviours and practices for norovirus transmission

The main risk behaviours and practices of food handlers in norovirus transmission are described below in detail and are summarised in **Table 1**.

Symptomatic and asymptomatic food handlers

It is recommended that individuals expressing symptoms of norovirus infection, particularly vomiting and diarrhoea, be excluded from food handling duties to prevent spread of this highly contagious pathogen to other employees, food and food preparing surfaces; however, this recommendation is not always adhered to. For instance, a study that assessed reported behaviour, knowledge and awareness of norovirus transmission of Dutch food handlers found that 20% (204 out of 960) of those working within catering companies had intentions to continue to work while experiencing diarrhoea, and 10% (99 out of 960) reported they would continue to work while experiencing vomiting (Verhoef *et al*., 2013). A similar study conducted in the USA found that ~ 20% (96 out of 486) of food workers reported that they had worked on one or more shifts while experiencing vomiting or diarrhoea, and 12% (58 out of 486) reported that they had worked on two or more shifts (Sumner *et al*., 2011).

Food handlers who experience gastroenteritis symptoms, but feel capable to work, may be reluctant to report their illness while working because of personal, social and financial reasons. Food catering jobs are typically low paid, and sick pay may not be available from day one, resulting in a loss of earnings. A qualitative study involving in-depth interviews with 25 food service workers in Baltimore, USA found that low pay impacted the ability to remain at home when feeling ill (Clayton et al., 2015). Furthermore, a number of participants interviewed indicated that they didn't have health insurance through work, and avoided doctor appointments because they are unaffordable. For these reasons they continued to work while feeling ill (Clayton et al., 2015).

Absence of policies requiring the workers to report their illness to their managers; lack of on-call workers; suboptimal managerial experience; did not feel ill; had a strong work ethic and did not want to miss work; and a high volume of meals served are some of factors that have also been associated with workers continuing to work while feeling ill (Sumner *et al*., 2011; Carpenter *et al.,* 2013).

In the UK it is a legal requirement that food workers report their symptoms to their managers or supervisors. Managers should exclude employees from working until 48 hours after symptoms have ceased (FSA, 2009). This length of exclusion, however, may not be sufficient to prevent the spread of the virus, as viral shedding has been reported to occur up to and even after 3 weeks (Atmar *et al*.,

2008; Murata *et al.*, 2007; Rockx *et al.*, 2002). If returning to work after 48 hours it is therefore imperative that personal hygiene measures, such as regular and thorough hand washing, are implemented to prevent spreading to other employees, food surfaces and food.

Another issue, which is difficult to control for is asymptomatic food handlers who are infected with norovirus, but do not display any of the associated symptoms. Asymptomatic food handlers can have the same level of virus shedding as symptomatic food handlers (Ozawa *et al.*, 2007). Research has shown their involvement in a number of food-borne outbreaks of norovirus in Denmark (Franck *et al.*, 2015), Ireland (Nicolay *et al.*, 2011), Japan (Ozawa *et al.*, 2007), Taiwan (Chen *et al.*, 2016) and Spain (Barrabeig et al., 2010). It is recommended in the "Food Handlers: fitness to work" UK guidelines, which were developed to help managers and their staff in the UK prevent the spread of infection in the workplace, that food handlers report to their supervisor any history of exposure i.e. if someone they live with has been diagnosed with norovirus within the last week (FSA, 2009). Asymptomatic workers may be reluctant to do this for the same reasons aforementioned as symptomatic workers i.e. social, personal and financial reasons.

A rapid screening test would permit food establishments to identify asymptomatic employees; however, this may be difficult and costly to implement. Currently, the gold standard clinical diagnostic test is the RT-qPCR assay, which has high specificity and sensitivity. This method however, is more suitable for research laboratories, and is not as rapid or simple as other methods, such as the Immunochromatographic (ICG) lateral flow assay that does not require laboratory equipment (Vinje, 2015). Conversely, the ICG is not as sensitive and is genotype dependent (Vinje, 2015).

Personal hygiene

Inadequate personal hygiene such as failure to wash and dry hands after attending the toilet, or not washing hands thoroughly with soap and running water, can result in faecal particles remaining on the hand, which subsequently could be directly transferred to food or food preparing surfaces, leading to norovirus contamination. The FSA's "Food Handlers: fitness to work" guidelines (FSA, 2009) states that for best practice a demonstration of good hand washing technique should be provided to all staff

at induction. Compliance to hand washing, however, is not always adhered to in food establishments. For instance, a catering workers hygiene survey of 1,000 food workers and managers within the UK, revealed that 39% failed to wash their hands after attending the toilet whilst at work, and 53% reported not washing their hands prior to preparing food (FSA, 2002). Furthermore, an observational study of food workers' hand washing practices in the USA found that hand washing was only performed for 32% of activities that require hand washing, such as food preparation, putting on gloves for food preparation and preparing raw animal products (Green *et al*., 2006).

The literature has identified reasons for food handlers not complying with hand washing guidelines. A qualitative study, for example, involving focus group discussions with food handlers on the main practices and barriers to hand washing in the restaurant environment, found that time pressures, inadequate facilities and supplies, lack of accountability, lack of involvement of managers and co-workers as well as support from organisations, were the main barriers to hand washing within the restaurant environment (Pragle *et al*., 2007). The EFSA recommends that the most effective method for reducing norovirus contamination on the hands is washing them for 20 seconds with soap and running water, and drying them for a further 20 seconds with disposable paper towels (EFSA, 2011). Working within a busy catering environment, however, creates time pressures, which potentially could prevent employees from washing their hands adequately or regularly between tasks, or instead provoke them to carry out a cursory wash. Furthermore, some food establishments may have an inadequate number of washing facilities making access difficult, or have no soap or drying towels available (Clayton *et al*., 2015). Another barrier to regular handwashing is the irritation and dryness caused by consistent use of soap and water (Clayton *et al*., 2015). Sanitary soaps can be abrasive with excess use, causing dryness and pain.

Conversely, a number of facilitators for hand washing compliance were identified by a focus group study conducted in the USA, involving food service workers and managers; these included personal preferences for clean hands, food preparation experience, concerns regarding consequences to customer and personal health, restaurant procedures that encouraged hand washing and worker motivation (Green and Selman, 2005).

Although alcohol-based hand sanitizers appear to be a convenient option during busy periods, evidence regarding their effectiveness in reducing norovirus transmission is inconclusive (Blaney et al., 2011; Macinga *et al*., 2008; Park *et al*., 2010; Sickbert-Bennett *et al*., 2005; Tuladhar et al., 2015). An experimental study found using finger pad tests that washing hands with soap and water (~15 degrees) was more effective in removing norovirus from hands than using alcohol-based hand disinfectants (Tuladhar *et al.,* 2015). Food establishments should encourage hand washing with soap and water, and avoid promoting the use of these hand gels until further conclusions are drawn regarding their efficacy.

A reasonable proportion of foodborne norovirus outbreaks where food handlers have been implicated, have been a result of food handlers using their bare hands to prepare RTE foods (Hall *et al*., 2014). Most food handlers within the food setting service are required to wear gloves for this reason. Wearing gloves, however, could be considered an inconvenience for some food employees, such as those that have the responsibility to prepare food and work the cash register simultaneously (Moe *et al*., 2009). Not washing your hands prior to gloving may also result in cross-contamination. An experiment carried out by Ronnqvist and colleagues (2014); using reverse transcription-PCR, found that human norovirus contaminated hands prior to gloving, which subsequently led to contamination of the clean gloves, which could potentially transfer to food. When handwashing is carried out prior to gloving, norovirus transmission to food is reduced (Mokhtari *et al.,* 2009).

Food establishment environment

Another transmission route for norovirus is through food preparation surfaces, clothing, and kitchen utensils including knives and chopping boards. These can become contaminated either through being in contact with the food handler's contaminated hands (Barker *et al*., 2004; Tuladhar *et al*., 2013) or contaminated food (Wang *et al*., 2013). Wang *et al.* (2013) showed that cross-contamination within the kitchen environment, between contaminated utensils and produce can easily occur. For example, kitchen utensils (knives and graters) were first used to cut contaminated produce including honeydew and cantaloupe melons, strawberries, cucumbers, tomatoes and carrots. Results indicated that

cucumbers, strawberries and tomatoes were more likely to contaminate the knives with MNV-1 than the two types of melon. Next the utensils (knife and grater) were freshly contaminated with MNV-1, which were then successively used to cut/grate seven non-contaminated tomatoes/carrots. MNV-1 was detected in all the pieces of the first tomato cut (ratio of transfer [positive count/ samples tested]: 12/13), and at least 20% of the first carrot grated (ratio of transfer [positive count/ samples tested]: 3/15). For the following six non-contaminated tomatoes/carrots there was a general trend of a decreasing number of positive MNV-1 virus positive samples for subsequent use of the utensils.

There is also evidence to suggest that norovirus is environmentally stable and can survive on food preparation surfaces for prolonged periods of time. A study investigating the survival of FCV, a surrogate marker indicating the contamination of human norovirus in foods and on a stainless steel surface, typically used in food establishments, found that norovirus virus could survive up to 7 days at room temperature and under refrigeration conditions (Mattison *et al.*, 2007). Another experiment found that norovirus after 21-28 days storage under ambient conditions had an average reduction ranging from 1.5 to 2.9 $\log_{10}$ genome equivalent particles (Liu *et al.*, 2009). The type of food preparing surface may also influence the survival time of norovirus. For instance, a study that examined the survival of MNV-1 at room temperature for 28 days on six different food contact surfaces, found that the reduction of MNV-1 was highest on a stainless steel surface (2.28 $\log_{10}$ plaque forming units/coupon) and lowest on a wood surface (1.29 $\log_{10}$ plaque forming units/coupon) (Kim *et al.*, 2014).

Ready-to-eat foods, such as fruit and vegetables, are considered high-risk commodities due to norovirus being environmentally stable in cold and ambient temperatures. Numerous norovirus outbreaks, specifically involving raspberries and leafy vegetables, have been reported in the EU and the US (Einoder-Moreno *et al.*, 2016; Ethelberg *et al.*, 2010; Hall *et al.*, 2012; Hjertqvist *et al.*, 2006; Maunula *et al.*, 2009; Muller *et al.* 2015; Savikivi *et al.*, 2012). Failure to adequately wash these food items during preparation could be another potential transmission route for the spread of norovirus. Research shows that simply washing fruit and vegetables with tap water can result in virus reductions of ~1-log, and with the addition of chlorine (200 ppm) a slight increase in reduction can be further

achieved (Baert *et al.*, 2009; Predmore and Jianrong, 2011). A study carried out in 2011 found, however, that disinfecting fresh produce with a combination of sodium hypochlorite (200 ppm) and a surfactant (e.g. sodium dodecyl sulphate) was a more effective method than using sodium hypochlorite solution (200 ppm) alone to remove MNV-1 (Predmore and Jianrong, 2011). The study showed a reduction of >3-logs in all fresh produce sampled.

Cooking/ heating foods can inactivate the virus. Temperatures ranging between 37 and 100^0 C inactivated FCV and canine calicivirus (CaCV) (Duizer et al., 2004), while temperatures of 63 to 72^0C inactivated FCV and MNV-1 (Cannon et al., 2006).

An infected food handler's uniform can also be a potential medium for norovirus transmission. Wiping dirty hands or using their uniform to dry their hands potentially could contaminate food. Employees may also be expected to wash their own uniforms at home. This is of concern, as the temperature used to wash the uniforms within a domestic setting may not be sufficient in killing norovirus. Professional laundry services should be utilised; however, the associated costs may prevent the facilitation of these services.

The above evidence indicates the importance of increasing food handlers' awareness about the importance of cross-contamination in the kitchen environment, particularly regarding kitchen utensils being potential virus vehicles, and that norovirus can remain on food preparing surfaces for a long period of time. Cleaning and disinfection protocols should be taking this evidence into consideration to prevent the spread of this highly contagious pathogen.

Recommendations

Multiple environmental barriers such as limited access to cleaning products and facilities, workload and pay concerns, in conjunction with limited knowledge and inadequate training are likely the causes for food handlers' role in norovirus transmission. The following recommendations based on the information above, and current UK legislation for food handlers, have been proposed that can be used in teaching and in practice to help prevent the spread of norovirus (see Table 1 for summary).

All employees, including supervisors should be aware of any food safety management systems such as HACCP within their workplace. EU legislation requires that all food handlers are supervised and trained in food hygiene matters related to their work and carry out the training courses that are a requirement of national law (EFSA, 2011). Training should be carried out regularly and on-the-spot checks should be carried out by supervisors to ensure what the employees have learnt is being put into practice; especially in relation to hand washing compliance. Training programmes to prevent and control norovirus contamination should provide detailed information regarding ways in which the virus can easily be transferred in the kitchen environment, how long the virus can survive in the kitchen environment, the importance of cleaning and disinfecting contaminated surfaces and utensils, and the importance of hand washing compliance, especially after experiencing an episode of gastroenteritis or after being in contact with faeces or vomit (EFSA, 2011).

Procedures for reporting an episode of gastroenteritis and information regarding the 48-hour after symptoms have stopped exclusion should be explained to food handler employees from their first working day. The importance of reporting their exposure history, i.e. if they have been in close contact with symptomatic individuals, should also be clearly accentuated.

Regarding the working environment, food handler employees should be aware of the importance of adequate cleaning and disinfection of food production areas as well as the bathroom, surface areas, equipment and utensils should be carried out following an episode of gastroenteritis (vomiting and/or diarrhoea). The EFSA recommends disinfecting food preparation surfaces with a solution of >1000 mg/L free chlorine, preferably hypochlorite solutions, as they can potentially reduce viral infectivity by over 10^{-3} (EFSA, 2011). All food establishments should provide the adequate facilities and materials for cleaning and disinfecting according to EU legalisation (EFSA, 2011). Furthermore, food handlers should also not be responsible for cleaning and disinfecting areas where vomiting/diarrhoea has occurred, as it is possible for droplets to remain on their skin. Trained personnel should take care of any spillages, ensuring they wear protective clothing such as disposal masks, gloves and aprons (EFSA, 2011).

To ensure all procedures and protocols are adhered to, positive incentives for employees are necessary. For instance, as mentioned above, some employees continue to work when experiencing gastroenteritis symptoms to avoid the loss of earnings, and some may return to work too early for this reason also. These behaviours increase the risk of spreading norovirus to customers and other employees. Implementing sick pay from day one should be considered as a potential mitigation strategy. Some employers may oppose to this strategy due to the associated costs of staff cover; however, the costs associated with other staff and customers becoming infected because of an infected employee would consequently be superior.

Inadequate personal hygiene such as failure to wash and dry hands after attending the toilet can result in norovirus contamination and spread. As mentioned above, some of the reasons for non-compliance to hand washing procedures are lack of facilities to wash and dry hands, irritation and dryness caused by consistent use of soap and running water and time pressures. According to EU legislation it is a general requirement for food premises to have an adequate number of washbasins and toilets and suitable materials to clean hands and to dry them (EFSA, 2011). Employers should purchase less abrasive soaps and should provide hand cream for relief to encourage regular hand washing. In relation to time restraints, managers should emphasise the importance of washing hands regularly, especially after attending the toilet, when preparing food and when switching tasks, regardless of time constraints. They should also have on-the-spot checks to make sure they are adhering to the procedures.

Provision of information alone to reduce food safety risk is not sufficient to prompt a change in food handlers' behaviour. It has been recommended that behavioural theories and models be used as a framework for understanding food handlers' practices. Social cognitive models, such as the Theory of Planned Behaviour (TBP) and the Health Belief Model have been used previously to predict behaviours including food handling (Clayton *et al.,* 2002; Seaman and Eves, 2008 and 2010) and hand hygiene practices (Clayton and Griffith, 2008). The findings from these studies show that there are many factors, other than increased knowledge that influence food handling practices, namely attitude, intentions, subjective norms and perceived behaviour control. They also highlight that although food

safety training to enhance knowledge should be encouraged, it does not always prompt an improvement in food handling behaviour.

A theory-based approach should also be used when developing training programmes to improve food handlers' behaviours. The Behaviour Change Wheel is a framework used to guide the development and evaluation of behavioural change interventions using a systematic approach (Michie *et al.,* 2011). Future training programmes should consider using such a framework when designing training programmes targeting food-handling behaviours to reduce norovirus transmission.

Future research

While conducting this review, it was evident that there are a limited number of qualitative studies conducted, especially in the UK that have examined food handlers' attitudes and behaviours regarding norovirus transmission. To date, the majority of qualitative studies have been undertaken in the USA and have focused on food safety practices in general rather than those specifically related to norovirus. More information on the barriers to and facilitators of hand washing compliance, the reporting of illness and working while ill of UK food handlers are required. Gaining an insight into what food handlers feel and believe, as well as determining the reasons for their behaviour, would aid in the development of norovirus mitigation strategies in the catering environment that are not only effective in reducing cross-contamination and spread of the virus, but concurrently are acceptable by food handling staff and are easy to implement. Mixed method research involving quantitative and qualitative data collection methods is warranted, especially in the UK to identify such strategies. Behavioural theories and models should also be used as a framework for understanding food handlers' practices.

Furthermore, a quick and sensitive test for diagnosing norovirus is needed. If a test was commercially available, infected systematic and asymptomatic food handlers would be identified more promptly, which subsequently could prevent and reduce the number of norovirus outbreaks that occur in food establishments.

Currently only surrogate markers are being used to determine the efficacy of control measures used to reduce the transmission and spread of foodborne norovirus. Research shows that HuNoV is more resistant to heat and disinfectants compared with surrogate markers; hence is more likely to remain in food, utensils and food preparing surfaces (Knight *et al.,* 2016). This makes it challenging to accurately quantify the risk of foodborne norovirus to human health, and the effectiveness of current recommended control measures used throughout the food chain. While a number of methods have been developed for HuNoV detection *in vitro,* only a few have been somewhat successful in detecting the virus accurately (DiCaprio, 2017). Further research into the development of an *in vitro* cultivation system for HuNov is warranted.

Conclusion

Norovirus is an extremely contagious pathogen that consequently presents a huge economic burden for health and social care institutions, as well as food establishments. Food handlers play an important role in norovirus transmission owing to their risk behaviours and practices such as inadequate personal hygiene, working while ill and not adhering to cleaning and disinfecting protocols. Adequate and effective training alongside regularly monitoring by supervisors and managers, improved and accessible facilities and monetary incentives should be considered as effective norovirus mitigation strategies. A theory-based approach should also be used when developing training programmes to improve food handlers' behaviours. More social science research on the attitudes and behaviours of food handlers in the transmission and prevention of norovirus contamination is warranted to aid the development of effective and engaging norovirus reduction interventions.

References

1. Adak, G.K., Long, S.M. and O'Brien, S.J. (2002), "Trends in indigenous foodborne disease and deaths, England and Wales: 1992 to 2000", *Gut*, Vol. 51No. 6, pp. 832-841.

2. Advisory Committee on the Microbiological Safety of Food, ACMSF. Ad Hoc Group on Foodborne Viral Infections. (2015), "An update on viruses in the food chain", available at: https://acmsf.food.gov.uk/sites/default/files/acmsf-virus-report.pdf (accessed 22 January 2016).

3. Atmar, R.L., Opekun, A.R., Gilger, M.A., Estes, M.K., Crawford, S.E., Neill, F.H. and Graham, D.Y. (2008), "Norwalk virus shedding after experimental human infection", *Emerging Infectious Diseases*, Vol. 14 No. 10, pp. 1553-1557.

4. Baert, L., Vandekinderen, I., Devlieghere, F., Van Coillie, E., Debevere, J. and Uyttendaele, M. (2009), "Efficacy of sodium hypochlorite and peroxyacetic acid to reduce murine norovirus 1, B40-8, Listeria monocytogenes, and Escherichia coli O157:H7 on shredded iceberg lettuce and in residual was water", *Journal of Food Protection*, Vol. 72 No. 5, pp. 1047-1054.

5. Barker, J., Vipond, I.B. and Bloomfield, S.F. (2004), "Effects of cleaning and disinfection in reducing the spread of norovirus contamination via environmental surfaces", *Journal of Hospital Infection*, Vol. 58 No. 1, pp. 42-49.

6. Barrabeig, I., Rovira, A., Buesa, J., Bartolome, R. Pinto, R., Prellezo, H. and Dominquez, A. (2010), "Foodborne norovirus outbreak: the role of an asymptomatic food handler", *BMC Infectious Diseases*, Vol. 10, pp. 269.

7. Blaney, D.D., Daly, E.R. Kirkland, K.B., Tongren, J.E., Kelso, P.T. and Talbot, E.A. (2011), "Use of alcohol-based hand sanitizers as a risk factor for norovirus outbreaks in long-term care facilities

in northern New England: December 2006 to March 2007, *American Journal of Infection Con*trol, Vol. 39 No. 4, pp. 296-301.

8. Cannon, J.L., Papafragkou, E., Park, G.W., Osborne, J., Jaykus, L.A. and Vinje, J. (2006), "Surrogates for the study of norovirus stability and inactivation in the environment: A comparison of murine norovirus and feline calicivirus", *Journal of Food Protection,* Vol. 69 No. 11, pp. 2761-2765.

9. Campos, C.J. and Lees, D.N. (2014), "Environmental transmission of human noroviruses in shellfish waters", *Applied Environmental Microbiology.* Vol. 80 No. 12, pp. 3552-3561.

10. Carpenter, L.R., Green, A.L., Norton, D.M., Frick, R., Tobin-D'Angelo, M., Reimann, D.W., Blade, H., Nicholas, D.C., Egan, J.S., Everstine, K., Brown, L.G. and Le, B. (2013), "Food worker experiences with beliefs about working while ill", *J Food Prot*, Vol. 76, No. 12, pp. 2146-2154.

11. Chen, M.Y., Chen, W.C., Chen, P.C., Hsu, S.W. and Lo, Y.C. (2016), "An outbreak of norovirus gastroenteritis associated with asymptomatic food handlers in Kinmen, Taiwan", *BMC Public Health*, Vol. 16, pp. 372.

12. Clayton, D.A., Griffith, C.J., Price, P. and Peters, A.C. (2002), "Food handlers' beliefs and self-reported practices", *Int J Environ Health Res,* Vol. 12, pp. 25-39.

13. Clayton, D.A. and Griffith, C.J. (2008), "Efficacy of an extended theory of planned behaviour model for predicting caterers' hand hygiene practices", *Int J Environ Health Res*, Vol. 18, No. 2, pp. 83-98.

14. Clayton, M.L., Clegg Smith. K., Neff, R.A., Pollack, K.M. and Ensminger, M. (2015), "Listening to food workers: Factors that impact proper health and hygiene in food service", *International Journal of Occupational and Environmental Health*, Vol. 21No. 4, pp. 314-327.

15. Danial, J., Cepeda, J.A., Cameron, F., Cloy, K. Wishart, D. and Templeton, K.E. (2011), "Epidemiology and costs associated with norovirus outbreaks in NHS Lothian, Scotland 2007-2009", *Journal of Hospital Infections*, Vol. 79 No. 4, pp. 354-358.

16. DiCaprio, E. (2017), "Recent advances in human norovirus detection and cultivation methods", *Cur Opin Food Sci*, Vol. 14, pp. 93-97.

17. Duizer, E., Bijkerk, P., Rockx, B., De Groot, A., Twisk, F. and Koopmans M. (2004), "Inactivation of caliciviruses", *Applied Environmental Microbiology*, Vol. 70 No. 8, pp. 4538-4543.

18. Einoder-Moreno, M., Lange, H., Grepp, M., Osborg, E., Vainio, K. and Vold, L. (2016), "Non-heat-treated frozen raspberries the most likely vehicle of a norovirus outbreak in Olso, Norway, November 2013, *Epidemiology and Infection*, Vol. 144 No. 13, pp. 2765-2772.

19. Ethelberg, S., Lisby, M., Bottiger, B., Schultz, A.C., Villif, A., Jensen, T., Olsen, K.E., Scheutz, F., Kjelso, C. and Muller, L. (2010), "Outbreaks of gastroenteritis linked to lettuce, Denmark, January 2010", *Eurosurveillance,* Vol. 15 No. 6, pii: 19484.

20. European Food Safety Authority (EFSA) Panel on Biological Hazards (BIOHAZ). (2011), "Scientific Opinion on the present knowledge on the occurrence and control of foodborne viruses", *European Food Safety Authority Journal*, Vol. 9 No. 7, pp. 2190.

21. European Food Safety Authority (EFSA) Panel on Biological Hazards (BIOHAZ). (2014a), "Scientific Opinion on the risk posed by pathogens in food of non-animal origin. Part 2 (Salmonella and Norovirus in leafy greens eaten raw as salads)", *European Food Safety Authority Journal, Vol.*12 No. 3, pp. 3600.

22. European Food Safety Authority (EFSA) Panel on Biological Hazards (BIOHAZ). (2014b), "Scientific Opinion on the risk posed by pathogens in food of non-animal origin. Part 2 (Salmonella and Norovirus in berries)", *European Food Safety Authority Journal.* Vol. 12 No. 6, pp. 3706.

23. Food Standards Agency. (2002), "Catering workers hygiene survey 2002", available at http://tna.europarchive.org/20110110150006/http://www.food.gov.uk/safereating/safhygres/fhccateringsurvey (accessed 20 January 2016).

24. Food Standards Agency. (2009), "Food handlers: Fitness to work. Regulatory guidance and best proactice advice for food business", available at: https://www.food.gov.uk/sites/default/files/multimedia/pdfs/publication/fitnesstoworkguide09v3.pdf (accessed 20 January 2016).

25. Food Standards Agency. (2014), "Norovirus", available at: http://tna.europarchive.org/20140807103012/http://www.food.gov.uk/science/microbiology/norovirus/ (accessed 22 January 2016).

26. Franck, K.T., Lisby, M, Fonager, J., Schultz, A.C., Bottiger, B., Villif, A., Absalonsen, H. and Ethelberg, S. (2015), "Sources of calicivirus contamination in foodborne outbreaks in Denmark, 2005-2011- the role of the asymptomatic food handler, Journal of Infectious Diseases, Vol. 211 No. 4, pp. 563-570.

27. Green, L.R. and Selman, C.A. (2005), "Factors impacting food workers' and managers' safe food preparation practices: A qualitative study", *Food Policy,* Vol. 25, No. 12, pp. 981-990.

28. Green, L.R., Selman, C.A., Radke, V., Ripley, D., Mack, J.C., Reimann, D.W., Stigger, T., Motsinger, M. and Bushnell, L. (2006), "Food worker hand washing practices: an observational study", *Journal of Food Protection*, 2006 Vol. 69 No. 10, pp. 2417-2423.

29. Hall, A.J., Vinje, J., Lopman, B., Woo Park, G., Yen, C., Gregoricus, N. and Parashar, U.D. (2011) "Updated Norovirus outbreak management and disease prevention guidelines", *MMWR Recommendations and Reports*, Vol. 60 (RR-3), pp. 1-18.

30. Hall, A.J., Eisenbart, V.G., Etingue, A.L., Gould, L.H., Lopman, B.A. and Parashar, U.D. (2012), "Epidemiology of foodborne norovirus outbreaks, United States, 2001-2008", *Emerging Infectious Diseases*. 2012; **18**: 1566-1573.

31. Hall, A.J., Wikswo, M.E., Pringle, K., Gould, L.H., Parashar, U.D. Division of Viral Diseases, National Centre for Immunization and Respiratory Diseases, CDC. (2014), "Vital signs: Foodborne Norovirus Outbreaks – United States, 2009-2012", *MMWR Morbidity and Mortality Weekly Report,* Vol. 63 No. 22, pp. 491-495.

32. Hjertqvist, M., Johansson, A., Svensson, N., Abom, P.E., Magnusson, C., Olsson, M., Hedlund, K.O. and Andersson, Y. (2006), "Four outbreaks of norovirus gastroenteritis after consuming raspberries, Sweden, June–August 2006", *Eurosurveillance*, Vol. 11 No. 9, E060907.1.

33. Kim, A-N., Park, S.Y., Bae, S-C., Oh, M-H. and Ha, S-D. (2014), "Survival of Norovirus on Various Food-contact surfaces", *Food and Environmental Virology*, Vol. 6 No. 3, pp. 182-188.

34. Knight, A., Haines, J., Stals, A., Li, D., Uyttendaele, M., Knight, A. and Jaykus, L.A. (2016), "A systematic review of human norovirus survival reveals a greater persistence of human norovirus RT-qPCR signals compared to those cultivable surrogate viruses", *Int J Food Microbiol*, Vol. 216, pp. 40-49.

35. Liu, P., Chien, Y.W., Papafragkou, E., Hsiao, H-M., Jaykus, L-A. and Moe C. (2009), "Persistence of human noroviruses on food preparation surfaces and human hands", *Food and Environmental Virology*, Vol. 1No, pp. 141-147.

36. Macinga, D.R., Sattar, S.A., Jaykus, L. and Arbogast, J.W. (2008), "Improved inactivation of nonenveloped enteric viruses and their surrogates by a novel alcohol-based hand sanitizer", *Applied Environmental Microbiology,* Vol.74 No. 16, pp. 5047–5052.

37. Marks, P.J., Vipond, I.B., Carlisle, D., Deakin, D., Fey, R.E. and Caul. E.O. (2000), "Evidence for airborne transmission of Norwalk-like virus (NLV) in a hotel restaurant", *Epidemiology and Infection,* Vol. 124 No. 3, pp. 481-487.

38. Marks, P., Vipond, I.B., Regan, F.M., Wedgwood, K., Fey, R.E. and Caul, E.O. (2003), "A school outbreak of Norwalk-like virus: evidence for airborne transmission", *Epidemiology and Infection.* Vol. 131 No. 1, pp. 727-736.

39. Matthews, J.E., Dickey, B.W., Miller, R.D., Felzer, J.R., Dawson, B.P., Lee, A.S., Rocks, J.J., Kiel, J., Montes, J.S., Moe, C.L., Eisenberg, J.N.S. and Leon, J.S. (2012), "The epidemiology of published norovirus outbreaks: a review of risk factors associated with attack rate and genogroup", *Epidemiology and Infection,* Vol. 140 No. 7, pp. 1161-1172.

40. Mattison, K., Karthikeyan, K., Abebe, M., Malik, N., Sattar, S.A., Farber, J.M. and Bidawid, S. (2007), "Survival of calicivirus in foods and on surfaces: experiments with feline calicivirus as a surrogate marker for norovirus", *Journal of Food Protection*, Vol. 70 No. 2, pp. 500-503.

41. Maunula, L., Roivainen, M., Keranen, M., Makela, S., Soderberg, K., Summa, M., von Bonsdorff, C.H., Lappalainen, M., Korhonen, T., Kuusi, M. and Niskanen, T. (2009), "Detection of human norovirus from frozen raspberries in a cluster of gastroenteritis outbreaks", *Eurosurveillance,* Vol. 14 No. 49, pii: 19435.

42. Michie, S., van Stralen, M.M. and West, R. (2011), "The behaviour change wheel: A new method for characterising and designing behaviour change interventions", *Implement Sci*, Vol. 6, pp. 42.

43. Moe, C.L. (2009), "Preventing norovirus transmission: how should we handle food handlers?" *Clinical Infectious Diseases*, Vol. 48 No. 1, pp. 38-40.

44. Mokhtari, A. and Jaykus, L.A. (2009), "Quantitative exposure model for the transmission of norovirus in retail food preparation", *International Journal of Food Microbiology*, Vol. 133 No. 1-2, pp. 38–47.

45. Muller, L., Schultz, A.C., Fonager, J., Jensen, T., Lisby, M., Hindsdal, K., Krusell, L. Eshoj, A., Moller, L.T., Porsbo, L.J., Bottiger, B.E., Kuhn, K., Engberg, J. and Engberg, S. (2015), "Separate norovirus outbreaks linked to one source of imported frozen raspberries by molecular analysis, Denmark, 2010–2011", *Epidemiology and Infection*, Vol. 143 No. 11, pp. 2299–2307.

46. Murata, T., Katsushima, N., Mizuta, K., Muraki, Y., Hongo, S. and Matsuzaki, Y. (2007), "Prolonged norovirus shedding in infants < or =6 months of age with gastroenteritis", *Pediatric Infectious Diseases Journal*, Vol. 26 No. 1, pp. 46–49.

47. Nicolay, N., McDermott, R., Kelly, M., Gorby, M., Prendergast, T., Tuite, G., Coughlan, S., McKeown, P. and Sayers, G. (2011), "Potential role of asymptomatic kitchen food handlers during a food-borne outbreak of norovirus infection, Dublin, Ireland, March 2009", *Eurosurveillance,* Vol. 16 No. 30, pii 19931.

48. Ozawa, K., Oka, T., Takeda, N. and Hansman, G.S. (2007), "Norovirus infections in symptomatic and asymptomatic food handlers in Japan", *Journal of Clinical Microbiology,* Vol. 45 No. 12, pp. 3996–4005.

49. Park, G.W., Barclay, L., Macinga, D., Charbonneau, D., Pettigrew, C.A. and Vinje, J. (2010) "Comparative efficacy of seven hand sanitizers against murine norovirus, feline calicivirus, and GII.4 norovirus". *Journal of Food Protection*, Vol. 73 No. 12, pp. 2232–2238.

50. Pragle, A.S., Harding, A.K. and Mack, J.C. (2007), "Food Workers' perspectives on handwashing behaviours and barriers in the restaurant environment", *Journal of Environmental Health*, Vol. 69 No. 10, pp. 27-32.

51. Predmore, A. and Jianrong, Li. (2011), "Enhanced removal of a human norovirus surrogate from fresh vegetables and fruits by a comination of surfactants and sanitizers", *Applied Environmental Microbiology*, Vol. 77 No. 14, pp. 4829-4838.

52. Rockx, B., De Wit, M., Vennema, H., Vinje, J., De Bruin, E., Duynhoven, Y. and Koopmans, M. (2002), "Natural history of human calicivirus infection: a prospective cohort study", *Clinical Infectious Diseases*, Vol. 35 No. 3, pp. 246–253.

53. Ronnqvist, M., Aho, E., Mikkela, A., Ranta, J., Tuominen, P., Ratto, M. and Maunula, L. (2014), "Norovirus transmission between hands, gloves, utensils and fresh produce during stimulated food handling", *Applied Environmental Microbiology*, Vol. 80 No. 17, pp. 5403-5410.

54. Rumble, C., Addiman, S., Balasegaram, S., Chima, K., Ready, D., Heard J. and Alexander, E. (2017), "Role of food handlers in norovirus outbreaks in London and South East England, 2013 to 2015", *Journal of Food Protection*, Vol. 80 No. 2, pp. 257-264.

55. Savikivi, E., Roivainen, M., Maunula, L., Niskanen, T., Korhonen, T., Lappalainen, M. and Kuusi, M. (2012), "Multiple norovirus outbreaks linked to imported frozen raspberries", *Epidemiology and Infection*, Vol. 140 No. 2, pp. 260–267.

56. Seaman, P. and Eves, A. (2008), "Food hygiene training in small to medium-sized care settings", *Int J Environ Health Res*, Vol. 18, No. 5, pp. 365-374.

57. Seaman, P. and Eves, A. (2010), "Efficacy of the theory of planned behaviour model in predicting safe food handling practices", *Food Control,* Vol. 21, pp. 983-987.

58. Sickbert-Bennett, E., Weber, D., Gergen-Teague, M., Sobsey, M.D., Samsa, G.P. and Rutala, W.A. (2005), "Comparative efficacy of hand hygiene agents in the reduction of bacteria and viruses", *American Journal of Infection Control.* Vol. 33 No. 2: 67–77.

59. Smith, A.J., McCarthy, N., Saldana, L., Ihekweazu, C., Mcphedran, K., Adak, G.K. Iturriza-Gomara, M., Bickler, G. and O'Moore, E. (2012), "A large foodborne outbreak of norovirus in diners at a restaurant in England between January and February 2009", *Epidemiology and Infection*, Vol. 140 No. 9, pp. 1695–1701.

60. Sumner, S., Brown, L.G, Frick, R., Stone, C., Carpenter, L.R., Bushnell, L., Nicholas, D., Mack, L., Blade, H., Tobin-D'Angelo, M., Everstine, K; Environmental Health Specialists Network Working Group. (2011), "Factors associated with food workers working while experiencing vomiting and diarrhea", *Journal of Food Protection*, Vol. 74 No. 2, pp. 215-220.

61. Tam, C. and O'Brien, S.J. (2016) "Economic cost of campylobacter, norovirus and rotavirus disease in the United Kingdom", *PLoS ONE*, Vol. 11, No. 2, e0138526.

62. Tam, C., Rodrigues, L., Viviani, L., Dodds, J.P. Evans, M.R., Hunter, P.R., Gray, J.J., Letley, L.H., Rait, G., Tompkins, D.S., O'Brien, S.J; iid2 Study Executive Committee. (2012), "Longitudinal study of infectious intestinal disease in the UK (IID2 study): incidence in the community and presenting to general practice", *Gut*, Vol. 61 No. 1, pp. 69-77.

63. Tuladhar, E., Hazeleger, W.C., Koopmans, M., Zwietering, M.H., Duizer, E. and Beumer, R.R. (2013), "Transfer of norovirus between fingers, fomites and food products", *International Journal of Food Microbiology*, Vol. 167 No. 3, pp. 346-352.

64. Tuladhar, E., Hazeleger, W.C., Koopmans, M., Zwietering, M.H., Duizer, E. and Beumer, R.R. (2015), "Reducing viral contamination from finger pads: handwashing is more effective than alcohol-based hand disinfectants", *Journal of Hospital Infections*, Vol. 90 No. 3, pp. 226-234.

65. Verhoef, L., Jaramillo Gutierrez, G., Koopmanns, M. and Boxman, I.L.A. (2013), "Reported behavior, knowledge and awareness toward the potential for norovirus transmission by food handlers in Dutch catering companies and institutional settings in relation to the prevalence of norovirus", *Food Control*, Vol. 34 No. 2, pp. 420-427.

66. Verhoef, L., Hewitt, J., Barclay, L., Ahmed, S.M., Lake, R., Hall, A.J., Lopman, B., Kroneman, A., Vennema, H., Vinjé, J. and Koopmans, M. (2015), "Norovirus genotype profiles associated with foodborne transmission, 1999-2012", *Emerging Infectious Diseases*, Vol. 21 No. 4, pp. 592-9.

67. Vinje, J. (2015), "Advances in laboratory methods for detection and typing of Norovirus", *Journal of Clinical Microbiology*, Vol. 53 No. 2, pp. 373-381.

68. Wang, Q., Erickson, M., Ortega, Y.R. and Cannon, J.L. (2013), "The fate of murine norovirus and hepatitis virus during preparation of fresh produce by cutting and grating", *Food and Environmental Virology*, Vol. 5 No. 1, pp. 52-60.

69. Webby, R., Carville, K., Kirk, M., Greening, G., Ratcliff, R.M., Crerar, S.K., Dempsey, K., Sarna, M., Stafford, R., Patel, M. and Hall, G. (2007), "Internationally distributed frozen oyster meat causing multiple outbreaks of norovirus infection in Australia", *Clinical Infectious Diseases*, Vol. 44 No. 8, pp. 1026–1031.

70. Westrell, T., Dusch, V., Ethelberg, S., Harris, J., Hjertqvist, M., Jourdan-da Silva, N., Koller, A., Lenglet, A., Lisby, M. and Vold, L. (2010), "Norovirus outbreaks linked to oyster consumption in the United Kingdom, Norway, France, Sweden and Denmark, 2010", *Eurosurveillance*, Vol. 15 No. 12, pii: 19524.

Risk behaviours and practices in norovirus transmission	Suggested barriers	Recommendations

Table 1. Food handlers' risk behaviours and practices in norovirus transmission, and recommended mitigation strategies

Personal Hygiene		
-Improper hand washing (cursory wash) and drying -Not washing hands regularly -Not using soap -Failing to wash hands prior to gloving -Not frequently changing gloves -Relying on sanitary hand gels	-Lack of knowledge/training -Lack of supervision and monitoring -Time pressures during shift -No access to hand washing facilities or products -Soap causes skin dryness and irritation -Evidence for use of sanitary hand gels is inconclusive	-Multi-disciplinary approach -Employers' should purchase less abrasive soaps and hand cream for relief -Hand washing and drying facilities separate for food handlers should be accessible.
Food handling		
-Using bare hands when preparing RTE food -Not changing gloves or washing hands after touching money	- Lack of knowledge/ training - Lack of supervision and monitoring - No gloves available	-Training programmes for food handlers and supervisors
Symptomatic and asymptomatic food handlers		
- Not reporting episode of vomiting/diarrhoea to manager - Continuing to work while experiencing symptoms - Returning to work too early - Asymptomatic food handlers failing to report exposure	-Lack of knowledge/ training - No protocol - No shift cover - Fear of job loss - Loss of earning	-Sick pay from day one -Swab test -48 hour after symptoms stop policy enforced
Washing, cleaning and disinfecting		
- Not washing fresh produce, such as fruit and vegetables - Inadequate cooking of shellfish - Not following procedures for cleaning and disinfecting contaminated surfaces, equipment and utensils - Not using appropriate cleaning products - Inadequate cleaning of staff uniform - Food handlers cleaning the area where an episode of vomiting occurred.	- Lack of knowledge/ training - Lack of supervision and monitoring - Lack of facilities and products - No cleaning staff - Domestic washing machines may not inactivate the virus owing to lower temperature settings	-Training programmes -Monitoring -Ensuring appropriate facilities and cleaning products -Professional laundry service for uniforms and cloths -Separate cleaning staff