REVIEW ARTICLE

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Foodborne Infectious Diseases Mediated by Inappropriate Infection Control in Food Service Businesses and Relevant Countermeasures in Korea

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Objectives: The objective of this review is to propose an appropriate course of action for improving the guidelines followed by food handlers for control of infection. For this purpose, previous epidemiological reports related to acute gastroenteritis in food service businesses mediated by food handlers were intensively analyzed.
Methods: Relevant studies were identified in international databases. We selected eligible papers reporting foodborne infectious disease outbreaks. Among primary literature collection, the abstract of each article was investigated to find cases that absolutely identified a causative factor to be food handlers' inappropriate infection control and the taxon of causative microbial agents by epidemiological methodologies. Information about the sites (type of food business) where the outbreaks occurred was investigated.
Results: A wide variety of causative microbial agents has been investigated, using several epidemiological methods. These agents have shown diverse propagation pathways based on their own molecular pathogenesis, physiology, taxonomy, and etiology.
Conclusion: Depending on etiology, transmission, propagation, and microbiological traits, we can predict the transmission characteristics of pathogens in food preparation areas. The infected food workers have a somewhat different ecological place in infection epidemiology as compared to the general population. However, the current Korean Food Safety Act cannot propose detailed guidelines. Therefore, different methodologies have to be made available to prevent further infections.

Key Words: foodborne infectious disease, acute gastroenteritis, food handler, infection control, propagation mode, food service business

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INTRODUCTION

Microbiological problems in food environments are inevitable and have been occurring constantly in response to climate warming. In particular, the increases in foodborne infectious diseases result in severe social uncertainties, and this emergency is prevalent worldwide, including Korea [1–7]. The outbreak of *Vibrio cholerae* serotype O1 in 2016, imported from overseas is especially noteworthy, in that the disease almost reached an epidemic stage for the first time in 14 years. The first annual case of *Vibrio* sepsis was identified 5 months earlier than usual. In particular, the lack of administrative safety rules in the Korean Food Safety Act [8] for food handlers in food service businesses where they are directly exposed to infections has led to the widespread confusion.

Specifically, the control of acute gastro-enterities, which has a high risk of transmission and affects food handlers particularly, has become an important issue in Korea. Indeed, this is relevant because the infected food handlers can mediate epidemics of foodborne diseases, affecting large unidentified populations or local communities. However, definitive statutory guidance for managing food handlers during an outbreak and to cope with such a public health crisis is yet to be addressed in the Korean Food Safety Act. In 2016, several mid- to small-size food franchises were faced with inevitable bankruptcy during *Vibrio cholerae* crisis in Korea, resulting in widespread fear.

Continuous control of infectious diseases mediated by food is critical for securing food safety [9]. A hazard analysis and a critical control point system have been introduced rapidly into the manufacturing businesses in the United States [10] as well as in Korea. The belief is that foodborne infectious diseases could successfully be controlled, using this system. However, following the 2016 crisis, we recognize that aggravated microbial risks and confusion may arise from food handlers unprepared to combat novel infections in food service businesses. This indicates a necessity for differentiated criteria for food safety control in food service businesses. The solution may rest in appropriate infection control countermeasures for food handlers. Indeed, additional management criteria could be required in food service businesses that have entirely different processing environmental characteristics compared with food manufacturing plants. This is of particular importance in public health crises due to global warming or climate changes.

Therefore, this review, which is a part of an interdisciplinary research study, has considered previous studies of microbiology, etiology, and epidemiology related to the cause of foodborne diseases in food service businesses (e.g., restaurants and meal service facilities), which are on the rise owing to economic or sociocultural conditions. Based on the reported results, some guidelines will be proposed for use in an infection control system.

LITERATURE SEARCH

First, a literature search of MEDLINE and PubMed was conducted (using keywords foodborne, disease, illness, and infection) to identify published reports of foodborne infectious disease outbreaks. Second, among the primary literature articles collected, our research collaborators investigated the abstract of each article to find cases that absolutely identified a causative factor to be food handlers' inappropriate infection control and the taxon of causative microbial agents by epidemiological methodologies. Third, information about the sites (type of food business) where the outbreaks occurred was investigated. Reports of outbreaks in food service businesses were selected. Food service businesses included meal service facilities, such as restaurants, catering services, bakery operations in diverse places (such as school meal programs, camps, social welfare facilities, public facilities, and hospitals). Reports of outbreaks caused by the direct ingestion of manufactured or distributed food were eliminated from this study. Published reports were reviewed independently by four reviewers during the literature investigation stage. Disagreements were resolved through discussions.

SURVEILLANCE OF OUTBREAKS IN FOOD SERVICE BUSINESSES

To date, diverse health statistical analyses of foodborne infectious diseases have been used and reported. Several studies have reported their findings based on retrospective analyses, either in a country-by-country approach or by addressing spheres that share similar health environments according to the surveillance data (e.g., Asia and South America) [11–14]. In the Republic of Korea, the national notifiable disease surveillance system (NNDSS) is sustained by the Infectious Disease Control and Prevention Act and its enforcement ordinances and regulations [15]. The NNDSS is a passive surveillance system aimed at major infectious disease outbreaks that have broken out, or likely to break out, or diseases that have prevailed abroad and pose a risk of being transmitted into the Republic of Korea, as described in clause 2 in the Infectious Disease Control and Prevention Act. Designated groups of 1 to 5 infectious diseases that are classified in Clause 2 of the same act are being sustainably monitored [15]. Meanwhile, the US surveillance system is sustained by the NNDSS and a national electronic telecommunications system specifically designed for surveillance [16]. In Britain, there is an integrative system operated by the Health Protection Agency [17]. Polyphasic analyses have been performed based on primary epidemiological databases collected by administrations, resulting in an ongoing reporting of the occurrence or propagation patterns of infectious diseases. In Korea, monthly, yearly, seasonal, regional, or demographic factors related to the attack rate of the outbreak can be analyzed. However, these cannot provide ratios for more specified criteria, such as the statistics of occurrence in different types of food businesses. In contrast, the surveillance database of each foodborne outbreak has been monitored and analyzed, using criteria that are more specific in other countries. In previous studies [11–14], such as those based on these detailed national databases, retrospective analyses have been conducted, based on the national outbreak reporting system of the US, a web-based platform. Although occurrence patterns of these diseases in Korea between 1998 and 2012 has been reported [7], relatively limited analyses have been conducted, and only causative agents and their correlation to several base materials for food manufacturing have been proposed [7].

Currently, base material and food processing management are regarded as more critical control targets than the infection control or hygienic state of the food handlers, for the following reasons: 1) until recently, the food industry has been developed focusing on the manufacturing business; 2) the evenly defined food manufacturing processes and/or food handlers are completely isolated from the outer environment; and 3) most of the microbial hazardous factors can be controlled given that their critical control point in the process or the compartment of processing environment are well established [10]. Indeed, most of the studies performed to secure high levels of microbiological safety for the manufacturing industry have been developed based on such approaches. In contrast to food manufacturing businesses, the food workers in food service businesses are directly exposed to the external environment and are always in contact with numerous unspecified customers, whereas the disposition, organization, and number of food-related personnel vary on a constant basis. These unique characteristics of the food service business, together with the lessons learned from the previous retrospective analysis reports on food handler-mediated infectious disease outbreaks [11–14] indicate the need for differentiated administrative countermeasures.

EPIDEMIOLOGICAL METHODOLOGY

Epidemiology and subsequent investigations in food service businesses, such as restaurants, meal service facilities (facilities providing meals to many specified groups of individuals, including cafeterias of dormitories, schools, hospitals, welfare facilities, enterprises, local government, and public institutions), canteens, catering businesses, have been performed to identify the causative microbial agents or the cause-effect relationships. Causal relations can be revealed by cross-sectional, case-control, or retrospective cohort studies (Tables 1 [18–38] and 2 [13,39–51]). These analytical epidemiological methods are ideal for revealing the epidemiology of foodborne infectious diseases, regardless of the socioeconomic traits of the outbreak regions [4,52]. The reported causative agents (*Salmonella typhi*, *S. paratyphi*, *S. typhimurium*, pathogenic *Escherichia coli*, and Norwalk-like virus, among others) in food handler-mediated infectious diseases are listed in Tables 1 and 2.

The occurrences by asymptomatic carriers have been reported continuously [7,13,18,19,39–41,53]. The absence of visible symptoms in asymptomatic carriers who might be in a shedding period makes infections difficult to control. In fact, this can be reversed in the case of a massive foodborne outbreak arising from asymptomatic carriers or following epidemiological investigations [52]. A recent cross-sectional study on food handlers has enabled accurate identification of asymptomatic carriers [52] and has provided the fundamental data for the development of appropriate political countermeasures [4] (Tables 1 and 2). In addition to asymptomatic carriers, patients who no longer have visible symptoms may also be convalescent carriers. The prolonged shedding of causative pathogens can occur in the absence of proper medical care or diagnostic standards [19,42,54,55]. Most of the foodborne oral infectious diseases are self-limiting illnesses for which conservative or non-antibiotic treatments can be administered. However, in the case of the typhoid verotoxin *E. coli* infection and campylobacteriosis an antibiotic treatment must be administered until laboratory confirmation of the end of shedding period [9]. However, according to the Korean medical treatment system, which is based on the national healthcare service (NHS) and adopts a fee for service protocol [56–58], patients can voluntarily stop their antibiotic treatment, resulting in prolonged bacterial shedding [9]. In summary, despite the disappearance of visible gastrointestinal symptoms, there can be prolonged bacterial shedding that depends on several host-related factors (sex, age, and the point at which medication commenced). In the case of a gastrointestinal infection, shedding period occurs after the expression of initial symptoms; therefore, the shedding period is critical for halting the propagation of foodborne diseases. Virulence factors related to prolonged shedding and their genetic elements that are often clustered in pathogenicity islands are continuously reported [20,54]. Bacterial species that evolutionarily developed endurance to environmental stress can be transmitted directly or indirectly to other targets after escaping from their host via shedding [21,54,59–65]. When infected food handlers (primary cases) were initially isolated (case isolation) and subsequently returned to their workplace after resolving their visible symptoms, they can still transmit the infection either directly to close contacts at the same workplace or indirectly to customers via fecal-oral route by contaminating the food. In Korea, food handlers as a specific group of the population have been monitored yearly by Article 40 of the National Food Safety Act [8]. *S. enterica* serovar *typhi*, which displays a strong tropism to humans and are the causative agents of typhoid fever, are

Table 1. Causative bacterial agents and their epidemiology

Causative (infectious) microbial agent		Type of food service business; location of occurrence	Type of epidemiologic study	Reference
Genera	Species			
Vibrio	*cholera*	Meeting restaurant; Thailand	Case-control	Swaddiwudhipong et al., 2012 [24]
	vulnificus	-	-	-
	hemolyticus	-	-	-
	parahemolyticus	Company restaurant; Guangdong, China	Retrospective cohort	Liu et al., 2015 [25]
Escherichia	*coli O157:H7* (EHEC)	Restaurant; Japan	Case-control	Harada et al., 2013 [18]
	coli O104:H4 (EAEC)	Family restaurant; Germany	Retrospective cohort	Diercke et al., 2014 [26]
	coli O111:NM (EHEC)	Buffet-style restaurant; Oklahoma, USA	Case-control	Bradley et al., 2012 [27]
	coli O157:H45 (EPEC)	High school lunch program; Incheon, Republic of Korea	Case-control	Park et al., 2014 [28]
Campylobacter	*jejuni*	High school lunch program; Madrid, Spain	Retrospective cohort	Jiménez et al., 2005 [29]
		Luncheon program of cafeteria; USA	Retrospective cohort	Olsen et al., 2001 [30]
	coli	-	-	-
Salmonella	*enterica serovar typhimurium* (non-typhoid)	Local restaurant; California, USA	Retrospective cohort	Holman et al., 2014 [19]
		Korean-style restaurant; Adelaide, Australia	Case-control	Hundy and Cameron., 2002 [31]
	enterica serovar thompson (non-typhoid)	Franchise restaurant; USA	Case-control	Kimura et al., 2005 [32]
	enterica serovar enteriditis (non-typhoid)	Convention center; Texas, USA	Retrospective cohort	Beatty et al., 2009 [20]
	enterica serovar typhi, paratypihi (typhoid)	University restaurant; Ethiopia	Cross-sectional	Mama et al., 2016 [22]
		Public School; Móstoles, Madrid, Spain	Case-control	Usera et al., 1993 [33]
	enterica sp.	Bread takeaway shop; Ben Tre City, Vietnam	Case-control	Vo et al., 2014 [34]
	enterica serovar enterica (typhoid, non-typhoid)	General restaurant; Karachi, Pakistan	Case-control	Siddiqui et al., 2015 [21]
Shigella	sp.	University restaurant; Ethiopia	Case-control	Mama et al., 2016 [22]
	sonnei	Canteen of a public institution; Flemish Brabant, Belgium	Case-control	Gutiérrez Garitano et al., 2011 [35]
	sp.	Canteen of a public institution; Flemish Brabant, Belgium	Case-control	Gutiérrez Garitano et al., 2011 [35]
Clostridium	*perfringens*	Wedding party; London, United Kingdom	Case-control	Eriksen et al., 2010 [36]
	botulinum	-	-	-
Staphylococcus	*aureus*	General restaurant; Australia	Literature analysis	Pillsbury et al., 2013 [23]
		Catered dinner party; Turin, Italy	Retrospective cohort	Gallina et al., 2013 [37]
Bacillus	*cereus*	-	-	-
Listeria	*monocytogenes*	-	-	-
Yersinia	*enterocolitica*	Summer diet camp; New York State, USA	Case-control	Morse et al.,1984 [38]

Table 2. Causative viral agents and their epidemiology

Causative (infectious) microbial agent	Type of the food service business; location of occurrence	Type of epidemiologic study	Reference
Norwalk-like virus	Canteen of distillery; Kinmen, Taiwan, China	Case-control	Chen et al., 2016 [40]
	Food and healthcare unit; Barcelona, Spain	Case-control	Sabrià et al., 2016 [42]
	Social welfare homes; Shenzhen City, China	Case-control	He et al., 2016 [46]
	University canteen; Xiamen City, China	Case-control	Guo et al., 2014 [47]
	Elementary school meal program; Incheon, Republic of Korea	Retrospective cohort	Yu et al., 2010 [44]
	Pusan; Republic of Korea	Cross sectional	Koo et al., 2016 [43]
	High school meal program; Gyeonggi Province, Republic of Korea	Case-control	Cho et al., 2016 [48]
	Outbreak food catering facility; Hokkaido, Japan	Case-control	Okabayashi et al., 2008 [41]
	Wedding dinner; Austria	Retrospective cohort	Maritschnik et al., 2013 [49]
	Residential summer camp; Barcelona, Spain	Retrospective cohort	Barrabeig et al., 2010 [39]
	Denmark	Literature analysis	Franck et al., 2015 [13]
Hepatitis E virus infection	Australia	Literature analysis	Rowe et al., 2009 [45]
Hepatitis A virus infection	Café; Melbourne, Victoria, Australia	Case series investigation	Rowe et al., 2009 [45]
	Australia	Case series investigation	Schmid et al., 2009 [50]
	Canada	Literature analysis	Tricco et al., 2006 [51]

the only target of the annual monitoring. In contrast, although outbreaks involving pathogens, such as the Norwalk-like virus and the *E. coli* infections are consistently reported among food handlers, these pathogens are not included in the annual legal monitoring [7,13,18,19,39–41]. Furthermore, convalescent carriers of typhoid fever who are going through the shedding period are not the targets of sustainable monitoring. The current Food Safety Act does not provide the necessary criteria for patients during shedding. Under these hazardous circumstances, several recent cross-sectional studies on norovirus in Korea [43,66] have revealed the state of the asymptomatic carriers by analyzing stool samples of the food handlers. The samples were collected for legal monitoring of *S. typhi* at the local health centers. The results revealed that at least 3.7% of all individual fecal samples tested were positive based on genotyping in winter, and winter was the most prevalent season. These reports show that it is necessary to take countermeasures for asymptomatic carriers. This is further supported by the fact that most bacterial foodborne infectious diseases are life threatening as compared to viral diseases, such as norovirus.

Although cross-sectional studies are ideal approaches for revealing the distribution or the state of asymptomatic carriers in a given population, they are often insufficient for identifying the cause-and-effect relationships [52]. Therefore, case-control or retrospective cohort studies, which use the time-tracking concept, have been used. The most adopted type of study is the retrospective cohort study that establishes exposure and non-exposure groups, while backtracking the time (Tables 1 and 2). Owing to the cost and time effectiveness of cross-sectional studies, surveillance aimed at asymptomatic patients has been conducted [22,43,66]. In contrast, only a few cohort studies have been conducted in Korea compared with foreign nations, most probably because of their shortcomings, such as increased cost and/or duration [44]. Nonetheless, historical retrospective cohort studies have been conducted to investigate important accidental infections. Yu et al. [44] reported on the epidemiology of a massive norovirus outbreak in 2008 that occurred in elementary school meal programs located in the Incheon city. However, the inflow route of the virus has not been fully elucidated, and the presumption was that shedding from infected food handlers was the route of propagation. However, Park et al. [67] fully identified the infection route in the 2013 case of a norovirus outbreak at the public school meal program in Jeonju City as the contaminated Korean fermented food *Kimchi* manufactured by a certain company. Generally, the epidemiology of foodborne illnesses mediated by manufactured foods is not easy to elucidate, but this case was not a trivial case. This phenomenon reflects the vulnerability in meal service facilities that are at the center of the social identity of Korea. Recently, foodborne intoxication by *Staphylococcus aureus* shed by food handlers has been reported [23]. Moreover, accidental norovirus infections in the residential summer camp and school meal programs mediated by infected food handlers have also been reported in a retrospective cohort study [39] (Tables 1 and 2).

Case-control studies are both time and cost-effective which makes them advantageous compared to cohort studies. Therefore, case-control studies can also be conducted for relatively small as well as massive outbreaks [57] (Tables 1 and 2). Indeed, the epidemiology of small outbreaks such as those in canteens, cafés, wedding ceremonies, and social welfare homes have been reported (Tables 1 and 2). Family weddings and social welfare homes might share many of the same demographic features. Moreover, all of these cases represent outbreaks in a limited area and/or within a limited time (Tables 1 and 2).

CAUSATIVE AGENTS AND THEIR TRANSMISSION CHARACTERISTICS

Widely reported foodborne bacterial infectious diseases consist of the following: 1) *V. cholera*, *V. vulnificus*, *V. hemolyticus*, *V. parahemolyticus*; 2) pathogenic *E. coli*, serotypes EPEC, EAEC (entero-aggregative *E. coli*), EIEC, EAEC, ETEC; 3) *Campylobacter jejuni* or *C. coli* which have been issued in recent days; and 4) typhoid or non-typhoid species and *Shigella* spp, *Clostridium* including *C. perfringens* and *C. botulinum*, *S. aureus*, *Bacillus cereus*, *Listeria* spp., and *Yersinia* spp. (Tables 1 and 2).

However, outbreaks mediated by food handlers, involving the well-known pathogens, such as *V. vulnificus*, *C. coli*, and *C. botulinum*, and *L. monocytogenes* have not yet been reported (Tables 1 and 2). This might be because there is no bacterial shedding of *V. vulnificus* or *C. botulinum* by an infected person. Therefore, these causative agents cannot be transmitted by the fecal-oral route or direct contact. Human infections with these pathogens occur only by handling of bacterial pathogens in natural raw food.

In contrast, *Staphylococcus* species, especially *S. aureus*, are present as the skin flora of humans in aerobic states [68], and they are present in natural and artificial environments, depending on the strength of their resistance [69]. Therefore, efforts to control *S. aureus* should be focused on the unsanitary state rather than shedding or propagation modes. On the other hand, *C. perfringens* flourishes in the anaerobic parts of the intestine as part of the human microflora and its distribution in most of the gut in humans has been demonstrated [68,70,71]. Therefore, intoxication may be the result of neglecting sanitation procedures, which triggers the germination, or manipulation of vegetative cells in foodstuffs rather than the concept of infection.

The pathogenic *E. coli* group is divided into EPEC, EAEC, EIEC, EAEC, and ETEC based on their respective molecular pathogenesis and according to the different medical treatment criteria designed for each serotype [69,72], not by their taxon. Non-pathogenic *E. coli* species are constituents of the intestinal flora and display a certain level of mutualism, but not deep interdependency [68]. The mucosal membrane of the intestinal tract provides optimal conditions for lateral gene transfer [68]. Therefore, both pathogenic and non-pathogenic *E. coli* species can exchange chromosomal genetic elements, including pathogenicity islands. Therefore, although the mediation of an EIEC outbreak via food handlers has not yet been reported (Table 1), the value of the separately differentiated pathogenic *E. coli* species in general is not important in this study.

Cholera, typhoid fever, paratyphoid fever, and pathogenic *E. coli* infections have been clearly attributed to both direct and indirect transmission in the general population. Indeed, they can propagate by direct or indirect contact with the general population and by infected food handlers that spread these pathogens to mass customers via food contaminated by shedding [21,54,59–65,73]. Furthermore, viral infectious diseases, such as hepatitis A virus (HAV), hepatitis E virus (HEV) infection, and norovirus also have similar transmission modes; direct contact transmission and fecal-oral route transmission have been reported [45,74–77]. These propagation characteristics can be assumed at food workspaces, but might pose a different risk to the general citizen. Direct transmission often occurs via direct contact, such as vertical or droplet infection through vomiting, talking, coughing, nasal discharge, skin contact, and hand shaking [52]. Therefore, this type of transmission may occur by contact with the food area. When a food handler infected with the pathogen (the primary case) works in the food area, he/she can transfer the pathogen to others in close contact, such as colleagues, and can also contaminate the foodstuff via shedding. The infected close contact from the primary case (colleague) can then transfer the pathogen to foodstuff.

In contrast to these causative agents, *Campylobacter* spp., *C. perfringens*, *Listeria* and *Yersinia* species have been reported to propagate by indirect transmission, whereas direct contact transmission has not been reported so far [72,78–80]. This mode can also be assumed in food workspaces, but might show a different pattern; an infected food handler working with food may contaminate foodstuffs via shedding. In the case of *B. cereus*, an endospore-forming bacterium, direct contact or fecal-oral route transmission remains unclear based on previous case reports. Nevertheless, it has been demonstrated that the toxin type of vegetative cells isolated from stool, environmental samples, and contaminated foods was identical [81]. The most plausible interpretation of these findings is that the outbreak of *B. cereus* intoxication (a vomiting type infection) or gastrointestinal infection (diarrhea type) can occur in the presence of multiple factors, such as incomplete time-temperature management, resulting in the contamination of food or utensils by endospores that originated from infected handlers in shedding period, or conveyed from food materials, or a contaminated surrounding environment.

In summary, causative microbial agents have different transmission modes based on their microbial etiology. These include 1) a direct contact transmission within the same food workplace, 2) an indirect oral-fecal route transmission, and 3) an infection caused by pathogens occupying the flora of the food handlers in specific negligence situations in the food workplace, which can subsequently be transmitted from food handlers (via fecal shedding) or the environment.

PROPOSAL FOR APPROPRIATE GUIDELINES FOR INFECTION CONTROL

Depending on etiology, transmission, propagation, and microbiological traits, we can predict the transmission characteristics of pathogens in food preparation areas. The infected food workers have a somewhat different ecological place in infection epidemiology as compared to the general population. Therefore, different methodologies have to be made available to prevent further infections. However, the current Korean Food Safety Act cannot propose detailed guidelines. The clause related to the personal hygiene criterion in the same act and lower statutes quote the same clauses of the Infectious Disease Prevention and Control Act. Clause 50, which delineates the kinds of infectious diseases that prohibit personnel from their work, the enforcement regulations of the Food Safety Act state the following: "diseased persons who are in the group 1 infectious diseases described in the Infectious Disease Control and Prevention Act have to be prohibited from their working areas." However, the Infectious Disease Control and Prevention Act quoted in the Food Safety Act is aimed at the general public, not specifically at food handlers. Major insufficiencies and appropriate orientations for legal revision or establishment of countermeasures proposed in this study can be summarized in three main points. 1) The current Food Safety Act states that anyone showing gastrointestinal symptoms has to be prohibited from entering the food areas. However, major or related clauses in the act do not propose the criteria for managing the primary cases or close contacts when food handlers infected with causative agents, such as cholera, typhoid, paratyphoid, *E. coli*, HAV, HEV, and norovirus. These pathogens can all be propagated by direct contact or indirect transmission, and there should be detailed legalization of criteria based on epidemiological fundamentals [52], including health quarantine or close observation of close contacts. Infection control in infectious diseases should be carried out under a strong and supportive legal system [4]. Furthermore, infection control procedures should be performed with laboratory identification of the causative agents. However, the absence of any mandatory legal clause for microbial tests constrains these essential procedures. In contrast to directly transmissible agents, primary isolation or confirmation of the end of shedding period is more essential than close contact management in the case of pathogens that have an indirect (fecal-oral route) transmission mode. 2) The current Korean Food Safety Act emphasizes only the isolation of someone who displays visible symptoms. However, no further indications have been proposed for the follow-up of the primary case. Symptomatic patients with infections can experience a prolonged shedding period. Therefore, isolating someone during the expression of visible symptoms does not suffice. To prevent this hazard, at least three control points are essential: a. isolation of the primary case, b. laboratory inspections to identify the microbial agents, and c. compulsory confirmation of the end of shedding period. 3) The current Korean Food Safety Act does not propose the management for asymptomatic patients. In this situation, if a massive foodborne infectious disease occurs in the customer population by another pathogen, the structure of the Food Safety Act compels the individual food businesses or franchises to undertake all the legal or civil responsibilities. Nonexperts have limited accessibility to such in-depth microbiological or public health information. Public health issues, especially with respect to infectious disease, are becoming international or inter-zonal problems. They are not manageable at the individual or local government level anymore [82]. One of the current issues in foodborne infectious disease management is the occurrence of classical bacterial pathogens being on a continuous rise, and their occurrence patterns and regional ranges have been changing drastically [5,6]. Several causative pathogens mediated by infected food handlers listed in Tables 1 and 2 share a similar taxonomical location with specific pathogens, of which the outbreak pattern can be directly affected by climate change (*Salmonella*, *Campylobacter*, *Vibrio* spp. *E. coli*, *Yersinia*, *L. monocytogenes*, and HEV) [6]. This coincidence means that infection control in food handlers can become an important issue in relation to climate changes.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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