Identifying Vulnerable Populations at Risk of Foodborne Infection: People with Diabetes Mellitus

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SUMMARY

Individuals with compromised immunity have an increased risk of foodborne infection; however, many of these individuals are not aware that they are more vulnerable to foodborne infections. Consequently, such individuals need to become aware of their increased risk and of food safety practices necessary to reduce the potential risk of foodborne disease. Consumer food safety research suggests that highly focused, targeted interventions are the most effective means of consumer food safety education. Interventions that enable immunocompromised individuals to understand their increased susceptibility to infection may empower this vulnerable group to adopt risk-reducing food safety practices. The aim of this article is to explore the association between foodborne infection and diabetes mellitus to increase the understanding of this underrepresented group within food safety research. Findings may help inform the development of future food safety educational interventions specifically intended for people living with diabetes mellitus.

OVERVIEW

Who are the vulnerable groups at an increased risk of foodborne infection?

Although foodborne infection can affect anyone, current advice about the risks of contracting a foodborne illness tend to focus on specific populations who are considered particularly vulnerable *(26)*. In countries such as the United Kingdom and the United States, 20% of the population may be more susceptible to foodborne illness than the general population *(34)*. Consumer food safety research often identifies vulnerable groups as pregnant women, children, older adults, and immunocompromised individuals *(16, 55)*. Susceptibility can result from chronic or acute illness, medication *(33)*, and/or immunosenescence (age-related deterioration in immune responses) *(2, 6)*.

Substantial proportions of immunocompromised people have increased susceptibility to foodborne illness compared with nonimmunocompromised people *(33)*, and infection rates of notifiable foodborne infectious diseases such as campylobacteriosis, listeriosis, and salmonellosis are higher among such groups *(7, 46)*. Immunocompromised individuals are vulnerable to foodborne infection because an impaired immune system cannot respond appropriately to enteric pathogens, resulting in persistent and generalized infections in the immunocompromised host *(16)*. These foodborne infections are some of the most challenging for health care providers to treat because the illness tends to be long term, adds to the burden of debilitation in the patient, and can result in a significant higher mortality rate than would occur in non-immunocompromised persons *(16)*.

CLASSIFYING IMMUNOCOMPROMISED GROUPS FOR FOOD SAFETY EDUCATION

Health promotion interventions aim to engage and empower individuals to choose health-promoting or risk-reducing behaviors *(39)*, and such approaches can be utilized by food safety educators to deliver food safety information. Although raising awareness among vulnerable population groups is required to reduce the risk of foodborne infection within the immunocompromised population *(56)*, food safety educators may need to adopt a targeted approach when considering food safety education interventions for immunocompromised patients *(36)*. Immunocompromised populations are underrepresented as targets of food safety interventions *(50)*, and the high level of variability among persons classed as immunocompromised may limit the ability of educators to provide effective food safety interventions.

Immunocompromised individuals associated with a greater risk of foodborne infection include pregnant women *(46)*, people who have undergone organ transplants *(41)*, people taking medications that interfere with immune function (e.g., cytotoxic drugs for the treatment of cancer *(43)* or disease-modifying drugs for active relapsing remitting multiple sclerosis *(24)*), people with autoimmune diseases *(48)* (e.g., multiple sclerosis, inflammatory bowel disease, rheumatoid arthritis, and lupus), and people with conditions that impact immune function (e.g., diabetes mellitus *(4)*, human immunodeficiency virus and AIDS *(23, 28)*). Approaching all immunocompromised individuals within a one-size-fits-all program may not be

TABLE 1. Estimated prevalence of individuals with diabetes in the United States, the United Kingdom, and worldwide for 2019 and 2030

Country	Estimated prevalence of individuals with diabetes ($\times 10^6$)		
	2019	2030	Source
United States	31 million	34 million	*(47)*
United Kingdom	3.8 million	5.5 million	*(13)*
Worldwide	463 million	578 million	*(47)*

TABLE 2. Complications of diabetes adapted from World Health Organization *(58)* and Chawla et al. *(8)*

Complication	Disease	Description
Microvascular	Retinopathy (eye)	Leading cause of blindness and visual disability caused by small blood vessel damage in the back layer of the eye (retina), resulting in progressive loss of vision.
	Nephropathy (kidney)	Caused by damage to small blood vessels in the kidneys and can lead to kidney failure and possibly death. In developed countries, nephropathy is a leading risk factor for dialysis and kidney transplants.
	Neuropathy (nerve)	Damage to peripheral nerves within the body may result in pain, burning or a loss of sensation (sensory neuropathy) or can cause loss of control of internal organs, including the gastrointestinal tract (autonomic neuropathy).
Macrovascular	Cardiovascular	Blood vessels may be damaged through "atherosclerosis" (blocking of arteries with fatty plaques). This damage can decrease blood flow to the heart muscle (causing a heart attack), brain (leading to stroke), or extremities and can lead to pain (claudication) and decreased healing of infections.
	Foot	Reduction in blood flow and the resulting neuropathy in the lower limb can lead to ulceration and subsequent limb amputation.

Adapted from the World Health Organization *(58)* and Chawla et al. *(8)*

appropriate or effective for conveying accurate food safety advice, particularly because needs and circumstances differ greatly between groups *(32)*. Educators should identify and target vulnerable populations at risk of foodborne infection according to their specific underlying conditions.

DIABETES MELLITUS AND RISK OF FOODBORNE INFECTION

One vulnerable group known to have an increased risk of foodborne infection but tend to be overlooked within the food safety literature are individuals with diabetes *(49)*. Diabetes mellitus is a serious, chronic disease characterized by hyperglycemia (high blood glucose concentration) that occurs in type 1 diabetes when the pancreas does not produce enough insulin (a hormone that regulates blood glucose) and in type 2 diabetes when the body cannot effectively use the insulin it produces *(57)*. The prevalence of diabetes has been steadily increasing worldwide over the past few decades *(Table 1)*. Current trends indicate that the estimated worldwide prevalence of the condition will rise by 20% over the next 10 years *(47)*. Aging of the overall population is considered a significant driver of the diabetes epidemic *(29)*.

Diabetes is often wrongly assumed to be a condition affecting only blood glucose levels, resulting in minimal health consequences *(35)*. However, diabetes can affect the majority of organs within the body, leading to a number of complications *(Table 2)*, which can be divided into those caused due to damage

to the microvascular (small blood vessels) and macrovascular (larger blood vessels) systems *(8, 58)*.

People with diabetes are at increased risk of foodborne infection *(20, 38, 40, 51, 52)*. During a *Salmonella* Enteritidis outbreak in a hospital setting, a case-control study revealed that patients with diabetes who required medication to control their blood glucose levels (insulin or oral hypoglycemia medication) were more likely to develop salmonellosis *(52)*. Neal and Slack *(40)* studied notified cases of *Campylobacter* gastroenteritis in adults over a 14-month period in the United Kingdom and found that diabetes mellitus increases the risk of campylobacteriosis, similar to the scenario seen with salmonellosis. Risk of listeriosis also may be elevated among people with diabetes *(51)*. Mook et al. *(38)* reported that diabetes increased the risk for serious infection from *Listeria monocytogenes*; patients with diabetes had an 11-fold increased risk of developing listeriosis. Even greater risk of infection with listeriosis was suggested by Goulet and Marchetti *(20)*, who stated that patients with insulin-dependent diabetes were 25 times more likely to develop listeriosis than were healthy, non-diabetic individuals.

Aside from the increased risk of contracting foodborne infections for people with diabetes, the symptoms associated with foodborne illness could trigger life-threatening diabetes complications in this vulnerable group. Excessive vomiting can lead to hypoglycemia (low blood glucose concentration), which can be abrupt and if left untreated can lead to blurred vision, slurred speech, confusion, and even loss of consciousness *(10)*. Diabetic ketoacidosis is another potentially dangerous condition that may develop in people with diabetes as a result of foodborne infection *(37)*. Diabetic ketoacidosis is most commonly associated with type 1 diabetes and occurs when the body has insufficient insulin to allow enough glucose to enter cells, causing the body to burn fatty acids and produce acidic ketone bodies *(11)*. A high concentration of ketone bodies in the blood can cause particularly severe illness, including coma or death, when not treated quickly *(1)*.

WHY ARE PEOPLE WITH DIABETES AT AN INCREASED RISK OF FOODBORNE INFECTION?

The increased risk of foodborne infection among people with diabetes is likely due to autonomic neuropathy, in which elevated blood glucose causes damage to nerves that control involuntary bodily functions, including digestion *(53)*. Within the digestive system, autonomic neuropathy may result in gastroparesis, a condition in which reduced smooth muscle control slows or stops the movement of food from the stomach to the small intestine *(25)*. The resultant prolonged gastrointestinal transit time can give harmful bacteria time to multiply *(30)*. Gastroparesis probably affects 20 to 50% of the individuals with diabetes and is especially common in those with type 1 diabetes or those with long-standing (>10 years) type 2 diabetes *(3)*. Production of gastric acid, which is responsible for the breakdown of food and beverages in the stomach, may also be reduced. Because hydrochloric acid functions as a barrier to ingested bacteria, reductions in this acid would limit the bactericidal activity in the stomach *(17)*.

Poor glycemic control (inability to maintain appropriate blood glucose concentrations) seems to be an important risk factor in the increased susceptibility of infection for people with diabetes and is powerfully associated with serious infections *(9)*. A review of epidemiological studies revealed clinically important (ca. 1.5 to 3.5 times higher) infection risks associated with poor glycemic control *(45)*. Poor glycemic control also is associated with impaired neutrophils *(27)*, white blood cells that are important in the early stages of the immune response to foodborne infection *(13)*. Therefore, how well an individual manages her or his diabetes and maintains blood glucose concentrations may impact the risk of foodborne infection. In particular, those individuals with type 1 diabetes are less likely to have good glycemic control *(9)* and thus may be at approximately double the risk of foodborne infection compared with individuals with type 2 diabetes *(5)*. Poor glycemic control among individuals with type 1 diabetes also has been associated with low socioeconomic status and depression and is more likely to occur in young adults *(22, 31)*.

HOW TO REDUCE THE RISK OF FOODBORNE INFECTION AMONG PEOPLE WITH DIABETES?

Considering the number of people with diabetes worldwide, the increased risk of foodborne infection, and the potentially life-threatening diabetic complications associated with foodborne infection; individuals with diabetes are an important group to target in the context of food safety education. Engagement with this vulnerable group and promotion of food safety education is of particular importance. People with diabetes often are unaware that they are at increased risk of foodborne infection *(15)*. Optimistic bias and feelings of personal invulnerability are common, whereby any risk is perceived to be greater to others than to themselves *(14)*. Consequently, food safety education initiatives may be overlooked because they are perceived to be aimed at those individuals at greater risk *(44)*.

Given the importance of attitudes in relation to behavior change *(42)*, targeted interventions must address an individual's perceptions of risk, control, and responsibility for foodborne infection *(14)*. Interventions must be clear concerning 'why' these individuals are more susceptible to foodborne infection, highlight 'what' practices should be followed, and demonstrate 'how' engagement with the recommended practices will be beneficial in reducing the associated risks. Individuals with diabetes should be encouraged to assess risk and determine whether they are going to adopt risk-reducing behaviors. Constructs of the Health Belief Model *(18)* should be considered in the development of targeted interventions. For example, when

individuals regard themselves as susceptible to foodborne infection, believe that such infections would have potentially serious consequences, believe that action would be beneficial for reducing the risk, and believe that the benefits of taking action outweigh the potential barriers, they may be more likely to adopt the recommended actions.

Interventions should be designed through cocreation with individuals with diabetes and key stakeholders. Cocreation is essential to enhance the credibility and suitability of the intervention through involvement of the intended target audience in the design, development, and evaluation of the intervention *(21, 32)*. Interventions should also be delivered by trusted sources of information such as health care professionals that are commonly involved in the care and treatment of people with diabetes. Wohlgenant et al. *(54)* reported that health care providers (e.g., physicians, registered nurses, nurse practitioners, physician assistants, and home health care providers) perceive food safety education as important. However, health care providers may lack sufficient training, knowledge, or willingness to provide food safety information *(54)*. There is a need to determine who The key health care professionals that are regularly seen and trusted by people living with diabetes should be identified so that educators can determine their food safety training, awareness of patient group susceptible to foodborne infection, and attitudes toward the provision of food safety education. Food safety education should be integrated into preventive health care *(19, 54)*.

Continuing research is needed to determine whether the educational needs of patients living with type 1 diabetes are different from the needs of those living with type 2 diabetes because of the increased risk of infection associated with type 1 diabetes. The demographic characteristics of people with diabetes should also be considered because of the variability within this group. The importance of glycemic control should also be incorporated into food safety education because of the link between glycemic control and the risk of foodborne infection in individuals with diabetes.

Individuals with diabetes are at increased risk of foodborne infection that can result in potentially life-threatening complications, making this group particularly vulnerable in the context of food safety education. Identifying and communicating specifically-targeted and highly-focused food safety education interventions to individuals with diabetes may promote more positive food safety attitudes and enable implementation of appropriate food safety behaviors to reduce the risk of foodborne infection. Raising awareness of the association between diabetes and foodborne infection may increase understanding of the perceived risk to individuals with diabetes and increase adoption of risk-reducing food safety behaviors.

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In Memory

Robert L. "Bob" Sanders

Pensacola, Florida

IAFP expresses our deepest sympathy to the family of Robert L. "Bob" Sanders, who passed away in July 2020 at the age of 92. Mr. Sanders joined IAFP in 1954 when it was known as the International Association of Milk and Food Sanitarians, Inc. (later known as IAMFES, the International Association of Milk, Food and Environmental Sanitarians). He served as IAMFES President in 1991 and received the Association's Honorary Life Membership Award in 2000 and the IAFP Fellow Award in 2010.

An Iowa native, Mr. Sanders graduated from Iowa State University in 1950 and took a position with the City of Des Moines as a milk inspector that same year. After his promotion to Chief Milk Sanitarian, he joined the Iowa Milk Association and the International Association in 1954. He eventually moved to the State Health Department as a State Milk Sanitation Rating Officer before joining the U.S. Public Health Service as a Reserve Officer. Called to active duty in 1963, Mr. Sanders was assigned to the Chicago regional office and was eventually sent to the University of Michigan, where he received his Master's in Public Health. After an assignment in New York, he spent the next 20 years working in Washington, D.C. as Deputy Chief and Acting Chief of the Milk Sanitation Branch for the U.S. Public Health Service, retiring in 1992. Throughout his career, he has been a member of the Iowa, Illinois, and New York Affiliates.

IAFP will always have sincere gratitude for Mr. Sanders' long-time contributions to the Association and the profession.