CHAPTER 11

NUTRITIONAL MANAGEMENT OF DIARRHOEA

Joy Fraser and Alice N. Brako

Outline

• Diarrhoeal diseases as a public health problem
• Epidemiological features of diarrhoeal diseases
• Major pathogens associated with diarrhoeal diseases
• Impact of diarrhoeal diseases on nutritional status
• Role of nutrition in the prevention of diarrhoea
• Role of clean water, hand washing, and latrines in the prevention of diarrhoea
• Nutrition and the treatment of diarrhoea

Objectives

After completing this chapter, you should be able to:

• Describe the public health significance of diarrhoeal diseases
• Identify and describe the epidemiology of diarrhoeal diseases, including geographical distribution, risk factors, incidence, seasonality, and duration
• Name the major pathogens associated with diarrhoeal diseases and explain how infectious agents produce disease
• Describe how clean water, hand washing, and latrines help prevent diarrhoea
• Explain how nutritional status affects diarrhoeal illness and how diarrhoea affects nutritional status
• Describe the role of nutrition in the treatment of diarrhoea
1. INTRODUCTION

Diarrhoeal diseases are a major cause of childhood illness and death in developing countries. Nutritional risk factors, such as being underweight and having poor hygiene, are closely associated with diarrhoeal mortality. Diarrhoea is a symptom marked by an increase in stool frequency and decreased consistency, and the cause is usually an infection from a bacteria, virus, or parasite that may be present in animal or human faecal matter or in contaminated food, milk, or water. Researchers have often assigned different definitions to diarrhoea because frequency and consistency of bowel movements in individuals vary greatly depending on age and culture. A widely accepted standard has, however, been established in which diarrhoea is defined as a condition in which three or more liquid stools are passed within any 24-hour period. This definition is less appropriate for infants younger than 2 months, who normally pass stools that are loose and of high frequency. Dysentery is the diarrhoeal condition in which blood is present in watery stools, and persistent diarrhoea is characterized by an episode of diarrhoea that lasts 14 days or longer. A bout of diarrhoea is considered over when an individual experiences three consecutive diarrhoea-free days (Lanata & Black, 2008). Further information on clinical evaluation and case management of diarrhoea can be found in a World Health Organization (WHO) treatment manual (WHO, 2005).

This chapter covers the historical background, epidemiological factors, and development of diarrhoeal diseases; associations between nutritional status, dietary management, and diarrhoeal diseases; and nutritional preventive measures for diarrhoeal diseases.

2. PUBLIC HEALTH SIGNIFICANCE OF DIARRHOEA

According to the WHO, diarrhoeal diseases account for an estimated 1.5 million deaths in children each year, and most of these occur in children less than 2 years of age. Recurring bouts of diarrhoea can lead to undernutrition as a result of loss of fluids and electrolytes. Loss of fluid can cause severe dehydration and death.

2.1 Historical Background

The conditions associated with diarrhoeal diseases include poverty, poor sanitation and hygiene, inadequate water supplies, and limited education. Current developed countries experienced high infant and child death rates prior to the mid-twentieth century. Summer outbreaks of diarrhoea in infants and children less than 5 years of age were common in large cities such as Paris and London during the latter half of the nineteenth century (Newman, 1906; Woods & Woodward, 1984). Improved sanitation, hygiene, child-feeding practices, water supplies, and education greatly reduced the incidence of diarrhoeal diseases in industrialized countries, and the burden of these illnesses has now shifted to developing countries.

Among diarrhoeal diseases, cholera has been the most widely studied. It is a bacterial infection that is transmitted through contaminated food or water, and it is characterized by acute diarrhoea that can quickly lead to severe dehydration and death. Cholera occurs endemically in south and southeast Asia and parts of Africa, but has also been associated with pandemics that occurred into the twentieth century following human migration and trade routes (Lee, 2007).

3. EPIDEMIOLOGY OF DIARRHOEA

3.1 Geographical Distribution

Black and Lanata (2002) published a detailed review of the epidemiology of diarrhoea in developing countries. Although diarrhoeal diseases occur globally, they are more prevalent in developing countries, where they are associated with conditions of poverty, inadequate sanitation, poor hygiene, lack of access to clean water, and insufficient education. Diarrhoeal diseases are also widespread in urban slums where there is inadequate housing and overcrowding. Warmer climates promote the growth of pathogenic microorganisms, contributing to increased prevalence. Most diarrhoeal deaths occur in densely populated areas where conditions of extreme poverty and lack of proper health care persist (Parashar et al., 2006).
3.2 Risk Factors
Several risk factors are associated with an increase in diarrhoea morbidity and mortality. Faecal contamination of hands is correlated with increased diarrhoeal incidence. Lack of clean water and poor sanitation are linked to contamination of hands. The temperature of food preparation, how soon food is eaten after preparation, and use of refrigeration affect the levels of bacteria in food. Fruits and vegetables may contain faecal coliforms from sewage-contaminated irrigation water. Bacterial contamination may result from feeding utensils, such as baby bottles, baby bottle nipples, cups and spoons, and food containers (Lanata & Black, 2008). The importance of various risk factors in the control of diarrhoea is explored later in this chapter.

Reports indicate that houseflies may contribute to an increased risk of diarrhoea in developing countries. Evidence of this can be found in the successful reduction of diarrhoeal diseases through the implementation of fly control interventions (Chavasse et al., 1999). Children’s contact with vectors such as chicken faeces is thought to be linked to diarrhoea associated with Campylobacter jejuni. In addition to environmental factors, there are host factors that influence the development of diarrhoeal diseases. These include undernutrition, micronutrient deficiencies, a previous attack of diarrhoea, hypochlorhydria, and poor immune function (Lanata & Black, 2008).

3.3 Incidence
The reported incidence of diarrhoeal disease has fluctuated over the years depending on study design. The use of non-standardized definitions of diarrhoea may be a factor in this. Nevertheless, many epidemiological studies show a pattern of diarrhoea incidence that has remained high since the 1980s. The reported global median incidence rate for diarrhoeal diseases in children less than 5 years of age (reported as episodes per year per child) was 2.6 between 1980 and 1990 (Bern et al., 1992) and 3.2 between 1990 and 2000 (Kosek et al., 2003). Although diarrhoea morbidity remains little changed, there has been a sharp reduction in diarrhoea mortality; this is due to effective treatments such as oral rehydration therapy (ORT). The high rates of diarrhoea are a reflection of persistent risk factors such as limited access to clean water, poor sanitation, and lack of latrines; these factors need to be addressed, particularly for children younger than 2 years of age, in whom the incidence rate is highest.

Most diarrhoea episodes are of short duration and resolve within one week, with a smaller number of cases lasting up to 2 weeks. Persistent diarrhoea that lasts more than 14 days accounts for 3% to 20% of all diarrhoea episodes, the incidence being highest in children less than 5 years of age, and declining with older children (Lanata & Black, 2008).

3.4 Seasonality
Diarrhoeal diseases caused by bacterial infections peak during hot or wet months, confirming a faecal–oral route of transmission. On the other hand, Rotavirus infections, which are responsible for a large proportion of childhood diarrhoeal diseases, respond to changes in climate, with the highest number of infections found at the colder and drier times of the year in both temperate and tropical regions. But for other climates, the virus is always present, suggesting that low-level transmission occurs all year round (Levy et al., 2009).

4. CLINICAL FEATURES AND PATHOPHYSIOLOGY
The loss of fluid that accompanies diarrhoeal disease leads to dehydration, fever, electrolyte imbalances, anorexia, convulsions, and micronutrient and macronutrient deficiencies.

4.1 Major Pathogens Involved in Diarrhoeal Diseases in Children
Most diarrhoeal diseases are caused by bacterial, viral, and protozoan pathogens. In many studies reporting on community-based and hospital-based incidences of diarrhoeal disease, Escherichia coli was found to be the major cause of gastro-intestinal infections. Table 11.1 lists the leading causative agents of diarrhoea in children (Lanata et al., 2003).
Table 11.1: Leading infectious causes of diarrhoeal disease in children worldwide

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Pathogen type</th>
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<tbody>
<tr>
<td>Campylobacter jejuni</td>
<td>Bacterium</td>
</tr>
<tr>
<td>Clostridium difficile</td>
<td>Bacterium</td>
</tr>
<tr>
<td>Cryptosporidium parvum</td>
<td>Protozoa</td>
</tr>
<tr>
<td>Entamoeba histolytica</td>
<td>Protozoa</td>
</tr>
<tr>
<td>Escherichia coli (enterotoxigenic and enteropathogenic strains)</td>
<td>Bacterium</td>
</tr>
<tr>
<td>Giardia lamblia</td>
<td>Protozoa</td>
</tr>
<tr>
<td>Rotaviruses</td>
<td>Virus</td>
</tr>
<tr>
<td>Salmonella</td>
<td>Bacteria</td>
</tr>
<tr>
<td>Shigella types</td>
<td>Bacteria</td>
</tr>
<tr>
<td>Vibrio cholera</td>
<td>Bacterium</td>
</tr>
<tr>
<td>Yersinia enterocolitica</td>
<td>Bacterium</td>
</tr>
</tbody>
</table>

4.2 Pathophysiology
The symptoms of acute diarrhoea depend on whether the infectious pathogen causes disease by producing a toxin or by invading host tissues. Enterotoxigenic (toxin-producing) diarrhoeas are caused by E. coli strains and Vibrio cholera. The presence of toxin in the intestinal lumen causes secretion of fluid and electrolytes and subsequent diarrhoea. Rotaviruses infect cells lining the intestinal tract and may result in mucosal damage that impairs lactase activity and absorption of carbohydrates. Enterotoxigenic and viral diarrhoeas are not characterized by inflammation of the intestinal mucosa. Invasive diarrhoeal disease is caused by species of bacteria such as Shigella, Salmonella, Yersinia enterocolitica, Campylobacter jejuni, and enteroinvasive E. coli, and it is associated with an acute inflammatory process (Keusch, 1983).

4.3 Effects of Malnutrition on Mortality
Evidence based on epidemiological studies shows that malnutrition is directly associated with mortality as a result of diarrhoeal disease. The risk of dying for malnourished children is 14 to 24 times higher than that of normally nourished children. Additionally, mortality risk is proportional to the level of malnutrition. For example, a large prospective study reported that the risk of dying increased 1.6 times for each one-unit decrease in weight-for-age Z-score. Mortality rates are also higher when malnutrition is associated with persistent diarrhoea compared to acute diarrhoea. Of the three million annual premature deaths from diarrhoeal diseases, 58% are linked to malnutrition (Wapnir, 2000).

4.4 Effects of Malnutrition on Morbidity
Malnutrition has a closer relationship with duration of diarrhoeal morbidity than with increased incidence, especially for infections with Shigella and enterotoxigenic E. coli pathogens. A three-fold or greater increase in duration of diarrhoeal illness has been observed in undernourished children. The longer period of diarrhoeal illness further compounds the poor nutritional status and may lead to persistent diarrhoea and the likelihood that such children will require hospitalization and longer hospital stays (Black et al., 1984; Black, 1993).

Although the link between undernutrition and diarrhoeal incidence is weaker than that between the duration of illness and poor nutritional status, children with previous malnutrition have a 1.5- to 2.0-fold elevated risk of developing a diarrhoeal episode. Children who are undernourished are also more likely to have recurring diarrhoea episodes, particularly with Cryptosporidium parvum infections (Sarabia-Arce et al., 1990).
4.5 Effect of Diarrhoea on Growth of Children

Diarrhoea causes reduced weight gain in children rather than a reduction in height or length gain. The weight shortfall is indirectly related to the duration of a diarrhoeal episode. Since a poor diet seems to be associated with the negative effects of diarrhoea, a normal diet can reverse these effects within 14 to 30 days following a diarrhoeal episode. Plotting the duration of diarrhoeal episodes shows a continuous distribution with skewness toward long durations. Durations greater than 14 days (persistent diarrhoea), although accompanied by higher risks of dying, are less common, and occur in children in areas with a generally high prevalence of diarrhoea (Black, 1993). An adequate diet is protective against the subsequent nutritional impact of diarrhoea, and infants who are breast-fed suffer less harmful effects with respect to growth.

Evidence shows that both symptomatic and asymptomatic infections have unfavourable effects on growth. In a community-based study conducted with Peruvian children, a reduction in weight gain was observed in children infected with both symptomatic and asymptomatic forms of C. parvum (Checkley et al., 1998). Other studies suggest that asymptomatic infections have even greater negative effects on growth than symptomatic ones because of their higher prevalence. According to a review published by Humphrey (2009), large numbers of faecal bacteria colonize the small intestines of children and produce a subclinical condition known as tropical enteropathy. The changes associated with this, such as a hyperpermeable gut, inflammation, and villous atrophy, may result in reduced nutrient intake and absorption and subsequent growth reduction in children aged 2 years or younger.

4.6 Effect on Dietary Intake

Diarrhoea illnesses are linked to a reduction in dietary intake during the disease period, and the reduction in energy consumption in infants can be as much as 15% to 20% in non-breast-feeding children. For breast-fed infants, the impact is less, especially if they receive more than half of their energy intake from breast milk. Hospitalized children show a greater reduction in energy intake than those in the community, possibly because of differences in food characteristics, and these children may also have been suffering more severely from the disease, both before and after entering hospital (Lanata & Black, 2008).

4.7 Effects on Nutrient Absorption and Intestinal Function

There are several methods by which diarrhoea may reduce intestinal absorption. These include direct intestinal cell damage by a pathogen or its toxins, immune response of the host, accelerated intestinal motility accompanied by reduced transit time, and less bile acids due to faecal losses or breakdown by bacteria. The malabsorption and impaired digestion of macronutrients brought on by these mechanisms result in further build up of fluid and intraintestinal osmotic pressure, worsening the diarrhoea. More often, infections with rotaviruses seem to bring on these conditions (Sack et al., 1982).

5. PREVENTION OF DIARRHOEA

5.1 Relationship with Nutrition and Immunity

The evidence above demonstrates that undernutrition is a major risk factor for diarrhoea, especially in children. Here we look more closely at specific components of nutrition.

5.1.1 Undernutrition

Undernourished children have a high risk of infection that may be explained by the link between severe malnutrition and impaired immune response. Studies in developing countries have shown that children with impaired immune responses have a higher incidence of diarrhoeal diseases compared to those who are immunocompetent. This is also the case with persistent diarrhoea where failure to mount a cell-mediated response is associated with an elevated risk of diarrhoea (Shell-Duncan & Wood, 1997).
5.1.2 Vitamin A

Having diarrhoea predisposes a child to the development of vitamin A deficiency, which is known to impair epithelial integrity and systemic immunity, and in turn further increases the incidence and severity of infections, including diarrhoea (Brown, 2003; Villamor & Fawzi, 2000). The association is particularly strong between severe and persistent diarrhoea and with xerophthalmia or low vitamin A status assessed biochemically. In children with acute Shigella diarrhoea, a transient low serum retinol has been observed, probably because of impaired reabsorption of the transport protein that binds to retinol (Mitra et al., 1998). While Villamor and Fawzi’s (2000) review showed that vitamin A supplements reduce the severity of diarrhoea in some trials but not in others, they concluded that vitamin A supplements are effective in reducing total mortality; in particular, vitamin A supplements are likely to be more effective in populations suffering from nutritional deficiencies.

Similarly, a recent review reported that vitamin A supplementation in community settings reduces diarrhoea specific mortality by 30% in children aged 6 to 59 months (Imdad et al., 2011). It is known that vitamin A deficiency increases the relative risk of dying from diarrhoeal episodes; therefore supplementation is seen as a low-cost intervention for controlling severe and potentially fatal diarrhoeal episodes.

5.1.3 Zinc

Zinc plays a variety of roles in the body, contributing to growth and development, and assisting in immune function. This makes it a key micronutrient in helping children fight infectious diarrhoeal and respiratory diseases. Zinc is available in many foods, especially high-protein foods. Good sources of bioavailable zinc come from meat (Hunt, 2003). Unfortunately, traditional diets in developing countries often fail to meet zinc needs in children, especially if they are plant-based (see Chapter 9).

A detailed review of clinical studies concluded that children who receive a zinc supplement have significantly fewer episodes of diarrhoea, severe diarrhoea, dysentery, and persistent diarrhoea, and fewer total days of diarrhoea (Aggarwal et al., 2007). While there is evidence that zinc is effective for preventing and treating diarrhoea, these authors noted various problems associated with the studies, indicating a need for larger, high-quality studies to identify subpopulations most likely to benefit from zinc supplements. Nevertheless, UNICEF and WHO (2009) suggest that zinc is an important nutrient in the prevention of diarrhoeal diseases in children and efforts should be increased to insure its widespread distribution. Not only is zinc deficiency associated with higher rates of diarrhoea and other infectious diseases, but diarrhoea also results in depletion of zinc stores in the body. Therefore, zinc supplementation is important for both the prevention and treatment of diarrhoea.

5.1.4 Other minerals

Copper is a trace mineral that is a part of several enzymes that participate in the body’s natural defence mechanisms. Thus copper deficiency is linked to preventing infectious disease in children, and copper supplements have been shown to relieve persistent diarrhoea. Selenium, another trace mineral, is one of the body’s antioxidant nutrients. Infants’ requirements for selenium are greater than those for older children; it is therefore especially an essential mineral for infants who are at risk of diarrhoeal disease. The level of selenium may vary in breast milk depending on maternal intake. Studies with animals show that selenium-deficient diets cause an increase in oxidative levels and suppression of the immune response, which are reversed with supplemental selenium (Arthur et al., 2003).

5.2 Breast-feeding

Breast-feeding has major health benefits, including greatly reducing the risk of diarrhoea (Chapter 5). With few exceptions, all infants should be exclusively or predominantly breast-fed for at least the first 6 months of their lives. The preventive action of breast milk against diarrhoea has been demonstrated clinically. For example, Bahl et al. (2005) conducted a study of 9400 infants, aged 18 to 42 days, in Ghana, India, and Peru, and found that those who were exclusively or predominantly breast-fed had a significantly lower rate of diarrhoea and acute respiratory illness in comparison with infants who were not breast-fed or were partially breast-fed. Similar findings were made by Arifeen et al. (2001) in a study of infants in slum areas of Dhaka.
Bangladesh, who were followed from birth for 12 months. Infants who were partially or not breast-fed had a
2.2-fold higher risk of death from all causes, with deaths from diarrhoea 3.9 times more likely, than infants
who were exclusively breast-fed. Lawrence and Pane (2007) reviewed 12 studies, most of which examined
exclusive breast-feeding versus exclusive formula feeding. They concluded that there is a significant difference
in outcomes in terms of diarrhoeal diseases, with clear preventative benefits of breast milk. The WHO and
the American Academy of Pediatrics estimate that if infants were exclusively breast-fed until 6 months of
age, followed by breast-feeding for up to one year along with eating solid foods, more than one million infant
deaths from diarrhoea could be prevented each year (Morrow & Rangel, 2004; Story & Parish, 2008).

5.3 Improved Weaning Practices

Even after 6 months, when infants are weaned from breast milk and introduced to other foods, there is a
high risk of bacterial contamination, especially in developing countries where the food and water are more
likely to be contaminated (timely and inadequate weaning implies early and unhygienic introduction of
non-human milk and other foods and contributes to diarrhea (Bhutta et al., 2008). Therefore, it is important
that adequate, hygienic food is provided to infants when they are going through the weaning phase. Decades
ago, researchers identified enteric pathogens, such as E. coli, in feeding bottles and traditional weaning gruels
in Nigeria, which could be traced to poor bottle hygiene, prolonged precooking, improper food storage,
inadequate hygiene in cleaning methods, and/or unsatisfactory feeding practices (Cherian & Lawande, 1985).
There is strong evidence that weaning foods are still frequently heavily contaminated with pathogens that
cause diarrhoea (Motarjemi et al., 2003) because of unhygienic conditions during preparation.

5.4 Use of Safe Water

It has been estimated that poor hygiene, inadequate sanitation, and insufficient and unsafe drinking water
account for 7% of the total disease burden and 19% of child mortality worldwide (Prüss-Üstün et al., 2008).
The crucial importance of a safe water supply, good hygiene, and good sanitation was recently reviewed
(Bartram & Cairncross, 2010; Mara et al., 2010; Hunter et al., 2010). There is clear evidence that supplying
safe water and improving sanitation is cost-effective.

The United Nations Children’s Fund, in their The State of the World’s Children report on maternal and
newborn health (UNICEF, 2008), identified safe water as an important factor in preventing diarrhoea in
children. An adequate supply of clean water helps to encourage proper hand washing and cleaning of eating
utensils. These practices can interrupt the spread of infectious agents that cause diarrhoea. Clean water is
essential for drinking and for cleaning and preparing food. Unfortunately, much of the world does not have
access to clean water; methods to disinfect water therefore need to be made readily available.

Quick et al. (2002) implemented a diarrhoea-prevention intervention in Zambia that consisted of water
treatment, safe storage, and community education about the link between water and diarrhoea. They found
that households storing water safely increased from 42% (before the intervention) to 89% (after), and this
water was significantly less contaminated with E. coli. Occurrence of diarrhoeal disease was lowered by 48%.
The researchers concluded that in families who lack access to potable water, this intervention is effective in
preventing waterborne diseases linked to diarrhoea. Much less success was achieved by Rainey and Harding
(2005), who examined the acceptability of solar disinfection of drinking water in a village in Nepal where
40 households were randomly selected and senior women were taught how to disinfect the water. Only 9%
of households adopted the intervention. The researchers concluded that although participants became aware
of the benefit of treating water to reduce stomach ailments, awareness was not enough to compensate for the
barriers of heavy domestic and agricultural workloads, cultural barriers, and lack of knowledge that untreated
drinking water causes diarrhoea. The authors suggested that, given the low level of education and the women’s
work constraints, other options for disinfecting water are needed.

There is clearly an acute need for simple, inexpensive water-filtering or treatment systems in developing
countries where access to safe, potable water is limited. Strategies for developing safe water systems must
also include public health education about waterborne diseases, source water protection, and a motivational
component to achieve implementation and sustained use.
5.5 Hand Washing

In the home and in the community, hands are a major source of transmission of intestinal pathogens. “The hands are the last line of defence against exposure to pathogens which can occur either directly from the hand to the mouth, eye, nose, or other area of the skin, or indirectly by ‘handling’ of food or water” (Bloomfield & Nath, 2009). Epidemiological studies show that in both developed and developing countries, the burden of infectious and parasitic diseases can be significantly reduced through hand washing. It can reduce gastrointestinal infections (Fewtrell et al., 2005) by anywhere from 26% to 79% in developing countries and by 48% to 57% in developed countries (Bloomfield et al., 2007). Roberts et al. (2000) conducted a randomized, controlled trial of an infection control intervention in child-care centres in an Australian city. After staff members were trained about transmission of infection and hand washing, diarrhoeal episodes were reduced by 50% to 66%, although the impact was confined to children more than 2 years old.

In an extensive review, Bloomfield and Nath (2009) emphasized that a number of factors must be considered for the hand-washing process to be effective, including the use of soap or another material to help detach microbes, parasites, and other substances from the skin, the amount of friction used, the amount and quality of water used to rinse the hands, and the technique used for drying the hands. While UNICEF and WHO (2009) suggest the need to use soap, studies have shown that in many low-income countries, people often use soil, mud, or ash as alternatives (Bloomfield & Nath, 2009). These authors found that although the use of contaminated soil, mud, or ash poses potential microbiological and toxicological risks, in communities that cannot afford soap, the promotion of clean and dried soil and ash is preferable to using no agent, as these substances are effective in removing organisms from the hands. Furthermore, they make the point that people’s hygiene behaviours are complex and are moderated by social, educational, cultural, religious, and economic factors. Local issues and contexts must therefore be considered for any activities intended to promote hand washing.

5.6 Latrines and Proper Disposal of Human Waste

Kleinau et al. (2004) described several large-scale intervention programmes in developing countries where improvements in the sanitary disposal of faeces had a significant impact on reducing diarrhoeal diseases in young children. They noted that faeces disposal by toddlers in open fields was identified as perhaps the most important contaminant in the environment around households, and therefore the prevention of open defaecation and direct contamination with children’s faeces is an important priority. These authors stress the need for health promotion programmes that facilitate the use of nappies (diapers) for young infants and appropriate methods of disposing or washing them, the use of potties for toddlers, and the immediate removal of faeces from the house and its disposal in latrines or by burying in soil away from the house and water source.

A well-maintained latrine is one of the best methods for reducing the risk of diarrhoea, especially when combined with a good water supply and education on hand washing. A latrine is a receptacle for deposition, retention, and, possibly, decomposition of excreta (Cotton et al., 1995). Some latrines are similar to an “outhouse” or toilet, but most are much simpler and less costly to construct. Huuhtanen and Laukkanen (2006) describe different types of latrines, including the specifications and relative costs to construct them, as well as issues associated with their desired location and required maintenance. To be effective in terms of enhancing human health, the excreta must be kept separate from the user, the latrine must be away from water supplies in order to prevent community exposure to excreta through contamination of water, a screen or cover must be used to prevent flies or other harmful animals coming in contact with excreta and transmitting pathogens to humans, and excreta must remain covered and/or pathogens made harmless.

5.7 Measles Immunization

Measles immunization is effective at reducing the risk of diarrhoea (Kappor & Reddaiah, 1991). The World Gastroenterology Organisation (2008) stated, “Measles immunization can substantially reduce the incidence and severity of diarrheal diseases. Every infant should be immunized against measles at the recommended age.” This is one of the strategies in the 7-point plan recommended by UNICEF and WHO (2009) in their prevention and treatment strategies for diarrhoea.
5.8 Vaccines

As noted previously, rotavirus infection is the most common cause of severe diarrhoeal disease and a leading cause of morbidity and mortality. Glass et al. (2005) and Dennehy (2008) maintain that vaccination would be the most likely intervention to significantly impact the incidence of this disease. An active rotavirus immunization was developed in the 1990s but was taken off the market after a few months because there was a high incidence of undesired side effects (Canadian Paediatric Society, 2003). Two new live oral vaccines licensed in 2006 have been reported to be safe and effective against rotavirus, and are being used in various countries (Dennehy, 2008). Bhutta et al. (2008) caution that there are economic considerations related to the use of vaccines for treating diarrhoeal diseases that have not yet been resolved, especially in countries with limited resources. In addition, they raise a concern that rotavirus and other vaccines might not have much impact in some regions where mucosal vaccines may be less effective, such as Asia. They call for ongoing surveillance of diarrhoeal disease burden after the vaccines have been introduced. These authors agree with Glass et al. (2005) that many challenges remain before any of the vaccines for the prevention of diarrhoeal diseases can be incorporated into full-blown childhood immunization programmes in the developing world. Vaccine efficacy and safety have not been clearly demonstrated in children in poor regions in Africa and Asia. Furthermore, there is a need for financing strategies to ensure that new vaccines are affordable and available in the developing world.

6. TREATMENT OF DIARRHOEA

6.1 Oral Rehydration Therapy

The treatment of diarrhoeal diseases varies according to the cause and severity of the diarrhoea and the degree of dehydration. The WHO has developed treatment plans based on three categories of dehydration in children: (1) no signs of dehydration, (2) signs of some dehydration, and (3) severe dehydration (WHO, 2005). Cases that fall into category A can be treated at home with plain water or fluids that contain salt. Appropriate drinks include: oral rehydration solution (ORS), salted drinks such as salted rice water or salted yogurt drinks, soup with salt, or other fluids that the mother or caregiver has access to and that the child will drink. Treatment usually begins at home, and all families should be encouraged to have ORS products at home at all times (King et al., 2003) as this is a key feature in the successful treatment of diarrhoea. Oral rehydration therapy (ORT) includes an ORS, which is a mixture of clean water, salt, and sugar that can be safely prepared at home. The solution can also include trisodium citrate and potassium chloride. ORT has been shown to be an effective treatment for diarrhoea in children and adults that is caused by cholera bacteria and other infectious agents (WHO, 2005).

If the child or adult shows some signs of dehydration, the WHO recommends ORT be given in a health facility, to ensure that future dehydration does not occur. Caregivers must be taught when to seek medical care, especially for infants, who need medical evaluation at the first signs of distress because they are much more prone to dehydration than older children. Either the standard WHO ORS solution (with 90 mmol/L of sodium) or the reduced, low-osmolarity (75 mmol/L of sodium) solution may be given (WHO, 2005). However, if the child is less than 6 months old and not breast-fed, the WHO recommends giving an additional 100 to 200 ml of clean water along with the ORS, if the standard WHO ORS solution is used. Regardless of which is used, the amount of ORS solution must be calculated according the child’s weight and/or age. While still dehydrated, adults can have as much as 750 ml of ORS per hour and children up to 20 ml per kg body mass each hour (WHO, 2005).

There has been some debate about whether the old ORS solution or the new reduced-osmolarity ORS solution is more effective for the treatment of diarrhoea, especially if it’s caused by cholera. However, the latest recommendation from UNICEF and WHO (2009) is that the new reduced-osmolarity formula be provided for all children with acute diarrhoea. Patients with severe dehydration require intravenous rehydration but can also be given ORS solution if they can still drink. ORT should encompass a maintenance phase that includes both ongoing replacement of fluid and electrolytes, and appropriate dietary intake (King et al., 2003).
6.2 Nutritional Management

In addition to ORS, the provision of food for children with diarrhoea helps with the absorption of fluids and further prevents dehydration; continued eating also maintains nutrition and improves the patient’s ability to fight infections (WHO, 2005; UNICEF & WHO, 2009). Infants who are breast-feeding should continue to do so, and those who are not should be fed their usual formula. In addition to milk, children more than 6 months old should be given an age-appropriate diet of cereals, vegetables, and other foods that have a high content of energy and provide adequate amounts of essential micronutrients (UNICEF & WHO, 2009). Vegetable oil should be added to cereals to improve caloric intake, and meat, fish, egg, and potassium-rich foods such as bananas, coconut water, and fruit juice should be given if available. Foods high in simple sugars should be avoided. King et al. (2003) suggested that highly specific diets are unnecessarily restrictive and may provide suboptimal nutrition. In general, the most appropriate food for the treatment of diarrhoea in children is non-fibrous food that is easily digestible, high in energy, rich in potassium, and, if possible, locally grown (Bhattacharya, 2000).

6.3 Mixed Diets

Studies have been made using mixed diets based on locally available staple foods such as potato, pea flour, beans, maize, rice, and milk. Children generally fare at least as well with mixed diets as they do with highly processed formulas (Brown, 2003). Treatment failures due to recurring dehydration are lower for children fed these foods than in those given soy protein infant formulas. Studies have reported that increasing the energy density of staple foods by fermentation, germination, or adding green bananas reduces duration of diarrhoea and results in sustainable weight gain in malnourished children with shigellosis, preventing the loss of protein in the stool normally associated with this illness (Kosek et al., 2010; Rabbani et al., 2009).

6.4 Timing of Feeding

The most recent guidelines from UNICEF and WHO (2009) state that for acute diarrhoea with no blood or dehydration, it is important for the child or adult to continue eating their usual diet; food should never be withheld or diluted. While children experiencing bloody diarrhoea may lose their appetite until the diarrhoea subsides, they should be encouraged to eat and offered small feedings every 3 to 4 hours. For children with some dehydration, no food, except breast milk or formula, should be given during the first 4 hours of rehydration therapy, and if the rehydration therapy is successful in preventing further dehydration, children should be given food every 3 to 4 hours immediately after rehydration. Patients with severe dehydration require intravenous (IV) therapy, but until the IV is running, they should be given ORS by mouth if they can drink. All infants should be given ORS solution within 3 to 4 hours, and for older patients within 1 to 2 hours, when they can drink without difficulty. Whether diarrhoea is mild or severe, rapid introduction of usual feedings, whether breast milk, non-human milk, or solid foods, is important for maintaining nutrition and preventing weight loss.

6.5 Lactose

Children with mild or no dehydration and those whose dehydration was managed using recommended protocols can be treated as successfully with lactose-containing diets as with lactose-free diets (Brown et al., 1994). There appears to be no justification for routinely diluting milk or using lactose-free milk formulas, especially if the diarrhoea has been managed with ORT and early feeding with solids and milk. However, infants with malnutrition or severe dehydration may recover more quickly with lactose-reduced formulas or, alternatively, cereal-milk mixtures or fermented milk products (Brown et al., 1994). Bhatia and colleagues (2008) recommend avoiding soy-based formulas, but in the rare case that infants have galactosaemia, hereditary lactase deficiency, or are on a vegetarian diet, isolated soy protein-based formulas may be used. However, if breast-feeding, even infants with severe dehydration should continue, because although human milk contains more lactose than does cow’s milk, it is much better tolerated by infants and more easily absorbed (Lawrence & Pane, 2007). This is an important reason why breast-feeding should be continued when the mother or the infant has a diarrhoeal infection. If the mother is not breast-feeding, WHO recommends continuing full-
strength, lactose-containing non-human milk in children with diarrhoea, unless they have severe diarrhoea and simply cannot tolerate it, in which case they should receive medical treatment and be given mixed foods such as potatoes, noodles, or rice.

6.6 Dietary Fibre
Companies market formulas containing soy fibre to consumers and physicians. For older infants and toddlers, these formulas may lead to some reduction in the duration of diarrhoea when the problem is associated with antibiotic use (Burks et al., 2001). However, when given to children with acute watery diarrhoea, while soy fibre was reported to reduce stool liquidity overall, stool output was unchanged (Brown et al., 1993). King et al. (2003) suggested that this “cosmetic effect” might be beneficial in terms of reducing nappy (diaper) rash and facilitating an early return to a normal diet. However, overall, there is no good evidence to support the use of soy fibre (King et al., 2003; Canadian Paediatric Society, 2003). In fact, soy fibre has several disadvantages, including reduced absorption of nutrients and antibiotics in the intestine as well as masking the severity of fluid loss into the intestine (Canadian Paediatric Society, 2003).

6.7 Probiotics
Probiotics – live microorganisms in fermented foods–purportedly improve the balance of intestinal microflora and inhibit the growth of pathogenic bacteria through immune-stimulating properties (de Vrese & Mateau, 2007). However, Guandalini (2008) reviewed the research on probiotics for diarrhoea in children in different settings, and concluded that they are of limited clinical importance and only for some strains of diarrhoea. De Vrese and Marteu (2007) reported that other clinical trials on the treatment of infectious diarrhoea in children have shown a moderate benefit of mostly Lactobacillus GG, L. reuteri, and Saccharomyces boulardi in the treatment of acute watery diarrhoea, especially retroviral, in infants and children. However, the effects appear to result in only a short reduction of duration of diarrhoea (just more than 1 day) and mostly when the diarrhoea is due to retrovirus. Furthermore, the beneficial effects are dependent on the strain of probiotics and dose. De Vrese and Marteu (2007) concluded that with the exception of nosocomial infections or antibiotic-associated diarrhoea, the evidence is not sufficient to recommend the use of probiotics for the treatment of diarrhoea.

Others have also come to a rather negative conclusion. In an evaluation of the use of probiotics it was concluded that there is insufficient evidence to recommend their use for preventing or treating Clostridium difficile-associated diarrhoea (CDAD), the most common form of nosocomial diarrhoea (Xie et al., 2009). Similarly, Wolvers et al. (2010) and Allen et al. (2010) conducted reviews of the research on the use of probiotics in selected infections, including infectious diarrhoea in children. They stated that firm conclusions cannot be made because there are still only a limited number of studies, and the studies that have been conducted were on different types of infections with different probiotics. Also, there is lack of consistency among studies in terms of design, outcome parameters, and study populations. These authors did note that in terms of infectious diarrhoea in infants, traveler’s diarrhoea, antibiotic-associated diarrhoea, and necrotizing enterocolitis, there are data to support the use of certain probiotics, under certain conditions, and in certain populations, but the data are too limited to make any clinical recommendations about this.

A different story emerges when we look at antibiotic-associated diarrhoea. Here, there is solid evidence that probiotics are effective both in prevention and treatment (Hempel et al., 2012).

6.8 Prebiotics
Prebiotics are substances that escape intestinal digestion and therefore reach the colon, where they are fermented by intestinal microflora. This results in products that selectively stimulate the growth and/or activity of intestinal bacteria associated with health and well-being (Gibson et al., 2004). Many questions about prebiotics use remain unanswered. Although research on animals has shown promising results, there appear to have been no reports of successful clinical use of prebiotics. For this reason, insufficient evidence exists to recommend their use, either for the prevention or treatment of diarrhoea (de Vrese & Marteau, 2010).
6.9 Short-chain Fatty Acids

Dietary carbohydrates and some dietary fibre escaping digestion/absorption in the small bowel undergo fermentation in the colon and are converted to short-chain fatty acids (SCFA) by bacteria (Roy et al., 2006). SCFA are the primary source of energy for the functioning of colonocytes. Acetate, propionate, and butyrate are the three main acids that stimulate sodium and fluid absorption in the colon and affect the proliferation of colonocytes. Studies in animals have shown that SCFA stimulate the growth of lactobacilli and bifidobacteria, and play a significant role in the physiology and metabolism of the colon (Roy et al., 2006). SCFA production represents an adaptive process for conserving calories, fluid, and electrolytes. Inhibition of SCFA synthesis by the administration of antibiotics or other substances that are not metabolized by colonic microbiota results in diarrhoea (Binder, 2010). Conversely, when starch that is relatively resistant to amylase digestion is added to ORS, there is increased production of SCFA, and this improves the efficacy of ORS in the treatment of acute diarrhoea in children less than 5 years of age (Binder, 2010).

Green bananas (GB) are rich in amylase-resistant starch, some of which escapes digestion and is fermented into SCFA. Rabbani et al. (2009), in a controlled clinical trial with children aged 6 to 60 months who had severe bloody dysentery due to *Shigella* infection, found that when added to a regular diet, GB enhance recovery from persistent diarrhoea. These researchers observed clinically significant improvements in excretion of mucus and blood, stool volume, and stool frequency in children given GB, concluding that the addition of GB is an effective treatment. Rabbani et al. (2010) also studied children with diarrhoea aged 6 to 36 months in rural Bangladesh. Children with both acute and prolonged diarrhoea who were fed cooked GB had significantly faster recovery rates. These findings indicate that the addition of GB to the diet improves clinical severity of diarrhoea, suggesting that it could be an inexpensive and useful adjunct treatment.

6.10 Micronutrient Supplementation

Specific micronutrients, in particular zinc and vitamin A, have been evaluated as therapeutic agents in acute diarrhoeal diseases.

6.10.1 Zinc

Research has shown that zinc supplements, given during and just after episodes of acute diarrhoea, provide beneficial effects in terms of reducing stool volume and duration of the problem, while also lowering the incidence of diarrhoea in the following 2 to 3 months (Penny & Lanata, 1995). There are also indications that zinc can help reduce morbidity and mortality from other childhood infections.

Studies of the effects of supplementary zinc on diarrhoea in children less than 5 years of age reported a 15% lower probability of continuing diarrhoea in the trials of acute diarrhoea and a 42% lower rate of treatment failure or death in the trials of persistent diarrhoea (Bhutta et al., 2000). A systematic review concluded that adding zinc to the treatment of severe diarrhoeal diseases can reduce mortality by 23% (Walker & Black, 2010). However, another recent review was more cautious as to the benefits of zinc supplementation in the prevention and treatment of diarrhoea (Patel et al., 2010); this raises questions about the blanket use of zinc in children. Based on the significant variability of responses to zinc seen among the subgroups, Patel et al. (2010) highlight the need to revisit the strategy of universal zinc supplementation. They emphasize the need to better understand and investigate the predictors of the efficacy of zinc in the treatment of children with acute diarrhoea in developing countries, including: the role of disease causality; the type of zinc salts used; the dose, frequency, and duration of supplementation; and the acceptability to the child.

The WHO and UNICEF concluded that there was sufficient evidence to recommend, as part of the clinical management of acute diarrhoea, supplementation with zinc for up to 2 weeks, in conjunction with oral rehydration (WHO, 2005; UNICEF & WHO, 2009). Zinc supplementation is a safe, effective, and low-cost intervention that is critical to the treatment of diarrhoea. The real problem is that it is not readily available in the countries that need it the most.
6.10.2 Vitamin A
While vitamin A supplementation has been reported to have a preventative effect on diarrhoea, studies to date have provided little evidence of its impact on the treatment of diarrhoea (Brown, 2003). One exception may be infants who are not breast-fed, for which studies show a slight decrease in the number of bowel movements and duration of illness but with no change in the overall rate of diarrhoeal attacks.

6.11 Dietary Management of Persistent Diarrhoea
Persistent diarrhoea is defined as an episode of diarrhoea that lasts 14 days or longer (UNICEF & WHO, 2009). The cornerstone of its management is optimal nutritional therapy (Boggs et al., 2007). In a comprehensive review of diarrhoeal diseases and nutrition, Bhutta et al. (2004) maintained that persistent diarrhoea can usually be managed by providing children with diets that include complex carbohydrates, such as rice, maize, legumes, lentils, and bananas, as well as vegetable oil, and milk for protein. Breast milk is recommended but cow’s milk (and in some cases soy formula) is also acceptable. Bhutta et al. noted that L-glutamine, nucleotides, corticosteroids, preparations containing growth factors, and immunoglobulins are potentially effective treatments. When milk is not tolerated, protein can be obtained from egg white or chicken.

Enteral protocols used in developed countries that include specialized formulations, such as lactose-free or semi-elemental diets, are not usually appropriate for developing countries because they are too expensive, require continuous administration, and are frequently unpalatable and not acceptable to children. The Integrated Management of the Childhood Illness (IMCI), established by WHO, includes guidelines for the management of persistent diarrhoea, based on a study in six countries (International Working Group on Persistent Diarrhoea, 1996). The WHO concluded that severe cases of persistent diarrhoea can be effectively and safely treated with simple diets prepared from locally available, culturally appropriate foods, vitamin and mineral supplements, and specific antibiotics when required.

7. CONCLUSIONS
It is evident that nutrition and diarrhoeal diseases are closely related, and that this relationship is bidirectional: undernutrition is often an underlying cause of mortality from diarrhoea, and, conversely, diarrhoeal diseases also have a negative impact on the nutritional status of children, especially where people have poor access to a nutritious diet. Poor-quality weaning diets may not permit catch-up growth following recovery from diarrhoeal disease. Children who are not well-nourished to begin with not only have a greater risk of infection, but they also tend to have more severe episodes and are at much greater risk of succumbing to this group of diseases.

Of utmost importance for the reduction in the incidence of diarrhoea is the promotion of exclusive breastfeeding for at least 6 months (whenever possible) and timely and adequate weaning with hygienic, nutritious foods. It is well established that early and unhygienic introduction of non-human milk and other weaning foods are predisposing factors to the development of diarrhoea. These risk factors are prevalent in poor countries where the nutritional management of diarrhoea requires the alleviation of poverty and the implementation of social sector support mechanisms.

Environmental factors must also be considered, including access to clean water and strategies to promote sanitation services and proper hand washing. The use of adequate latrine/toilet facilities and proper handling and disposal of excrement is imperative. Latrines, when properly planned, built, used, and maintained, ensure safe and adequate sanitation and provide significant health benefits. However, in order to be effective, technical solutions are not enough; hygiene education is also a vital ingredient. Several nutritional factors have positive effects on the management of diarrhoeal disease; however, dietary therapy using inexpensive, locally available, and culturally relevant foods and safe handling and cooking techniques are appropriate for most developing countries. But, ultimately, as the Mexican nutritionist Joaquin Cravioto long ago observed, we must recognize that the basic origin of distresses of childhood, such as malnutrition and diarrhoeal diseases, “is to be found in the malfunctioning of society as a whole and the accompanying injustices” (cited in Arroyo & Mandujano, 2000): these are what must be addressed.
DISCUSSION QUESTIONS AND EXERCISES
1. Discuss the factors that contribute to a high incidence of diarrhoeal diseases in developing countries.
2. Although diarrhoeal morbidity has remained high for many years, diarrhoeal mortality has sharply declined over the same period. Explain why.
3. What is the difference between
   a. enterotoxigenic and invasive infectious diarrhoeal diseases, and
   b. symptomatic and asymptomatic diarrhoeal infections?
4. Discuss the short-term and long-term effects of diarrhoeal illness on children’s nutritional status and growth, and indicate particular nutrients that are affected.
5. Discuss the size of the challenge of diarrhoeal diseases in your country/community.
6. How much scope is there for reducing the problem of diarrhoeal diseases in your country or community by improvements in (a) access to clean water, (b) building latrines, and (c) education on hygiene?

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ADDITIONAL RESOURCES


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