



## Are fecal indicator bacteria appropriate measures of recreational water risks in the tropics: A cohort study of beach goers in Brazil?



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### ABSTRACT

Regulating recreational water exposure to pathogens within the tropics is a major public health and economic concern. Although numerous epidemiological studies estimating the risk to recreational marine water exposure have been conducted since the 1950s, few studies have been done in the tropics. Furthermore, many have suggested that the use of fecal indicator bacteria for monitoring recreational water quality in temperate regions is not appropriate in the tropics. We analyzed a large cohort study of five beaches in Sao Paulo, Brazil, conducted during consecutive weekends in the summer of 1999 that estimated risk to water, sand, and food exposures. Enterococci and *Escherichia coli* concentrations were measured each day of the study. Elevated risks were estimated for both swimming (OR = 1.36 95% CI: 1.05–1.58) and sand contact (OR = 1.29 95% CI: 1.05–1.58). A 1 log increase in enterococci concentration was associated with an 11% increase in risk (OR = 1.11 95% CI: 1.04–1.19). For *E. coli* a 1-log increase in concentration was associated with 19% increase in risk (OR = 1.19 95% CI: 1.14–1.28). Most countries with beaches in the tropics are lower or middle income countries (LMIC) and rely on tourism as a major source of income. We present data that suggests fecal indicator bacteria such as enterococci are an appropriate indicator of risk in tropical urban settings where contamination is coming from predominantly human sources. Additional studies in tropical settings could help inform and refine guidelines for safe use of recreational waters.

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### 1. Introduction

Recreational activities in coastal waters are a major economic driver worldwide, especially in lower and middle income countries (LMIC) (Ghermandi and Nunes, 2013). Increasingly, these waters have been documented to be contaminated by human fecal contamination through numerous sources including: sewage

outflow, urban runoff, and other point and non-point sources (Abdelzaher et al., 2010; Korajkic et al., 2011; McQuaig et al., 2012; Wong et al., 2009). Associations between these contaminated recreational water exposures and disease have been documented since 1950s (Prüss, 1998; Wade et al., 2003). As a consequence, water quality criteria were developed (United States Environmental Protection Agency, 2012; WHO, 2003) and applied around the world based on epidemiologic studies conducted in the United States (Cabelli et al., 1982; Dufour, 1984) and United Kingdom (Kay et al., 1994). It is notable that LMIC countries are underrepresented in the scope of these global recreational water quality and epidemiological studies. Nonetheless they rely on World Health Organization (WHO) water quality criteria with relatively little

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information known about their local applicability (Henrickson et al., 2001). Exceptions include studies performed in beaches from Egypt in 1983 and South Africa in 1995 (Prüss, 1998). In addition, it has been suggested that in tropical environments, fecal indicator bacteria such as enterococci may persist and regrow in soils and waters and as a result may not be appropriate indicators for such locations (Fujioka, 2001). Epidemiological studies of water quality and swimming associated illness in tropical environments were recently identified as a major data need (Boehm et al., 2009). Based on this lack of representation and questions regarding applicability of widely used fecal indicator bacteria in many parts of the world including Latin America, the Environmental Agency of São Paulo State - Brazil (CETESB) undertook a prospective cohort study on the disease risks associated with swimming in five beaches along the São Paulo coast.

Due to the expense of measuring pathogens, as well as the vast number of pathogens that may be present in the marine waters, surrogate indicators (organisms that inhabit the intestinal tract of humans) are generally measured. In the 1950s, Stevenson (1953) first reported that incidence of illness occurred more frequently in swimmers than in non-swimmers at freshwater beaches and that data was used by the National Technical Advisory Committee (NTAC, 1968) to develop guidelines suggesting the use of fecal coliforms for measuring recreational water quality. These guidelines provided the basis for using fecal coliforms to characterize water quality at marine and freshwater beaches throughout the United States for the next 30 years. Later, enterococci for marine waters and *Escherichia coli* for freshwater replaced the coliform criteria based on epidemiology studies conducted in the 1970s and 1980s (Cabelli et al., 1982; Dufour and Strickland, 1979), which suggested these were superior indicators to fecal coliforms. However few other countries monitor for enterococci (Henrickson et al., 2001). The WHO “Guidelines for safe recreational water environments”, developed a decade ago (WHO, 2003), are based on enterococci and provide guidance for countries worldwide on marine water quality. However, to this day most South American countries continue to employ thermotolerant coliforms or *E. coli* criteria for marine recreational water quality. Brazil is an exception, as they established a federal law in 2000 that stipulated recreational water quality criteria for marine water using enterococci (Brazil, 2000). These criteria were based on the WHO guidelines draft (WHO, 1998) and a pilot epidemiological study conducted at Sao Paulo Coast in 1987 that demonstrated enterococci levels in bathing water were more strongly correlated to health effects than fecal coliforms (data not published). Even with these federal standards, most Brazilian states currently test waters for thermotolerant coliforms or *E. coli*.

To inform locally-specific risks associated with water and sand exposure, we describe a large cohort study performed at five urban beaches near São Paulo, Brazil. The objectives of this study were to provide locally-specific data to: 1) investigate the rates of gastrointestinal (GI) illness for swimmers and non-swimmers, for those with and without sand contact, and for swimmers exposed to waters with different enterococci concentrations; 2) determine health risks for different age groups following sand and water exposure; and 3) use water quality and epidemiological data to evaluate whether a dose–response relationship exists for swimmers using the fecal indicator bacteria enterococci.

## 2. Materials and methods

### 2.1. Study sites

São Paulo State is located in the southeastern region and represents 10% of the Brazilian coast, with 292 beaches. There are

15 coastal counties with a population of 2 million inhabitants that can double during the summer months. This study was conducted in five marine beaches (Enseada, Pitangueiras, Asturias, Aparecida and Ocian) located in four coastal municipalities of São Paulo State (Fig. 1). These beaches were selected based on: 1) representing a range of bathing water quality; 2) high bather density; and 3) presence of families with children at the beach. At the time of this study, the major municipalities in the study regions (e.g. Santos, Guarujá and Praia Grande) had sewer systems that provided preliminary treatment and chlorination before discharging effluent approximately 4 km offshore. However, many of the outer lying communities had unimproved sanitary systems, partial population connections, or were occupied by slums (Table S1), leading to contamination of streams that flow into the ocean and nearby beaches. Although conditions have improved somewhat, these beaches continue to be influenced by untreated sewage.

### 2.2. Epidemiological study design

Visitors to each of the five study beaches were enrolled into a prospective cohort study over five consecutive weekends (Saturdays and Sundays) during the summer period from January 9th to February 6th 1999 utilizing eleven trained interviewers per beach. Families were approached on the beach and provided with information on the study. Anyone who reported contact with other types of water, such as another beach, lake, or river in the previous seven days was excluded from the study. Verbal consent was obtained from all eligible individuals who agreed to participate. Following consent, participants were interviewed in parallel with microbiological water quality assessment (see below). An adult member (>18 years of age) answered questions for the other household members. A follow-up questionnaire was conducted by telephone 7–10 days later to assess whether the participants had developed any gastrointestinal (GI) or other potentially related symptoms. Questionnaires, protocols, consent procedures, and study materials were reviewed by the School of Public Health at the University of Sao Paulo. In Brazil, the National Committee of Ethics in Research was created in October 1996; however, the first operational manual was not published until 2002. IRB approval to conduct secondary data analysis for this study was obtained from the University of Michigan and the University of Arizona.

### 2.3. Beach questionnaires

Beach questionnaires were administered upon enrollment to gather demographic data and anticipated exposure information, such as contact with water and sand. Because participants were approached while on the beach, they were asked, “did you enter or do you intend to enter the water today?”. They were then asked if they usually swallow water or usually submerge their head. Sand contact was defined based on whether a participant usually sits or lies down directly on the sand. Beyond level of exposure to water (i.e. enter water only, usually submerge head, or usually swallow water) and sand contact, other variables known to contribute to GI illness were also collected such as (a) consumption of food sold on the beach (juices, drinks, snacks, ice-cream, etc.); and (b) regular consumption of seafood while at the coast.

### 2.4. Follow-up questionnaires

Individuals were contacted by telephone within 7–10 days of their initial beach interview to determine the onset of any symptoms that occurred following the beach visit, such as stomachache,

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