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Across Sectional Study among Egyptian Young Swimmers investigating Microbial Bowel Infections and Biological Parameters affecting Swimming Performance

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Abstract

Background: Swimming pool hygiene is influenced by swimmers' hygiene. In swimming pools, not showering before swimming is thought to be a risk factor for the spread of microbial infections. Therefor we intended to determine the prevalence of microbial infections among young swimmers in Egypt, as well as other biological aspects and characteristics.

Materials and Methods: Starting from August 2020 to June 2021, a cross-sectional study was done on 528 swimmers from a public club the swimmers were divided into groups 1 and 2 if they had high or low scores in swimming, respectively. Informed consent was obtained before collecting demographic data, and blood, and stool samples. Fresh stool samples were subjected to *Helicobacter pylori* Ag detection, other samples were concentrated and stained to be examined for parasites. Hemoglobin levels were determined using EDTA-blood samples. Physical factors (i.e. blood pressure and heart rate) were measured directly after swimming.

Results: The overall rate of microbial infections was 54% for intestinal parasitosis and 2.8% for *H. pylori*. Note that, *Blastocystis spp*. and *Cryptosporidium spp*. exhibited the highest rate of infection (24.1 % and 23.3%, respectively). In comparison to group 1, group 2 showed a significantly high rate of infection in terms of gender, age, duration, and frequency of swimming. Blood pressure, heart rate, and hemoglobin tests all yielded similar results. Swimmers who practiced swimming for <5 years were at higher risk (3- fold) as compared to ≥5 years. In addition, less frequent swimming (<4 days) was associated with a higher risk (5- fold) of infection compared with swimming ≥4 days.

Conclusion: The current study revealed a high prevalence rate of intestinal parasitic infections *H. pylori*, *Blastocystis spp*., and *Cryptosporidium spp*. Swimming habits, frequency, and duration were found to be linked with infectious status. Infection rates were also influenced by irregular blood pressure and heart rate, as well as anemia. To solve the challenges, measures need to be taken to raise awareness of the importance of swimmer hygiene and targeted health education.

Keywords: Intestinal parasitic infections; Microbial bowel infection; Swimming habits; Abnormal blood pressure; Swimming pools

Introduction

Water-borne infections are a serious public health concern with a global impact, as it causes more than 2.2 million deaths per year [1]. Swimming pools are of special concern because of their warm and moist environment, which allows pathogenic organisms to thrive. Pools pose a significant public health hazard Because of the large number of potential pathogens and transmission routes [2]. Swimming pools contaminated with pathogens associated with swimmers, such as vomit, saliva, mucus, and perspiration, causing respiratory, dermal, and central nervous system disorders [3]. Swallowing recreational water infects swimmers, leading to outbreaks in both developing and developed countries [4]. If the pool had been well-managed, several outbreaks related with swimming pools may have could been avoided. Swimming offers a variety of advantages, including physical activity, socialization, and competition [5]. It could, however, lead in the acquisition of a variety of infectious diseases. Physical contact among athletes and the sharing of equipment such as wearing personal protective equipment or braces, towels, showers, and locker rooms, could all be factors in the transmission of infections [6]. Athletes are at risk of intestinal parasite infections because of poor environmental conditions in sports situations (IPIs). Athletes are exposed to inadequate food and environmental hygienic conditions during preparation camps, national team camps, and frequent travel [7]. In addition, competition stress may render athletes temporarily more vulnerable to infectious illness [8]. Athletes who engage in long-term and strenuous exercise frequently have their immune systems suppressed [9]. Heavy exercise increases the risk of illness by allowing microorganisms to enter the body [10]. As a result, athletic performance may be impaired, and the severity of the disease process could be augmented. [11]. Innate and adaptive immunity play critical roles in guarding against Cryptosporidium infection and in the clearance of this parasite, which is frequently detected among swimmers. Innate immune responses involve intestinal epithelial cells, natural killer cells, and nitric oxide. The adaptive immune system consists of highly specialized, cells, such as T cells, and B cells, and processes that eliminate or prevent pathogenic challenges [12]. Regular exercise is well acknowledged as a first-line approach for preventing blood pressure (BP) rises [13]. Most studies in this field employed walking, jogging, or cycling activities [14]. There is little information available regarding the beneficial effects of regular swimming on BP despite the fact that this modality is an ideal physical activity for individuals with bronchospasm, heart disorders, and/or obesity [15]. One possible non-pharmacological intervention that is available at low cost to most children is exercise [16]. Endurance training, such as swimming, alters traditional markers of physical fitness in athletes, along with changing in various cardiovascular parameters, including a Heart Rate (HR) reduction [17]. Left ventricular dilatation, a normal wall thickness to dimension ratio, and increased stroke volume with appropriate diastolic filling reflect the cardiac adaptations to swimming [18]. HR variability in athletes has been recognized as a useful tool for examining long-term changes associated with exercise and autonomic nervous system activity during exercise [19]. As well as fitness and performance monitoring [20]. However, studies on the influence of swimming on HR and its value in professional application are rare. During, exercise the increased demand for oxygen is met by increasing muscle blood flow [21]. And by decreasing hemoglobin_oxygen (Hb-O2) affinity to improve oxygen unloading from Hb [22]. IPIs may cause anemia in athletes and adversely affect performance [23]. Hb concentration is low during anemia, which is most commonly caused by iron deficiency. Iron is an essential mineral for optimal athletic performance because of its role in energy metabolism, oxygen transportation, and acid_base balance. Moreover, it promotes athletic performance by increasing the oxygen-carrying capacity [24]. In turn, reduced iron content negatively affects aerobic capacity, muscle strength, and endurance [25]. Water-borne disease monitoring and analysis are critical for prevention and control. Given the scarcity of the scientific literature on this subject, and the popularity and potential benefits of swimming, the current study aimed to investigate the prevalence of microbial bowel infections and biological parameters affecting swimming performance among young swimmers.

Subjects and Methods

Sample collection and processing

A structured questionnaire based on known risk factors was developed. The participants in the study (the parents in the case of younger swimmers) were interviewed to collect socio-demographic data, as well as information on behavioral and hygiene practices. Fresh stool samples were subjected to H.

pylori Ag detection, and fresh thin smears were prepared to be stained by trichrome, and quick hot Gram chromotrope after air drying for detecting intestinal protozoa, and *Microsporidia spp*. respectively [26, 27].

Another portion from the stool sample was concentrated using the formol-ethyl acetate sedimentation technique, and then two permanently stained smears were prepared from the sediment, fixed, and stained with the MZN technique according to standard procedures [28].

Only 291 EDTA-blood samples were collected for determining hemoglobin levels. In addition, physical parameters (i.e., Bp and HR); blood pressure, and heart rate were measured directly after swimming.

Statistical analysis

Data were entered, verified, and analyzed using SPSS v.25.0 (IBM, Armonk, USA).

Differences and associations were tested using Pearson's chi-squared or Fisher's exact test, and Odds Ratio (OR) with its corresponding 95% Confidence Interval (CI) was calculated to identify the possible predictors of infection or association as shown in Table 1.

OR <1	**95% CI**	**Interpretation**
0.71	0.68-0.84	Significant protective value
0.71	0.42-1.06	Possible protective value but not Significant
OR >1	95% CI	Interpretation
1.21	1.07-1.56	Significant risk factor
1.21	0.72-1.69	Possible risk factor but not Significant
OR=1	95% CI	Interpretation
1	1.00-1.00	No effect, or no association

Table 1: Interpretation on the odds ratio.

Results

The table 2 shows that males were more likely than females to undertake the study (64.2% vs. 35.8%). Swimmers' age under 10 years and younger was lower than that of swimmer who were older than 10 years (43.2% vs. 56.8%). The percentages of swimmers was approximately equal among those who practiced swimming for less than 5 years and those who practiced the sport for ≥5 years were almost equal (51.1% vs. 48.9%). The percentage of swimmers who swam <4 days/week was higher than that of those who swam ≥4 days/week (63.1% vs. 36.9%). The rate of first 30 swimmers who achieved a shorter time in a championship was lower than that of those who achieved a longer time (17% vs. 83%). Regarding the clinical characteristics of swimmers, rhinitis was the most frequent of the non-GIT symptoms (26.7%), followed by headache, skin rash, and fever (11.9%,9.7%, and 6.8%, respectively), then by eye allergy, chest allergy, and otalgia (4.5%,4.0%, and 1.7%, respectively). Yet, GIT symptoms including abdominal colic showed the highest rate (28.4%), followed by constipation and equal rates of diarrhea and abdominal discomfort (17.6%,13.6%, respectively), then nausea, stomachache, and equal rates of anal itching and dysentery) (6.3%,5.1%, and 3.4%, respectively). As for physical and physiological measurements, the rates of swimmers who showed an abnormal HR, abnormal BP, and anemia were (8.5%, 21.6%, and 9.3%, respectively).

Demographic data	**Swimmers (N=528)**	
	No.	**%**
Gender		
Male	339	64.2
Female	189	35.8
Age (years)		
≤ 10	228	43.2
>10	300	56.8
Swimming pattern:		
Duration of swimming (years)		
<5	270	51.1
≥ 5	258	48.9
Frequency of Swimming (day/week)		
<4	333	63.1
≥4	195	36.9
Alexandria Championship Scores		
1st 30 (Gp1)	90	17
Late (Gp2)	438	83
Clinical Characteristics of Swimmers:		
Non-GI Symptoms		
Skin rash	51	9.7
Eye allergy	24	4.5
Chest allergy	21	4
Eye & chest allergy	3	0.6
Otalgia	9	1.7
Rhinitis	141	26.7
Fever	36	6.8
Headache	63	11.9
GI-Symptoms:		
Diarrhea	72	13.6
Nausea	33	6.3
Constipation	93	17.6
Abdominal colic	150	28.4
Anal itching	18	3.4
Abdominal discomfort	72	13.6
Dysentery	18	3.4

Stomach ache	27	5.1
Physical Measurements		
Heart rate:		
Abnormal	45	8.5
Normal	483	91.5
Blood Pressure:		
Abnormal	114	21.6
Normal	414	78.4
Physiological Measurements:		
Hemoglobin: (N=291)		
Anemic	27	9.3
Normal	264	90.7

Table 2: Demographic data, swimming pattern, clinical characteristics and physical and physiological measurements among young swimmers.

The table 3 shows that *Blastocystis spp*. and *Cryptosporidium spp*. exhibited the highest rates of microbial infections (24.1%,23.3%, respectively) followed by *G. lamblia* and *E. histolytica* (14.2%, and 12.7%, respectively), whereas *Cyclospora, H. pylori, Microsporidia spp., I. belli, D. fragilis, E. coli, A. lumbricoides and E. vermicularis* were present at lower rates (5.7%,2.8%,2.5%,1.7%,1.1%,1.1%,0.6%, and 0.4%, respectively). The table 4 shows that IPIs infected 285 of the 528 swimmers (54%). The rate of IPI among group 2 (Gp2) for both males and females were higher than Gp1 (57.2% vs. 37.3%, and 57.5% vs. 40%, respectively). Moreover, females showed significantly high risk to IPI (3.3-fold) as compared to males; (P <0.001). Gp 2 showed higher rates of IPI compared with Gp1 58.2% vs. 0.0% among swimmers aged ≤ 10 years; and 56.3% vs. 39.1% among swimmers aged >10 years, with significantly higher risk to IPI (30.6-fold) among simmers aged up to 10 years compared with those older than 10 years (P<0.001). As for the duration of swimming, Gp1 showed higher rate of infection among swimmers who practiced swimming for <5 years was higher than that detected in those who practiced swimming for ≥ 5 years (55.6% vs. 30.2%), and vice versa in Gp2 ((53.9% vs. 61.5%), with the former exhibiting a significantly higher (3-fold) risk compared with the latter (P <0.001). Regarding the frequency of swimming, the rate of infection among swimmers who swam <4 days/week was higher than that of those who swam ≥ 4 days/week in Gp1 (44.4% vs. 34.9%); approximately similar rates were detected in Gp2 (56.9% vs. 58.3%). Moreover, the former had a significantly higher (5-fold) risk compared with the latter (P <0.001). As for BP, the rates of IPI among Gp2 were higher than Gp1 for both normal and abnormal BP (59.3% vs. 37.3%, and 50.1% vs. 40.1%, respectively), and swimmers with an abnormal BP exhibits a higher risk (1.5-fold) of IPI than did normal swimmers. Concerning heart rate, swimmers with abnormal heart rate showed higher rates of infection compared to normal swimmers (100% vs 35.6% respectively among Gp1, and 69.0% vs 56.1%, respectively among Gp2). Regarding hemoglobin, swimmers with normal Hb in Gp1 have a high infection rate as compared to anemic swimmers but vice versa was detected among Gp2 (44.9% vs 0.0%, respectively in Gp1& 53.8% vs 87.5%, respectively in Gp2). Swimmers with abnormal blood pressure, heart rate, and anemia were at risk to IPI (1.5,3, and 3-fold; respectively) with no statistically significant difference (p>0.05) as compared to normal swimmers.

Intestinal Parasitosis	**Swimmers (N=528)**	
	No.+ve	**%**
B. hominis	127	24.1
Cryptosporidium	123	23.3
Cyclospora	30	5.7
I.belli	9	1.7
Microsporidia	13	2.5
G. lamblia	75	14.2
E. histolytica	67	12.7

Dientameba fragilis	6	1.1
E. coli	6	1.1
Ascaris lumbricoides	3	0.6
Enterobius vermicularis	2	0.4
H. pylori	15	2.8

Table 3: Prevalence of Microbial Infections among studied young swimmers.

Discussion

The current prevalence of IPIs and H. pylori was associated with non-gastrointestinal symptoms including headache, skin rash, and fever (11.9%, 9.7%, and 6.8%, respectively), which stem from pathogens that brought into the pool by infected swimmers or by inadequate hygiene. Rhinitis showed the highest rate of non-gastrointestinal symptoms followed by eye chest allergy, and otalgia (4.5%, 4.0%, and 1.7% respectively). However, the most common gastrointestinal symptoms were abdominal colic (28.4%), constipation (17.6%), and diarrhea and abdominal discomfort (13.6%), followed by nausea (6.3%), stomachache (5.1%), and anal itching and dysentery (3.4% each). Recent research. [29] Reported that gastroenteritis was the most prevalent waterborne disease, followed by infections of the upper respiratory tract, skin, eye, and nasal cavity. In addition, a previous study found outbreaks of GI symptoms linked to the use of disinfected recreational water as swimming pools [30]. Illness from exposure to recreational water exposure is common. In field studies of swimmer illness, diarrhea rates of 3% - 8% were found in follow-up health surveys [31]. It was reported that 10,000 cases of diarrheal illness were associated with 32 recreational water-borne disorders outbreaks associated with disinfected water. This number was probably higher because diarrheal illness is underreported to the public health authorities [32]. Sanborn and Takaro [33]. Reported that there is a 3% - 8% risk of Acute Gastrointestinal Illness (AGI) after swimming. Children aged <5 years, the elderly, and immunocompromised patients are vulnerable groups for AGI. Children are at a higher risk because they swallow more water when swimming. Concurrent infection with two or more parasites was observed among the study participants. The predominant microbes detected were *Blastocystis spp*., *Cryptosporidium spp*., *G. lamblia, and E. histolytica* (24.1%, 23.3%, 14.2%, and 12.7%, respectively). Other less common infections were also detected including *Cyclospora, H. pylori, Microsporidia spp., I.belli, D. fragilis, E. coli, A. lumbricoides*, and *E. vermicularis* infections (5.7%, 2.8%, 2.5%, 1.7%, 1.1%, 1.1%, 0.6%, and 0.4%, respectively) [34]. reported that *Giardia spp* are found in swimming water at much higher concentrations. In 2003–2004, *Cryptosporidium spp* 55.6%; *Giardia spp*. 5.6% were responsible for gastroenteritis outbreaks related to swimming pools in the US [35]. The majority of AGI outbreaks in swimming pools recorded during the peak swimming season (32 out of 34) between 2011 and 2012 were related to *Cryptosporidium* spp. Cryptosporidiosis incidence in the U.S. is doubled in children compared with adults, and infections predominantly occur following exposures to pool water contaminated with *Cryptosporidium* shed by infected swimmers [36]. Cryptosporidiosis incidence increased to 1.6 instances per 100,000 people in 2012, according to the annual report of the British Columbia Centre for Disease Control (BCCDC), whereas giardiasis cases remained steady at 13.3/100,000 population [37]. The greater infection rates detected in young children may be attributed to the fact that their immune systems are underdeveloped, and they ingest more pool water than do adults [38]. Despite being important and popular, swimming pools pose some public health risks to swimmers because of microbiological contamination [39]. Swimming involves sharing water with many other persons in a pool; consequently, the water contains various bodily fluids, dirt, and debris that wash off bodies during swimming activities [40]. Although chlorine is an effective disinfectant, it does not kill all pathogens [41]. Some pathogens, such as *Cryptosporidium* parasite, are highly resistant to the chlorine concentrations routinely used in pools [42]. Causes of microbiological contamination of swimming pools include irregular chlorination, deficiency infiltration, and high load swimmers. In addition, the sanitary condition of swimmers would be more difficult to control [43]. Improvements in swimmer's health require changes in knowledge, attitude, and behavior. Therefore, interventions based on social and behavioral science theories are necessary. Implementation of a public health education program for swimmers is essential [44]. The large number of young swimmers exposed to IPIs from pool water in this study provides a strong incentive to review the factors associated with IPI transmission and improve the recommendations to reduce the transmission of gastrointestinal disease caused by swimming pools. These recommendations are meant to eliminate infectious disease transmission by advising swimmers to avoid pool water swallowing and refraining from swimming when experiencing diarrhea. Showering before and during swimming, as well as regular bathroom breaks should be promoted among young children [45]. Epidemiological studies of the prevalence of IPIs in different localities have a primary goal of identifying high-risk factors related to communities and designing appropriate interventions [46]. In line with this view, the current study attempted to assess the prevalence of different IPIs and the associated risk factors among young swimmers in a public swimming pool in Alexandria, Egypt. The findings of this study revealed a particularly high prevalence of several intestinal parasites with public health implications among young swimmers. Several factors, including swimming duration, frequency, BP, HR, and anemia, were found to be linked to IPIs in young swimmers. These infections put swimmers at risk of developing morbidities. In addition, swimmers may be a source of infection for the wider community. Therefore, there is a need for their consideration in ongoing interventions by placing special emphasis on the identified factors, to meet national and international goals for eliminating these infections as a public health concern should be considered. The current findings demonstrated that the female study participants had a higher risk of having IPIs than did males as illustrated by the prevalence of IPIs among young male and female swimmers. Regarding the age of the participants, a higher risk of IPIs was found to be among swimmers aged up to 10 years compared with those who were than older than 10 years old. This may be attributed to the fact that older swimmer are usually more familiar with the importance of hygiene and comply with swimming-related health education than younger swimmers. Heaney et al., reported that children aged < 10 years of age contract more illness from recreational water because they stay in the water longer, have hand-to-mouth exposure, immerse their heads more often, and swallow more water while swimming [47]. The duration of swimming was one of the parameters that were significantly associated with parasitic infection. According to the current study, it was shown that the rate of infection among swimmers who practiced swimming for <5 years was higher than that detected among those who practiced swimming for ≥ 5 years in group 1, whereas in group 2, higher infection rates were observed among swimmers who practiced swimming for ≥ 5 years vs. those who practiced swimming for <5 years. This can be partially explained by the frequent suppression of the immune system in athletes who perform long-term and heavy exercises, which renders making them more susceptible to infections, and results in poor performance [48]. The rate of infection among swimmers who practiced swimming less frequently in the current study (less than 4 days/week) was 5-fold higher than that observed among swimmers who practiced swimming 4 days or more per week. In contrast, a previous study reported that swimming frequency does not appear to affect swimmers, and consequently does not affect the infection rate among swimmers. The current findings demonstrated that abnormal BP was among the hazards for the acquisition of IPIs. Leitch and He revealed that *Cryptosporidium* infection appeared to be associated with hypotension among the participants in the present study, this could be partially explained by the fact that immunity plays a critical role in protecting against *Cryptosporidium* infection and in parasite elimination. As previously documented in several studies, intense exercise as that occurring during competition, causes immunosuppression [49]. Which is responsible for hypotension [50]. Moreover, moderate exercise activates the immune system against diseases, with T cells playing a significant role in the induction of hypertension [51]. This might explain the hypertension observed among some swimmers in this study. A significant interaction between the autonomic and the immune systems plays a critical role in the initiation and maintenance of hypertension and results in cardiovascular diseases, end-organ damage, and mortality. In addition, a consistent association exists between hypertension, proinflammatory cytokines, and cells of the immune system [52]. Regarding heart rate, swimmers with an abnormal HR showed higher rates of infection compared with a normal HR. During exercise, substantial cardiovascular adjustments occur to meet the competing metabolic demands of the working muscles and the thermoregulatory demands of the skin blood flow [53]. Exercise, particularly endurance training, is associated with increases in parasympathetic activity at rest [54]. Resulting in a decreased HR which could explain the bradycardia observed among the current study participants. Changes in cardiac autonomic activity and/or alterations of electrophysiology of the pacemaker cells have been previously reported to be among the mechanisms that explain the resulting relative bradycardia [55]. The effects of training on HR autonomic regulation have also been previously investigated in the recovery phase at the end of the exercise, where a faster kinetic of HR decay has been shown to occur as a consequence of training [56]. The anemic swimmers in the current study were at a higher risk of having IPIs compared with normal Hb. Anemia is commonly caused by IPIs in athletes and is associated with iron deficiency, loss of weight and diarrhea among children. Intestinal parasites, which were asymptomatic in the current study, do not cause iron-deficiency anemia in athletes. Symptoms might occur at the time of weakening of the immune system. Intestinal parasites are resistant to elimination from the host because of the weak natural immunity aganist these parasites. Consequently, most of the intestinal parasites are chronic as they can adapt to the host's natural defense mechanisms and continue to multiply.

Conclusion

In conclusion, this study revealed a high prevalence rate of IPIs among young swimmers in Alexandria. *Helicobacter pylori, Blastocystis spp., and Cryptosporidium spp.* were among the parasites found. Swimming habits, frequency, and duration of swimming dramatically affected the infectious status of swimmers. Furthermore, abnormal BP, HR, and anemia were among the factors that were related to the infection rates. Therefore, measures have be adopted to curb this problem by increasing the awareness of the importance of swimmers' hygiene and targeted health education. Further studies with a longer follow-up period are necessary to investigate the effects of different interventions on the eradication of intestinal parasites among swimmers.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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