Journal of the Egyptian Society of Parasitology, Vol.52, No.3, December 2022
J. Egypt. Soc. Parasitol. (JESP), 52(3), 2022: 381 – 388
(Online: 2090-2549)

CORRELATION BETWEEN SOME HAEMATOLOGICAL PARAMETERS, INTESTINAL PARASITIC INFECTION AND ANTHROPOMETRIC INDICATORS IN FAYOUM SCHOOL CHILDREN

By
RAMY WAHBA HENIN and FATEN AHMED MAHMOUD
Department of Medical Parasitology, Faculty of Medicine Fayoum University
(Correspondence: Rwh00@fayoum.edu.eg & fam02@fayoum.edu.eg)
01225808475 , 01014814087

Abstract

Under-nutrition is one of the major causes of child mortality and morbidity; manifested by protein-energy malnutrition, iodine deficiency disorder, iron deficiency anemia, and vitamin deficiency related problems. Both problems have a great impact on children physical and mental status

Intestinal parasites are major health problems in preschool and school aged children in developing countries and further lead to under-nutrition through reduced food intake, mal-absorption, endogenous nutrient loss and anemia related nutritional problem. This study aims to focus on the vicious cycle between malnutrition and intestinal parasites. In this cross sectional study 138 of school children were examined for intestinal parasites and nutritional deficiency.

Keywords: Fayoum, Anemia, children, parasites, under nutrition, vitamin.

Introduction

In Egypt, helminthic and protozoa zoonoses are endemic, the intestinal parasites exceeded the accepted level and widespread leading to gastrointestinal troubles especially in children in rural areas (Abdelrahman *et al,* 2017). Soil-transmitted helminthes are mainly *Ascaris, Ancylostoma*, and *Trichuris*, with heavy infections cause public health problems among school aged children in rural areas including abdominal pain, diarrhea, blood & protein loss, rectal prolapse, and physical, mental and cognitive growth retardation (CDC, 2022). The Egyptian water transmitted protozoa in rural areas in a descending order of abundance were *Cryptosporidium parvum*, *Giardia lamblia*, *Entamoeba histolytica*, *Blastocystis hominis*, *Iodamoeba* sp., *Isospora belli*, *E. coli*, *Cyclospora cayetanensis*, and *Chilomastix mesnilli* (El Shazly *et al,* 2007). The risk factors included living in rural areas, poor income, poor sanitation, no clean water, poor personal hygiene and low or no awareness on bad hygiene that led to school-aged children highest parasitosis (Osman *et al,* 2016). Besides, intestinal parasites infections were associated with weakness and low academic performance of school children (Wesam *et al,* 2018).

The impact of the gastrointestinal parasitic infections was more on children due the vulnerability to the nutritional deficiencies, poor income in developing countries experience a cycle where under nutrition and re-infections ending into excess morbidity, which could continue from a generation to another (Opara *et al,* 2012). Also, zoonotic intestinal parasites cause malnutrition state due to the anorexia decreased oral intake, interference with absorptive surface, inflammation and intestinal obstruction (Ihejirika *et al,* 2019).

According to the convention on the rights of the child, children have the right to drink safe water, eat healthy food and live in a clean and safe environment (UNICEF, 2015). World Bank (2004) reported that anemia is ignored in most developing countries, even though; it is one of the most prevalent public health problems and has serious consequences for national development. Iron deficiency causes at least 50% of all anemia, and almost a million deaths a year; three-quarters of the deaths occur in Africa and South-East Asia associated with poor access to essential nutrients due to poverty or illiteracy.

In Egypt, despite the a notable decline in children mortality, malnutrition rates remain high with a significant public health, affecting 1 in 5 children, Wasting has increased significantly since year 2000, and particularly among girls than in boys; wasting and under-weight stand at 8 & 6%, respectively (El Shafie *et al,* 2020). Moreover infectious diseases, Poor sanitation and hygiene practices caused the cycle of infectious disease burden and under-nutrition with the anemia overall prevalence was 38.7%; among males 23.3%, & among females 53.8% (WHO, 2021).

Children aged 5 to14 years suffer from the highest burden of infectious diseases, partly due to their increased behavioral risk, frequent outdoor exposure, and poor personal hygiene, the global prevalence of zinc deficiency at 31%, ranging from 4 to 73% across different regions in the world (Wessells and Brown, 2012). Zinc is required as a cofactor for the function of intracellular enzymes that may be involved in protein, lipid, and glucose metabolism. It may participate as an integral component of several antioxidants enzymes as a superoxide dismutase enzyme. It is an important element for the immune system, energy production, and absorption of vitamins. So, zinc deficiency can lead to chronic diarrhea in the both infants and children (Skrajnowska *et al,* 2019). Iron deficiency anemia (IDA) is one of the commonest nutritional deficiencies globally. It affects 20% to 50% of the world's population, also Vitamins and micronutrients are vital and essential for growth, reproduction, and development with regulatory, immunologic, and antioxidant functions due to their action as esential components or cofactors of enzymes throughout metabolism. Low serum levels of such elements could cause impairment in cellular, physiological, and enzymatic functions (Gombart *et al,* 2020). Micronutrient deficiencies can be caused by insufficient intake and the presence of absorption inhibitors in the diet, as well as by disease states, such as parasitic infections which are highly prevalent in rural areas in developing countries (Mrimi *et al,* 2022). The main cause of mineral and vitamin deficiencies is due to low dietary intake of these elements also parasitic infections and demographic factors most notably lack of clean water supply and proper disposal of human excreta played an important role as predictors of these deficiencies (UNICEF, 2013).

The present study aimed to assess the nutritional status and intestinal parasites effecting children nutrition and as well health parameters in an Elementary School at El-Khamseen Village, Etsa Center, Fayoum Governorate

Subjects and Methods

Study area: A cross sectional study was carried out in El-Khamseen Village (Etsa Center) located 30 km south west from Fayoum. It is a poor rural small village with neither sanitary drinking water, nor sewage disposal, which was used in irrigation (Ramy, 2021).

A total of 138 children aged 6-13 years were randomly selected. After having official permission from the school administration, their guardians were informed about the study and written consents were taken. The protocol was approved by the Fayoum University, Ethics Committee, which agreed with the Helsinki's Guidelines (2000)

Anthropometric measurements as weight and height were taken, BMI was calculated. Data were standardized into age-sex-specific z-scores measured SD from child population reference. Z-scores of height-for-age (HAZ), weight-for-height (WAZ) and body mass index-for-age (BMIAZ) were calculated using the software Anthro-Plus (WHO, 2019).

Laboratory examinations: Morning stool & urine samples were taken in clean labeled containers. Urine was examined by sediment ation for *Schistosoma* eggs. Stools were macroscopically examined for pinworms and gravid segments. The stool was microscopically by stained direct smears and sedimentations for parasites (Dyab *et al,* 2016).

Quick immunochromatographic test was used to identify *Cryptosporidium*, *Entamoeba*, and *Giardia* in stool samples (Rida® Quick ICA Combi, R. Biopharm, Germany).

Hematological parameters: EDTA blood sample was examined for CDC. Zinc element was colorimetrical measured (Sigma, Aldrich). Serum iron & total iron binding capacity (TIBC) were measured by E-BC-K77 2-M, E-BC-K071-M Kits, & ferritin was assayed by CLIA ELISA (Elabscience® USA)

Statistical analysis: Data were analyzed by using Social Sciences (SPSS) version 18.0. Simple and multiple linear regression and ANOVA analyses were used. Man-Whitney U test compared and evaluated differences anthropometric indicators, hematological & trace element status among groups.

Results

The children were 61 (44.2%) boys and 77 (55.8%) girls, with aged ranged from 4 to 13 years old.

Detailed given in tables (1, 2, 3, 4 & 5)

Table 1: Anthropometric characteristics of children (n=138)

Anthropometric Index	Median	Minimum	Maximum	No. (%)
Age (Y)	8	4	13	
Height (Cm.)	120	94	154	
Weight (Kg.)	22.0	11.3	44.0	
HAZ	-1.49	-3.11	0.78	
Stunting≤2SD				87 (63)
Normal				51 (37)
WAZ	-1.02	-3.05	0.78	
Wasted(WAZ≤2SD)				94 (68.1)
Normal				44 (31.9)
BMIAZ	-0.21	-2.08	0.93	
Underweight (BMIAZ≤2SD)				87 (63)
Normal				51 (37)
Overweight(BMIAZ>2SD)				0(0)

Table 2: Frequency and type of parasites in children (n = 138).

Intestinal parasites	No. (%)
No parasites	50 (36.2)
Number of different parasites	88 (63.7)
1 type of parasites	70 (50.7)
2 types of parasites	11 (8)
3 types of parasites	6 (4.3)
4 types of parasites	1 (0.7)
Type of parasite	
Giardia lamblia	30 (21.7)
Entamoeba hystolytica	28 (20.3)
Entamoeba coli	32 (23.2)
Cryptosporidium parvum	6 (4.3)
Ascaris lumbricoides	7 (5)
Trichuris trichiura	3 (2.2)
Hymenolepis nana	6 (4.3)
Ancylostoma duodenale	2 (1.4)

Table 3: Biochemical, hematological and trace elements status.

Variations	Median	Minimum	Maximum	below%	normal%	above%	Reference value
Hemoglobin g/dl	10.5	7.0	14.6	72	28	-	11.5 15
Hematocrit %	33.0	18.0	46.0	61	28	11	33- 36
WBCs×1000/mm3	5.3	2.4	14.4	34	41	25	4- 10
Zn ug/dl	55.0	40.9	81.4	87	13	-	60- 110
Fe ug/dl	32.9	11.0	95.1	84	16	-	50- 120
Ferritin ng/ml	18	2	70	56	44	-	7- 140
TIBC ug/dl	421	139	763	2	30	68	240-400

Table 4: Relationship between parasitic infection and hematological parameters

	Parasite (50 –ve, 88+ve			*Giardia lamblia*		*E. histolytica*		*C, parvum*		*A. lumbricoides*		*A. duodenale*	
	-ve	+ve	P value	+ve	P value	+ve	P value	+ve	P value	+ve	P value	+ve	P value
Hemoglobin	11±3.4	10±2.2	0.12	9.9±1.4	0.045	9.8±1.5	0.66	11±2.3	0.44	11±3.1	0.78	9±2.0	0.02
Hematocrit	27±2.1	25±1.3	0.09	26±1.1	0.06	26±3.1	0.87	27±3.2	0.92	25±2.1	0.54	18±1.3	0.03
WBCs	6.7±4.3	8.7±2.3	0.78	6.8±2.4	0.453	6.8±2.4	0.77	6.6±4.0	0.77	6.5±3.3	0.05	9.4±2.0	0.43
Zn	59±15.3	41±12.3	0.02	46±11.3	0.04	34±11.3	0.04	57±15.3	0.68	54±12.3	0.03	33±11.3	0.04
Fe	44±23	31±23	0.034	34±23	0.04	23±11	0.02	44±21	0.66	40±22	0.04	23±11	0.02
Ferritin	54±12	43±11.2	0.042	44±8.8	0.04	39±12	0.07	53±11	0.67	43±12	0.76	30±11.1	0.04
TIBC	243±72	566±77	0.05	566±72	0.07	477±78	0.067	266±78	0.76	288±78	0.56	579±78	0.04

P < 0.05 significant

Table 5: Tested parameters and parasites in relation to anthropometric measurements

Variable items	Stunted n:87		Wasted n:94		Low BMI n:87	
	No	P value	No	P value	No	P value
Parasite +ve (88)	80	0.03	84	0.02	81	0.002
Parasite –ve (50)	7		10		6	
G. lamblia	28	0.02	27	0.03	29	0.03
E. histolytica	20	0.03	25	0.02	3	0.03
C. parvum	5	0.03	4	0.03	4	0.02
A. lumbricoides	5	0.04	5	0.03	5	0.03
A. doudenale	2	0.03	2	0.001	2	0.03
<Hb ref value	70	0.05	71	0.002	69	0.02
<Ferritin ref value	54	0.04	50	0.007	55	0.04
<Zn ref value	80	0.03	66	0.03	62	0.03
<Fe ref value	81	0.01	84	0.01	80	0.01

$P < 0.05$ significant

Discussion

The current study showed high prevalence of intestinal parasites (63.7 %) in children mostly due to bad sanitation, poor community, and scarcity of pure water supply and use of waste water for household and irrigation. The most common detected protozoa were *Giardia* (21.7%), *E. histolytica* (20.3%) followed by *Cryptosporidium parvum* (4.3%) with low prevalence of helminthic infections *A. lumbricoides* (5%), *H. nana* (4.3%), *T. trichiura* (2.2 %) and *A. duodenale* (1.4%). This agreed with Atwa and Thabet (2016) in Egypt they found that the prevalence of *G. lambia* was 24.7%, and *E. histolytica* was 17.5%. Also, Elmonir *et al.* (2021) in urban and rural Egyptian communities among preschool and school children (996) randomly selected reported that the overall gastrointestinal parasites were 46.2%, the great prevalent were *E. histolytica* (12.7%) and *A. lumbricoides* (12.7%) followed by *E. vermicularis* (8.6%), *G. lamblia* (7.1%), *C. parvum* (1.5%), and low prevalence for *H. nana*, and Hookworms with less than 1%. Ahmed and Abu-Sheishaa (2022) in Dakahlia rural school children found the overall prevalence of parasites was 32.9%, *E. histolytica* (12.3%), *G. lamblia* (8.5%), followed by *H. nana* (7.7%), and the *A. lumbricoides* (5.7%).

In the present study, multiple infections was quite uncommon as 50.7% of the children had one parasite, 8% had two types of parasites, 4.3% had three types of parasites and 0.7% had four types of parasites. The simple linear regression analysis to evaluate the effect of each parasite on the levels of hemoglobin, ferritin, zinc and iron in serum showed that parasitic infected patients had significant reduction in zinc, iron & ferritin level. This agreed data with Van Nhien *et al.* (2008) in Vietnam they reported giardiasis among schoolchildren as a caused malnutrition, which affected growth in them as the infection causes iron deficiency anemia, micronutrient deficiencies as zinc, copper, magnesium, and selenium. Also, Humberto *et al.* (2015) in Mexico who reported that there was growing evidence that zinc can have pathogen-specific protective effects. Giardiasis was a common yet neglected cause of the acute-chronic diarrheal illness worldwide that causes disturbances in zinc metabolism of infected children, representing a risk factor for zinc deficiency. But, zinc metabolism is compromised by *Giardia* that didn't well understood; zinc status could be altered by intestinal mal-absorption, organ redistribution or host-pathogen competition. Besides, Fançony *et al.* (2022) in Angola reported that the zinc deficiency may impair the immune response to infections and/or that intestinal parasites could have developed mechanisms to avoid zinc-limited environments.

In the present study, 72% of the children showed low hemoglobin (87%) associated with low zinc, low iron, low ferritin level, and 68% of them have high TIBC the essential criterion of iron deficiency anemia. The lowest hemoglobin concentration was detected among children infected with *A. duodenale*, *G. lamblia* and *E. histolytica* associated with significant reduction in ferritin and serum iron. This agreed with Bayoumy *et al.* (2018) in Egypt who reported the lowest ferritin in children with giardiasis (37.5%) and mixed parasites (18.8%). Gopalakrishnan *et al.* (2018) in India reported high prevalence of anemia among intestinal parasites female school children (*Giardia*, Hookworm and *Ascaris*). They added that prevention such as periodic deworming and health education about nutritional balanced diet, iron supplements, and personal hygiene practices have to be given to both the parents and their children to prevent and reduce disease burden. Generally, Shaw and Friedman (2012) in USA reported that iron deficiency anemia affected the health of more than one billion people worldwide, with the greatest burden of disease experienced in lesser developed countries, particularly women of reproductive age and children. They added that the causes of anemia in the developing world are multifactorial and include nutritional deficiencies, extra-corporal blood loss, high prevalence of hemoglobinopathies, and inflammation but iron deficiency remains the most common nutritional deficiency and cause of anemia worldwide

In the present study, there was highly significant relationship between growth retardation and both parasitic infections and nutritional deficiencies. That is to say most stunted, wasted or children with low BMI have parasitic infections, iron deficiency anemia, low iron, ferritin, and zinc levels. This agreed with Astiazarán-García (2015) who reported that deficiencies or excess of these minerals; the acute zinc deficiencies diminish the innate and adaptive immunity response, and increases the infection related anemia particularly with giardiasis**.** Generally, zinc deficiency was associated the delayed wound healing, and increased susceptibility to infection. Petry *et al*. (2016) in Switzerland reported that iron deficiency was commonly assumed to cause half of all cases of anemias, with hereditary blood disorders and infections such as hookworm and malaria being the other major causes. In countries ranked as low, medium, and high by the Human Development Index. They concluded that anemia-reduction strategies and programs should be based on an analysis of country-specific data, as iron deficiency may not always be the key determinant of anemia. Mahmoud *et al.* (2017) in a village, Dakhalia Egypt reported that parasites were 37% of total 102 school children. Overall, helminthes was more prevalent 22% as compared to protozoa 8% and mixed infections 8%; *A. duodenale* (9.8%), *H. nana,* and *G. lamblia* (7.8%), Strongyloidiosis *stercoralis* (5.9%), *E. histolytica* and *C. parvum* (3.9%) for each one and *E. vermicularis*, *T. trichiura* and *Schistosoma mansoni* with two cases each (1.9%). The parasites were was higher females (52.6%) than males (47.4%), but without significantly. Anemia was mild with Hb (11.12±1.35)g/dl. Of the children 51% were anemic, but with slightly high non-significant prevalent among infected children (52.6%) compared with non-infected (50%). Iron deficiency anemia (IDA) was 88.5% of anemic all children, 90% of anemic cases in the infected children and 87.5% of anemic cases in non-infected children.

Okafor *et al.* (2017) in Nigeria found that anemia in pregnancy was a major public health problem. They added that mean haemoglobin and hematocrits were significantly reduced in pregnant women from the two rural communities. Serum iron, serum ferritin and transferrin saturation showed no significant difference while total iron binding capacity and soluble transferrin receptor significantly increased among pregnant women. The pregnant women in their third trimesters and the multi-gravidae had the highest prevalence of iron depletion and iron deficiency anemia, while prevalence of iron deficiency and anemia were higher in the primigravidae and pregnant women in their second trimester. They concluded that both the anemia and iron deficiency anemia were higher among the pregnant women in the rural communities as compared to those in the urban areas. Also, Cláudia *et al.* (2022) in Angola among the schoolchildren reported that Zinc was a signaling molecule which up-regulated the Th1 response and down-regulated the Th2 response which played important role in helminthic infection.

In the present study, anthropometric measurements showed that 63% of children were stunted, 68.1% were wasted, and 63% were underweight. EDHS (2014) showed that examination of the height-for-age data from the EDHS (Egypt Demographic and Health Survey) showed a considerable rate of stunting amongst Egyptian children. They reported that 20% of children were stunted, 7% were wasted and 6% were underweight These lower estimation may be due to the fact that El-Khamseen village is one of the poorest villages in Fayoum as 63% of houses with neither piped water supply nor sanitary disposal of sewage (Ramy, 2021). More than 143 of the poorest villages in Egypt were targeted by the first stage of the presidential initiative for a generous life. Egypt stands as one of the 36 countries, where 90% of global burden of malnutrition falls (UNICEF, 2015). With the reclamation of Tahya Misr most of these villages were reclaimed.

Conclusion

Parasitic infection and nutrient deficiency could be two faced coin and a viscous cycle can occur between them that can lead to retarded growth cognitive and developmental delay. Children with malnutrition are more susceptible to parasitic infections due to decreased immunity and micronutrient deficiency.

The low zinc and iron level was common with chronic parasitic infection especially *Giardia lamblia* and *Entamoeba histolytica* and should be treatment to overlap anemia.

Much effort should be paid to improve the nutritional status of young children, periodic screening programs and mass treatment should be urgently applied.

Recommendations (WHO, 2002)

1- Raise awareness across sectors: Advocate and educate to prevent and control anemia

2- Build partnerships in health, agriculture, food and pharmaceutical sectors, among govvernent ministries and agencies, NGOs, donors, industry, and commerce Develop interventions and implement plans

3- The identify priorities, responsibilities, & the time frames, specific objectives, and identify collaborating groups (universities, government agencies, NGOs, civil groups, commercial entities).

4- Review existing programs and determine and develop anemia prevention and control activities

5- Determine and secure staffing, funding and other resources to implement activities

6- Develop a monitoring and evaluation plan and indicators, using reduction of anemia as a benchmark for program success in IDA, malaria and helminthes control programs

References

Abdelrahmán, RZ, Morsy, ATA, Morsy, T A, 2017: Aseptic meningitis in adults causing by virus, bacteria, drug with special references to zoonotic parasites. JESP 46, 2:329-50.

Ahmed, HM, Abu-Sheishaa, GA, 2022: Intestinal parasitic infection among school children in Dakahlia Governorate, Egypt: A cross-sectional study. Egypt Pediatric Assoc. Gaz. 70:6-10

Al-Yousofi, A, Yan, Y, Al Mekhlafi, AM, Hezam, K, Abouelnazar, FA, *et al,* 2022: Prevalence of intestinal parasites among immunocompromised patients, children, and adults in Sana'a, Yemen. J. Trop. Med. 8:20-2.

Astiazarán-García, H, Iñigo-Figueroa, G, Quihui-Cota, L, Anduro-Corona, I, 2015: Crosstalk between zinc status and *Giardia* infection: A new approach. Nutrients.7:4438-52.

Atwa, Z, Thabet, M, 2016: Intestinal Parasitic Infection in Egyptian Children: Could it be a risk factor for iron deficiency anemia?. J. Egypt. Soc. Parasitol. 46:533-540.

Bayoumy, A, Hassan, Kh, Geneidy, M, Metawea, A, 2018: Impact of intestinal parasites on hematological parameters among school children in Gharbia governorate, Egypt. JESP 48, 1:157-64

Bourke, CD, Berkley, JA, Prendergast, AJ, 2016: Immune dysfunction as a cause and consequence of malnutrition. Trends Immunol. 37, 6:386-98.

CDC, 2022: Parasites - Soil-transmitted helminths. https://www.cdc.gov › parasites

Cláudia, F, Ânia, S, João, L, Miguel, B, 2022: Zinc deficiency interacts with intestinal/ urogenital parasites in the pathway to anemia in preschool children, Bengo–Angola Nutrients 14, 7: 1392-9.

Collinet-Adler, S, Ward, HD, 2010: Cryptosporidiosis: Environmental, therapeutic, and preventive challenges. Eur. J. Clin. Microbiol. Infect. Dis. 29, 8:927-35.

Dyab, AK, El-Salahy, MM, Abdelmoneiem, H M, Amin, M, Mohammed, MF, 2016: Parasitological studies on some intestinal parasites in primary school children in Aswan Governorate, Egypt. J. Egypt. Soc. Parasitol. 46, 3:581-58

EDHS, 2014: Ministry of Health and Population [Egypt], El-Zanaty and Associates [Egypt], and ICF International: Cairo, Egypt and Rockville, Maryland, USA: Ministry of Health and Population and ICF International.

El Shazly, AM, Elsheikha, HM, Soltan, DM, Mohammad, KA, Morsy, TA, 2007: Protozoa pollution of surface water sources in Dakahlia Governorate, Egypt. J. Egypt. Soc. Parasitol. 37, 1:55-64

Elmonir, W, Elaadli, H, Amer, A, El-Sharkawy, H, Bessat, M, *et al,* 2021: Prevalence of intestinal parasitic infections and their associated risk factors among preschool and school children in Egypt. PLoS One 29: l 16:9-16.

El-Shafie, AM, Kasemy, ZA, Omar, ZA, Alkalash, SH, Salama, AA, *et al,* 2020: Prevalence of short stature and malnutrition among Egyptian primary school children and their coexistence with Anemia. Ital. J. Pediatr. 46, 1:91-4.

Fançony, C, Soares, A, Lavinha, J, Brito, M, 2022: Zinc deficiency interacts with intestinal/ uro-genital parasites in the pathway to anemia in preschool children, Bengo-Angola. Nutrients 14, 7:1392.

Ghenghesh, KS, Ghanghish, K, BenDarif, ET, Shembesh, K, Franka E, 2016: Prevalence of *Entamoeba histolytica, Giardia lamblia,* and *Cryptosporidium spp*. in Libya: 2000-2015. Libyan J. Med. 29, 11:32-88.

Gombart, AF, Pierre, A, Maggini, S, 2020: A review of micronutrients and the immune system-working in harmony to reduce the risk of infection. Nutrients 12, 1:236-9.

Gopalakrishnan, S, Eashwar, VMA, Muthulakshmi, M, Geetha, A, 2018: Intestinal parasitic infestations and anemia among urban female school children in Kancheepuram District, Tamil Nadu. J. Family Med. Prim. Care 7, 6: 1395-400.

Humberto, AG, Gemma, IF, Luis, QC, Iván, Humberto, AG, Gemma, IF, Luis, QC, Iván, AC, 2015: Crosstalk between zinc status and *Giardia* infection: A new approach. Nutrients 7, 6:4438-52.

Hunter, PR, Hughes, S, Woodhouse, S, Raj, N, Syed, Q, *et al,* 2004: Health squeals of human cryptosporidiosis in immunocompetent patients. Clin. Infect. Dis. 39:504-10

Ihejirika, OC, Nwaorgu, OC, Ebirim, CI, Nwokeji, CM, 2019: Effects of intestinal parasitic infections on nutritional status of primary children in Imo State Nigeria. Pan Afr. Med. J. 16, 33:34-6.

Kirkpatrick, BD, Noel, F, Rouzier, PD, Powell, JL, Pape, JW, *et al,* 2006: Childhood cryptosporidiosis is associated with a persistent systemic inflammatory response. Clin. Infect. Dis. 43:604-8

Long, KZ, Rosado, JL, Montoya, Y, Solano, MDL, Hertzmark, E, *et al,* 2007: Effect of vitamin and zinc supplementation on gastrointestinal parasitic infections among Mexican Children. Pediatrics 120:e846-55.

Mahmoud, AM, Abdul Fattah, M, Zaher, TI, Abdel-Rahman, SA, Mosaad, N, 2017: Intestinal parasitic infections and iron deficiency anemia among school children in El Khalige Village, Dakhalia, Egypt. Afro-Egypt. J. Infect. End. Dis. 7:28-36

Mrimi, EC, Palmeirim, MS, Minja, EG, Long, KZ, Keiser, J, 2022: Malnutrition, anemia, microntrient deficiency and parasitic infections among schoolchildren in rural Tanzania. PLoS Negl. Trop. Dis. 4, 16:3-8.

Okafor, IM, Okpokam, DC, Antai, AB, Usanga, EA, 2017: Iron Status of Pregnant Women in Rural and Urban Communities of Cross River State, South-South Nigeria. Niger J. Physiol. Sci. 31, 2:121-5.

Opara, KN, Udoidung, NI, Opara, DC, Okon, OE, Edosomwan, EU, *et al,* 2012: The impact of in-testinal parasitic infections on the nutritional status of rural and urban school-aged children in Nigeria. Int. J. MCH/AIDS. 1, 1:73-82.

Osman, M, El Safadi, D, Cian A, Benamrouz, S, Nourrisson, C, *et al,* 2016: Prevalence and risk factors for intestinal protozoan infections with *Cryptosporidium, Giardia, Blastocystis* and *Dientamoeba* among schoolchildren in Tripoli,

Lebanon. PLoS Negl. Trop. Dis.14:103-8
Petry, N, Olofin, I, Hurrell, RF, Boy, E, Wirth, JP, *et al,* 2016: The proportion of anemia associated with iron deficiency in low, medium, and high human development index countries: A systematic analysis of national surveys. Nutrients Nov. 2;8, 11:693. doi: 10.3390/nu8110693.
Ramy, WH, 2021: Soil transmitted parasites in vegetables irrigated with waste-water in Fayoum governorate, Egypt. J. Egypt. Soc. Parasitol. 51, 2:371-6
Shaw, JG, Friedman, JF, 2011: Iron deficiency anemia: Focus on infectious diseases in lesser developed countries. Anemia 260380. Doi: 10. 1155/2011/260380.
Skrajnowska, D, Bobrowska-Korczak, B, 2019: Role of zinc in immune system and anti-cancer defense mechanisms. Nutrients 11, 10: 2273-9.
UNICEF, 2013: Scaling Up Nutrition in the Arab Republic of Egypt Investing in a Healthy Future, www.unicef.org/egypt/reports/scaling-nutrition-arab-republic-egypt.
UNICEF, 2015: Convention on the Rights of the Child text, https://www.unicef.org/egypt/reports/children-egypt
Van Nhien, N, Khan, NC, Ninh, NX, Van Huan, P, Hop, T, *et al,* 2008: Micronutrient deficiencies and anemia among preschool children in rural Vietnam. Asia Pac. J. Clin. Nutr. 17, 1: 48-55.
Wesam, S, Morad, MD, ALIF, A, Allam, MD, 2018: Deterioration of school performance as a cons-equence of parasites. Med. J. Cairo Univ. 86, 8:439-402.
Wessells, KR, Brown, KH, 2012: Estimating the global prevalence of zinc deficiency: Results based on zinc availability in national food supplies and the prevalence of stunting. PLoS. One. 7(11).
WHO 2002: World Health Report http://www.who.int/publications/en/ This site also includes useful publications on malaria, helminthes and nutrition.
WHO, 2019: Recommendations for Data Collection, Analysis and Reporting On Anthropometric Indicators in Children Under 5 Years Old © World Health Organization and the United Nations Children's Fund (UNICEF).
WHO, 2021: The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all Rome, FAO. https:// doi.org/10.4060/cb4474en
World Bank, 2004: Poverty & Income: The Poverty Group. http://devdata.worldbank.org/ hn pstats/ pvd.asp).