Growth and development in children of developing countries: The impacts of water, sanitation & hygiene interventions

A Systematic Review

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June 2012.

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KEY WORDS: Children, infants, early childhood, water, sanitation, hygiene, growth, wasting, developmental outcomes, neurodevelopment, cognitive, motor, language development, diarrhoea, health

ABBREVIATIONS

MUAC – Mid-Upper Arm Circumference
OR—Odd Ratios
PICOS – Population, Intervention, Comparator, Outcome & Setting
RR – Risk Ratio
WHO – World Health Organisation
UNICEF – United Nation's Children Education Fund
WISC-R - Wechsler Intelligence Scale for Children
CI—Confidence interval
HH – Households
MDGs – Millennium Development Goals
LA – Latin America
SSA- Sub-Saharan Africa
SA- South Asia
RTCs – Randomised Controlled trials
POUWT- Point of use water treatment
POSWT- Point of source water treatment
NOS- New Ottawa Scale
HAZ – Height-for-age Z-Score
WAZ – Weight-for-age Z-Score
LAZ – Length-for-age Z-Score
PEM- Protein Energy Malnutrition
ETEC- Enterotoxigenic Escherichia Coli
IQ- Intellectual Quotient
US- United States
MeSH – Medical subheading terms

FINANCIAL DISCLOSURE: The author had no financial relationships relevant to this article for disclosure

Abstract

CONTEXT: In countries of high endemicity for water and sanitation-transmitted acute gastroenteritis infections; helminth parasites Ascaris lumbricoides; Trichuris trichiura; and hookworm; physical growth of children can be detrimental as impacts are mostly irreversible at certain stages and even affect children's cognitive development. Improved water and sanitation provision is the main strategy to prevent a web of impacts. However, most developing countries are resource constricted and this hampers the achievement of public health goals and the MDG 4 with optimal efficiency and sustainability.

OBJECTIVE: To examine epidemiological evidence for relationships between water and sanitation interventions in separation or in combination and the occurrence of childhood illnesses and the resulting growth and developmental effects.

METHODS: We conducted a comprehensive systematic review to assess the effect of water (quality and quantity), sanitation (access and usage) of facilities for the safe disposal of human urine and faeces on infection and growth and other developmental impacts. Psychoinfo; PubMed, Embase, ISI Web of Science, UNICEF and the World Health Organization Library Database were searched without language restrictions and year of publication (search performed until April 2012). Bibliographies of identified articles were hand-searched. All types of studies reporting data on sanitation availability (i.e., having access at own household or living in close proximity to sanitation facility), or usage, and soil-transmitted helminth infections at the individual level were considered. Reported odds ratios (ORs) of the protective effect of water and sanitation on diarrhoeal and soil-transmitted helminth infections were extracted from the papers and calculated from reported numbers. The quality of published studies was assessed with a panel of criteria developed by the authors. 15 publications, consisting of several datasets, met our inclusion criteria.

RESULTS: Availability and exclusiveness in use of water and sanitation facilities was associated with significant growth: latrine ownership on weight gain (OR = 0.174 to 5.4) 95% CI 0.494, 0.842. Regarding the use of sanitation on growth, ORs of 0.58 (95% CI 0.46–2.14, 0.33 (95% CI 0.61–2.46), and 0.59 (95% CI 0.27–1.31) were determined for T. trichiura, hookworm, and A. lumbricoides, respectively. The overall ORs, combining sanitation availability and use, were 0.51 (95% CI 0.44–0.61) for the three soil-transmitted helminths combined, 0.54 (95% CI 0.43–0.69) for A. lumbricoides, 0.58 (95% CI 0.45–0.75) for T. trichiura, and 0.60 (95% CI 0.48–0.75) for hookworm. Water and sanitation affecting cognition: OR=0.8, 95% CI -9.4, 10.9

CONCLUSIONS: Our results revealed that water and sanitation are associated with a reduced risk of childhood growth faltering and developmental impacts. Access to improved water and sanitation should be prioritized alongside preventive chemotherapy and health education to achieve a durable reduction of the burden of malnutrition.

Keywords: developing countries, Linear Growth, wasting, cognition, infancy, childhood, water, sanitation and hygiene

La Croissance et le Développement Chez les Enfants des Pays en Développement: Les Impacts des Interventions de l'Eau, l'Assainissement et l'Hygiène

Résumé

CONTEXTE: Dans les pays de forte endémicité pour l'eau et l'assainissement infections transmises par la gastro-entérite aiguë; helminthes Ascaris lumbricoides; Trichuris trichiura et les ankylostomes, la croissance physique des enfants peut être préjudiciable que les impacts sont pour la plupart irréversibles à certains stades et même influer sur le développement cognitif des enfants. Amélioration de l'eau et d'assainissement est la principale stratégie pour éviter une toile de l'impact. Cependant, la plupart des pays en développement sont la ressource la constriction, ce qui entrave la réalisation des objectifs de santé publique et de la OMD 4 avec une efficacité optimale et la durabilité.

OBJECTIF: Pour examiner les preuves épidémiologiques pour les relations entre l'eau et d'assainissement dans la séparation ou en combinaison et l'apparition de maladies de l'enfance et de la croissance résultant et effets sur le développement.

MÉTHODES: Nous avons effectué un examen complet systématique pour évaluer l'effet de l'eau (qualité et quantité), de l'assainissement (accès et utilisation) des installations pour l'élimination sans danger de l'urine et les fèces humaines sur l'infection et la croissance et d'autres impacts sur le développement. Psychoinfo; PubMed, Embase, ISI Web of Science, l'UNICEF et l'Organisation mondiale de la Santé Bibliothèque Base de données ont été fouillés, sans restriction de langue et année de publication (recherche effectuée jusqu'à Avril 2012). Les bibliographies des articles identifiés ont été recherchées à la main. Tous les types d'études sur la disponibilité des données des rapports de l'assainissement (c'est à dire ayant accès à son propre ménage ou vivant à proximité de centre de l'assainissement), ou d'utilisation, et transmis par le sol contre les helminthiases au niveau individuel ont été pris en considération. Signalés odds ratios (OR) de l'effet protecteur de l'eau et l'assainissement sur les maladies diarrhéiques et les infections transmises par le sol helminthes ont été extraites des documents et calculé à partir de chiffres communiqués. La qualité des études publiées a été évaluée par un panel de critères mis au point par les auteurs. 15 publications, consistant en plusieurs ensembles de données, se sont réunis nos critères d'inclusion.

RÉSULTATS: Disponibilité et l'exclusivité de l'utilisation des installations d'eau et d'assainissement a été associée à une croissance significative: la possession de latrine sur le gain de poids (OR = 0,174 à 5,4) IC à 95% 0.494,0.842. En ce qui concerne l'utilisation de l'assainissement sur la croissance, les RUP de 0,58 (IC à 95% de 0,46 à 2,14, 0,33 (IC à 95% de 0,61 à 2.46), et de 0,59 (IC à 95% 0.27 à 1.31) ont été déterminées pour T. trichiura, l'ankylostome, et A . lumbricoides, respectivement. les ORs globales, associant la disponibilité de l'assainissement et l'utilisation, étaient de 0,51 (IC à 95% de 0,44 à 0,61) pour les trois géohelminthiases confondus, de 0,54 (IC à 95% 0,43 à ,69) pour A. lumbricoides, 0,58 (95% 0.45 à 0.75 CI) pour T. trichiura, et de 0,60 (IC à 95% de 0,48 à 0,75) pour l'ankylostome eau et d'assainissement sur la cognition:. OR = 0,8, IC 95% -9,4, 10,9

CONCLUSIONS: Nos résultats ont révélé que l'eau et l'assainissement sont associés à un risque réduit de croissance pendant l'enfance chancelante et impacts sur le développement. L'accès à l'eau et l'assainissement devrait être une priorité aux côtés de la chimiothérapie préventive et l'éducation de la santé pour parvenir à une réduction durable de la charge de la malnutrition.Mots-clés: croissance linéaire, un amaigrissement, de la cognition, la petite enfance, de l'eau et l'assainissement

Mots-clés: pays en développement, la croissance linéaire, le gaspillage, cognitive, la petite enfance, l'enfance, de l'eau, l'assainissement et l'hygiène

CHAPTER ONE: BACKGROUND INFORMATION

1.1 Introduction

After a range of different studies in the year 1990s -linking unprotected water provision and unsanitary living environments to morbidity and mortality, concern has kept on growing about the impacts of water and sanitation interventions on childhood physical growth and other developmental functions in children. Because the provision of water and sanitation facilities in developing countries has been below standards in recent decades, it has been noted that water and sanitation related infections have been so detrimental on human populations; especially on children aged 0-14.

Until recently no plausible biological mechanism was available to explain such observations possibly because evidence from individual studies was not as strong to justify significance of observations. In the past decades, developing countries have implemented numerous interventions focussing on childhood health. Such interventions includes: 1) portable water provision; 2) sanitation; and 3) enhancement of sound hygiene practices [1]. Widely known as WASH; the trio have at least been significant in alleviating childhood diarrhoeal and other infectious diseases. However, the contribution they have had on childhood physical growth and development is not well known yet [1, 2]. In line with WASH interventions; the United Nations also came up with eight Millennium Development Goals (MDGs); most of which -also mention of 'enhancing childhood health' [2]. The fourth goal in the bunch of eight MDGs; is the MDG 4: that aims at reducing childhood morbidity and mortality rates -to at least 33.3% by 2015 [2]. One of the most notable approaches for achieving MDG 4 is through provision of better childhood nutrition [1]. Childhood nutrition largely relies on safe water provision and sanitation for households and communities in which children live [3]. But for some resource hiccups, there has been a few water and sanitation infrastructure implementation in such countries of the world [2]. So far – the developing world has seen a lot of research being initiated on water provision and sanitation. However, most of such research has been focussing on different outcomes of water and sanitation interventions (like diarrhoeal incidence and others) [3]; and with less emphasis on children's growth and development [2]. In addition, there have been no formal systematic reviews to combine the scanty evidence that has arisen from handful primary research in the developing world. This is one of the many reasons why we implemented such a systematic review of the existing evidence.

As we have said earlier on: water and sanitation research is not necessarily a new discipline in the WASH domain; as evidenced from numerous studies done in such a vast area; and with different outcomes of interests. The following is a highlight of a few different types of research in the water and sanitation (WASH) domain:

In 1997 - Adair et al [4] conducted a research on the impacts of childhood infections. In their findings these authors incriminated early childhood infections to poor nutrition outcomes. However their evidence needed a combination of a number of other evidences and in a form of systematic reviews to make them more significant in meaning. As such -this prompted us to consider this review study and fill up such an existing research gap. In studies done by Fewtrell et al [5] and Murray et al 1997 [6];(implemented in developing countries) confirmed that close to 33% of the infection burdens in the world -are 'water and sanitation' related and that such increased burdens mostly lie in developing countries of the world. And basing on such findings –we were prompted to implement this systematic review with 'water and sanitation' as our main component of the interventions of interest and also with 'countries of the developing world' as our study setting.

In 2008: Black et al [7] examined critical windows of exposure of infections in children aged 0-5 years. In their results - they concluded that the period ranging from conception to 24 months after birth are the most crucial stages in childhood development. In 1997, Murray et al [6] investigated on global burdens of diseases and mortality. They mentioned of childhood malnutrition and their variety of causes; but without linking such a childhood condition to water and living sanitation; not even to child growth. Such studies made us consider our review to be focussed on children of such an age arrange (0-5 years). In Kenya, Ngare et al 1999 [8] investigated on prevalence of malnutrition; but their study suffered a lot of methodological concerns and neither focussed on children nor childhood growth. These merely increased research gaps –which this review wants to fill up. A prospective cohort study done in a Sudanese community; by Samani et al 1988 [9] - investigated on malnutrition and diarrhoea of children aged below the age of 5 – but this study like Ngare et al 1999 [8] also had the same type of fate flouted procedures.   Other studies done by Yoon et al, 1997 [10] ; Fawzi et al 1997 [11] and Bhutta et al,1997 [12] also found significant associations between poor childhood growth and increased mortality in infancy and later life. But the interventions of interest in such studies were not any of the three components of WASH. This also prompted this systematic review to zero down on WASH components as interventions of interest.

On the other hand, Berkman et al, 2002 [13] studied childhood growth. And their results indicated significant associations between faltered childhood growth and brain impairment and also on school performance of the affected children. However, much as interventions of interest in such a study [13] was water and sanitation: this particular study lacked 'complicity' to support their found evidence – necessitating this systematic review. Three other different studies of Daniel et al, 1991 [14]; Ricci et al 1996 [15] and Huttly et al 1990 [16] were also implemented on various outcomes of interests. All with different settings, designs and study populations - tried to establish the linkages between traditional (not improved) water provisions; compromised living sanitation and childhood nutrition. But the trio [14, 15, 16] also had their own methodological errors in addition to not being focussed on childhood growth and development. Ricci et al 1996 [15] studied the childhood risk factors for stunting and wasting; but much as these authors included sanitation component in their interventions; they never went as far as establishing the degree of association between their interventions and the variable childhood growth.

However - in 2005: Fewtrell et al [5] conducted a rigorous systematic review: combining several different studies -that had a focus on the roles of safe water provision; human waste disposal and personal hygiene on diarrhoeal outcomes in less developed countries. In their findings these authors indicated that 'safe water consumption coupled with safe human waste disposal might be a fundamental component of enhancing human health'. But their findings suffered follow up studies and in addition to the fact that outcomes were not childhood growth and development. Just like Berkman et al, 2002 [13]: Huttly et al 1990 [16] and Daniel et al, 1991 [14] also needed some explicit combination of evidence from relevant studies. Such a review of previous literature vindicated an increased number of anomalies. All such gaps help explain great justifications for this systematic review on water and sanitation; and child growth and development: hence the importance of such a systematic review. We expect that this review will assist provide the missing scientific evidence in the world of water and sanitation research.

In this paper, we describe the review objectives, questions; and the methodology for the study of the impacts which water and sanitation possesses on the physical growth and development of children of developing the countries of the world. We have chosen South Asia (SA), sub-Saharan Africa (SSA) and Latin America (LA) as our presentation of the developing world because that's where increased burdens of water and sanitation rank so high, especially in children 0-14 years. In addition to the methodology itself, we shall present the combined evidence of results (and implications to the scientific world) of 15 experimental studies that were conducted in the countries of the mentioned developing regions of the world (SA, SSA and LA) (refer to table 2.0) in order to test the usefulness of the procedure and also the validity of combined evidence. Our method involves the systematic review of evidence from each of the 15 included studies, and the concurrent measurement of physical and non physical (cognitive and intelligence as measured from performance in class) growth changes in the 33, 332 plus children (refer to tables 2.0 and 3.0).

CHAPTER TWO: REVIEW OBJECTIVES AND QUESTIONS

2.1 Objectives

Aims of this review included: 1) Establishing impacts of water provision (in terms of supply and quality); community and household sanitation and hygiene practices on growth and development of children of the developing countries of the world; 2) Identifying and establishing the existing web of causation for various inter-twining factors of childhood malnutrition. 3) Identifying existing research gaps and suggesting more sustainable interventions in the world of water, sanitation and hygiene promotion programming for developing countries.

2.2 Review Questions

Review questions comprised of: 1) In what ways does water quantity and quality; sanitation facilities and hygiene practices impact the nutrition statuses of children? 2) How do compromised nutritional statuses of children lead to other ‘second round’ health and developmental effects? 3) Are such second round effects short or long-term impacts, and what are the known repercussions of such deficiencies in children’s lives and global development?

CHAPTER THREE: METHODOLOGY

3.0 METHODS:

3.1 Search terms, Selection criteria, Data sources and extraction, Critical appraisal or Quality assessment, Study characteristics

3.2 Search strategy and Sources of literature

Four different strategies were used in locating literature: 1) Use of electronic search engines (through use of computer held databases); 2) searches of reference lists (bibliographies of relevant studies); 3) manual searches (hand searches on relevant journals relating to the subject of study); 4) and direct follow ups (contacting authors directly and also organisations implementing interventions on childhood growth and development and also water plus sanitation interventions). We developed a rigorous search strategy (with a wide range of search terms – refer to appendix 2.0) for purposes of identifying as much (and as wide) range of relevant published material so that we answer our research question in a more comprehensive manner.

3.3 Study consideration criteria

Types of studies: Our target studies were of a wide range. Initially, we aimed at randomised Controlled Trials (RTCs - though we never came across appropriate RTCs). This prompted us to use the various Quasi-randomised or non-randomised controlled trials (RCTs); Cohort studies; longitudinal and cross-sectional studies (refer to table 2.0).

3.4 Types of participants: Our participants were children up to the age of 14.

3.5 Description of interventions: We aimed at studies whose interventions were either: 1) water provision (water quality or quantity); 2) sanitation (environmental or household); and 3) hygiene practices. We categorised the different WASH interventions into 5 categories -as follows:

- **Water quality**: Comprising of various water treatments methodologies of alleviating the microbial contamination (pasteurisation; chemical treatments; boiling; solar disinfection and others). In this category fell most of the point of use or source water treatments (POSWT or POUWT).
- **Water supply**: Comprising of provision of improved water systems (new water supplies; improvements and distribution).
- **Sanitation:** Comprising of latrines (excreta disposal in schools; public places; communities and household levels)
- **Hygiene**: Comprising of behavioural change interventions (practices; attitudes and knowledge; health education -on water; sanitation and hygiene; hand washing; disposal methods of human excreta and other unsanitary wastes)
- **Multiple interventions**: Comprised of combinations of sanitation; water -quality or quantity; hygiene.

3.6 Inclusion and exclusion criteria

Inclusion criteria: We included all primary research relating to water, sanitation and hygiene and children's growth and development; English published studies; Post-1980 studies and with either Latin America, sub-Saharan African and south Asian setting.

Exclusion criteria: We excluded all studies that failed short of meeting the mentioned criteria of inclusion.

Types of outcome measures: Our outcome measures included – 1) Primary **(**morbidity and mortality). 2) Secondary (physical growth and other relevant developmental growths).

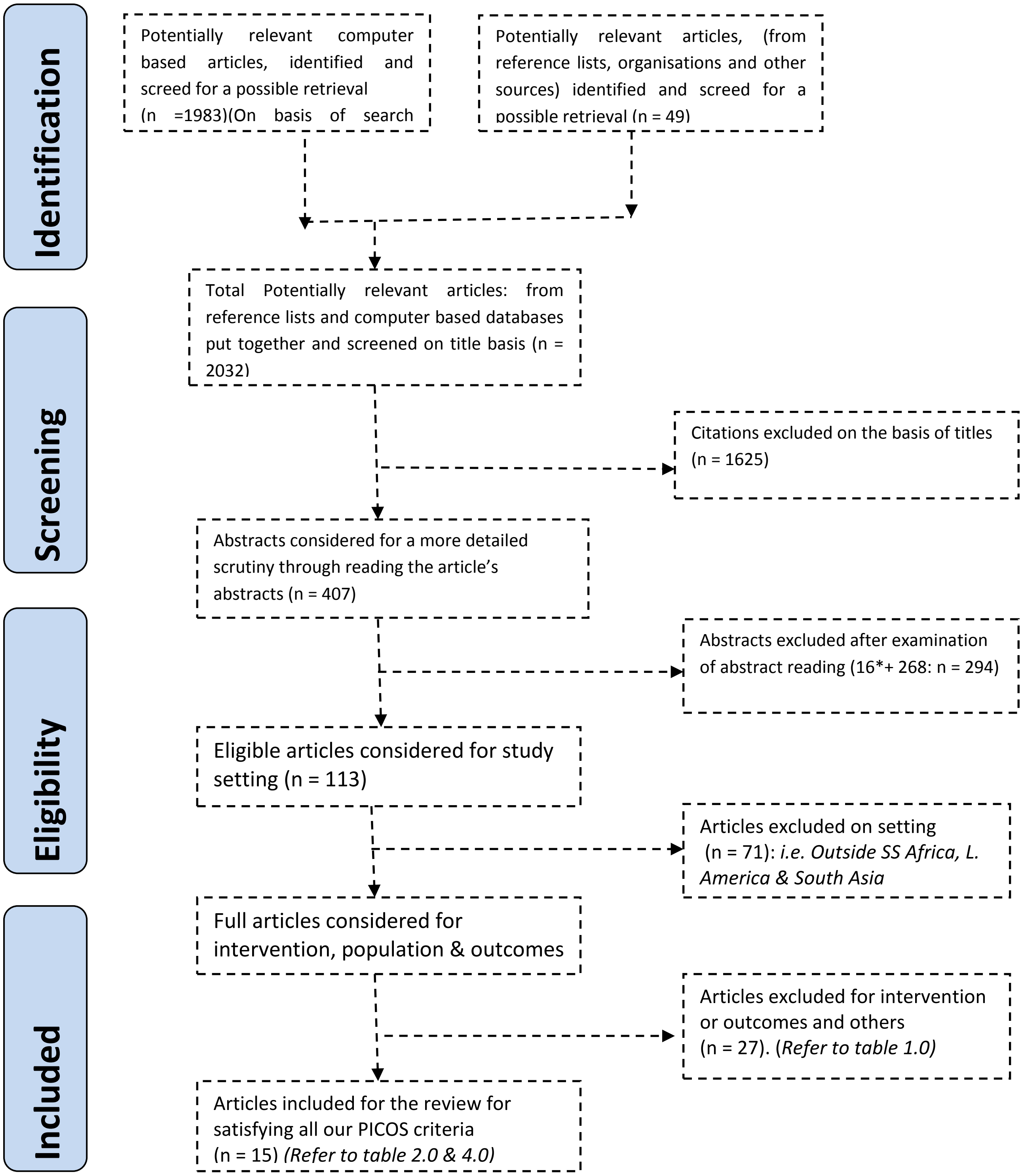
3.7 Data sources

For each of the mentioned outcomes – we came up with various combinations of search terms (refer to appendix 1.0). We then conducted rigorous searches in the following computerised databases: Embase; Journal of Public Health; Cochrane Library; pscho-info; Medline, Pascal Biomed Medline; Tropical Diseases Bulletin; CINAHL; Pubmed; Scopus; Sage Journals; CAB Abstracts; Abstracts on Hygiene and Communicable Diseases; and Science Citation Index. The following is a brief documentation of our search results: 1) We found most of our sanitation interventions from the following databases: Pub med; Scopus, Science Direct; Embase; Abstracts on Hygiene and Communicable Diseases and Medline. 2) Sage journals and Pascal Biomed provided a substantial amount of literature relation to water quality and quantity – but we had difficulties in retrieving them as most of them were not in full texts. 3) We had a substantial number of studies in foreign languages (French, Dutch, Portuguese and Chinese) from: Pascal Biomed and LILACS. 4) Medline and Embase databases provided most studies that had mentioned cognitive development as an end point of interventions. 5) Pscho-info; Tropical Diseases Bulletin; CINAHL also provided a substantial amount of English studies that had a setting of developing countries (most of them from Latin America and sub-Saharan Africa. 6) We also hand searched for references cited in the identified and potentially relevant articles. Only peer-reviewed studies and based in English language were searched in full texts. 7) We also retrieved all relevant technical reports and other agency documentations related to childhood growth and development (with a water or sanitation component in them) from UNICEF and WHO websites.

3.8 Selection of eligible studies

As the study flow diagram (Refer to figure 1.0) indicates: We retrieved a total of 2032 potentially relevant studies for a possible retrieval (from all computerised databases; reference lists and other sources). From the 2032 studies – we discarded a total of 1625 articles on 'irrelevance basis' of their language of their titles. Thus we remained with 407 studies -to be considered for a further rigorous scrutiny. We read the abstracts of the 407 studies, made sense out of them and discarded a total of 294 studies. We had remained with 113 studies to be considered for a full-text reading. After an in-depth reading of 113 (full texts) – we discarded 71 studies that had setting outside sub-Saharan Africa; South Asia and Latin America. Thus we remained with just 42 studies which were again scrutinised if they had satisfied all the inclusion criteria. We then discarded 27 studies (Refer to table 1) that had either of the following: Outcomes were neither growth nor developmental; interventions not any of the WASH components (refer to table 3.0); Population not children aged withing the ranges of 0-14; and several other methodological factors. Finally we had our 15 studies [17-31] (refer to table 2.0) for this review study.

3.9 *Figure 1*: PRISMA Study Flow Diagram



Adapted from: Moher et al 2009 [65] . The primary reason for exclusion noted with asterisk (*) includes 11 articles that had not full articles for further reading and also 5 others that needed purchasing, but our capacities could not manage purchasing the papers

3.10 *Table 1.0*: Characteristics of excluded studies (in alphabetical order)

#	Study	Reason for exclusion
1)	Biondi et al 2010	Intervention was neither water nor sanitation nor hygiene.
2)	Blum et al1990	Outcome was neither growth, nor development.
3)	Bose et al 2009	Secondary research and poor methodological quality
4)	Bourne et al 207	Outcome was neither growth nor development
5)	Cameron et al 2005	Intervention was neither water, nor sanitation and hygiene.
6)	Daniels et al 1990	Outcome was neither growth nor development: But diarrhoeal diseases
7)	Feachem et al1983	Outcome was neither growth nor development; but helminth incidence
8)	Fotso et al 2007	Outcome was not growth nor development
9)	Gartner et al 2001	Outcome was neither growth nor development; nor was intervention water and sanitation nor hygiene
10)	Gasana et al 2002	Intervention was neither water and sanitation nor hygiene
11)	Grantham-McGregor et al 2007	Secondary research
12)	Good et al 2011	Intervention was neither water and sanitation nor hygiene
13)	Harris et al 2009	Outcome was neither growth nor development
14)	Huttly et al 1987	Outcome was neither growth nor development: but diarrhoea
15)	Kimani et al 2011	Intervention was neither water and sanitation nor hygiene: but HIV & Aids
16)	Kikafunda et al 2006	Intervention was neither water and sanitation nor hygiene
17)	Mason et al 1986	Outcome was neither growth nor development; but parasitism of helminths
18)	Olsen et al 1998	Outcome was neither growth nor development
19)	Onyango et al 2010	Outcome was neither growth nor development
20)	Pongue et al 2006	Secondary research
21)	Quick et al 2002	Outcome was neither growth nor development
22)	Sasaki et al 2008	Outcome was neither growth nor development
23)	Stephenson et al 1992	Outcome was neither growth nor development; also intervention was Albendazole
24)	Tomkins et al 1989	Outcome was neither growth nor development; also intervention was neither water and sanitation nor neither hygiene
25)	Tumwine et al 2003	Outcome was neither growth nor development; also population of interest was all segments
26)	VanDerslice et al 1994	Outcome was neither growth development
27)	Young et al 1987	Outcome was neither growth nor development

Note: This is a list of the 27 studies [32-59] we excluded at the last part of the selection criteria (see Fig. 1.0). The reasons for their exclusion are listed in the right column.

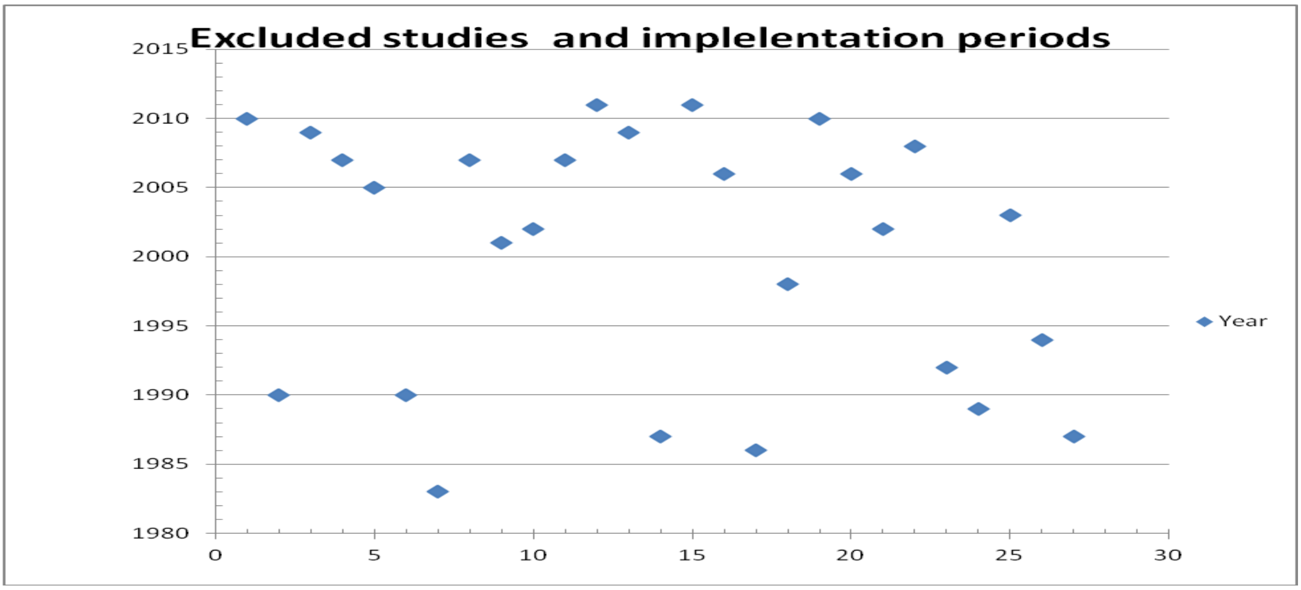


Figure 2.0: An illustration of the same excluded studies in terms of periods of implementation, with most of them having been implemented between the periods after the year 2000-10

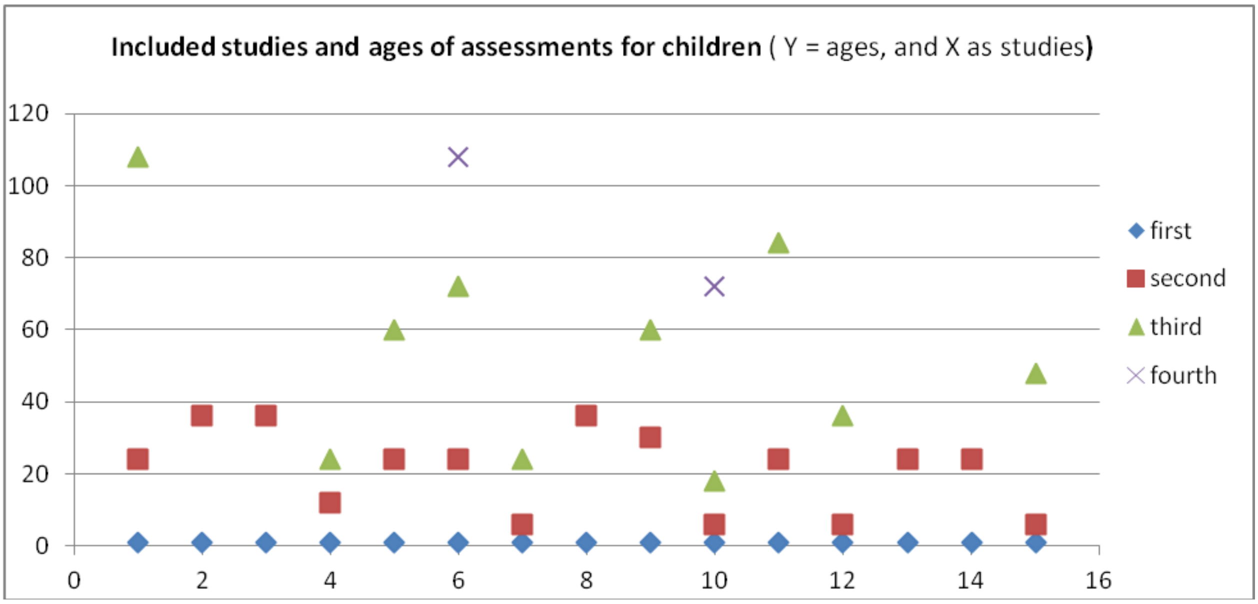
3.11 *Table 2.0*: **Characteristics of included studies**

Authors and location	Study design	Age of assessment	Description of children			Point estimate	Primary objectives
			Intervention	Control	Exclusion		
Berkman et al 2002 Pampas de san Juan, Peru	Prospective cohort and longitudinal study	0-2 and 2-9 years	n =239	-	-	Mean	Assessing diarrhoea and *C.Parvum and G.lamblia* effects on infancy infections and cognition in late childhood.
Checkley et al 2004 Pampas de san juan, Peru	Prospective cohort study	0-36months	n=230	-	-	Mean	Assessing water and sanitation effects on linear growth, diarrhoeal diseases and prevalence of parasites.
Checkley et al 1998 Lima, Peru	Longitudinal cohort study	0-36months-	n=253			Mean	Examining effects of *cryptosporidium parvum* infection on childhood growth after the onset of infection.
Esrey et al 1992 Lesotho	Prospective and retrospective cohorts	0-12 to 24 months	n=119	-	-	Mean	Examining water quantity and sanitation, alone and in combination on infant weight and length gain.
Esrey et al 1988 Lesotho	Prospective cohort study	0-60 months	n=125	122	-	Mean	Establishing growth and morbidity rates of young children in from exclusive and non exclusive use of improved water supplies.
Guerrant et al 1999 Fortaleza, Northern Brazil	Prospective and retrospective cohorts	0-2 and 6-9 years	n=26	-	-	Mean	Assessing potential, long-term deficits associated with early childhood diarrhoea and parasitic infections
Gupta et al 2007 Northern Senegal	Cross-sectional study	0-6 and 23 months	n=374	-	-	Mean	Assessing association between early introduction of water and complementary foods (CFs) and children's nutritional status.
Huttly et al 1990 Imo, Nigeria	Cross-sectional & Prospective Longitudinal follow up studies	0-36 months	n=935	470	-	Mean	Assessing impacts of *dracunculiasis* and diarrhoea on nutritional statuses of persons of all ages including children
Kikafunda et al 1998 Uganda	Cross-sectional & Prospective Longitudinal follow up studies	0-30 months up to 60 months	n=261	-	-	Mean	Assessing dietary and environmental factors impacting stunting and other childhood poor nutritional statuses.
Merchant et al 2003 Crezira Region, Sudan	Prospective cohort study	0-6, and -18 months up to 72 months	n=25,483	-	-	Mean	Assessing household water and sanitation and childhood stunting risk and reversal of stunning

Moor et al 2001 Fortaleza, Brazil	Prospective and retrospective cohorts	0-24 and 84 months	n=119	-	-	Mean	Examining associations between early childhood enteric infections and growth faltering, intestinal *helminthiases* & nutritional status
Pickering et al 1985 Gambia, west Africa	Prospective cohort study	0-6 and 36 months	n =493	-	-	Mean	Assessing impact of diarrhoea and childhood growth
Rowland et al 1988 Banjul, Gambia, west Africa	Prospective cohort study	0-24 months	n =126	-	-	Mean	Assessing association of morbidity on childhood growth
Taguri et al 2009 Benghazi, Tripoli Libya	Cross-sectional & Prospective Longitudinal follow up studies	0-24 months	n =4549	-	-	Mean	To ascertain major predictors of childhood stunting
Tomkins et al 1988 Malumfashi, Nigeria	Cross-sectional & Prospective Longitudinal follow up studies	6-48 months	n = *	-	-	Mean	Assessing impacts of water supply on childhood nutrition status

Note that symbols: 1) the 'minus' depicts that we had some missing information, as authors never took that into account. The * also mean the same thing but in terms of the sample size of studies (control plus intervention or each one separately). In figure

Figure 3.0: Assessment ages in the included studies: showing the ages at which the different studies implemented specific assessments



3.12 Critical appraisal

After completing comprehensive searches for all published studies, we initiated a critical appraisal to assess the quality of our 15 included studies [17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, and 31]. We discarded 27 studies [32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58] on the following explanations: Outcomes were neither growth nor developmental; Or interventions were not any of the WASH components (Refer to section 3.3) and also the poor methodological quality and other. However, for the sake of complicity - we still appraised all the 42 studies [17-31 and 32-58] and 27 of them [32-58]. We also scrutinised and documented the characteristics of the 27 excluded studies as in table 1.0 and figure 2.0

3.13 Quality Assessment

All the included studies investigated childhood growth and other developmental milestones. The 15 studies assessed childhood anthropometry in the following domains: 1) Weight-for-age (wasting); 2) Weight-for-height (stunting); 3) Height-for-age (stunting); 4) Growth faltering; 5) Catch up growth; 6 Physical fitness; 7) Cognitive development or functioning (through school performance) as in table refer to table 4.0. The ages of children ranged from birth up to 14 years. At a certain point we somehow had some limited consensus on how to best critic the quality of such health outcomes in the 15 studies [17-31]. Nevertheless, Newcastle-Ottawa Scale (NOS) framework [59] provided a handy quality-assessment framework for critical appraisal of evidence relating to children's growth and developmental outcomes. In addition to other areas indicated in table 1.0 and 2.0: Newcastle-Ottawa Scale (NOS) framework appraised 6 areas liable of possible bias: 1) study attrition; 2) prognostic factor measurement; 3) study participation; 4) confounding quantification and accountability; 5) general outcome measurement; 6) and analysis of study findings. We assessed studies on the following four factors: 1) if the comparison groups were clearly defined; 2) if the outcomes were measured in the same (preferably blinded), objective way in both groups; 3) if the known confounders were identified and appropriately controlled for; 4) if the follow-up of patients were sufficiently long and complete. We defined methodological quality in terms of 'internal validity': defined as the extent to which the included study designs, their conduct, and analysis had managed minimizing selection, measurement, and confounding biases. We used the Newcastle-Ottawa Scale (NOS) framework for assessing the quality of nonrandomised studies in meta-analyses [59] (refer to appendix 2.0 and 3.0) We classified our studies for the ratings of their methodological qualities (i.e. Good, Fair or Poor) and according to the presence of the quality proof for that level of evidence - where: 1) Good studies = had most/all of the relevant quality items; 2) Fair studies = had some of the relevant quality items; and 3) Poor studies = had few of the relevant quality items (but sufficient value to include for further review) (Refer to tables 1.0, 2.0 and 3.0). On the other hand, although some published studies had presumably best qualities (due to being peer-reviewed documents): we went ahead also assessing their quality to increase the review's rigour.

3.14 *Table 3.0*: **Domains abstracted from included studies**

No.	Components of the 7 domains of interest
1.	Appropriate sample size of the study
2.	Outcome measure appropriateness
3.	Publication year and names of publishers
4.	Clearly defined source population
5.	Clearly described study population
6.	Representatively of the study to the general or source population
7.	Description of the completeness in the follow-up of study subjects
8.	Quality and adequacy of study design
9.	Clearly defined outcomes
10.	Outcome measured appropriately and in line with objectives
11.	Well measured and defined confounders
12.	Well documented (or accounting)of possible confounders
13.	Adequacy of follow-up period of the intervention group
14.	Credibility of authors
15.	Definitions of prognostic factors (if any)
16.	Appropriately measured diagnostic factors (if any)
17.	Good descriptions of analytical procedures
18.	Appropriate analysis
19.	Sufficient presentation of data from analytical procedures
20.	Validity and specificity in the results
21.	Appropriateness of length of follow-up the control population
22.	Description of the length of follow-up
23.	Study setting or geographic area of implementation
24.	Good definition of the research question
25.	Quality of evidence and relevance of supporting conclusions

3.15 Data Extraction

We designed specially data extraction forms for abstracting data from our 15 studies and abstracted the domains as indicated in table 2.0. In addition to the information (listed in table 3 and appendix 2 and 3): these specially designed forms also abstracted the following information: 1) Study authors and publication year; 2) Study design and sample sizes; 3) Baseline information (of both study and comparison-groups); 4) Exclusion and inclusion criteria; 5) age at periodic assessments; and 6) primary objectives. We then tabulated the retrieved summary data as in table 4.0. It is also wealthy explaining that our original review methodology was designed to examine six domains of childhood growth and development. These domains comprised of: 1) Weight gain (measured through weight-for-height: wasting, weight-for-age – wasting); 2) Height-for-age: stunting/linear growth); 3) Growth faltering; 4) Catch up growth (in later childhood); 5) physical fitness (measured through activeness of children amongst the peers); 6) Cognitive development (measured from school performance after adjusting for possible confounders); and 7) General health and other water related illnesses.

3.16 Data management

As mentioned in section 3.9: we listed and tabulated all the abstracted data from our 15 studies [17-31] and from this abstracted data; we made analyses and interpreted the meanings of the data into the information (results section – refer to chapter 4) and discussion sections (section 6.1) of this review. Initially our plan was to analyse the abstracted summary measures through a meta-analysis software package. But in the course of the review we discovered that our studies were of varying categories of outcomes – making the meta-analysis impossible: and as this made us revert to implement this systematic review through semi-meta analytical or quantitative methodologies. In our results sections we also explained summary measures of the stunting, wasting, growth faltering, physical fitness, cognitive deficits impacts for the 15 studies as being either Relative Risks (RR); Odds Ratios (OR); Rates Ratios (RR) and others (refer to table 2.0). If different articles had cited findings from other previous studies of interest, we also reached out to such referenced studies. However, to ensure consistency of the review objectives we made sure that our main results section concentrated on the findings from 15 studies [17-31].

Different studies used different measures to indicate the level impacts. However, we had some problems in abstracting the meanings of results as some studies were not able to indicate the measures of impacts (indicated with 'stars or –'' or empty spaces in the results table). In interventions that were not able to indicate various measures of risks, such as incidence density ratios or odds ratios or cumulative incidence ratios; we instead, employed other qualitative approaches of data analysis [60]. Such methodologies served purposes of deriving at the meanings of such non quantified information. In quantified studies - we used estimates adjusted for covariates, in situations that the adjusted and non-adjusted measures were instead reported in specified articles. In the results and discussion sections, we have explained the relative risks and 95% confidence intervals. The RRs or OR of < 1.0 meant a reduction of the impacts of water provision, sanitation and hygiene impacts in intervention group(s) than in the control one(s) that had RR or OR of > 1.0. And RRs or OR of > 1.0 meant an increase of the health or growth or cognitive impacts in control groups of individual or multiple intervention(s) - compared to findings from the control group(s). On the other hand RR or OR of = 1.0 meant the impacts of th control and treatment groups were the same (refer to table 4.0).

CHAPTER FOUR: ANALYSIS

4.1 Description of Included Studies

All included studies are summarized in Table 4.0. Of the 15 studies that documented infants aged 0-24 months old; 5 of them focused on children born in Latin America [19] and sub-Saharan Africa [20, 23, 29, 30]; while 10 studies included a subgroup of infants aged 2 -9 years [17, 18, 21, 22, 24, 25, 26, 27, 28, 31]. 10 of the 15 studies were conducted within developing countries of sub-Saharan Africa [20, 21 and 23-31] in the following 7 countries: 1) 2 in Lesotho [20, 21]; 2) 1 in Senegal [23]; 3) 2 in Nigeria [24, 31]; 4) 1 in Uganda [25]; 5) 1 in Sudan [26]; 6) 2 in Gambia [28]; and 7) 1 in Libya [30]. We had 5 studies done in Latin America: 1) 3 in Lima Peru [17, 18, and 19] and 2) 2 in Brazil [22, 27]. All of the 15 included studies were undertaken within the previous 20 years. We retrieved some few studies from countries of south Asia, but for methodological qualities and other reasons: not even one qualified for inclusion. Of the 15 included studies [17-31]: 5 of them were prospective and retrospective cohort and had used already existing study designs: 17, 24, 25, 30, and 31 (refer to table 2.0). Of the remaining 10 studies, 5 were prospective cohorts [18, 21, 26, 28, 29]; 1) 3 of the last 5 studies were retrospective and prospective cohorts; 2) 1 was a retrospective and prospective cohort and longitudinal (all in one) design [17]; 3) 1 was a cross-sectional design [23]; and 4) 5 were cross-sectional and longitudinal in nature [17, 24, 25, 30, 31]. Results detailed in the following paragraphs were based on a narrative synthesis of studies retrieved from the existing health and developmental outcomes of infants and children within the four mentioned domains of childhood development that comprise:1) physical growth (Wasting on Cognition: presented through weight-for-height Z score ≤ -2 (WHO), and stunting on cognition : presented through height-for-age Z score ≤ -2 (WHO)) weight gain and linear growth); cognitive development (cognitive deficits: presented as either mental retardation or intellectual capabilities, through WISC-R scores); general health (diarrhoeal prevalence or diarrhoeal+ days/surveillance or days of diarrhoeal illnesses affecting malnutrition) ; and other water related pathogenic illnesses. A summary of these results is shown in Table 4.0

CHAPTER FIVE: SUMMARY OF EVIDENCE

5.0 RESULTS

5.1 Wasting and stunting; Catch-Up Growth and physical fitness; Growth faltering and Cognition deficiencies

We abstracted data from our 15 [17=31] studies and the table below displays such data. In the next sections (after table 4.0) described the result summaries and then in the next chapter, we discuss the findings.

5.2 *Table 4.0:* Result summaries of included studies

Outcome Domain	Age at assessment	Health Outcome: definition and/or measurement	Children (n)	Measure of association	β 95% CI	*P*-Value
Berkman et 2002 Pampas de san Juan, Peru	From birth up to 2 and 2-9 years	Stunting on Cognition: Height-for-age Z scores ≤-2 (WHO).	143	- 0.6	- 0.3, 0.1	<0.162
	0-6	Age at first stunting in months	38	reference	reference	reference
	0-6	Age at first stunting in months	105	-4.2	-8.0, -4.0	<0.032
	Never	Age at first stunting in months	97	reference	reference	<0.173
	0-5	Age at first stunting in months	6	-0.1	-9.5, 9.3	<0.983
	6-11	Age at first stunting in months	18	-2.0	-7.3, 3.3	<0.458
	12-17	Age at first stunting in months	18	-6.5	-11.6, -1.4	<0.014
	≥ 18	Age at first stunting in months	4	0.8	-9.4, 10.9	<0.882†
	Never or stunted at other age	Age at first stunting in months	107	reference	reference	reference
	6-17	Age at first stunting in months	36	-4.3	-8.3, -0.5	<0.031
		Persistence of stunting, infancy to late childhood				
	Never		91	reference	reference	<0.129
	Persistent		19	-4.6	-9.7, 0.5	<0.077
	Catch-up		27	-2.1	-6.5, 2.3	<0.347
	Late incident		6	5.4	-2.9, 13.7	<0.200‡
		Severity of stunting on cognition deficit	133	reference	reference	reference
	Non or not severe		10	-5.4		
	0-11 months 9non or not severe)		138	reference	reference	reference
	Severe		5	0.1	-10.7, 10.9	<0.989
	≥ 12 (non or not severe)		107	reference	reference	reference
	severe		10	-10.0	-17.5, -2.4	<0.011
		Prevalence of diarrhoeal (days per month)				
	0-5 months		143	-0.2	-0.8, 0.4	<0.530
	6-11 months		142	0.3	-0.5, 1.1	<0.508
	12-17 months		116	-0.1	-1.2, 1.1	<0.888
	≥18 months		72	0.1	-1.0, 1.1	<0.918
	0-11 months		143	0.0	-0.9, 0.8	<0.951
	≥12 months		116	-0.2	-1.4, 0.9	<0.670
		The incidence of *Giardia lamblia* parasites				
	≤ 1 occasion		66	0.0	reference	reference
	>1occasion/yr		77	-0.2	-8.0, -0.2	<0.039
Checkley et al	From birth up to	Estimated height difference at 24	230			

2004 **Pampas de san juan, Peru**	35months	months				
	24 months	Households with best conditions for water for water and sanitation(sewage, water connection plus good storage)	58(25%)	1.3	*	*
	24 months	Worst conditioned houses(no sewage, no water connection, storage+) Linear growth through water and sanitation	53(23%)	-.7	*	*
	24 months	Best conditions	0	-0.8	*	*
	24 months	worst conditions prevalence of diarrhoea by water and sanitation		1.6	*	*†
		Water source	#Diarrhoeal episodes			
	24-36 months	Home connection	743	1.00	reference	reference
	24-36 months	Cistern truck or stand pipe	75	1.09	0.60,1.98	*
	24-36 months	Neighbour	569	1.21	0.96,1.52	*
		Water storage				
	24-36 months	Large	628	1.00	reference	reference
	24-36 months	Medium	106	1.12	0.60,1.96	*
	24-36 months	Small	653	1.28	1.01,1.63	*
		Sanitary facilities				
	24-36 months	Sewage	567	1.00	reference	reference
	24-36 months	Latrine or equivalent	508	1.17	0.88,1.56	*
	24-36 months	No facility	312	1.19	0.89,1.6	*
Checkley et al 1998 **Lima, Peru**		**Effects of *cryptosporidium parvum* infection on childhood growth after the onset of infection(p-likelihood ratio test)**				
	24 months	Weight-for-height(wasting)		*	*	<0.71
	24 months	Length –for –age(stunting)		*	*	<0.001
Esrey et al 1992 **Lesotho**	From birth up to 12 and then 24 months	Effects of water quantity and sanitation, alone and in combination to assess infant weight and length gain				
		Latrine ownership on linear growth		*	- 0.373,0.875	
		Latrine ownership on weight gain		*	- 0.088,0.442	
		Water quantity on linear growth (+0.035cm)	*	-0.022	- 0.016,0.084	*
		Water quantity and weight gain (+0.019kg)		-0.002	- 0.003,0.041	*
		Variation on water quantity usage on linear growth((6.6-10.5l/day=0.230cm)	*	*	- 0.423,0.883	*
		Variation on water quantity usage on weight gain (6.6-10.5l/day=0.317kg)	*	*	0.044,0.590	*
Esrey et al 1988 **Lesotho**	From birth up to 60 months	Growth and morbidity rates on exclusive and non exclusive use of improved water supplies				
	1-12months	6months weight growth & drinking water usage – exclusive users	122	0.174	- 0.494,0.842	*
	13-60 months	6months weight growth & drinking water usage – mixed users	122	0.462	- 0.000,0.924	*
		Total over all		0.404	- 0.006,0.814	*
Guerrant et al 1999 **Fortaleza, Northern Brazil**	From birth up to 2 and then 6-9 years	Potential, long-term deficits from early childhood diarrhoea and parasitic infections				
	4-7 years later	Anthropometric (n=26)	26	-0.361(OR)	*	<0.076
	4-7 years later	Height for age Z	26	-0.417(OR)	*	<0.038
	4-7 years later	Weight for age Z	26	-0.411(OR)	*	<0.041
	4-7 years later	Weight for height Z	26	-.615(OR)	*	<0.004
Gupta et al 2007	From birth up to 6	Early introduction of water and				

Northern Senegal	and 23 months	children's nutritional status				
	6-23 months	Introduction of water on wasting (WHZ less than -2)	374	0.99	0.46,2.14	<0.97
	6-23 months	Introduction of water on stunting (HAZ less than -2)	374	0.68	0.34,1.36	<0.3
	6-23 months	Source of water(river/pond) on wasting (WHZ less than -2)	374	2.57	1.45,4.56	<0.001‡
	6-23 months	Source of water(river/pond) on (HAZ less than -2)	374	0.33	0.15,0.72	<0.005
	6-23 months	Recent diarrhoea on wasting (WHZ less than -2)	374	1.22	0.61,2.46	<0.6
	6-23 months	Recent diarrhoea on (HAZ less than -2)	374	0.59	0.27,1.31	<0.2
Huttly et al 1990 Imo, Nigeria	From birth up to 48 months	D*racunculiasis* and diarrhoea on nutritional statuses	935 & 470 (int. & control rsp)			
	5-14 years	Household daily water collection time on diarhoea	465	2.91	1.39,6.09	*‡
		Distance of more than 250m from borehole on diarhoea	465	1.23	0.97,1.55	*
		Wight for height on	465	0.67	0.39,1.116	<0.005
Kikafunda et al 1998 Uganda	From birth up to 30 months up to 60 months	To assess dietary and environmental factors impacting stunting and other childhood poor nutritional statuses	261			
		Exclusive water use and stunting	261	-2.09RC*	0.44SE*	<0.001
		Exclusive water use and wasting		-0.24RC*	0.40SE*	<0.001
Merchant et al 2003 Crezira Region, Sudan	From birth up to 6, and 18 months, then to 72 months	Household water and sanitation on childhood stunting risk and reversal of stunning				
		Reversal of stunting		RR*	MARR*	*P*-value
	<1, 1-3 &3+ years	Water and sanitation	7499	1.17	0.99,1.38	0.88
	<1, 1-3 &3+ years	Water, and no sanitation	3209	1.23	1.13,1.34	0.89
	<1, 1-3 &3+ years	No water but sanitation	2685	1.15	1.08,1.24	0.18
	<1, 1-3 &3+ years	No water , nor sanitation	12090	1.00	reference	reference
		Incidence of stunting				
	<1, 1-3 &3+ years	Water and sanitation	7499	0.79	0.69,0.90	0.88
	<1, 1-3 &3+ years	Water, and no sanitation	3209	0.79	0.74,0.85	0.89
	<1, 1-3 &3+ years	No water but sanitation	2685	0.86	0.81,0.91	0.18
	<1, 1-3 &3+ years	No water , nor sanitation	12090	1.00	reference	reference
Moor et al 2001 Fortaleza, Brazil	From birth up to 24 and 84 months	Early childhood enteric infections on growth faltering, intestinal *helminthiases* & nutritional status				
			380	*	-0.41,0.30	<0.001
Pickering et al 1985 Gambia, west Africa	From birth up to and 36 months	To assess the impact of diarrhoea and childhood growth				
		Children's height on:	Sample size			
	<6, 6-36 months	Sanitation	493	*	*	<0.001
	<6, 6-36 months	Water vessels/pails	243	*	*	<0.001
	<6, 6-36 months	pail	24	*	*	<0.001
	<6, 6-36 months	None	44	*	*	<0.001
	<6, 6-36 months	Flush toilets	11	*	*	<0.001
Rowland et al 1988 Banjul, Gambia, west Africa	From birth up to 24 months	Childhood diarrhoeal morbidity on growth of children	126	*	*	<0.01
Taguri et al 2009 Benghazi, Tripoli Libya	From birth up to 24 months	Bivariate analysis of factors associated with childhood stunting and water, and sanitation				
		Source of drinking water on stunting	521/2522	1.00	reference	reference
	<6, 8-24 months	Wells without pump	88/318	1.46	1.12,1.90	<0.005
	<6, 8-24 months	Rainfall catchment	23/70	1.84	1.11,3.06	<0.02

	<6, 8-24 months	Luck of water storage	231/1068	1.00	reference	reference
	<6, 8-24 months	Tin container storage	25/76	1.80	1.09,2.96	<0.02
	<6, 8-24 months	Others	49/155	1.69	1.17,2.44	<0.005
		Water treatment	885/4305	1.00	Reference	reference
	<6, 8-24 months	Filtering treatment of water	7/11	6.01	1.82,19.82	<0.003
	<6, 8-24 months	Toilet provision	438/2372	1.00	Reference	reference
	<6, 8-24 months	Latrines with containers	165/612	1.63	1.32,2.00	<0.000
	<6, 8-24 months	Pit latrines/rubbish pits	17/35	4.06	2.08,7.93	<0.000‡
	<6, 8-24 months	Open air sanitation	17/53	2.09	1.16,3.76	<0.02‡
		Methods of disposing garbage		1.00	reference	reference
	<6, 8-24 months	Containers without lids	288/1609	1.38	1.117,1.63	<0.000
	<6, 8-24 months	Street throwing	434/1871	2.18	1.15,4.14	<0.02‡
	<6, 8-24 months	Others methods	14/44	7.26	2.58,20.44	<0.000‡
	<6, 8-24 months	Use of external garbage disposal	9/15	1.38	1.13,1.70	<0.002†
	<6, 8-24 months	Diarrhoea on stunting	93/339	1.53	1.19,1.96	<0.001†
Tomkins et al 1988 Malumfashi, Nigeria	From 6 up to 48 months	Water supply on children's nutrition status	*	*	*	<0.05

Note: List of the result summaries abstracted from the 15 studies [17-31] with population 33, 332 children. The * indicate unavailable data. The first column indicates authors and study settings, the second: the age when children were enrolled and assessments were done and then end of study times. The third: indicate interventions/outcomes of interest. The fourth: the sample sizes; the fifth: the Odd or Risk ratios; the sixth column indicate the 95% CI and the last one indicate the p-values. For some studies that appear brief – there was no enough data from such studies (e.g. Tomkins et al 1988 [31].

5.3 Growth faltering: Wasting and Stunting

All 15 studies [17-31] took into consideration anthropometry of conditions of being wasted and also being stunted (refer to table 4.0]. The following is a summary of evidence from our 15 included studies:

Berkman et al 2002 [17] examined 239 infants and children of Pampas de san Juan (Peru – Latin America) from birth up to 9 years. They investigated effects of diarrhoeal and parasitic infections during infancy and childhood on linear growth and cognition of children. Using the weight-for-height and length-for-age anthropometric measurements: they observed that stunting in infancy contribute to losses of cognition in later childhood with RR=-0.6 95% CI -3, 0.1 p-value < 0.162. When stunting was ≥ -2 Z score value, 105 children indicated RR= -4.2, 95% CI -8.0, -4.0 p-value < 0.032. Those that had stunted in the 0-5 months (n=6) of infancy indicated RR= -0.1 95% CI -9.5, 9.3 p-value < 0.983. Those within 6-11 months (n=18) of stunting indicated RR= -2.0 95% CI -7.3, 3.3 p-value < 0.458. Those within 12-17 months (n=18) of stunting indicated RR= -6.5 95% CI -11.6, -1.4 p-value < 0.014. Children within ≥ 18 months (n=4) of stunting indicated RR= 0.8 95% CI –9.4, 10.9 p-value < 0.882. While children that had stunted between 6-17 months (n=36) showed a RR= -4.3, 95% CI -8.3, -0.5 p value < 0.031. On persistent of stunting they compared the rest to those that had never stunted (n=91) and had the following results: (1) persistently stunted n=19, RR=-4.6, 95% CI -9.7, 0.5 p-value < 0.077. (2) With a 'catch-up' growth: n=27, RR=--2.1, 95% CI –6.5, 2.3 p-value < 0.347. (3) Late incident stunted n=6, RR=5.4, 95% CI –2.9, 13.7 p-value < 0.200. On severity of stunting they compared the rest to those that had never had severe stunting (n=133) and had the following results: (1) moderately severely stunted n=5, RR= 0.1, 95% CI -10.7, 10.9, p-value < 0.989. (2) Severely stunted n=10, RR= -10.0, 95% CI -17.5, -2.4, p-value < 0.011. On diarrhoeal prevalence on cognition loss -they compared n=143 children and yielded the following results: (1) 0-5 infancy months of diarrhoeal n=143, RR= -0.2, 95% CI -8, 0.4, p-value < 0.530. (2) 6-11 childhood months of diarrhoeal n=142, RR= 0.3, 95% CI -0.5, 1.1, p-value < 0.508. (3) 12-17 months of childhood diarrhoeal n=116, RR= -0.1, 95% CI -1.2, 1.1, p-value < 0.888. (4) ≥ 18 childhood months of diarrhoeal n=72, RR= 0.1, 95% CI -1.0, 1.1, p-value < 0.918. (5) 0-11 childhood months of diarrhoeal n=68, RR= *, 95% CI -0.9, 0.8, p-value < 0.951. On incidence of *Giardia lamblia* parasites prevalence on cognition loss -they compared n=63 children (occasional *G.lamblia* infections) and yielded the following results: (1) frequent *G.lamblia* infections infancy months n=77, RR= -0.2, 95% CI -1.4, 0.2, p-value < 0.039. These authors concluded significant association between prevalence of diarrhoeal and parasitic infections on children's linear growth and the resultant loss of cognitive development. However, due to small sample size and luck of follow up in later lives of their sample size –this study failed being more credible.

Checkley et al 2004 [18] assessed impacts of water and sanitation on the health (with an emphasis on linear growth). Theirs was a cohort of 230 children of Pampas de san Juan (Peru – Latin America) and aged in the ranges of 0-35 months. Households with water sources n=743 were compared to the some sections of sample sizes and realised the following: 1) Households with cistern trucks or standpipe (n=75) had diarrhoeal episodes with RR=1.09, 95% CI 0.60, 1.98, p-value *; 2) Households with neighbourhood water sources (n=566) had diarrhoeal episodes with RR=1.21, 95% CI 0.96, 1.52, p-value *; On water storage, they compared selected HHs to 628 standard HHs with large storage facilities to: 1) medium containers (n=106), RR=1.12, 95% CI 0.60,1.96, p-value *; 2) small containers (n=653), RR=1.28, 95% CI 1.01,1.63, p-value *; On sanitary(latrines) facilities, they compared selected HHs to 567 standard HHs with latrines facilities to: 1) latrine households (n=508), RR=1.17, 95% CI 0.88,1.56, p-value *; 2) On no facility HHs (n=312), RR=1.19, 95% CI 0.89,1.6, p-value *. Children with the worst conditions for water quality and quantity and living sanitation were 1.0 cm shorter(95%CI 0.1-0.8) such a cohort of children also had 54% (95%CI -1,240) diarrhoeal morbidity that the intervention cohort. Children that came from household that had small or no water storage facilities were 28% (95%CI 1, 63) than in the control group. Children without home connection were 0.6 cm shorter (95%CI -1,-1.4) than in a cohort with home connections. Children whose households or communities had no adequate sewage disposal facilities had a height of 0.9cm (95%CI 0.2, 1.7). Better water connection (alone) also had 1.8 cm shortness as contrasted from children that had both clean water and adequate sanitary facilities. Conclusions were that: much as adequate sanitation and better quality water have a positive impact on childhood linear growth and weight gain, nevertheless - water alone or sanitation was not any beneficial in the absence of the other; and therefore suggested the need for the two interventions complementing each other in impact communities.

Checkley et al 1998 [19] assessed 253 children (age ranges of 0-24 months) on the effects of *cryptosporidium parvum* parasite infection on growth faltering and subsequent catch up growth in the later childhood of the lives of Peruvian children that lived in a shanty town of Lima Peru (Latin America). Households with sound water and hygiene were compared to sections and realised the following: 1) Latrine ownership on weight gain (n=*) had weight gains with RR=*, 95% CI 3.73, 8.75, p-value *. 2) Water quantity on linear growth (n=*) had increases with RR= 1.22, 95% CI 0.16, 0.84, p-value *. 3) Water quantity on weight gain (n=*) had gains with RR= *, 95% CI 0.003, 0.041, p-value *. Their conclusions were that children infected with *cryptosporidium parvum* experienced weight and linear growth faltering as early as the first onset of the parasites. However, children infected after a 6 months of their birth experienced a catch up growth, but those that fell victims to these parasites before the age of 6 months exhibited an average growth deficit of 0.95 cm, 95%CI 0.46,1.53 (when contrasted to the non infected ones or those that got infected after the age of 6 months. A re-infection of the already stunted children also indicated failure for catch up growth with a height deficit of 1.05 cm (95% CI 0.46, 1.66) in relation to the non infected ones or first time stunted ones. Their results confirmed that *cryptosporidium parvum* has a permanent adverse impact on linear growth especially when acquired before the ages of 6 months and also when infection takes place after a current or previous stunting.

Esrey et al 1992 [20] reported a prospective and retrospective cohort study from Lesotho (sub-Saharan Africa). Theirs was a study of complementary effects of latrines and increased or variation of water usage (in combination and individually) on linear growth and weight gain of 119 children aged between 0-12 and ≤24 months of age. Potential confounders were considered and controlled for. There results confirmed that the combined interaction between the two interventions were significant (water quantity and latrines on weight gain: p-value=0.007, and on liner growth: p-value=0.006). Increased weight or length gains were discovered in children whose households possessed latrines and also increased usage of water especially in the wet and warm seasons. In a complimentary effect of the two interventions, infants increased their weights and length with 1.031kg (95% CI 0.42, 1.642) and 2.028kg (95% CI 0.523, 3.533). When water use was increased as contrasted to when not; study findings indicated 0.105kg (95% CI -0.175, 0.385) more gain in weight and -0.309cm (95% CI -1.005, 0.387) more length in the absence of latrine ownership. When both interventions were in operation, infants showed a weight gain of 1.106kg (95% CI 0.484, 1.728) and length increase of 2.076 cm (95% CI -0.559, 3.593). With water alone, the difference between latrine possession had the effect of diverting the weight to 0.180kg (95% CI -0.093, 0.453) and -0.261 cm (95% CI -0.951, 0.429). With such overwhelming evidence, authors concluded that water programs must be considering usage of more quantities of water for personal hygiene and also sanitation programs should hand in hand with water programs to enhance hygiene and sanitation for improved health in children of Lesotho.

The same authors Esrey et al 1988 [21] back in 1988 conducted a prospective cohort study of 247 children (125 intervention group, 122 control group); and examined growth and morbidity of children on exclusive and non-exclusive usage of drinking water. They examined children in the ages of ≤60 months in the 10 villages of rural Lesotho and results indicated that children whose households relied exclusively on new water supplies had grown 0.438 cm (RR=1.74, 95% CI 0.494, 0.842, p-value *) and 0.235kg more (RR=1.462, 95% CI 0.000, 0.924, p-value * ; 6 months period of observation) than those that relied on traditional sources. These authors observed a great change in children ≥12 months than those < 12 months of age. These authors concluded that improved drinking water sources have greater benefits on pre-school children and especially when such water is 'exclusively' being used in children's homes. However this study fell short of tangible statistics (odd ratios and confidence intervals) to quantify their evidence. However, despite not having vital statistics of OR, RR and CI – this started verified the importance of water and sanitation on childhood growth.

Gupta et al 2007 [23] reported associations between early introductions of water and complementary foods (CPs) and the resultant childhood nutritional status in northern Nigeria. These authors conducted a prospective and retrospective study design and studied 374 children aged between 0-6 and 23 months old. They assessed behaviours and knowledge of mothers of 374 infants through individual interviews. They introduced water to 85% of the target population which was also fed with 62% of CPs prior to 6 months. Results indicated 16% were clinically and significantly stunted (height-for-age Z score ≤ 2) and wasted (weight-for-height Z score ≤ 2). However the design failed to indicate significant associations between stunting or wasting and water introduction at ages < 3 months WHZ: OR=0.99, 95% CI 0.46, -2.14, *p*-value = 0.97; HAZ: 0.68, 95% CI 0.34, -1.36, p-value=0.3. Results were the same even after introduction of CFs at ages < 6 months: (WHZ: 0.81, 95% CI 0.46,-1.42, p-value=0.5; and HAZ: 0.79, 95% CI 0.46, 1.35, p-value=0.4. This study, nevertheless, managed to find a significant association between wasting and male children and age specific infants of a close by *Guede* community on aspects of drinking river or pond water and large family sizes. These authors concluded that early introduction of water and CFs to infants is not any associated to increased chances of malnutrition in children of northern Nigeria and also acknowledged possibilities of reverse causality. However, the same authors indicated that water is a vital element of children's proper growth and developmental activities.

In a cross-sectional (initial study termed ''phase 1'') and the resulting longitudinal follow up study (phase 2) done in Imo state of Nigeria – sub-Saharan Africa: Huttly et al 1990 [24] investigated the effects that Guinea worm parasites also known as *dracunculus medinensis* (causing *dracunculiasis* parasitic disease) on nutrition status of 935 children (intervention) and 470 (control) children with an age range of ≤6months, ≥6months and 48 months (phase 1 study); then made a follow up study on the same children at ages of 5-14 years. Data was collected through repeated cross-sectional surveys and results indicated a low level of *dracunculus medinensis* endemicity. There was not significant demonstration of impact from point or period prevalence rates (cross-sectional study). However, a prospective longitudinal design that followed up indicated significant impacts of the parasitic infections on the growth and development of 970 children (intervention group). The control group had no any measurable or observable impacts. Cross-sectional results indicated that children drinking (exclusively) borehole water had reduced occurrences of stunting and weigh loss impacts and therefore -authors suggested a significant association of exclusive water availability (and usage) to good childhood growth. They also mentioned that water quality alone is not a necessary contributor to childhood health as evidenced from 3 fold declines in stunting and wasting OR=2.91, 95% CI (1.39,6.09); (<80% weight-for-height & length or height-for-age) (water and sanitation); Though no statistically significant, children 5-14 also indicated a 3fold decline in impact with OR=1.97,95% CI 0.58, 6.62; and for children aged 0-4 that were within 250 metres of potable water sources experienced more diarrhoea with OR=1.23, 95% CI (0.97,1.55). Proportions of children with declines of impacts due to provision of borehole water was on a stead trend in 3 intervention villages x^2 linear trend=8.83, 1 df, p-value < 0.005 as contrasted from control villages that had poor impacts of x^2 linear trend of 1.02, 1 df, p-value < 0.25. There was no observable change in children with heights or lengths below 90% of the referent values.

In what commenced as a cross-sectional study design and then later ended as a longitudinal study design: Kikafunda et al 1998 [25] investigated the environmental and dietary factors that impacted on childhood stunting and other categories of compromised nutritional status of children in rural communities of Uganda. They investigated 261 children aged between 0-30 months (cross-sectional) then 30-60 months (longitudinal) using a multistage random sampling. Health status of children was inquired through questionnaires to mothers of the 261 children and weight, supine length, and mid-upper arm circumference (MUAC) was instituted. Salter scales were used to the nearest 0.1kg using standardised Salter scale Spring Balance (Salter Weight Tronix Ltd, West Bromwich, West Midlands UK). Short infants/height measuring boards, to the nearest cm – were used for supine length. Results indicated a larger minority of children (21.5%) severely malnourished. 57% had marasmic conditions p-value=0.43 and 3.8% kwashiorkor p-value=0.19. Low MUAC, stunting and underweight was at 21.6%, 23.8% and 24.1% respectively, overall p-value

< 0.001. In their conclusion: rural living that comprised of poor sanitation, personal hygiene and use of unprotected water sources – were all incriminated.

In a large prospective cohort study of 25,483 children, age ranges 6-72 months; implemented in Crezira Region of Sudan; Merchant et al 2003 [26] examined the association between household water and sanitation and the chances of stunting and then reversal of stunting. Their mean height-for-age Z-scores were baseline and end of the trial were: -1.66 (water cohort) and -1.55 (sanitation cohort), and -2.03 (non-water cohort) and -1.94 (non-sanitation cohort) after adjustments for age and other potential confounders. Results indicated the following: In children with normal baseline height-for-age, risk for stunting (height-for-age z-score < -2 were lowest in those that had their homes (exclusively) connected with water and sanitation (multivariate RR=0.79, 95% CI 0.69, 0.90 than not. For stunted children at baseline, the ones from homes that had water and sanitation had 17% chances of reversing stunting (adjusted RR=1.17, 95% CI 0.99-1.38) than those that never had such facilities. This also exonerated the importance of water and sanitation in childhood physical growth. However this large cohort failed short of detecting a synergistic linkage between an access to water and living sanitation; but concluded that water and sanitation are associated with improved growth in children aged 6-72 months.

Moor et al 2001 [27] reported long-term linear growth impacts from their prospective and retrospective cohort study that examined children aged 0-84 months; using anthropometrics and diarrhoeal surveillance. These authors studied 493 children from Fortaleza, Brazil (Latin America) and discovered that diarrhoeal episodes at ages 0-2 years were strongly correlated with growth faltering at ages 2-7 years; even when infancy nutritional status was controlled. The average 9.1 episodes of diarrhoea (before age of 2) was strongly linked with height decrease of 3.6 cm, 95% CI 0.6, 6.6 at ages of 7. Early helminthic infections were also associated with a further decrease in height of: 4.6 cm, 95% CI 0.8, 7.9 cm - indicating that water and sanitation are a necessary component of childhood linear growth. These authors concluded that early childhood diarrhoeal diseases and helminthiases (independent of each other) are associated with tremendous growth shortfalls that continue to be manifested at ages of 6 and thereafter.

In the investigating the relationship between different environmental variables, diarrhoeal and growth of children aged 0-24 months; Pickering et al 1985 [28] studied 493 children of Gambia in the western part of sub-Saharan Africa. These authors observed 273 children for diarrhoeal morbidity over a period of 15 months (wet season) and again a further 322 more, recording their anthropometric measurements as well. Computer analyses revealed 30 children with no diarrhoeal and a further 30 with diarrhoea in more than 24% of the time. End of study results were compared with the National Centre for Health Statistics standards of height-for-age and other variables and a statistical significance was observed: indicating childhood growth being a direct effect of good water and sanitation.

Roland et al 1985 [29] reported data from a prospective cohort study done in a rural place of Banjul of Gambia in the western part of sub-Saharan Africa. They examined the impacts of water and sanitary related infections on the growth of 126 Gambian children aged between 0-36 months. Their Findings indicated that diarrhoeal diseases like *enterotoxigenic Escherichia coli* (ETEC) had a direct impact on the growth of infants, especially on weight faltering. In Benghazi and Tripoli, Libya Taguri et al 2009 [30] conducted a cross-sectional and some longitudinal follow up studies on a cohort of 4549 children. They investigated major predictors of stunting in children aged < 5 years from 6707 poor households. Logistic regressions were used in bivariate and multivariate analyses to identify individual causes of stunting. Results indicated the following: Children that used filtered water were less stunted: OR=8.45, 95% CI 2.31, 30.95(use of filtered water); OR=13.81, 95% CI 2.33,81.72 (environmental sanitation/garbage in the surroundings); diarrhoeal causes: OR=1.58, 95% CI 1.09, 2.99. Protective factors included hygienic water storage: OR=0.70, 95% CI 0.54,0.90 and had a 20% overall cause of stunting. These authors concluded that ages of 1-3 are so crucial for childhood growth and hence clean water supply and sanitation would be of better value. Tompkins et al 1978 [31] conducted a cross-sectional and longitudinal follow up study of children aged 6-48 months old; assessing linkages between water provision and childhood nutrition statuses. Increased levels of protein energy malnutrition (PEM) resulted from gastro-enteritis. Scanty and unprotected water sources had compromised weights-for-height (<80%) anthropometry in 37.9% of study population. Children with protected water sources had just 10.2% stinging of < 90% height-for-age. All such findings highlighted the necessity of water in childhood growth and hence the need to make such interventions available in localities.

5.4 Catch up growth

Classified as an incident of 'being stunted or wasted in infancy but not being stunted or wasted anymore in later childhood': 5 studies mentioned catch up growth [18, 26, 27, 28, 29] (refer to table 2 and 4) Four of these were prospective cohorts and only one was both prospective and retrospective in nature. Checkley et al 2004 [18] assessed effects of water and sanitation on the health (particularly on linear growth) on a prospective cohort of 230 children of Pampas de san Juan (Peru – Latin America); age range 0-35 months and concluded a reversal of stunting in children that were stunted less frequent in infancy and were treated to exclusive use of improved drinking water and improved sanitation: a height of 0.9cm (95%CI 0.2, 1.7) more than the ones that continued being treated to traditional water sources. Merchant et al 2003 [26] with a study of 25,483 children, age ranges 6-72 months; implemented in Crezira Region of Sudan; examined the association between household water and sanitation and the chances of stunting and then reversal of stunting. Their mean height-for-age Z-scores baseline and end of the trial were: -1.66 (water cohort) and -1.55 (sanitation cohort), and -2.03 (non-water cohort) and -1.94 (non-sanitation cohort) after adjustments for age and other potential confounders. Results indicated the following: In children with normal baseline height-for-age, risk for stunting (height-for-age z-score < -2 were lowest in those that had their homes exclusively connected with water and sanitation (multivariate RR=0.79, 95% CI 0.69, 0.90 than not. For stunted children at baseline, the ones from homes that had water and sanitation had 17% chances of reversing stunting (adjusted RR=1.17, 95% CI 0.99-1.38) than those that never had such facilities. However this large cohort failed short of detecting a synergistic linkage between an access to water and living sanitation; but concluded that water and sanitation are associated with improved growth in children aged 6-72 months. Moor et al 2001 [27] reported long-term linear growth impacts from their prospective and retrospective cohort study, examining children aged 0-84 months. They studied 493 children from Fortaleza, Brazil (Latin America) and discovered that diarrhoeal episodes at ages 0-2 years were strongly correlated with growth faltering at ages 2-7 years; even when infancy nutritional status was controlled. The average 9.1 episodes of diarrhoea (before age of 2) was strongly linked height decrease of: 3.6 cm, 95% CI 0.6, 6.6 at ages of 7. Early helminthic infections were also associated with a further decrease in height of: 4.6 cm, 95% CI 0.8, 7.9 cm. They concluded that early childhood diarrhoeal diseases and helminthiases (independent of each other) are associated with tremendous growth shortfalls that continue to be manifested at ages of 6 and thereafter. Pickering et al 1985 [28] studied 493 children of Gambia (sub-Saharan Africa) and observed 273 children for diarrhoeal morbidity (wet season) and again a 322 furthermore. Computer analyses were done. End of study results were compared with the National Centre for Health Statistics standards of height-for-age and other variables and a statistical significance was observed: reversal of stunting was evidenced from those that were treated to improved water supplies and sanitation. Children that originated from household with no latrines were still stunted and wasted at end of the study. Roland et al 1985 [29] reported data from a prospective cohort study of 126 children (0-36 months age range); done in Banjul, a rural township of Gambia (sub-Saharan Africa) and examined impacts of water, sanitary and related infections on childhood growth. However their findings had yielded insufficient evidence to prove catch up growth.

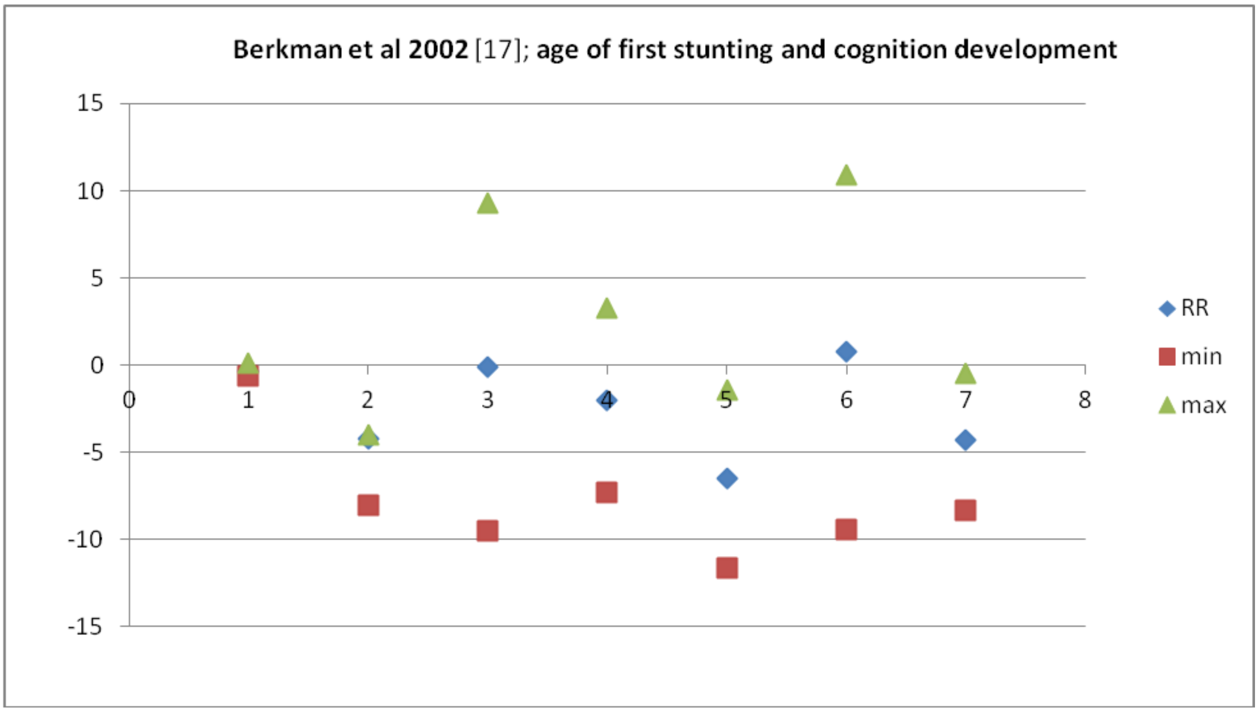
5.5 Physical fitness

Defined as ''any bodily movement produced by skeletal muscles that demands substantial energy expenditure'', and an indicator of good health and nutrition in children. Of the 15 included studies, only Guerrant et al 1999 [22] reported on physical fitness of children. Guerrant and others [22] studied a prospective and retrospective cohort of 26 children (aged 0-9 years) in a poor urban community of Fortaleza (north-eastern Brazil – Latin America). They established existing associations between early childhood diarrhoea and (between ages of 0-2) and *cryptosporidium parvum* infections on impairment of physical fitness and also cognitive deficit in the same cohort in later childhood (7-9 years). They used Harvard Step Tests, controlled for other confounders like muscle area effects, intestinal helminths, anaemia, and other potential confounders and confirmed an association between diarrhoeal occurrence at 0-2 years with reduced physical fitness at 6-9 years of age (p-value=0.03). *Cryptosporidium parvum,* and diarrhoeal infections, in early infancy strongly correlated with reductions in physical fitness; even when other nutritional status confounders were controlled. The authors concluded that early childhood diarrhoea and (between ages of 0-2) and *cryptosporidial* morbidity leads to impairment of physical fitness and subsequent global disability adjusted life years; and as such recommended concerted efforts in water and sanitation programming.

5.6 Growth faltering on Cognitive development

Cognition development is defined as 'a developmental process through which an infant becomes an intelligent person, acquiring knowledge with growth and improving his or her ability to think, learn, reason, and abstract information''. Of the 15 included studies, only 3 [17, 18, 22] mentioned the children's cognitive developmental impacts of sanitary infections. Berkman et al 2002 [17] examined 239 infants and children of Pampas de san Juan (Peru – Latin America) in the ages of 0-2 and then 2-9 years. These authors learnt the effects of diarrhoeal and parasitic infections during infancy on linear growth and cognition of later childhood. Using the Wechsler intelligence scale for children-revised (WISC-R: standardised on 2,200 children and possessing outstanding psychometric properties, with reliability coefficient (RC) of 0.96; standard error (SE) measurement of 3.19; test &re-test stability constant of 0.95) Weschler D [65] – translated into Spanish (for local hospitals): the authors examined cognition development at ages of 7-9. 6 well trained psychology interns under the supervision of a licensed psychologist from the Department of psychology of the *Hospital Nacional Hopolito Unanue* (Lima, Peru) conducted the examinations. Blinding on nutritional status of children was instituted to get rid of possible biases. Confounders like maternal age, school background, school type and class sizes and others were taken care of. Validity studies with intelligence tests, receptive vocabulary, peer achievements and school performance and grades yielding concurrent validity coefficients from the upper part of 0.30s to low 0.80s. Results indicated that children that had persistent stunting in infancy also scored low in WISC-R cognitive tests than those that never stunted in infancy or first 2 years of life. Children that were not stunted had the best scores, and those that had undergone a moderate stunting in infancy also had mild WISC-R scores as contrasted to the severely stunted cohort. *Cryptosporidium parvum & Giladia lamblia* were strongly associated with cognitive deficits and low scales in the WISC-R scores (Refer to table 4.0). Checkley et al 2004 [18] also assessed effects of water and sanitation on the health (with an emphasis on cognition) on a prospective cohort of 230 children of Pampas de san Juan (Peru – Latin America, aged in the ranges of 0-35 months. Results from Berkman et al 2002 [17] also indicated poorer academic performance and increased difficulties with school related activities. Guerrant and others [22] studied a prospective and retrospective cohort of 26 children (aged 0-9 years) in a poor urban community of Fortaleza (north-eastern Brazil – Latin America). They also confirmed a significant association between early childhood diarrhoea and (between ages of 0-2) and *cryptosporidium parvum* infections on impairment of cognitive development in later childhood (7-9 years) of 26 children. However, due to smallness in sample size, this study failed identifying independent effects of diarrhoeal and intestinal *helminthic* parasites, bacterial and viral *entero-pathogens* on severity of cognitive development.

Figure 4.0: Portraying findings of Berkman et al for ages of first stunting on cognitions: showing the variation of the minimum and maximum values of the values of age specific stunting stages and the cognition



5.7 Quality Assessment of Included Studies

We used Wells et al Checklist and guidelines to assess quality in prognostic studies [59]. We conducted a quality assessment of the included studies (refer to table 3 and 4, and appendix 2 and 3). The following is a documentation of the methodological findings:

5.8 Study designs and sample sizes: 5 prospective and retrospective cohort studies had used already existing study designs: 17, 24, 25, 30, 31 [refer to table 2.0]. Of the 5 studies, only 3 [17, 24, 30] had fully documented quality assessments of their original study designs. The 5 studies also defined later childhood growth and developmental outcomes basing from existing data of their initial study designs than being resolute designs. Almost all the 15 studies never had substantial losses to follow ups, despite the fact that loss to follow-up and missing data are inherent concerns in prospective and longitudinal cohort studies. However, 1 study [22] had a very limited sample size of 26 and also lacked a comparison group. While some specific studies never mentioned the control groups openly, 1 other study [31] did not have even mention the sample size they had; despite of good literature it possessed on water and sanitation and childhood growth and development. Of the 15 studies: 5 were prospective cohorts [18, 21, 26, 28, 29]; 3 retrospective and prospective cohorts; 1 retrospective and prospective cohort and longitudinal design [1]; 1 cross-sectional design [23]; and 5 cross-sectional and longitudinal in nature [17, 24, 25, 30, 31].

5.9 Use of standardised Outcomes: Except for Pickering et al 1985[28], all the 14 studies used standardized health outcome measurements such as cognition development examination, length and weight gains, physical fitness and catch up growth. Almost all studies mentioned it when there were some missing data or losses to follow ups. Studies that had talked of cognition [1, 2, 6] also highlighted WISC-R scores coding and also authors highlighted subjective nature of diagnosis and the potential for confounders like parental educational background and other social factors. However, some studies [29, 30] lacked intensive rigour as evidenced from the non-exhaustiveness of their findings; possibly due to limited resources.

CHAPTER SIX: DISCUSSIONS

6.1 DISCUSSION

From across the reviewed studies - we have observed that quality of provision for improved water and sanitation has distinct implications for both children, especially in infancy. Many of the illnesses related to inadequate water sanitation provision and contact with excreta affect children more adversely than adults. This may be explained, partly through, a function of children's behaviours: the fact that children are in frequently in closer contact with the ground and have less appreciation of sanitation and hygiene and needs increased volumes and quality of water. This can result in higher rates of infection. But it is also due to their relatively lower immunity to diarrhoeal pathogens that also puts their health at increased risk. Children are more frequently liable to nutritional infections and they often have higher diarrhoeal and worm burdens. Problems with water and sanitation can be exacerbated by inadequate drainage and waste removal, which also present particular challenges for children in developing countries.

We have also seen that compromised quality and quantity of drinking water and sanitary facilities significantly link with burdens of diarrhoea and intestinal infections and in turn with growth children's growth faltering. In this review Checkley et al [18] further indicated how children living in homes with no sewage or water connections and also children that stay in homes which use small water-storage containers had 54% increased occurrences of diarrhoea as contrasted from those with sewage facilities, water connections and also children coming from households that use large containers or sizable water storage vessels. Further to this, although possession of water connection -children that lacked adequate sewage connections; and children that used small water-storage containers had 1·8 cm growth deficits as contrasted from their peers in households with enough sewage connections and also who used large water storage vessels. The most distressing thing to note is that diarrhoeal infections leads to even more adverse consequence than the mere loss of physical statures and physical fitness. Findings of Checkley et al [18] also revealed a significant association between early childhood diarrhoea and intestinal infections and stunting and wasting with long-term reductions in children's cognitive development and school performance. Evidence from Berkman et al [17] and Checkley et al [19] also indicates that the mechanisms which relate to contaminated water provision and inadequate sanitation and early childhood diarrhoeal infections also lead to impaired physical growth in children. The impaired physical growth impacts on cognitive development; possibly because diarrhoeal infections involve an impairment of absorption of important micro and macro nutrients. The reason for an impaired absorption could possibly come about because of intestinal infections or inflammations during the critical windows of exposure for the affected children. We have also noted that early childhood diarrhoeal infections are the best single predictor of the Test for Nonverbal Intelligence scores (during infancy) and even in school performance (at ages 6–12 years). We also came to note that the best proxy predictor of cognitive development and school performance are height-for-age *Z* score or length-for-age z-scores < -2 and wight-for-age Z scores -during the first 24 months of birth (HAZ-2). The three measures are also anthropometric measures that best correlates with increased burdens of diarrhoea at ages 0–2 years. Findings from Checkley et al [18] and Esrey et al [20] have also strongly indicated that effects of contaminated water and poor sanitation in children's environments (on height) were at least partly independent of each other. These findings also equalled those of Huttly et al [24] that even waterborne faecal pathogens which are connected with apparently asymptomatic infection (such as *Cryptosporidium parvum*, enter aggregative *Escherichia coli* and *Giardia* spp) can equally impair children's linear growth and cognition. These findings are made more robust by the modelling which shows that income and maternal education are not associated with growth in rural community settings.

Infants and children below the age of 5 years represent an epidemiologically significant group of the world population with increased risk of morbidity and mortality and yet the degree of adverse growth and developmental outcomes in their formative years remains mostly under researched. In this review of literature from 15 studies [17-31] pertaining to early childhood growth and development on water and sanitation provision up to ages of 5 years were located. All the 15 included studies focused on infant and childhood growth and development (with water and sanitation as interventions of interest) – which highlights our population and interventions of interest in this review study. However, authors of all 15 included studies reported analogous trends of adverse early infant and late childhood growth and developmental outcomes in the study population as a whole.

In almost all the 15 studies - children were at increased risk of stunting and wasting disabilities up to the age of 5. Infants that had experienced more diarrhoea episodes and intestinal or other helminthes (*cryptosporidium parvum, entero-toxigenic Escherichia coli* (ETEC), *dracunculus medinensis)* and others indicated a poorer performance on standardized cognitive development testing, and had increased diagnoses of growth and developmental delay in comparison to infants that had been exposed to exclusive use of protected water supplies and sanitation. We have seen that children from household that had no latrines were often diarrhoeal; and in poor health and also indicated persistent stunting in infancy. Such a cohort of children also scored low in WISC-R cognitive tests than those that were never stunted in infancy or the first 2 years of life. Children that were not stunted had the best scores, and those that had undergone a moderate stunting in infancy also had mild WISC-R scores as contrasted to the severely stunted cohort. We also observed that significant cognitive development of the infant brain happens during the first 6 months of infancy; and peaks up in the next 18 months; and that there is a fourfold increase in cortical volume during the first 24 months of infancy with 35% brain weight in such a critical window of exposure: justifying an increased need for proper water provision and living sanitation interventions for proper growth and cognition of a child. It was interesting to note that 3 included studies [17, 18, 22] reported a requirement for exclusive water usage and sanitation interventions on children's cognitive development and growth, especially at 0-6 and then 6-24 months of infancy after adjustment for potential confounding factors. This further highlights the significance of 'exclusiveness' in the usage of improved water sources and sanitation facilities on early childhood growth and cognitive development.

Poor water provision or use of traditional (contaminated) water sources, and compromised living sanitation and hygiene (that are so rampant in the developing countries of the world) may contribute to adverse growth; physical health; cognitive development and school performance outcomes in later lives of the affected infants and children; and hamper the achievement of the MDGs of the affected countries. In addition, complex infant and childhood medical problems; that emanate mostly from poor water provision; lack of sanitation facilities and hygiene practices in the developing countries, may further compound and overburden the health systems of the concerned countries. It is unfortunate to note that water and sanitation interventions of developing countries continue to lag behind the required standards; as evidenced from literature of the 15 reviewed studies. Throughout this review process, none of the potentially relevant articles that identified in the developing world had mentioned the emphasis for water provision, neither its exclusiveness of usage, nor the significance of sanitation interventions on childhood growth and development. Something that was so consistent in all the 15 studies is that infants and children under the age of 5 are more are not prioritised in communities and thus have more unfavourable health outcomes than adults. From such evidence, we write to indicate that there is a need for more concerted efforts of such types of interventions for better childhood growth and developmental gains. Evidence out of the 15 reviewed studies also indicated unremitting relationship between decreasing infant ages of exposure to water and sanitation hazards and the resultant increasing risk of adverse growth and developmental outcomes in later childhoods of the concerned infants. This was true of stunted children at baseline, the ones from homes that had water and sanitation had 17% chances of reversing stunting (adjusted RR=1.17, 95% CI 0.99-1.38) than those that never had such facilities in the Sudanese study by Merchant et al 2003 [26] with a study of 25,483 children, age ranges 6-72 months. Esrey et al 1992 [20] and Kikafunda et al 1998 [25] in the discussions highlighted the complexity of prioritising water and sanitation programs in developing countries; but also mentioned their significant importance in alleviating the increasing health burdens in developing countries. Checkley et al 1998 [19] mentioned that not only would concerted efforts on water and sanitation interventions lead to improved childhood health alone, but also to global development and noted that if left uncared for, especially in the children's formative years, then such repercussions may have a negative cumulative effect on economic development. These impacts of infections from unsanitary living environments, lack of toilets for disposal of human excreta and use of traditional and contaminated water sources was more apparent in those studies relating to academic ability (school performance) and also on catch up growth. All children that suffered from diarrhoeal or helmitnths or other intestinal infections in early infancy performed less well than their peers that had been free from such illnesses and required more special education or academic support. In studies that mentioned cognition [17, 18, 22] indicated that children that were severely stunted before the age of 24 months had increased impairments on cognition. The 3 studies also indicated that children that were persistently stunted into late childhood also had considerably more likely to had reduced chances of catch-up growth. In line with cognition development, results of this review suggest that strategies to promote cognitive functioning in schools going children of the developing countries should have a focus on securing good nutrition and wellbeing of children in their earliest days of their lives.

The principal aim of this review was to gain insights of early childhood growth and development in that emanates from exclusive use of improved water sources and living sanitation on children of the developing world. Although infants were previously considered similar to adult population, emerging proof suggests existence of significant adverse growth and developmental outcomes from use of traditional contaminated water sources and insufficient living sanitation in communities of developing countries of sub-Saharan Africa, South Asia and Latin America. Evidence further indicates that longer-term growth and developmental outcomes of infancy morbidity remain a concern even for late childhoods of the affected infants and the trend continue to proliferate until the adulthoods of such cohorts. This affects the economic development of such countries and hiders the achievement of the Millennium Development Goals by 2015.

6.2 Linear growth and wasting (retardation) on cognition deficit

From the 33, 332 (plus) children examined in our 15 studies (age range 0-14); close to 39% indicated moderate or severe linear growth retardation and wasting. The prevalence was > 50% in most sub-Saharan African studies and slightly lower in Latin American studies: indicating an increased burden in sub-Saharan Africa. Possible links between linear growth faltering and poor childhood development is therefore of enormous importance to the concerned individuals, policy makers and also to the national development of the concerned countries. 5 studies from Latin America: 3 in Lima (17, 18, 19) and 2 from Brazil (22 and 27) have shown significant associations between stunting and wasting in the first 36 months of exposure to traditional water sources and households without latrines. Such growth faltering also had a wide range of second round effects like school performance and cognition in later childhood or adolescent stages of 7-14 years. In studies that mentioned cognition [17, 18 and 22]; school-performance measures included literacy levels, numerical abilities, general knowledge, maximum school grades achieved, school achievement in the girl child, and school drop-out, grade repetition, and absenteeism. Cognitive deficits were found through Intellectual Quotient testing (IQ), vocabulary development, reasoning abilities, and verbal analogies, visual-spatial and auditory working memory, sustained attention in class, and also other information processing abilities. Children that had suffered chronic exposures to water and sanitation infections performed below standard (with most of them on the lowest scale of the WISC-R scores). The report by Berkman et al 2002 [17] added to the accumulating evidence concerning the long-term impacts of exposures to sanitary infections and subsequent linear growth faltering and wasting. Berkman et al also reported that severe growth retardation (height-for-age or length-for-age <-3 SD of the National Centre for Health Statistics references) in 143 Peruvian children (between 0-24 months of age) was associated with a 10-point deficit score in Intellectual Quotient (IQ) (using the Wechsler Intelligence Scale for Children-Revised (WISC) at 7 and 9 years). With the WISC-R: as the sizes of the deficits approach 1 SD –then it's an indication of clinical importance of the cognitive deficit. Findings of Berkman [17]et al are remarkably similar to those from Checkley et al [18] (another study from the same region of Peru) and also those of Guerant et al (Brazilian study) in which 230 and 26 children (respectively), aged 7-11 years - were severely wasted and stinted in infancy and then indicated a deficit of about 10 IQ points on the WISC-R score tests. In the same study done by Checkley et al [18]- moderately stunted children (n=70) indicated a 6-point WISC-R deficit, which suggests a direct dose response association between retardation and cognition. However as the WISC-R apparatus was manufactured and standardised in the USA (and based on the US Children) the robustness of its psychometric properties might not have been the same or applicable as in Peruvian and Brazilian children. Guerant et al [22] also examined the effect of age of the onset, prevalence, and persistence of growth retardation on cognitive development and catch up growth. However, in this study it was discovered that just a few children were stunted and wasted (growth retardation) before the ages ≤ 18 months: making it impossible to classify the impacts as absolutely significant. In a much larger study (Peruvian study by Checkley et al [18] the onset of growth retardation at < 6 months of age and persistence of the retardation up to 8-9years were significantly associated with cognitive deficits at 8 -11 years. However, such impacts seemed being mediated by a certain degree of retardation in the period ≤ 24 months of age. When Checkley et al took into account severity of stunting and the early onset of growth faltering - persistence of growth faltering was no longer as significant as before. It was also noticed that stunted and wasted children have increased probabilities of acquiring infections, particularly diarrhoeal ones throughout their childhood and even thereafter. But one important finding of the Peruvian studies [17 and 18] is that the effects of growth retardation were independent of the effects of diarrhoea. However, it was surprising that studies 17 and 18 also linked *Giardia lamblia* to adverse effects on WISC-R cognitive scores, which should have been independent of the effects of diarrhoea on growth retardation.

We also discovered that it is often difficult to assume or link *Giardia lamblia* and diarrhoea as being the sole contributors to children's cognitive deficits. This might have also been the same reason why Berkman et al [17] suggested that intestinal infections like diarrhoea and *Giardia lamblia* could only be a biomarker for other environmental conditions, or possibly related to other micronutrient deficiencies and mal-absorptions. The other hypothesis we had was that chronic inflammatory response might also have impacted children's cognition functioning. The other thing that we came to note is that -much as there are many studies that established concurrent associations between diarrhoea and other intestinal infections with children's cognitive deficiencies; but just a few of such studies have managed to fully examine longitudinal associations between their incriminated factors. In this review however, we found consistent evidence about growth retarded children also being at increased risk of suffering from cognitive deficits. But we also came to discover that it may be a huge mistake attributing the entire cognition deficit to water and sanitation infection or nutrition alone. We also noted that in most observational studies – there is a common problem of failing to control for the multitude of other adverse environmental factors that are also associated with decreased IQ, growth retardation and infections. Such adverse factors can have detrimentally effect on children's cognition as well.

This can be evidenced from Berkman et al [17] who managed to control for several confounders but we discovered that still more- there were other possible confounders (such as stimulation in the home) which could account for some (or all) of the relations between children's growth retardation and water and sanitation related infections. In a randomised controlled trial growth retarded children's development benefited from 2 years of supplementation, which suggested that poor nutrition caused at least some of their developmental deficit. Some studies in this review have proved that some children who were exposed to home stimulation, improved water supplies and latrines and food supplementation had a catch up growth just like in the non-growth retarded comparison groups. However, we also noted that further benefits from food supplementation were no longer significant at 11 years of age, even though benefits from home stimulation remained as significant. Thus linear growth retardation undoubtedly represents a colossal waste of human potential (in millions) of children of the world's developing countries. We therefore suggest that there must be an urgent attention on water provision and sanitation, food supplementation and home stimulation. However, as most developing countries are resource restricted and mostly food insecure too – there might be difficulties in obtaining sustained benefits from food supplementation programs and as such this review suggests that prevention must be the main goal in improving childhood physical growth faltering and cognitive deficiencies.

6.3 Limitations and justifications

We suggest that our review of primary studies of ''water and sanitation impacts on childhood growth and development in developing countries'' - has accomplished our study objectives of recounting recent scientific evidence; practices and also making ideal recommendations for future research. Nevertheless, our work might be having some limitations and we therefore would like to encourage future debate and more research on assessing such impacts of childhood development studies. In our review, we used systematic review methods and synthesised data from published primary studies. It is worthy pointing out that our methods of identifying relevant publications may have missed out some more appropriate publications. Our rigorous search strategy yielded studies published in English language; computer database indexed journals; peer-reviewed; and those that had adequate assignment of the indicated search keywords (refer to table 1.0) and Medical Subject Heading (MeSH) terms. The 15 included studies may be of higher quality than other non-located or identified studies and published in other languages than English based journals and in non-peer reviewed journals. In our recommendations, this may not have ranked such high as we had implemented a rigorous systematic search of relevant primary research and reached a saturation point on domain generation: such that we kept on retrieving studies that we had previously found already in the earlier search categories. Thus this makes us satisfied that our 15 sampled studies were adequate and hence sanctioned us to make the conclusions we have made in this review.

It would be ideal to also acknowledge that we collected data from the 15 included studies in accordance to the way in which primary researchers had assessed the mentioned impacts in the included studies. In some studies we faced limitations on the incompleteness of reporting methodologies. Such poor study methodologies by authors of such studies may have led us to take too lightly or overestimate the extents or comprehensiveness of water and sanitation impacts on childhood growth and development.

As this systematic review is meant for academic purposes - we might have had some limitations on reaching consensus on the exhaustiveness and non-biasness of identifying study domains and even on quality assessment of included studies. It would therefore, have been more ideal to conduct a more formal consensus procedure with many reviewers on board. Nonetheless; we tried our best to make sure that the exhaustiveness and rigour in this review were similar at every step of our investigation procedure. Thus we do not believe that –even if we had more researchers on board: a more comprehensive approach would have substantially changed the noted observation in this review.

CHAPTER SEVEN: CONCLUSION

7.1 CONCLUSION

More than 50% of child morbidity and mortality in developing countries are directly or indirectly attributable to unimproved water provision and lack of sanitary facilities. When children are infected they become malnourished and their bodies' defence systems are weakened. They get sick more easily and their illnesses are more severe and detrimental. Malnourished children have less energy and curiosity, and this can also impair their mental development resulting into cognitive deficits.

Children’s interests in food often diminish when they are ill and undernourished and so such a cycle perpetuates itself. Nutritional status is also affected most by the presence of intestinal parasites. Even a relatively mild infestation can consume 10% of children’s total energy and protein intake as well as interfering with digestion and absorption. Our review has indicated nutritional status as an ultimate endpoint of water and sanitation interventions and this emphasizes an increased need of improving interventions in developing countries. This would help us achieve the WHO Millennium Declaration that mentions of decreasing the number of people without adequate water sources and sanitation facilities to half by 2015. Anthropometrics of Weight-for-age (WAZ< -2), length-for-age (LAZ < -2) and height-for-age (HAZ< -2) provide a most useful way of evaluating interventions that aim at improving childhood nutritional status. In addition to being well-standardised and easy to collect, WAZ, LAZ and WAZ anthropometrics can serve both as ideal outcome measures and also as nutritional screening tools. Unlike other measures such as number of people with access to potable water or spot or period checks of water quality or quantity, the three anthropometric measures act as best outcome measures of nutritional related morbidities (water and sanitation inclusive) in communities. As a screening tool, anthropometrics can help identify infants and children who have already had adverse consequences of early childhood diarrhoea or inadequate and/or contaminated water and sanitation provisions. In turn such children could be enrolled in intensive nutritional rehabilitation units (INRU) and other nutritional educational programmes that might help alleviate the second and third round impacts of unimproved water and sanitation provision. In addition, these children might hint problems in the current water systems and sanitation programming and health authorities can quickly investigate stunted and wasted children’s water supplies and sanitation facilities. Diarrhoea and malnutrition are almost certainly linked, and efforts to address either of the two should encompass strategies to address both. Irrespective of mechanism, stunting and wasting also indicate being readily available and affordable measurable indicators of early childhood diarrhoeal infections and as markers of inadequate or contaminated water and sanitation provision that further leads to various developmental impairments. If used in the field, this measure may help to combat the long-term consequences of bad water and sanitation

7.2 Implications for practice: Conclusions from this review have shown both short and long-term impacts of unimproved water provision and inadequate sanitation facilities on childhood health growth and development. The mentioned impacts can be detrimental as they are irreversible at certain stages or life-long (in fact: inter-generational) and even impact on children’s cognitive development. The later affects future livelihoods of children and even affect social economic status of their communities, regions and countries. Since such effects are also felt at global levels - efforts of the public health community to meet the goals of the Millennium Declaration (MDGs) will also be hampered. As such more sustainable interventions are a must (and needed) as they would help stem down the staggering costs of the mentioned impacts. As public health specialist - we must not delay investing in measures that would help alleviate the devastating short and long-term societal costs of inadequate water, poor sanitation and early childhood diarrhoeal infections. In order to respond reliably to children's growth and development requirements, their health has to be mainstreamed into the processes that affect community change programs. Responding to children's health should be a routine component of more general efforts, embedded in community health development and not added as an afterthought or allowed to fall between the cracks. Finally, diarrhoea and malnutrition are almost certainly linked, and efforts to address either of the two should encompass strategies to address both

7.3 Implications for research: It has been shown that devastating impacts of readily preventable childhood diarrheal infections (and other enteric infections or helmiths) require that we devote ourselves in breaking such vicious cycles of poor water provision and sanitation interventions; diarrheal infections; malnutrition; and impaired child development with soonest priority. This would include not only community investments in improved water quality and quantity; sanitary facilities; and health education and breastfeeding - but also new methodologies to readily available oral rehydration and nutrition therapies. Further research in such a field would also help enhance the hidden knowledge. Children are imperative investments that we can no longer afford to ignore as they are the futures of the world.

7.4 Acknowledgments: The author thanks the following people: 1) professor Michele LEGEAS: for her commendable and valuable supervision throughout the internship period; also for many useful comments on earlier drafts of this manuscript; 2) Denis Zmirou: for the guidance and comments on earlier versions of this manuscript; 3) Martine Bellanger and Dominique Maison (WHO): for comments and discussion in the design stages of the study. 4) Francois Comeraie and William Sharllow: for administrative issues. 5) Myriam Le Guichard for computerised database literature searching and retrieval; 6) all my family members in Malawi for the love, psychosocial support and many others; and 7) all my friends in Malawi, France and United Kingdom for the support they rendered in my entire study period.

7.5 Grant Support: This review was partially funded by the *Département au santé, environnement et travail (DSET)* of the Ecole des Hautes Etudes en Santé Publique (EHESP – France). Throughout the 2 year study program, Patrick Madhlopa has also been supported by the Erasmus Mandus Scholarship scheme of the European Commission.

7.6 Conflict of interest: We have no any conflict of interest to declare.

7.7 Statement vis-à-vis conflict of interest: The researcher is a master of public health student at Sheffield (United Kingdom) and EHESP Universities (France). This review was compiled as a fulfilment of academic purposes of obtaining master of Public health qualifications from the two Universities of France and United Kingdom. Thus there is no any sort of conflict of interest

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CHAPTER NINE: APPENDICES

9.1 Appendix 1.1: Search Terms

Table 5: **Search terms – detailed search terms and their combinations**

Search set	Medline	Scopus	Embase	LILACS	GOOGLE SCHOLAR
1	water	Water	water	water	water
2	Sanitation	Sanitation	Sanitation	Sanitation	Sanitation
3	hygiene	hygiene	hygiene	hygiene	hygiene
4	Latrine OR toilet OR water closet OR privy	Latrine OR toilet OR water closet OR privy	Latrine OR toilet OR water closet OR privy	Latrine OR toilet OR water closet OR privy	Latrine OR toilet OR water closet OR privy
5	Water borne				
6	diarrhoea excreta disposal	diarrhoea excreta disposal	diarrhoea excreta disposal	diarrhoea excreta disposal	diarrhoea excreta disposal
7	1 OR 2 OR 3 OR 4 OR 5 OR 6	1 OR 2 OR 3 OR 4 OR 5 OR 6	1 OR 2 OR 3 OR 4 OR 5 OR 6	1 OR 2 OR 3 OR 4 OR 5 OR 6	1 OR 2 OR 3 OR 4 OR 5 OR 6
7	Child*	Child*	Child*	Child*	Child*
8	Infants$	Infant*	Infant*	Infant*	Infant*
9	development	development	development	development	development
10	growth	growth	growth	growth	growth
11	Stunt*	Stunt*	Stunt*	Stunt*	Stunt*
12	Wast*	Wast*	Wast*	Wast*	Wast*
13	anthropometry	anthropometry	anthropometry	anthropometry	anthropometry
14	Nutriti* Undernourish*	Nutriti* Undernourish*	Nutriti* Undernourish*	Nutriti* Undernourish*	Nutriti* Undernourish*
14	dwarfing	stunting	Catch up growth	wasting	anthropometry
15	faeces OR excrement OR defecation OR waste	Solid waste management	faeces OR excrement OR defecation OR waste	faeces OR excrement OR defecation OR waste	faeces OR excrement OR defecation OR waste
16	7OR8 AND 9-15	7OR8 AND 9-15	7OR8 AND 9-15	7OR8 AND 9-15	7OR8 AND 9-15
17			((Water AND (infection* OR illness*)	Entero bacteria	
19	Chorela OR shigell$OR giardia* OR escherichia OR clostridium OR dysentr$ OR cryptosporid$ OR helminth*	Chorela OR shigell$OR giardia* OR escherichia OR clostridium OR dysentr$ OR cryptosporid$ OR helminth*	Chorela OR shigell$OR giardia* OR escherichia OR clostridium OR dysentr$ OR cryptosporid$ OR helminth*	Chorela OR shigell$OR giardia* OR escherichia OR clostridium OR dysentr$ OR cryptosporid$ OR helminth*	Chorela OR shigell$OR giardia* OR escherichia OR clostridium OR dysentr$ OR cryptosporid$ OR helminth*

9.2-3 APPENDIX 1.2(a): QUALITY ASSESSMENT TEMPLATES

NEWCASTLE - OTTAWA QUALITY ASSESSMENT SCALE

CASE CONTROL STUDIES

Note: A study can be awarded a maximum of one star for each numbered item within the Selection and Exposure categories. A maximum of two stars can be given for Comparability.

Selection

1) Is the case definition adequate?

a) yes, with independent validation

b) yes, eg record linkage or based on self reports

c) no description

2) Representativeness of the cases

a) consecutive or obviously representative series of cases

b) potential for selection biases or not stated

3) Selection of Controls

a) community controls

b) hospital controls

c) no description

4) Definition of Controls

a) no history of disease (endpoint)

b) no description of source

Comparability

1) Comparability of cases and controls on the basis of the design or analysis

a) study controls for _______________ (Select the most important factor.)

b) b) study controls for any additional factor (This criteria could be modified to indicate specific control for a second important factor.)

Exposure

1) Ascertainment of exposure

a) secure record (eg surgical records)

b) structured interview where blind to case/control status

c) interview not blinded to case/control status

d) written self report or medical record only

e) no description

2) Same method of ascertainment for cases and controls

a) yes

b) no

3) Non-Response rate

a) same rate for both groups

b) non respondents described

c) rate different and no designation

9.2-3 APPENDIX 1.2(b): QUALITY ASSESSMENT TEMPLATES

NEWCASTLE - OTTAWA QUALITY ASSESSMENT SCALE

COHORT STUDIES

Note: A study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability

Selection

1) Representativeness of the exposed cohort

a) truly representative of the average _______________ (describe) in the community

b) somewhat representative of the average ______________ in the community

c) selected group of users eg nurses, volunteers

d) no description of the derivation of the cohort

2) Selection of the non exposed cohort

a) drawn from the same community as the exposed cohort

b) drawn from a different source

c) no description of the derivation of the non exposed cohort

3) Ascertainment of exposure

a) secure record (eg surgical records)

b) structured interview

c) written self report

d) no description

4) Demonstration that outcome of interest was not present at start of study

a) yes

b) no

Comparability

1) Comparability of cohorts on the basis of the design or analysis

a) study controls for _____________ (select the most important factor)

b) b) study controls for any additional factor (This criteria could be modified to indicate specific control for a second important factor.)

Outcome

1) Assessment of outcome

a) independent blind assessment

b) record linkage

c) self report

d) no description

2) Was follow-up long enough for outcomes to occur

a) yes (select an adequate follow up period for outcome of interest)

b) no

3) Adequacy of follow up of cohorts

a) complete follow up - all subjects accounted for

b) b) subjects lost to follow up unlikely to introduce bias - small number lost - > ____ % (select an adequate %) follow up, or description provided of those lost)

c) follow up rate < ____% (select an adequate %) and no description of those lost

d) no statement

9.4 APPENDIX 1.3: REVIEW PROTOCOL

1) Review Topic: Growth and development in children of developing countries: The impacts of water, sanitation & hygiene interventions: A Systematic Review

2) Background information: Until recently no plausible biological mechanism was available to explain such observations possibly because evidence from individual studies was not as strong to justify significance of observations. In the past decades, developing countries have implemented numerous interventions focussing on childhood health. Such interventions includes: 1) portable water provision; 2) sanitation; and 3) enhancement of sound hygiene practices [1] …. Widely known as WASH; the trio have at least been significant in alleviating childhood diarrhoeal and other infectious diseases. However, the contribution they have had on childhood physical growth and development is not well known yet [1, 2]. … This prompted us to conduct this systematic review

3) Objectives: Aims of this review will include: 1) Establishing impacts of water provision (in terms of supply and quality); community and household sanitation and hygiene practices on growth and development of children of the developing countries of the world; 2) Identifying and establishing the existing web of causation for various inter-twining factors of childhood malnutrition. 3) Identifying existing research gaps and suggesting more sustainable interventions in the world of water, sanitation and hygiene promotion programming for developing countries.

4) Questions: review questions will comprise of: 1) in what ways does water quantity and quality; sanitation facilities and hygiene practices impact the nutrition statuses of children? 2) How do compromised nutritional statuses of children lead to other 'second round' health and developmental effects? 3) Are such second round effects short or long-term impacts, and what are the known repercussions of such deficiencies in children's lives and global development?

5) METHODS: Use of electronic search engines (through use of computer held databases); 2) searches of reference lists (bibliographies of relevant studies); 3) manual searches (hand searches on relevant journals relating to the subject of study); 4) and direct follow ups (contacting authors directly and also organisations implementing interventions on childhood growth and development and also water plus sanitation interventions).

6) Types of studies: Randomised Controlled Trials (RTCs – Or Quasi-randomised or non-randomised controlled trials (RCTs); Cohort studies; longitudinal and cross-sectional studies. **Types of participants: C**hildren up to the age of 14. **Interventions:** studies whose interventions were either: 1) water provision (water quality or quantity); 2) sanitation (environmental or household); and 3) hygiene practices. We categorised the different WASH interventions into 5 categories -as follows: Water quality, supply, sanitation, hygiene and multiple interventions. **Inclusion criteria:** all primary research relating to water, sanitation and hygiene and children's growth and development; English published studies; Post-1980 studies and with either Latin America, sub-Saharan African and south Asian setting. **Exclusion criteria:** all studies that failed short of meeting the mentioned criteria of inclusion. **Types of outcome measures:** 1) Primary **(**morbidity and mortality). 2) Secondary (physical growth and other relevant developmental growths).

7) Timeframe

Activity	Responsible persons	Time frame
Registration of title with University of Sheffield and ÉHESP	Patrick	February 2012
Review of protocol development	Patrick et Michele	March 2012
Searches for studies	Patrick	March-April 2012
Assessment of relevance of studies	Patrick et Michele	March 2012
Extraction of data	Patrick et Michele	March-April 2012
Statistical analysis	Patrick et Michele	April 2012
Preparation of draft report	Patrick	April 2012
Presentation of draft report at EHESP	Patrick	May 2012
Revision of draft report	Patrick et Michele	May 2012
Submission to EHESP et Sheffield University	Patrick	11th of June 2012
Viva defence	Patrick	02 July, 2012

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9.5 APPENDIX 1.4: Student Declaration (Ethical Approval from University of Sheffield) (B)

School of Health and Related Research
Research Ethics Review
for Postgraduate-Taught Students

Form 1B: Student Declaration (for research that does not involve human participation or analysis of secondary data)

To be included in Appendices of dissertation

→ **Research Thesis Title:**

Growth and Development in Children of Developing Countries: The Impacts of Water, Sanitation & Hygiene interventions - A SYSTEMATIC REVIEW

In signing this Student Declaration I am confirming that:

My research **never** **involved people participating in research as either directly** (e.g. interviews, questionnaires) **and/or indirectly** (e.g. people permitting access to data).

My thesis did not therefore require any ethics review and I had not submitted a Research Ethics Application Form – apart from this clarification

→ **Name of student:** Patrick Vitima MADHLOPA
Sheffield University (UK) & EHESP (FRANCE)

→ **Signature of student:** **Date: 06/03/2012**

→ **Name of supervisor:** professor Michele LEGEAS
(**EHESP, FRANCE**)

→ **Signature of Supervisor:** **Date: 06/03/2012**

9.5 APPENDIX 4.2: Student Declaration (Ethical Approval from University of Sheffield) (A)

School of Health and Related Research

Research Ethics Review
for Postgraduate-Taught Students

Form 1B: Student Declaration (for research that does not involve human participation or analysis of secondary data)

To be included in Appendices of dissertation

Research Project Title:

Implications of inadequate provision of water and sanitation for children's health and general development in Sub Saharan Africa: SYSTEMATIC REVIEW & META-ANALYSIS

In signing this Student Declaration I am confirming that:

My proposed project will **not involve people participating in research either directly** (e.g. interviews, questionnaires) **and/or indirectly** (e.g. people permitting access to data).

My proposed project does not therefore require an ethics review and I have not submitted a Research Ethics Application Form.

Name of student: Patrick Vitima MADHLOPA

Signature of student: Date: 06/03/2012

Name of supervisor: professor Michele LEGEAS

Signature of Supervisor: Date: 06/03/2012