CHILD LABOR AND HEALTH: A SYSTEMATIC REVIEW

INTRODUCTION

The abolition of child labor is one of the four categories of rights adopted in 1998 by the International Labor Declaration (ILO) Declaration on Fundamental Principles and Rights at Work (Convention 2005; International Labour Office 2017). Although member states are committed to respect and promote these rights, even if they have not ratified the relevant conventions, hundreds of millions of children worldwide are still involved in various types of labor (Council 2016; Office 2011). In addition, ending child labor in all its forms by 2025 is one of the targets of Sustainable Development Goal 8, to "*promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*"(Boothe 2016).

Children are known to be especially vulnerable to both harmful workplace exposures (ergonomic, chemical exposure hazards) and injuries (Fassa et al. 2000). In addition, labor imposes physical and mental strain, which the working child is likely ill-equipped to handle ─the increased caloric requirements for strenuous labor, for example, may cause malnourishment to a child. These stresses and the loss of developmental opportunities could adversely impact children into adulthood and over the life-course (Cigno and Rosati 2005). Finally, time spent working severely constrains learning and playing time (Nishijima et al. 2015; Shendell et al. 2016).

However, it may be argued that work also has some positive effects on the working child. Working children might learn adaptation strategies that increase their resilience, which can help them cope better with adverse situations (Blair 1992). The skills they acquire in the work place may also give them an advantage over non-working children in later life. Additionally, the income from a working child may improve his or her nutritional status and overall health, and may confer health benefits to other family members as well (Genicot 2005). Finally, work and schooling are not mutually exclusive. Some policies allow certain types and quantities of work (Center 2017). Therefore, there is a lack of clarity in the overall relation between child labor and health.

Considering that child labor is more prevalent in developing countries(Council 2016) and that an expected health dividend from the elimination of child work is one of the major drivers of international efforts to intervene at the policy level, there is the need for a clearer understanding of how child work relates to health. This review synthesizes the available knowledge from the past two decades of research into the relationship between child labor and health in low- and middle-income countries (LMICs), identifies unexplored areas and discusses general limits of published evidence. The selected health outcomes are injuries (work-related and otherwise), nutritional outcomes (anemia, wasting and stunting) and conditions due to workplace toxic exposures (including exposure to loud noise, dust, extreme cold or heat, chemical, biological and radiation exposures). These outcomes are most commonly hypothesized to be the immediate (injuries and harmful exposures), and the long-term effects (nutritional status) of child labor (Parker 1997).

METHODS

The study protocol was registered in PROSPERO and it is available at (http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42016041317). We completed a systematic review following a registered protocol and PRISMA guidelines (**appendix 1**) (Moher et al. 2009). The search strategy was designed with the help of a professional librarian to favour sensitivity over specificity in an effort to be as comprehensive as possible (**appendix 2**). Four indexing and abstracting services (EMBASE, MEDLINE, Scopus, and ISI Web of Science) were searched in November 2017. All articles, without restrictions on language, were considered for inclusion. Manual searches for additional eligible studies were performed by reviewing the reference lists of included studies. **Figure 1** summarizes our literature search.

The population of interest for this review was all children under 18 years in LMICs, classified according to the World Bank Data Catalogue (WorldBank 2016).

The exposure was child labor, defined as paid or unpaid economic activity by children under 18 years of age either for family or outside the home (ILO 2011). The outcomes included were: injuries, nutritional outcomes (e.g. anemia, malnutrition, wasting, stunting, weight-for height), and harmful workplace exposures (e.g. chemical toxins, excessive heat/cold, physical risks such as working with heavy machinery without adequate protective measures). We included studies published since January 1996 that (1) described the incidence or prevalence of these outcomes among working children or (2) examined the association between child labor and these outcomes by including an unexposed control group. Studies were excluded if entirely qualitative, or if they only examined the prevalence of child work.

Data Extraction

Two investigators (BLBK and OO) independently reviewed titles and abstracts and applied the inclusion and exclusion criteria to select studies for full-text review. Discrepancies were resolved by consensus between all research collaborators. The following information was extracted for each study included during the full-text review: reference, country of study, study design, description of study, year of study, sample size, age range, exposure (including nature of child work studied), outcome (including details of units of measurement), covariates adjusted for, effect measures for each outcome as reported (captured separately for each outcome of interest), and subgroup analyses. Study quality was assessed using the Newcastle-Ottawa Scale which provides a quantitative measure of study quality based on study characteristics (Wells et al. 2011).

RESULTS

A total of 1090 citations were initially identified by the search strategy. Among the 153 articles selected for full text review, 64 satisfied our inclusion criteria. An additional 14 articles were added after reviewing the references of included articles. In total, 78 articles were extracted **(Figure 1)**.

Most studies were conducted in Asia and South America, with a fifth coming from India alone. 74 studies were conducted in individual countries **(Figure 2)** and four studies included more than one country. 38% of studies estimated the prevalence of at least one of the health outcomes **(Amiri et al. 2014; Ansari et al. 2015; Ayelo et al. 2013; Baig et al. 2005; Banerjee et al. 2008; Baron 2005; Beegle et al. 2009; Caglayan et al. 2010; Chandrashree 2014; Dalal et al. 2016; DM Satpathy 2005; El-Gilany et al. 2007; Elci et al. 2007; Gol 2016; Hawamdeh and Spencer 2003a; Hawamdeh and Spencer 2003b; Hawamdeh et al. 2001; Javed et al. 2013; Kana et al. 2010; Khan et al. 2007; Miquilin Ide et al. 2015; Nicolella et al. 2008; Oviedo-Trespalacios et al. 2013; Pinzon-Rondon et al. 2009; Roggero et al. 2007; Saha and Sadhu 2014; Tiwari et al. 2004; Vasconcelos et al. 2010; Zainab and Kadir ; Zaki et al.**

1998), 42% had at least one control group of non-working childrenand examined the association between child work and health **(Ahmed and Ray 2014; Ambadekar et al. 1999; Athanasiadou et al. 2008; Awan et al. 2010; Basema et al. 2003; Bose-O'Reilly et al. 2008; Cortez et al. 2007; Cuadra et al. 2007a; Cuadra et al. 2007b; Cuadra et al. 2009; Cuadra et al. 2006; Daga 2000; Das et al. 2011; Das et al. 2013; Doocy et al. 2007; Duyar and Ozener 2005; Etiler et al. 2011; Fassa et al. 2005; Furman and Laleli 2000; Graves et al. 2014; Hawamdeh and Spencer 2002; Hincapie 2007; Joshi et al. 1996; Junaid et al. 2017; Laraqui et al. 2000; Nuwayhid et al. 2005; Omokhodion and Omokhodion 2004; Saddik et al. 2005; Singhal et al. 2006; Sughis et al. 2012; Sughis et al. 2014; Tiwari 2013; Tiwari et al. 2009)**, and 20% compared outcomes across different types of work **(Aktas and Esin ; Carmen et al. 2003; Castro et al. 2005; Castro and Hunting 2013; Dey 2008; Esin et al. 2005; Fischer et al. 2003; French 2010; Gargy et al. 2011; Harari et al. 1997; Jildeh et al. 2014; Mohan et al. 2015; O'Donnell et al. 2005; Schlick et al. 2014).** A roughly equal proportion of studies examined each of the health outcome categories: 26% for nutritional status **(Ambadekar et al. 1999; Ansari et al. 2015; Banerjee et al. 2008; Beegle et al. 2009; Chandrashree 2014; Cortez et al. 2007; Daga 2000; Duyar and Ozener 2005; Etiler et al. 2011; Gross et al. 1996; Hawamdeh and Spencer 2002; Hawamdeh and Spencer 2003a; Hawamdeh and Spencer 2003b; Hawamdeh et al. 2001; Hincapie 2007; Kana et al. 2010; Mohan et al. 2015; Nicolella et al. 2008; O'Donnell et al. 2005; Roggero et al. 2007)**, 28% for injuries **(Ahmed and Ray 2014; Amiri et al. 2014; Ayelo et al. 2013; Baron 2005; Carmen et al. 2003; Castro et al. 2005; Castro and Hunting 2013; Cuadra et al. 2007b; Dalal et al. 2016; Dey 2008; El-Gilany et al. 2007; Fassa et al. 2005; Fischer et al. 2003; Graves et al. 2014; Javed et al. 2013; Jildeh et al. 2014; Khan et al. 2007; Pinzon-Rondon et al. 2009; Saha and Sadhu**

2014; Schlick et al. 2014; Tiwari et al. 2004; Vasconcelos et al. 2010), and 30% for harmful exposures **(Aktas and Esin ; Athanasiadou et al. 2008; Baig et al. 2005; Basema et al. 2003; Bose-O'Reilly et al. 2008; Cuadra et al. 2007b; Cuadra et al. 2009; Cuadra et al. 2006; Das et al. 2011; Elci et al. 2007; Esin et al. 2005; French 2010; Furman and Laleli 2000; Gargy et al. 2011; Harari et al. 1997; Junaid et al. 2017; Oviedo-Trespalacios et al. 2013; Saddik et al. 2005; Singhal et al. 2006; Sughis et al. 2012; Sughis et al. 2014; Tiwari 2013; Tiwari et al. 2009; Zaki et al. 1998).** The remaining studies **(Awan et al. 2010; Caglayan et al. 2010; Das et al. 2013; DM Satpathy 2005; Doocy et al. 2007; Gol 2016; Joshi et al. 1996; Laraqui et al. 2000; Miquilin Ide et al. 2015; Nuwayhid et al. 2005; Omokhodion and Omokhodion 2004; Zainab and Kadir)** examined more than one of these three outcome categories **(Table 1)**.

Nutritional Outcomes

Nutritional status was mostly assessed by height for age, weight for age, presence of anemia, and body mass index (BMI). Fourteen studies had a control group of non-working children **(Ambadekar et al. 1999; Awan et al. 2010; Das et al. 2013; Doocy et al. 2007; Duyar and Ozener 2005; Etiler et al. 2011; Hawamdeh and Spencer 2002; Hawamdeh and Spencer 2003b; Hincapie 2007; Joshi et al. 1996; Laraqui et al. 2000; Miquilin Ide et al. 2015; Nicolella et al. 2008; O'Donnell et al. 2005; Omokhodion and Omokhodion 2004)** and examined the relation between child work and nutrition. Only four studies had a longitudinal design **(Beegle et al. 2009; Laraqui et al. 2000; Nicolella et al. 2008; O'Donnell et al. 2005).**

Generally, studies found associations between child labor and poorer nutritional status. On average, child workers had lower weight and height for age **(Ambadekar et al. 1999; Chandrashree 2014; Cortez et al. 2007; Duyar and Ozener 2005; Gross et al. 1996;**

Hawamdeh and Spencer 2003a; Roggero et al. 2007), compared to non-working children or a reference population (commonly those of the United Kingdom or the National Center for Health Statistics in the United States). Packed cell volume was found to be below the threshold of anemia (35%) in Jordanian working boys **(Hawamdeh and Spencer 2003a; Hawamdeh et al. 2001)**, with working boys having lower values than their non-working siblings **(Hawamdeh and Spencer 2002).**

The relation between child work and nutrition may be non-linear; in a study from rural Cambodia, there was an inverse U-shaped association between the numbers of hours of labor and nutritional status **(Kana et al. 2010)**.This suggests that health status improves if the working hours of children is shorter than the turning point, which was around 18 hours/week. One study in rural Vietnam found that children engaged in paid work were heavier than their peers either working only for the household or not at all **(O'Donnell et al. 2005).** The association may also vary depending on the type of work; a study from Durg District in India showed that children engaged in sedentary work were significantly taller than children engaged in heavy work (Mohan et al. 2015). Few studies reported a relation between child labor and BMI **(appendix 3)**.

The cross-sectional design, small sample size and lack of covariate adjustment in half of the studies included were the major limitations to the interpretation of these findings.

Injuries

Almost all studies investigated nonfatal injuries. One-half of studies described the prevalence or incidence of injury among working children **(Amiri et al. 2014; Ayelo et al. 2013; Baron 2005; Caglayan et al. 2010; Dalal et al. 2016; DM Satpathy 2005; El-Gilany et al. 2007; Javed et al. 2013; Khan et al. 2007; Miquilin Ide et al. 2015; Pinzon-Rondon et al. 2009; Saha and**

Sadhu 2014; Tiwari et al. 2004) and the other half compared injury rates among different types of working activities **(Carmen et al. 2003; Castro et al. 2005; Castro and Hunting 2013; Dey 2008; Fischer et al. 2003; Jildeh et al. 2014; Schlick et al. 2014)** or between working and non-working children **(Ahmed and Ray 2014; Awan et al. 2010; Cuadra et al. 2007b; Das et al. 2013; Doocy et al. 2007; Fassa et al. 2005; Graves et al. 2014; Nuwayhid et al. 2005).**

An elevated prevalence of diverse types of injuries including work accidents, fractures, burns, cuts, falls, sprains, and musculoskeletal pain were observed among working children. Agricultural activities appear to be the most hazardous forms of child labor, with working children showing a prevalence of work-related injuries 4-5 times higher than those working in the non-agricultural sector **(Castro et al. 2005; Castro and Hunting 2013; Jildeh et al. 2014).** Those working in manufacturing and domestic services had a higher prevalence of back pain **(Fassa et al. 2005).** A prospective study among child laborers in rural communities in Bangladesh **(Dalal et al. 2016)** showed that younger age (<10 years) is associated with an increased incidence of injury-related illness. A retrospective study in Iran found that among construction workers, the accident rate among teenagers (15 to 19 years) was almost six times higher than that of young adults (20 to 24 years) **(Amiri et al. 2014).** Boys seems to sustain more severe injuries than girls **(Ahmed and Ray 2014; Baron 2005; Fischer et al. 2003; Jildeh et al. 2014; Vasconcelos et al. 2010).** As with nutritional status, injuries seem to increase steadily with the number of hours worked after a certain threshold of around 19 hours/week **(Ahmed and Ray 2014; Amiri et al. 2014) (appendix 3)**. However, 26 of the 29 studies had a non-longitudinal design, limiting the interpretation of these results.

Harmful exposures

Many types of harmful exposures were explored: chemicals, including polybrominated diphenyl ethers (PBDEs), 2,5hexanedione, cosmetics and shampoo; environmental toxins (lipid hydroperoxide in serum); and organic and inorganic solvents.

Only five studies of the 28 studies with harmful exposures as outcomes **(Baig et al. 2005; Elci et al. 2007; Gol 2016; Oviedo-Trespalacios et al. 2013; Zaki et al. 1998)** did not have a comparison group. The working environment of most working children was considered below the acceptable standards for proper arrangement of ventilation, light, garbage disposal, temperature, level of noise and minimal appropriate safety standards **(Baig et al. 2005; Esin et al. 2005; Gol 2016; Oviedo-Trespalacios et al. 2013).**

Five studies (four in Nicaragua and one in Bangladesh) investigated child labor in waste disposal sites **(Athanasiadou et al. 2008; Cuadra et al. 2007a; Cuadra et al. 2009; Cuadra et al. 2006; Gargy et al. 2011).** Of those, two studies found that serum levels of PBDEs among working children **(Athanasiadou et al. 2008; Cuadra et al. 2007a)** were 20-50 times the serum level of non-working children. These serums concentrations among children working and living at the waste disposal site were among the highest ever reported. Higher levels of several polychlorinated biphenyl congeners were observed among the children who lived and worked at a Managua-waste-disposal site **(Cuadra et al. 2006).** In addition, one study in the same site **(Cuadra et al. 2009)** found that children working at the waste disposal site showed higher blood levels of lead, mercury and cadmium, 28% having lead levels higher than 100 g/l, the level the US Centers for Disease Control (CDC) considers as actionable. Finally, a study in Dhaka, Bangladesh found that working in garbage dumping sites was also associated with DNA damage **(Gargy et al. 2011).** Compared to a non-working control group, working children had a higher levels of protein carbonyl, a well-known marker of protein damage, and a longer tail moment, a commonly used marker of DNA damage.

Children working in agricultural, construction and gem polishing sectors had a lower Peak Expiratory Flow (PEFR) compared to non-working children **(Das et al. 2011; Das et al. 2013; Joshi et al. 1996; Singhal et al. 2006).** Child labor was also associated with lead and mercury toxicity **(Harari et al. 1997; Nuwayhid et al. 2005; Zaki et al. 1998).** Children working in automotive spray painting, mechanical repair, searching for gold-amalgam, and furniture painting workshops who were exposed to solvents (e.g. mercury, lead) showed poorer performance in various tests (choice reaction time test, hand-eye coordination tests, symbol-digit test, spatial memory tests, matchbox test and the pencil tapping test) when compared to both working non-exposed children and non-working children **(Basema et al. 2003; Bose-O'Reilly et al. 2008; Saddik et al. 2005)**. Exposed working children also complained significantly more about excessive salivation and a metallic taste in the mouth**(appendix 3) (Bose-O'Reilly et al. 2008).**

DISCUSSION

This systematic review suggests that child labor in LMICs is negatively associated with some aspects of nutritional status, and increased prevalence of injuries and harmful exposures. Concerning harmful exposures, working children had high serum levels of many harmful elements, such as PBDEs, which are known to be associated with thyroid hormone disruption, memory impairment, impaired neurobehavioral development, iron deficiency, and impaired hearing (Amler and Smith 2001; Calderón et al. 2001; Siddiqi et al. 2003). In addition, working children exposed to solvents (e.g. mercury, lead) showed poorer performance in various memory tests. However, an overview of the extent of hazardous lead exposure in child laborers published in 2005 concluded that the potential magnitude of the hazard of lead exposure in child laborers is unclear (Ide and Parker 2005). Concerning nutritional status, working in non-sedentary sectors (e.g. agricultural, construction) was associated with lower height and weight, but not with differential BMI. This might be the result of child labor affecting height and weight in the same direction and magnitude. A high prevalence of non-fatal injuries and musculoskeletal pain was found in working children. The latter can lead to perceived thermodysregulation, hypervigilance and hypersensitivity (Clinch and Eccleston 2009).

Our findings build on a recent review by (Shendell et al. 2016). That review focused on lead and chemical exposure hazards, missed education, and health of street children who are quite distinct from the general population of child workers. In addition, it only included references available in the English language, and excluded many nutritional outcomes, a potential long-term consequence of child labor.

Our first observation on the state of the science is the poor methodological quality of most studies. For example, many papers reported odds ratios (OR) as measures of association, even if the outcome frequency was common, which exaggerates the relative risk(Rothman et al. 2008). Sampling was sometimes done in a non-representative fashion and almost all studies failed to report the frequency of missing data. In addition, only one third of studies having at least one control (non-working children) group adjusted for potential confounders in their analyses. The lack of adjustment for potential confounding factors added to the possibility that frail children might be less likely to find work at baseline (i.e. reverse causality).This might tend to underestimate the adverse effects of child labor observed, seriously limiting the causal interpretation of associations reported in these studies.

Secondly, there was no study conducted solely in China (China appears in one study including all developing countries) and only five in Africa were included. This regional imbalance was also present in the (Shendell et al. 2016) review. This imbalance needs to be explored, since no restriction in language was applied. Articles in Spanish, Portuguese, French and Turkish were included in our review. Therefore, it does appear that many regions are severely understudied. One possible explanation for the paucity of reports from China might be that few Chinese journals are indexed in databases such as PUBMED, EMBASE and Scopus (Fan et al. 2008; Xia et al. 2008). Concerning Africa, one study has shown that Sub-Saharan Africa lags in scientific and technical publications due to lack of a congenial political and academic environment in some countries, shortage of trained personnel to pursue academic research due to heavy teaching loads and inadequate financial support (Atuahene 2011). However, our review covers 26 LMICs which is fairly comprehensive.

Third, there might also be a high likelihood of publication bias in this review. Only three studies reported non-significant associations between child labor and health outcomes among all studies having a non-working control group. Finally, other aspects of child labor were not captured in this review, particularly, children involved in illicit activities such as prostitution and drug trafficking, which may be considerably more hazardous.

With over 170 million children involved in child labor, the limited peer-reviewed work identified in LMICs is clearly an indication that more research with longitudinal quantitative measures on child labor and health outcomes is urgently needed. Current evidence comes mostly from cross-sectional studies that are vulnerable to reverse causality and unmeasured confounding. We lack data from many parts of the developing world, particularly in China and Africa.

Ethical Statement

The manuscript has not been published previously (partly or in full), and no data have been fabricated or manipulated to support our conclusions. Consent to submit has been received explicitly from all co-authors.

Compliance with ethical standards

Funding: This study was founded by the Canadian Institutes of Health Research Operating Grant, “Examining the impact of social policies on health equity” (ROH-115209), the Foundation Grant “Development epidemiology: identifying evidence-based interventions for improving population health and promoting health equity (FRN 148467), and the Canada Research Chairs program.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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