# Are you adequately protecting working mothers? A review of key reproductive workplace physical hazards associated with pregnancy.

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Within the changing socio-economic climate and across cultural divides we are seeing more females in the workforce that whether by choice or necessity, remain at work well into the final stages of their pregnancy, often returning to work after only a short period away from the workplace. It is important that the occupational hygienist is aware of the potential increased risks associated with exposure of pregnant employees and their future children to some of these hazards. This paper reviews the literature in relation to three of these key physical exposures and highlights a selection of the more common risks that need to be identified and controlled. The review has found that exposure to these three physical occupational exposures can potentially place women at an increased risk of preterm delivery, spontaneous miscarriage and intrauterine foetal demise, but the threshold level of exposure to trigger these events is not easily ascertained. Other consequences found included intrauterine growth restriction, congenital foetal anomalies and potential for learning difficulties, but these are not confirmed. While heat exposure has many studies providing strong evidence of these adverse effects in relation to women and pregnancy, more research into the effects of noise and whole body vibration on pregnancy is required.

**Keywords:** Pregnancy, whole body vibration, heat, noise, occupational exposure,

## BACKGROUND

It was Bernardino Ramazzini, recognized as the father of occupational medicine that first asked the question, “What is your occupation?” In his book De Morbis Artificum Diatriba (Ramazzini, ("Diseases of Workers") he emphasized the importance of an individual’s occupation on their health and wellbeing. What is not as well known is that in relation to women as weavers he also stated “Now an occupation so fatiguing naturally has its drawbacks, especially for women, for if pregnant they easily miscarry and expel the fetus prematurely and in consequence incur many ailments later on”(Ramazzini, 2001).

Many centuries later the asking of that original question has become commonplace amongst occupational health professionals. However, is it a routine question asked by a general practitioner when a female worker is first diagnosed as being pregnant?
There are studies (Zenz 1994, Paul 2004, Sakr et al 2010) that outline the hazards associated with exposures to reproductive toxins, teratogens and mutagens and due to the enormity of the range of potential chemical and physical exposures impacting on pregnancy, the discussion in this paper will be limited to three particular occupational exposures: heat, noise and whole body vibration. These three hazards have been chosen as they are becoming key issues within the mining environment particularly as we see an increase in female heavy mobile equipment operators and the locations of many of the mines in regions of elevated temperature.

**Method**

This paper presents a narrative review of a number of papers from literature related to physical hazard exposures and potential outcomes associated for pregnant mothers and in the foetus. It will attempt to summarise a number of studies (including a meta-analysis) addressing the key areas of exposure. Literature was searched via a number of recognised scholarly literature search engines including but not limited to PubMed, Medline, CINAHL and UQ Summon.

**Discussion**

In the opening paragraphs of this paper Ramazzini's question relating to occupation was highlighted for a reason. We have seen by reviewing just three physical workplace hazards that there is indeed significant evidence that the pregnant mother is at increased risk in the workplace. Whilst this may not come as a surprise to many it still begs the question as to how many general practitioners, let alone employers ask the question of the mother's occupation, which should lead to understanding of potential work exposures. The first trimester presents as a key period of susceptibility. This is also often a time of uncertainty for the new mother, whether the pregnancy is unknown or they wish it to remain private until after this period of vulnerability is successfully completed.

1. ***Heat exposure in pregnancy***

A seminal study by Edwards et al (1978) identified the significant teratogenic potential of heat in many mammalian species. The impact of heat (hyperthermia) as a potential teratogen in

humans has also been acknowledged for many years. The influence of elevated temperatures on pregnant mothers is increased as the mother must dissipate not only her own excess heat but also the foetal body heat which is usually approximately one degree higher than her own. Pregnancy also tends to make the mother more susceptible to heat stress. This may be as a result of added fat deposits and the decrease in the ratio of body surface area to body mass. This has a negative impact on the ability of the pregnant mother's ability to cool via the loss of heat to the external environment. (Tillet 2011)

Epidemiological studies have shown correlation between reduced birth weights and mean annual temperatures in a number of different global regions (Roberts 1968). It can also cause intrauterine growth retardation during later stages of the pregnancy (Bell 1987). Of the more serious adverse effects the main target is the central nervous system (CNS), particularly in the first trimester of the pregnancy. The CNS is most affected because the rapidly multiplying cells are very sensitive to temperature elevations. (Upfold et al 1987).

Miller et al (2005) assessed the rate of birth defects induced by hot conditions during pregnancy. They found that there appeared to be no threshold for hyperthermic events and that temperature elevation for any duration during pregnancy has the potential for adverse effects. To this point Miller et al (2005) conclude, that there is unlikely to be a specific threshold and state: "any temperature increment for any duration has some effect". In an earlier study by Miller et al., (2002), where they evaluated peer-reviewed literature, the percent of embryological defects versus a specific thermal dose showed "an essentially linear relationship between thermal dose and percent embryological defects".

Over the years there have been a number of suggested thresholds for hyperthermia induced bio-effects (see table 1). These include but are not limited to:

- 1.5°C – 2.5°C above normal physiological levels (Edwards 1986)
- 2°C above normal (Kimmel et al (1993)
- No more than 1.5°C above normal physiological levels (Barnett et al 1994)

Table 1. Hyperthermia related bio-effects. (Adapted from Edwards et al 2003)

| **Early developmental effects (Embryonic)** | **Mid – late foetal effects** |
|---|---|
| Anencephaly | Pre-term delivery |
| Spina bifida | Growth retardation |
| anophthalmia | Abortion |

| | |
|---|---|
| Resorption or abortion | Learning deficits |
| Heart anomalies | Blindness |
| Neural tube defects | Cleft lip |
| Central nervous system | |

In 2014, a study by the University of Montreal's Department of Social and Preventative Medicine found a number of interesting observations. The study assessed data from over 300,000 births in Montreal over the period of 1981 to 2010. It was found that for pregnant women who reached 37 – 38 weeks of the term there was a 17% risk of early term delivery following a three day episode of 32°C or more. This increased to 27% if the episode lasted form 4 – 7 days (Auger et al 2014). There were limitations associated with this study, that were highlighted,

- miscarriages and caesarean deliveries were not included,
- confounding environmental factors such as smoking and potential use of air conditioning as mitigation controls,
- use of individual-level birth data rather than aggregated daily number of births.

Whilst there appears to be inconsistency in the level of the threshold temperatures (range of 0 to 2.5°C) this is most likely due to the developmental stage at which the exposure occurs and hence the variability of the sensitivity of the embryo/foetus. It would appear therefore that such values will vary and are tissue and developmental stage specific (Edwards et al 2003). Hence different time-temperature windows and thresholds will significantly impact on the different endpoint consequences (Ziskin et al 2011). Much of the data in this area is based on either general mammalian studies (Edwards et al 1978, Edwards et al 2003, NCRP 2002) or on a retrospective approach (Shiota 1982, Smith et al 1978, Erikson et al 1991) however there is significant evidence that exposure to elevated temperatures of the pregnant mother can be harmful to the developing foetus.

### *2. Noise exposure in pregnancy*

One of the biggest concerns with noise exposure is the effect on hearing loss, with noise-induced hearing loss being known as one of the major causes of preventable hearing loss for decades (Seidman and Standring, 2010). In relation to pregnancy, foetal hearing is developed by 24 weeks gestation, with maturation of auditory pathways by 28 weeks. In relation to noise

exposures to the foetus, the uterus is an effective sound attenuator. This attenuation of external noise varies from 39 decibels at 500 Hz to 50 decibels at 3000 Hz. (Zenz 1994, p. 832). An important aspect to also bear in mind is that the average sound level inside uterus due to physiological processes is 85 decibels (about the same as a passing diesel truck). This level of exposure is equivalent to most modern occupational exposure limits. It is thought that foetal hearing is through bone conduction rather than through external and middle ear systems, based on studies on ewes (Gerhardt and Abrams, 1996).

There is varying evidence in relation to the impact of noise exposure on the foetus in pregnancy.

Dzhambov et al (2014) found both negative effects and minimal effects in relation to prolonged noise exposure in pregnancy. This was based on performing a meta-analysis involving thorough investigation of 29 shortlisted studies and focusing on key factors identified in earlier studies in relation to impact of noise exposure. These studies spanned a 30-year time period in three different languages. They found no effect on preterm birth, preeclampsia, perinatal death or spontaneous abortion, but noise exposure impacted maternal blood pressure levels, increasing the risk of gestational hypertension. This causes uterine blood flow to the placenta to reduce as a result, thus causing an increased rate of intrauterine growth restriction.

Wu et al (1996) noted, in their study of the impact of noise exposure on the foetus, that there were no adverse effects on birth weight. The study involved monitoring noise exposure via the use of personal dosimeters, with a total of three different timeframes monitored (first, second and third trimesters). Wu et al (1996) also utilised known causes of low infant birth weight in conjunction with the noise exposure findings to make their conclusion. Rocha et al (2007) studied hearing in children exposed to occupational noise versus children who were not exposed, with no increased number of children affected by a hearing impairment after intrauterine exposure to occupational noise.

However there are a number of studies that have indicated adverse effects.

The main adverse effect of occupational noise exposure noted by many studies is a decrease in birth weight, either as small for gestational age, intrauterine growth restriction or low birth weight (Figa-Talamanca, 2006; Hartikainen et al, 1994; American Academy of Paediatrics Committee on Environmental Health, 1997; Nurminen, 1995). Other effects of noise exposure include increased risk of miscarriage (Figa-Talamanca, 2006), unnamed and named congenital

abnormalities such as urogenital abnormalities (Figa-Talamanca, 2006; Krueger et al, 2013), preterm birth (Figa-Talamance, 2006; American Academy of Paediatrics Committee on Environmental Health, 1997; Nurminen, 1995), decreased placental lactogen levels (Krueger et al, 2013; Nurminen, 1995) and intrauterine foetal demise (Zhang et al, 1992). Krueger et al (2013) also mentioned the risk of hearing deficits and abnormal childhood social behaviours as a result of occupational noise exposure in pregnancy, but no further evidence in relation to occurrence or significance was noted in the paper.

Another effect of noise exposure to the mother involves the activation of a stress response mechanism, resulting in the activation of the sympathetic-adrenal axis (Prasher, 2009). This in time releases catecholamines, which can increase maternal blood pressure and lower uterine blood flow, affecting placental blood flow and foetal oxygenation (Dzhambov et al, 2014; Krueger et al, 2013). Maternal cortisol is easily passed through the placental barrier, and can therefore affect the foetal hypothalamic-pituitary-adrenal axis, resulting in potential effects on neonatal cognitive development (Davis and Sandman, 2010). The increased cortisol release in relation to the stress response caused by noise exposure may also cause problems with reproduction disturbances and infertility, but the cortisol may not be a primary cause of reproduction issues based on a study by Herod et al (2011).

Whilst there is varying conjecture on the impact of noise during pregnancy the general consensus is that there can be adverse effects on the new born where the mother has been exposed to elevated noise levels. However, the extent of the impact on the new born, as well as the critical time at which the foetus is at greatest impact, is still inconclusive, with many studies contradicting each other, and only a small amount of human research involved. This is a field where ongoing research would be recommended.

### *3. Whole body vibration in pregnancy*

In general, there are limited studies into the effects of whole body vibration in relation to pregnant working mothers as has been noted by others (Burgess & Foster, 2012).
A number of studies were undertaken in the 1990's, and in a meta-analysis undertaken by Seidel (1993) vibration was linked to a number of adverse conditions including:

- uterine prolapse
- menstrual irregularity,

- spontaneous abortions, and
- still births

These were mainly associated with transport related occupations such as public transport and crane operators. This was also reflected in a literature review relating to hazards associated with air medical work during pregnancy (Van Dyke, 2009) including the comment *"Vibration exposure can probably contribute to the pathogenesis of disorders of female reproductive organs (decrease in uterine blood flow, menstrual disturbances, and anomalies of position) and disturbances of pregnancy (abortions, stillbirths)"* from a study by Penkov (2007). It is worth noting that the comment begins with "vibration exposure can probably…" which reflects some of the uncertainty still evident in the relationship between whole body vibration and the pregnant mother.

Zenz et al state that vibration exposure in the range of 5-10 Hz can be damaging when it resonates through the human body (Zenz 1994, p. 832). Whilst there is limited epidemiological information relating top whole body vibration there have also been a number of studies involving ether modelling of scenarios and animal studies.

Modelling of spinal load as a result of whole body vibration showed that pregnant mothers experienced a higher spinal load than non-pregnant women (Abrams 1993). Qassem and Othman (1997) developed a mechanical model of a 60 kg pregnant woman and subjected the model to a series of vertical and horizontal vibrations to assess the impact on the different body segments. The study revealed that the vibrations effect varied from segment to segment. Horizontal vibrations tend to affect the torso more so than the vertical vibrations which impact more on the thorax region.

In animal studies carried out by Nakamura et al (1996) vibration exposure to pregnant rats showed decreased uterine blood flow, prostaglandin E2 and decreased levels of progesterone there were also increased levels of corticosterone observed. Other such studies (Skilianov et al, 2005, Ohsu et al 1994) have identified potential impacts associated with chronic placental insufficiency.

This is being recognised in many regions and there are now more countries beginning to put in place guidance and regulations specifically in relation to this impact. For example in the Health and Safety Executive document on whole body vibration control, 118 Regulation 5(3)(c) requires the employer to "..take particular account of people who are more sensitive to vibration…… pregnant workers and those who have recently given birth."

**Conclusion and Recommendations**

There is strong evidence in the literature that exposure to elevated temperatures during pregnancy can result in deleterious consequences for the mother but from the studies reviewed, more specifically for the foetus. Impacts can include:

- CNS defects,
- neural tube defects,
- cardiovascular abnormalities,
- abortion, and
- pre-term delivery.

It is difficult to pinpoint a threshold as the impact of the temperature elevation is very dependent on the stage of the pregnancy and hence those particular mechanisms occurring in the embryonic or foetal development.

There is growing evidence that exposure to excessive levels of whole body vibration can result in serious consequences which can include:

- uterine prolapse,
- menstrual irregularity,
- spontaneous abortions, and
- still births.

There is still some uncertainty but there is growing evidence of the negative impact of whole body vibration on the pregnant mother and her child. There is a need for more information and research in this area in order to better characterise these risks.

There is less conclusive evidence on the consequences for the mother and child associated with exposure to noise, as there are fewer studies that focus on the effects of intrauterine noise exposure in humans. The main adverse effect of occupational noise exposure noted by many retrospective studies is a decrease in birth weight, either as small for gestational age and/or intrauterine growth restriction. Other significant effects such as preterm delivery, intrauterine foetal demise and hearing deficits in offspring have been noted in the literature, but more extensive research is needed to determine if these are true complications as a result of occupational noise exposure.

There is a very real need for the raising of awareness of prospective and expecting mothers. Whether their medical provider or occupational health professional undertakes this, it needs to be done to ensure that they and their employers understand there are potential risks being

faced and thus be able to make an informed decision in relation to their work and the possibility of adverse consequences to themselves and their children.

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