The decay of blood lead levels in workers suspended under the control of lead at work regulations

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Aims To study the rate of decline in blood lead levels post-suspension under Control of Lead at Work Regulations (CLAW) and thereby suggest sampling frequencies for follow-up blood lead measurements.

Methods A retrospective cohort of lead workers with blood lead levels over the current suspension level were identified from blood lead records. Data on their suspension and follow-up blood lead measurements were obtained.

Results Sixteen per cent of the identified cohort did not appear to return to lead work under CLAW. Twenty-seven suspension cases with an initial mean blood lead of 79 µg/dl (3.82 µmol/l) formed the dataset for analysis of decline in blood lead levels. The mean length of time between the blood sample indicating suspension and the first follow-up blood sample was 32 days. The mean length of suspension under CLAW was 61 days. The mean initial rate of blood lead decay was 0.659 µg/dl per day (0.032 µmol/l per day), although with a wide range. The rate of decline in blood lead after suspension was increased by the blood lead level at suspension, but was decreased by increasing past cumulative exposure.

Conclusions A follow-up blood lead sample 1 month after suspension should show a mean decrease between 13 and 26 µg/dl (0.63–1.25 µmol/l), which is substantially greater than that due to analytical ‘noise’ associated with two sequential measurements (approximately 5 µg/dl). Therefore, a follow-up blood sample taken around 3–4 weeks after suspension would seem practical. A decrease in blood lead of 7–8 µg/dl (0.36–0.54 µmol/l) or less in the month after suspension may suggest continuing lead exposure.

Key words CLAW; blood lead levels; lead workers; suspension levels.

Introduction

The Control of Lead at Work Regulations (CLAW) in the UK were revised in 1998 [1] after some 18 years of application, and included the introduction of new, tighter permissible blood lead levels. Recently, these regulations [2] were revised again to be in line with EC directive 98/24/EC, but included the same action and suspension levels for blood lead. The limits for blood lead were set after an extensive review of available toxicological literature defining dose–effect relationships for a wide number of body systems. Essentially, the suspension levels for adults based on blood lead measurements are 60 µg/dl for males and 30 µg/dl for women of reproductive age; for young people the limit is 50 µg/dl. The frequency of blood lead measurements under CLAW depends on the initial blood lead levels, but the interval of blood sampling is between 3 and 12 months. Suspensions under CLAW prior to 1998 were according to slightly higher levels of blood lead; the suspension level was 70 µg/dl for males prior to 1998. In practise, medical inspectors from the Health & Safety Executive (HSE) or doctors appointed by the HSE issue certificates of unfitness for those workers with blood lead levels over the suspension levels. Thereafter, it is the employer’s duty not to expose the worker to lead, which may be achieved by relocation to different duties or, if not possible, then the worker must stay away from his employment.

A number of related questions are often posed in relation to suspension for an excessive blood lead level; how quickly should the blood lead decline and, therefore, how often should a subject be resampled to ensure that their blood lead level has reduced to significantly lower than the suspension level. There is also the question of whether after certification of unfitness and suspension from lead work, their blood lead levels may indicate that removal from lead exposure is not being complied with.
Too short a blood sampling interval will lead to unnecessary venepuncture and wasted medical time, while too long an interval will involve a worker being removed from his employment for longer than is necessary. Two factors are involved in defining this time interval. Firstly, the rate of decay in blood lead levels after removal from any occupational exposure. Such a rate may depend on the worker’s historical exposure to lead, which may have produced a level of lead body burden that possibly acts to influence blood lead levels. These influences of lead redistribution from organs such as bone and liver may lead to different apparent rate of decay in blood lead levels after removal from current exposure. Secondly, the level of laboratory analytical imprecision of blood lead measurement will influence the ability to detect the true decline in blood lead levels when comparing two measurements at different times, both with some element of analytical uncertainty.

Data are available from workers who have been suspended from lead work because of their high blood lead levels. Each of these workers would have had to undergo at least one post-suspension blood lead measurement carried out to define when blood lead levels had returned to values where they could return to work. Some workers had several blood lead measurements while under suspension, but the time of any subsequent blood sampling has not been standardized. While use of these data should theoretically allow accurate definition of the rate of blood lead decay, it suffers from some uncertainties and possible bias. The time between placing or removing notices of suspension from lead work and the actual physical removal or return of the worker to the workplace is not exact. There are also concerns that some lead workers when suspended are not totally removed from any occupational lead exposure; outwith those cases where workers or management directly flout suspension.

This short paper describes the follow-up of a cohort of UK males working under CLAW after a blood lead level greater than the suspension level.

Methods

Medical inspectors from the HSE were contacted in 2002 for details of workers suspended under CLAW. These workers had been monitored at the workplace by HSE’s medical inspectors or by appointed doctors, and the blood lead analysis had been undertaken using electro-thermal graphite furnace atomic absorption spectrometry at the Health and Safety Laboratory (HSL), Sheffield. The accuracy and precision of the blood lead analysis is routinely controlled by internal and external quality assurance procedures. The coefficient of variation between batch is 4.8% at a blood lead level of 42 μg/dl and somewhat lower (3%) at the suspension levels of 60 μg/dl.

In practise, all index cases of blood lead levels over the suspension level in a 2 year period were identified and followed-up from HSL’s biological monitoring database. The respective medical inspector for the area was contacted for information on whether the worker had been suspended, the date of suspension and certification of fitness to return to work. Invariably, a blood lead level above the suspension level in a worker would lead to an urgent repeat venepuncture. In the case of this second blood sample confirming the breach of the appropriate suspension level, a suspension notice would be issued unless the ‘grandfather clauses’ was invoked. The ‘grandfather clauses’ allowed for some older, more chronically exposed workers to continue to be exposed above the current suspension level, albeit with attempts to reduce their exposure.

For some workers it was possible to construct an estimate of cumulative, occupational exposure to lead using the area under the time–blood lead curve (μg/dl years), defined from their start date of occupational lead exposure and using available blood lead levels over time. Initial rates of blood lead decay were calculated from the initial suspension lead level and the next venepuncture sample. Whether the initial rate of blood lead decay was significantly influenced by the blood lead concentration at suspension or the extent of past cumulative exposure was also investigated.

Results

Forty-nine adult males with blood lead over the suspension level were identified. The final analysis was performed on 27 suspension incidents in 23 workers. Exclusions from analysis were lack of suspension information for 8% of the sample, 16% had left lead-related jobs, one worker (blood lead = 109 μg/dl) had undergone chelation therapy and another was monitored by urinary aminolaevulinic acid measurements for medical reasons. Three cases were excluded due to the strong suspicion that they were still undertaking lead work. Three workers were not suspended due to the ‘grandfather clause’ in CLAW, while two workers were not suspended due to their immediate repeat measurements falling under the suspension level. One self-employed worker was also not suspended, as prior to 1998 CLAW such workers were exempt.

The data set also contained monthly blood lead measurements in a painter/decorator who had been suspended with a blood lead level of 85 μg/dl and who subsequently was not re-exposed to lead.

The mean blood lead level in the index samples for these 27 suspensions was 78.8 μg/dl (SEM 2.8 μg/dl) with a range of blood lead levels of 62–124 μg/dl. In the majority of these suspensions there was only one subsequent blood sample taken prior to the issue of
certification of fitness for return to work. The mean (standard deviation) of the time between the blood sample on which suspension was taken and the next blood sample to follow-up was 32.0 (20.7) days. The range for this parameter was wide at between 7 and 81 days.

The mean (standard deviation) of the duration of suspension from working with lead was 60.8 (42.0) days, with a range of 22–216 days and 95% confidence interval (CI) for 42–79 days. Linear regression and first order exponential decay curve were fitted to the blood lead data after normalization of all data points as a percentage of the index sample for the individual. The exponential regression model gave a better fit ($r^2 = 0.635$) than the linear model ($r^2 = 0.457$). However, the availability of only two data points (index and subsequent blood sample) for most individuals in the suspended worker cohort only allows application of a linear relationship to decay in lead levels for individuals. The mean rate of decline in normalized blood lead was significantly slower than the notional rate of turnover of red blood cells (Figure 1).

Analysis of the data from suspended workers using a linear model suggested that the mean (range) decrease in blood lead per unit time from the index blood sample to the next sample was 0.659 μg/dl (0.09–2.70 μg/dl) per day, the 95% CI was 0.45–0.869 μg/dl per day. This would suggest that with a month between venepunctures, on average the blood lead level from the index sample would have decreased by between 13 and 26 μg/dl. Only 10% suspension cases had rates of decrease in blood lead <0.247 μg/dl per day. It can be calculated with our current long-term analytical precision that at around the suspension level there is 95% confidence that a change of 5 μg/dl between two serial measurements in an individual with high blood lead levels signifies a real change, not analytical noise. However, the spread of decay rates in blood lead from the cohort of suspended workers was very wide and may be derived from a number of factors. Firstly, this study used the available data from the lead concentration in the index blood sample and the initial linear rate of decay in blood lead levels calculated from the index sample and subsequent blood sample (Figure 2). There was also an inverse relationship between the initial linear rate of decay in blood lead levels and the estimated cumulative, occupational exposure to lead in a smaller group where historical data were available ($r = -0.696$, $P = 0.0025$; $n = 16$). A comparison of fitting a linear or first order exponential decay curve to the monthly blood lead data from a painter monitored over an 8 month period after withdrawal from occupational exposure (Figure 3) suggested that the exponential model was a better fit ($r^2 = 0.987$ versus $r^2 = 0.908$, $F$-test $P = 0.0003$).

**Discussion**

This was not a comprehensive study of workers suspended under CLAW, and it is difficult to prove definitely how representative our sample may be. HSE’s national collated data for 1999/2000 [3] suggested that around 1% of all blood lead levels for over 16 000 males under CLAW were above the suspension level. Therefore, our initially identified cohort of over 40 suspension level blood lead results represents a significant sample of the annual incidence of suspensions, albeit collected over a longer time-frame than 1 year.

The data from our cohort of suspended workers suggests that on an average the blood lead level falls by about 13–26 μg/dl, 1 month after the original blood sample that caused suspension. This level of decrease in blood lead should be readily discernible with the precision of current analytical methods; for our method a difference >5 μg/dl between two serial measurements in an individual with high blood lead levels signifies a real change, not analytical noise. However, the spread of decay rates in blood lead from the cohort of suspended workers was very wide and may be derived from a number of factors. Firstly, this study used the available data from

![Figure 1](https://academic.oup.com/occmed/article-abstract/55/5/371/1418500/154324)

**Figure 1.** The pattern of blood lead results for the 27 suspensions expressed as a percentage of the blood lead value of the index sample in each subject. The dotted line represents the average replacement rate of red blood cells.

![Figure 2](https://academic.oup.com/occmed/article-abstract/55/5/371/1418500/154324)

**Figure 2.** The relationship between the initial rate of blood lead decay in the suspended workers and the initial blood lead level in the index sample initiating suspension.
On the basis of the data in this study, a period from 3 weeks to 1 month before any retesting of a suspended worker would seem appropriate, but this period may be adjusted according to the past history of lead exposure in the subject. Due consideration may need to be given as to whether an apparently slow decline in blood lead reflects continuing occupational exposure or the influence of their previous exposure. Continuing lead exposure could be unwitting, deliberate or through relocation to a ‘lead-free’ job where there is still some residual lead exposure. The distribution of rates of decay in blood lead levels in our study suggests that if the decline in blood lead is <7 μg/dl in a month after suspension, then some continuing lead exposure may be suspected.

References