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Cadmium in food chain and health effects in sensitive population groups

Agneta Oskarsson[1], Anna Widell, Ing-Marie Olsson & Kierstin Petersson Grawé
Department of Pharmacology and Toxicology, Swedish University of Agricultural Sciences, Uppsala, Sweden
[1]*Present address: Molecular Toxicology, School of Biomedical and Molecular Sciences, University of Surrey, Guildford, Surrey, GU2 7ZH, UK, (E-mail: A.Oskarsson@surrey.ac.uk)*

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Abstract

Even at the low exposure level of cadmium found in this study population living on farms in southern Sweden, there was an indication of effect on biochemical markers of renal function. Women had higher blood cadmium (BCd) and urinary cadmium (UCd) than men, which can be explained by higher absorption of Cd due to low iron status. In the present study, Cd in pig kidneys could not be used to predict human BCd or UCd even though cereals are a substantial part of both the human and the pig diet. The contribution of Cd from locally produced food to the total dietary intake in humans was relatively low and varied and the intake of Cd did not correlate with BCd or UCd. In contrast, Cd levels in pig kidney were significantly related to Cd levels in feed. However, there was no relationship between the locally produced cereals, constituting the main part of the feed, and Cd in pig kidneys. In pig feed, other non-locally produced ingredients contributed to a large part of the Cd in feed. The Cd in non-locally produced feed ingredients reaches the local circulation via excretion in faeces and application of manure to arable soils and will lead to increased levels in the crops. As indicated by experimental data from animals, neurochemical and neurobehavioral effects during development need to be further explored as sensitive endpoints for cadmium toxicity.

Introduction

Cadmium inputs to soil, mainly from atmospheric deposition, fertilisers and local emission sources, often exceed outputs in crops and drainage water, resulting in slowly increasing levels of cadmium in agricultural soils. After 20 years of restricted Cd use, Sweden is close to a balance between input and output of Cd in arable soils. However, soil Cd is still increasing by 0.03–0.15% every year, depending on geographical region and type of farming (Eriksson 2000). In contrast to other toxic metals, Cd in soil is easily taken up by growing plants through the root system and this is facilitated by the ongoing acidification of the environment (Thuvander & Oskarsson 1998). Vegetable food is the main source of cadmium exposure in the non-smoking, non-occupationally exposed population. The uptake and accumulation of Cd in growing crops are influenced by factors, such as Cd concentration in soil, plant species and cultivar, soil pH and organic matter content of soil (McLaughlin *et al.* 1999). A bioindicator of cadmium in the local agricultural environment could be useful for studies on temporal and spatial trends and for correlation with bioindicators of human exposure and health effects.

In the present investigations we studied Cd in the chain from soil via crops and feed to pig blood and kidney and the possibility to use Cd concentrations in kidneys from pigs as an indicator of bioavailable Cd in agricultural production was evaluated (Lindén *et al.* 2003). We also studied men and women living at the same farms and characterized some of the determinants of Cd status as well as kidney function (Olsson *et al.* 2002). Furthermore, in an experimental study we investigated neurobehavioural effects in rat offspring exposed to low dose Cd via milk (Petersson-Grawé *et al.*, 2004).

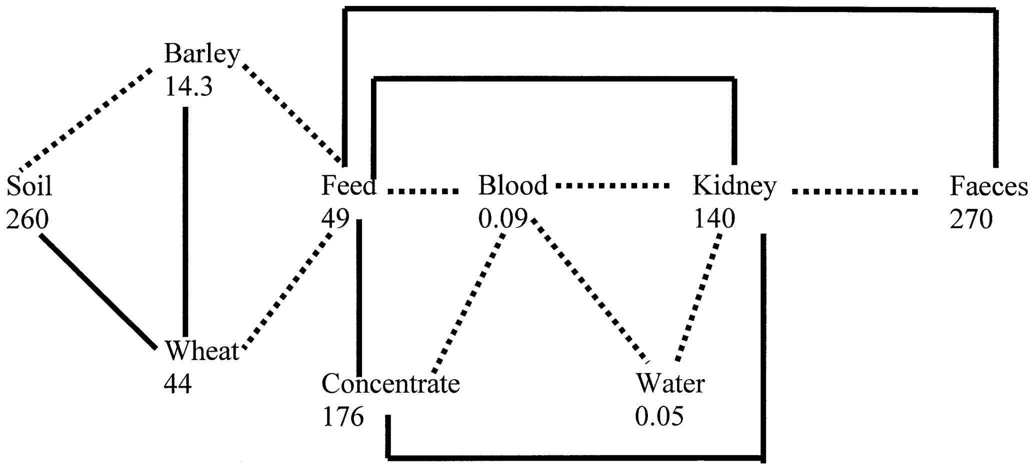

Fig. 1. Cadmium flow in the chain from soil to faeces in pigs from 49 farms in southern Sweden. Median concentrations (μg/kg) of cadmium are given. Full lines indicate statistically significant correlations and dotted lines no correlation ($p < 0.05$) (data from Lindén *et al.* 2003).

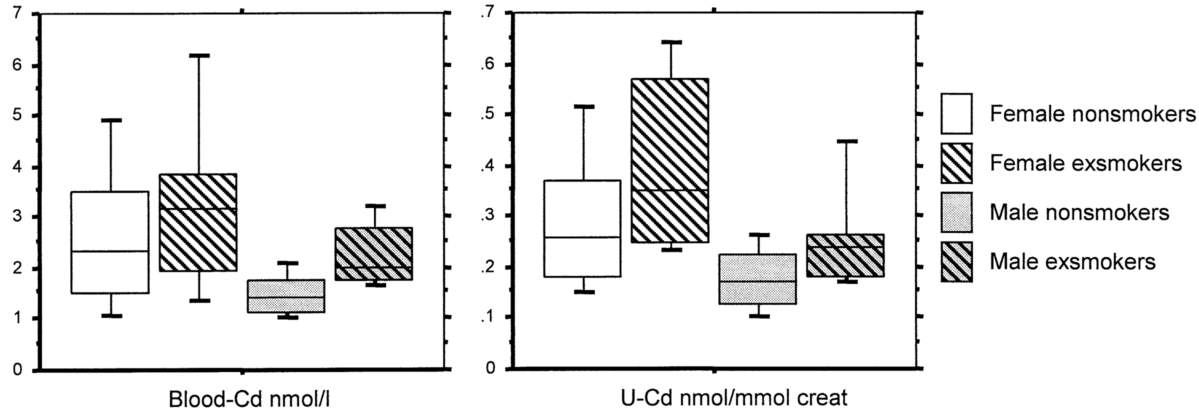

Fig. 2. Blood and urinary levels of cadmium in 105 women and men, never smokers and exsmokers, living on farms in southern Sweden. The horizontal lines show 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles (data from Olsson *et al.* 2002).

Pig kidney as an indicator of Cd in the agricultural environment

From a total of 2,400 growing/finishing pig producers in Skåne, a province in southern Sweden, 800 were randomly selected. From this group 49 farms were included in the study, fulfilling the selection criteria to have more than 50% of the feed produced at the farm, both man and woman willing to participate and both being non-smokers. Feed, water, pig blood and kidney were sampled for Cd analysis. Soil levels of Cd were interpolated values from a previous mapping (Eriksson *et al.* 1995). The feed components with the highest Cd concentrations were in the concentrate part, consisting of protein-rich components (e.g. rapeseed or soybean meal), minerals and vitamins. The mineral supplements may have been contaminated with Cd, as has been shown previously (Lindén *et al.* 1999; Lindén *et al.* 2001). Wheat had 2–3 times higher Cd concentration than barley. The accumulation ratio of Cd from feed mixture to kidney was on average 3. We found significant correlations between cadmium in wheat and soil, between wheat and barley and between cadmium in kidney and feed (Figure 1). However, animals from the same farm and raised under identical conditions had cadmium levels in kidneys that differed considerably and the ratio of the max and min levels from the same farm ranged from 1.2 to 3.6. This great variation together with the high cadmium contribution from non-locally produced feed components limit the possibilities of using cadmium in pig kidney as a bioindicator of available cadmium in this local agricultural environment. In addition, the geographical distribution pattern for Cd levels in soil, wheat and

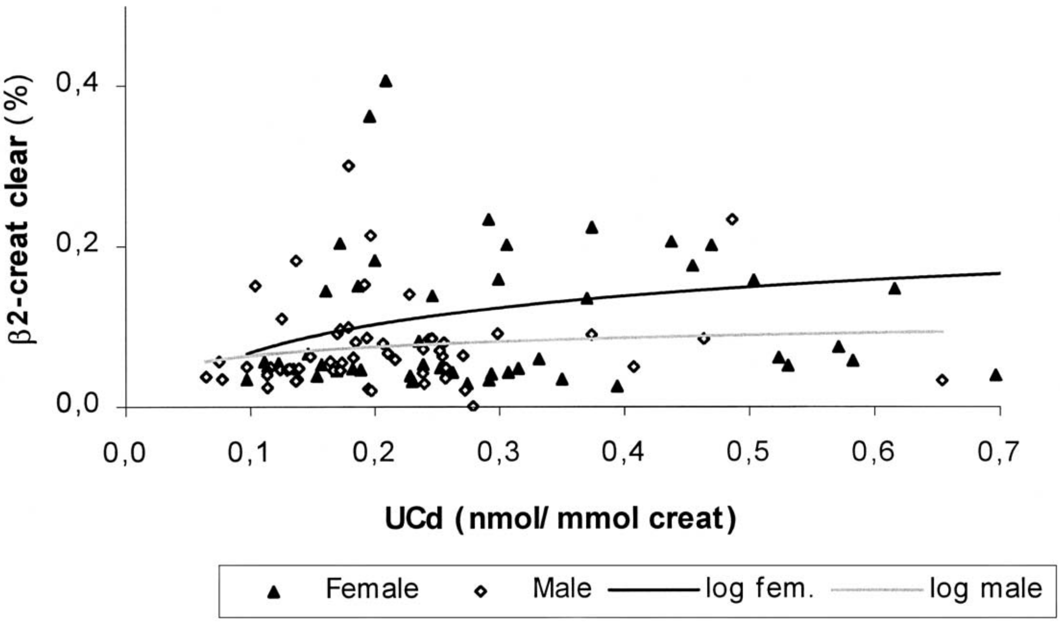

Fig. 3. β_2-microglobulin-creatinine clearance versus urinary cadmium excretion in 105 women and men living on farms in southern Sweden. Adjusted logarithmic lines are shown for females (black) and males (grey) (data from Olsson *et al.* 2002).

barley was different from that for kidney. Thus, Cd in pig kidney did not reflect Cd levels in the local environment, even though locally grown crops were the main component in the feed.

Exposure assessment and renal effects in men and women

Low level cadmium exposure and the effects on renal functions were investigated in 105 men and women living on the pig-producing farms. Men had a higher total dietary intake of cadmium than women. On average the vegetable food groups contributed 83% of the total intake. Bread was the largest contributor, followed by potatoes and roots and vegetables. Cadmium levels in blood (BCd) and urine (UCd) were not correlated to the intake of cadmium, probably due to a low and varying bioavailability of cadmium from food items. Women had approximately 1.4 times higher BCd and 1.6 times higher UCd than men (Figure 2), which could be explained by low iron status in women and a significant inverse correlation between BCd with S-ferritin in the women. Age and former smoking (Figure 2) had significant impact on BCd and UCd. The kidney function, measured as β_2-microglobulin-creatinine clearance (Figure 3), urinary N-acetyl-β-glucoseaminidase, protein-HC and albumin-creatinine clearance, was correlated with UCd in the total studied group. After adjustment for age β_2-microglobulin-creatinine clearance still was related to UCd. The contribution of locally produced food to the total Cd intake was low, with a mean of 17%, ranging from 0.5 to 41%. Males living in areas with low soil Cd had lower UCd than the others. However, BCd and UCd in humans did not correlate with Cd levels in the kidneys from pigs, raised on locally grown cereals from the same farms.

CNS effects of Cd – data from experimental animals

Renal and bone effects are generally considered as the critical effects of cadmium exposure. Much less attention has been paid to the effects of neonatal cadmium exposure and the susceptibility of the developing central nervous system to cadmium. We have previously demonstrated in animal experiments that the serotonergic system in the developing brain is susceptible to Cd (Andersson *et al.* 1997). In the present study, rat dams were exposed to 0, 5 or 25 mg/l Cd in the drinking water during lactation and neurobehavioural effects were investigated in the pups at ages up to 4 months of age. Significantly increased activity in the high dose group compared to controls was

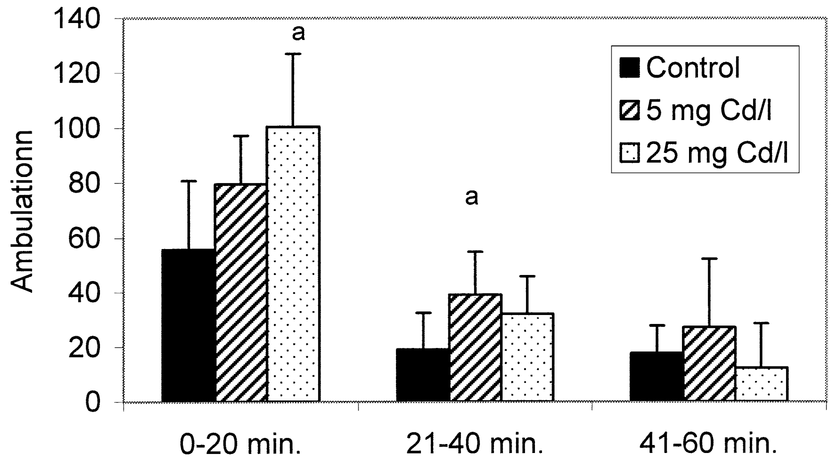

Fig. 4. a) Ambulation performance in rats exposed to cadmium via milk from dams receiving 0, 5 or 25 mg Cd/l drinking water. Results are presented as mean values ± SD. [a]Significantly different from control $p < 0.01$.

observed during the initial 20 min of a spontaneous locomotor test and during the next 20 min in the low dose group (Figure 4). The kidney levels of the dams were approximately 10 times lower than the levels that are generally associated with renal dysfunction. The results indicate that neurobehavioural effects during development may be a more sensitive parameter for Cd toxicity than renal dysfunction.

Acknowledgements

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