Non-Ionizing Radiation & Children's Health

International Joint Workshop
18 - 20 May 2011, Ljubljana, Slovenia

Animal Studies On Growth And Development

Alexander Lerchl

Jacobs University, Bremen, Germany

Actions of EMF on Development – Theoretical Targets

Brain (e.g., Growth Hormone, LH, TSH, TRH, Melatonin)

Thyroid Gland (Thyroxin)

Whole Body (e.g., Temperature, Metabolism)

Reproductive Organs (e.g, Testosterone, Estrogens)

Actions of EMF on Development – Theoretical Mechanisms

3.5 Mechanisms

The accepted health effects of RF field exposure are caused by temperature elevation; non-thermal effects are defined as bioeffects that are not caused by temperature elevation. However, in practice it is often difficult to assess whether temperature elevation has taken place. No alternative mechanism of interaction has been identified to date (Sheppard, Swicord & Balzano, 2008; Valberg, van Deventer & Repacholi, 2007).

No high-priority or other research needs were identified in the 2006 Research Agenda.

A recent communication of research findings has reported that non-linear responses indicative of the possible demodulation of a modulated RF signal did not occur at around 1 GHz carrier frequencies in cells in vitro (Kowalczuk et al., 2009).

High-priority research needs
None identified.

Other research needs
None identified.

WHO Research Agenda for Radiofrequency Electromagnetic Fields, 2010

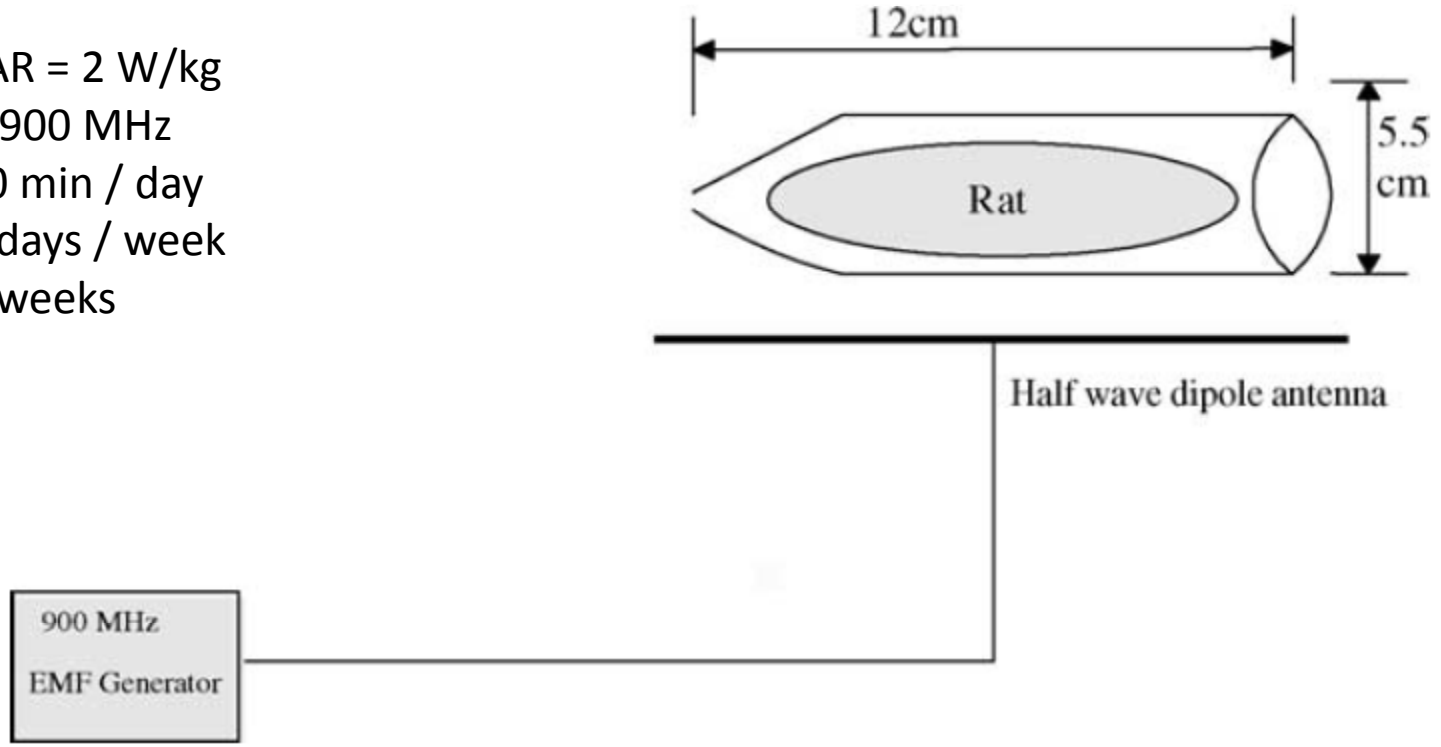
Search Results (PubMed) for Studies in Rats or Mice (NO Cancer Studies)

- Search Terms (Publications from 2000 – present): „electromagnetic AND fields AND (rats OR mice) AND xxxxx“

xxxxx	Results	Relevant	Effect
Thyroxin	5	1	Reduction
Melatonin	28	1	No Effect
LH	8	1	No Effect
Testosterone	24	1	Reduction
Estrogens	14	1	No Effect

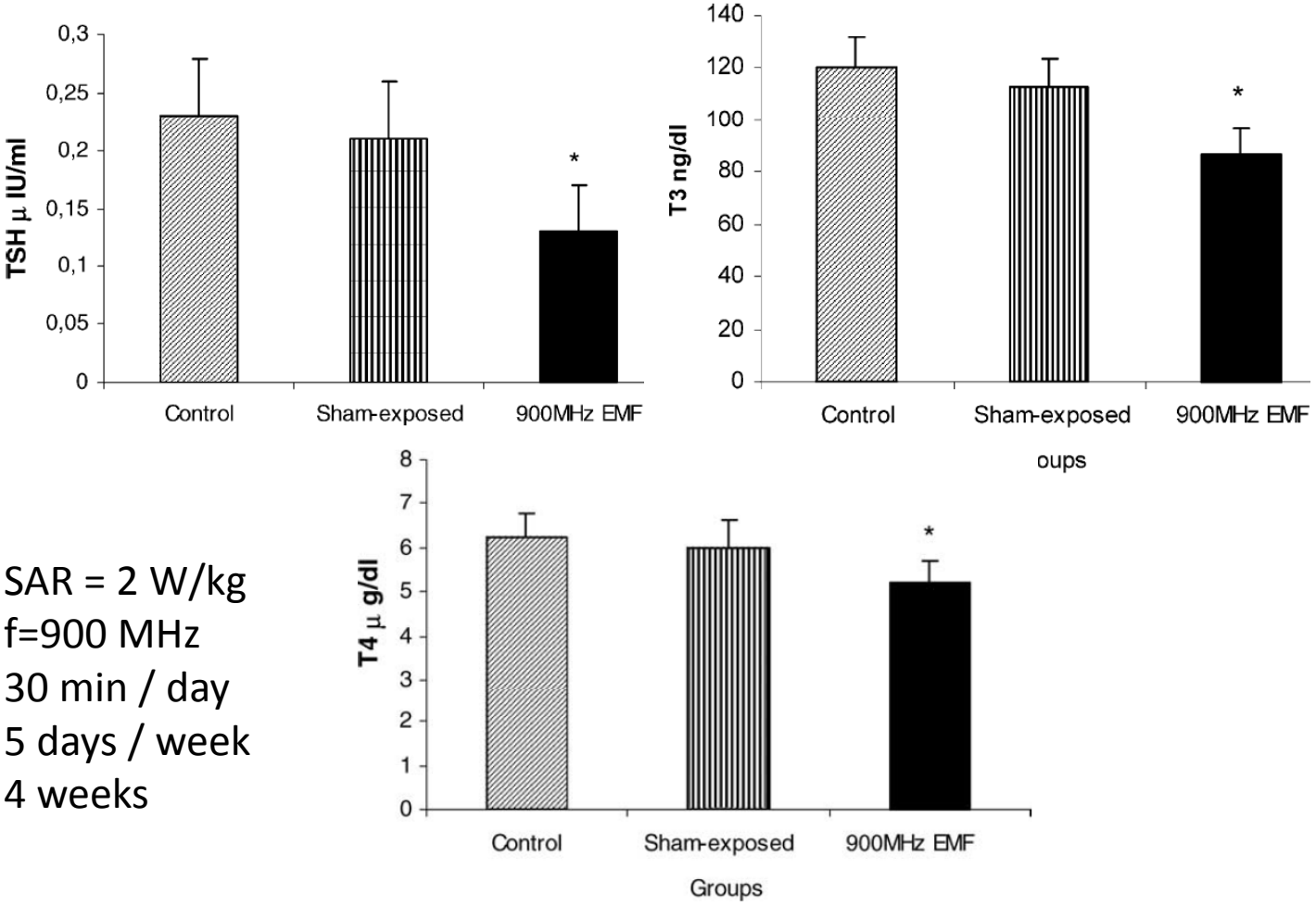
Reported Effects on Thyroxin / TSH

SAR = 2 W/kg
f=900 MHz
30 min / day
5 days / week
4 weeks



A. Koyu et al. / Toxicology Letters 157 (2005) 257–262

Reported Effects on Thyroxin / TSH



SAR = 2 W/kg
f=900 MHz
30 min / day
5 days / week
4 weeks

A. Koyu et al. / Toxicology Letters 157 (2005) 257–262

Reported Effects on Melatonin

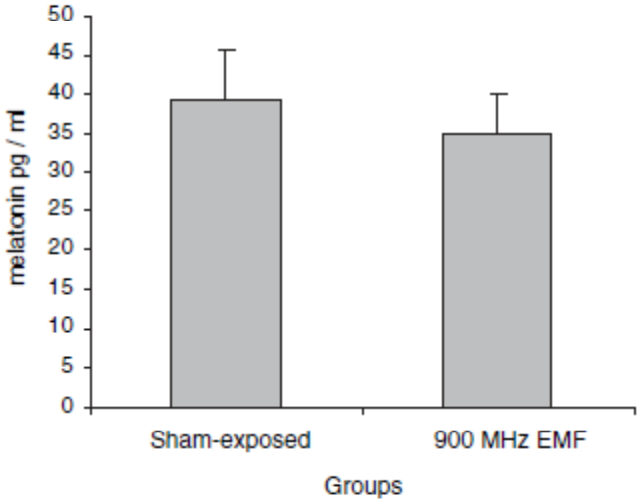


Figure 2. A comparison of average melatonin with SD between 900 MHz EMF and sham-exposed at 12:00 pm. $P>0.05$.

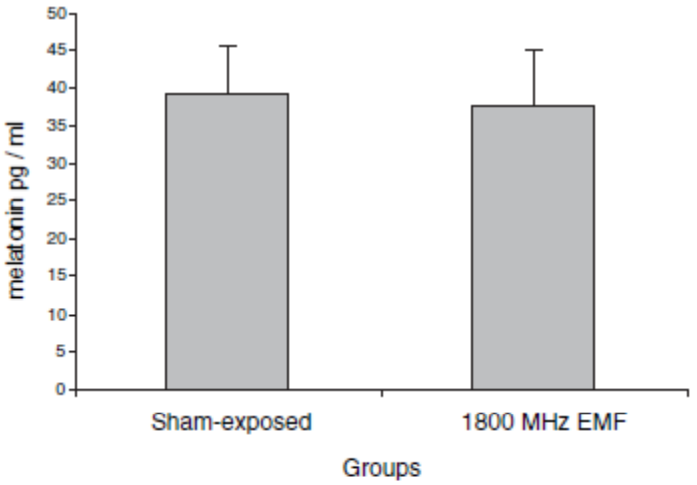


Figure 3. A comparison of average melatonin with SD between 1800 MHz EMF and sham-exposed at 12:00 pm. $P>0.05$.

SAR = 2 W/kg
f=900 MHz and 1800 MHz
30 min / day
5 days / week
4 weeks

Koyu et al., Toxicol Ind Health 21 (2005) 27-31

Reported Effects on Estrogens

TABLE 1. Uterine Wet Mass and Serum Estradiol Concentrations in Ovariectomized Sprague–Dawley Rats, Shown as Mean ± SEM

	Uterine wet mass			
	Grams	Fold increase	Serum estradiol concentration (pg/ml)	Body mass (g)
Cage	0.167 ± 0.006	—	4.6 ± 0.2	329 ± 3
Sham	0.149 ± 0.006	0.89	4.7 ± 0.3	304 ± 5
EM	0.171 ± 0.010	1.02	4.4 ± 0.4	296 ± 4
E2	1.014 ± 0.083*	6.07	59.8 ± 8.2*	306 ± 5

*$P < 0.0001$ compared with the other three groups by Student–Newman–Keuls test.

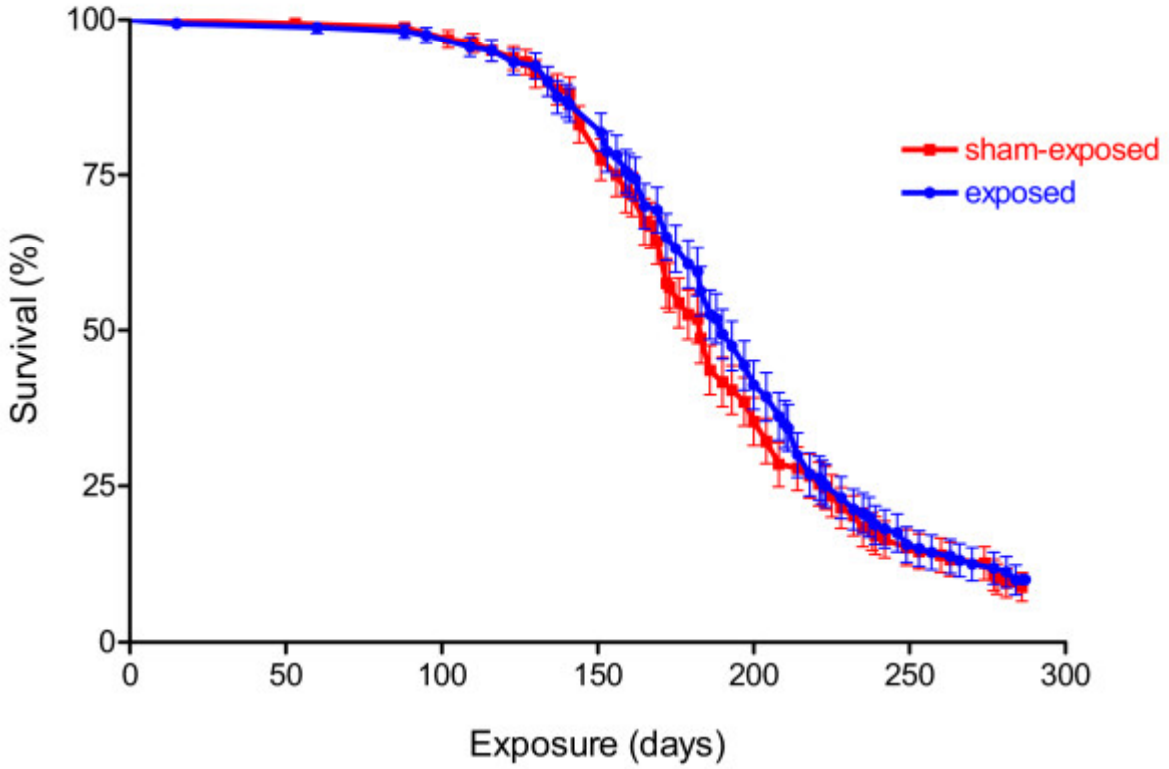
Yamashita et al., Bioelectromagnetics 31 (2010) 573-575

Studies in AKR/J Mice (900 MHz)

N=160 / group; SAR = 0.4 W/kg (24/7)
Blinded design

Sommer et al., BMC Cancer 4 (2005): 77

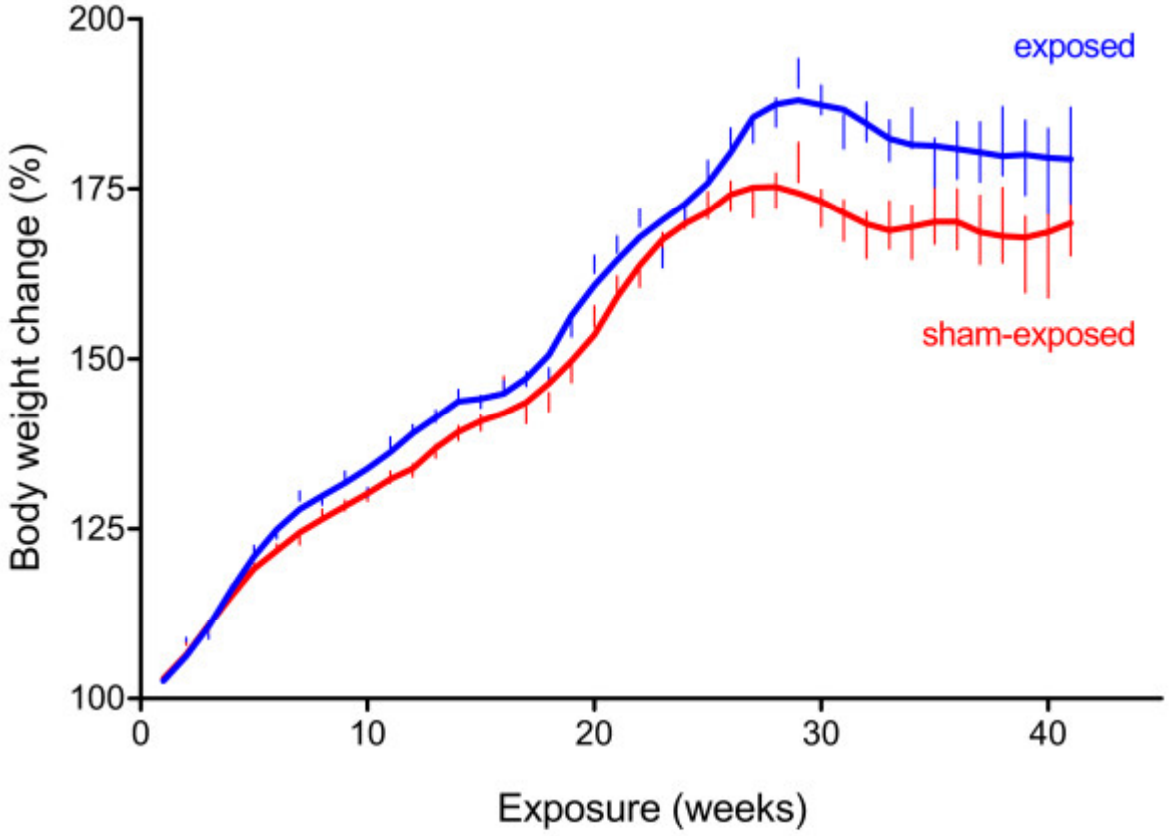
Studies in AKR/J Mice (900 MHz)



N=160 / group; SAR = 0.4 W/kg (24/7)
Blinded design

Sommer et al., BMC Cancer 4 (2005): 77

Studies in AKR/J Mice (900 MHz)



P<0.01

N=160 / group; SAR = 0.4 W/kg (24/7)
Blinded design

Sommer et al., BMC Cancer 4 (2005): 77

Effects of EMF (900 MHz) on Metabolism in Hamsters (Pilot Study)

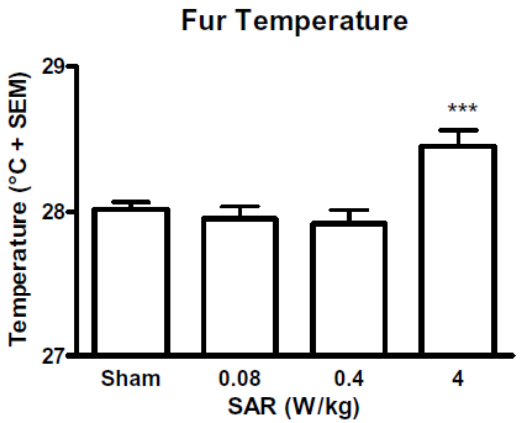


Fig. 1: Effects of exposure on fur temperature. ***, $p<0.001$ vs. sham. n = 4 per bar.

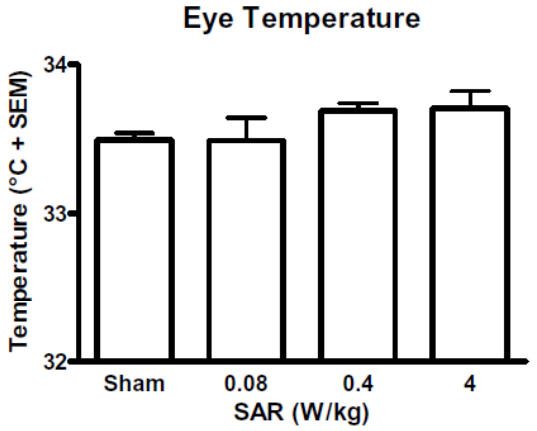


Fig. 2: Effects of exposure on eye temperatur n = 4 per bar.

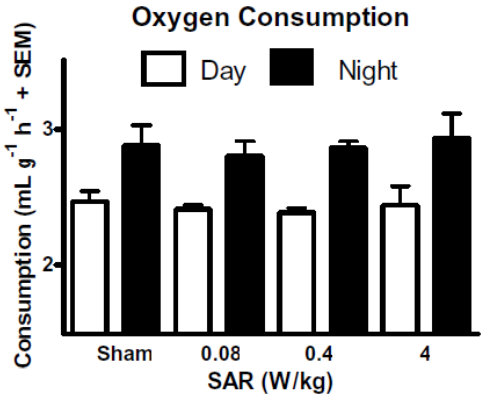


Fig. 3: Effects of exposure on O_2 consumption. n = 4 per bar.

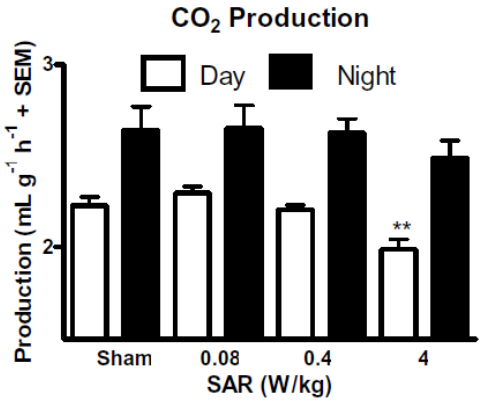


Fig. 4: Effects of exposure on CO_2 production. **, $p<0.01$ vs. sham. n = 4 per bar.

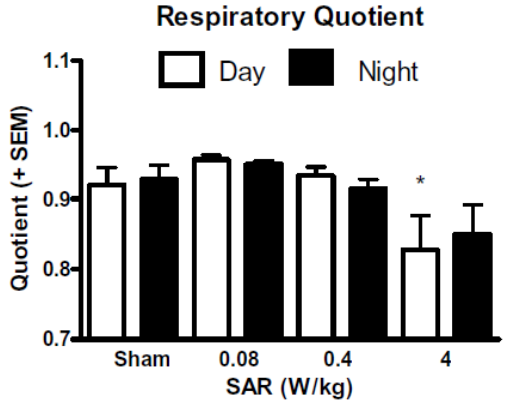
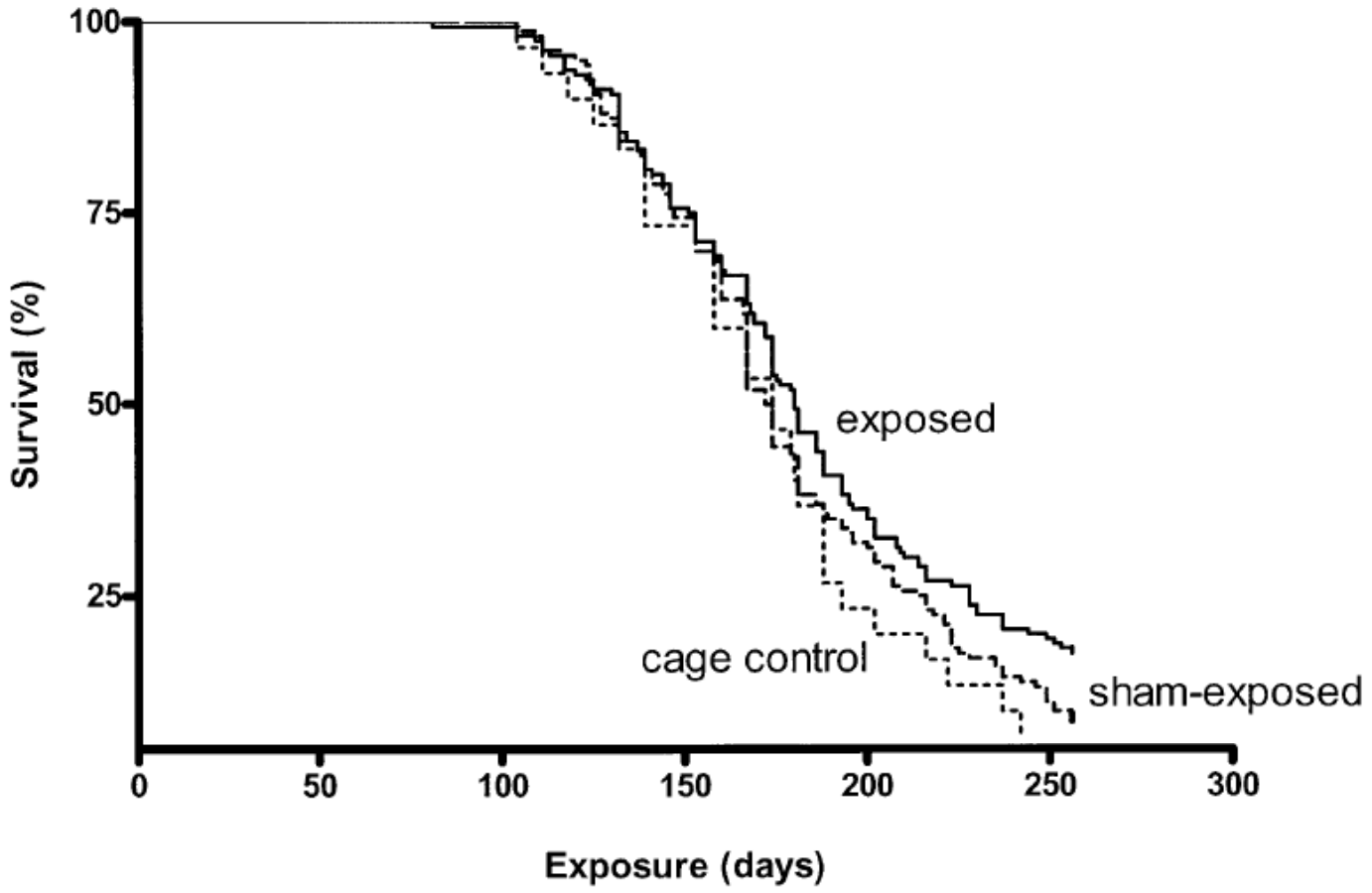


Fig. 5: Effects of exposure on the respiratory quotient. *, $p<0.05$. n = 4 per bar.

Lerchl et al, BEMS 2008

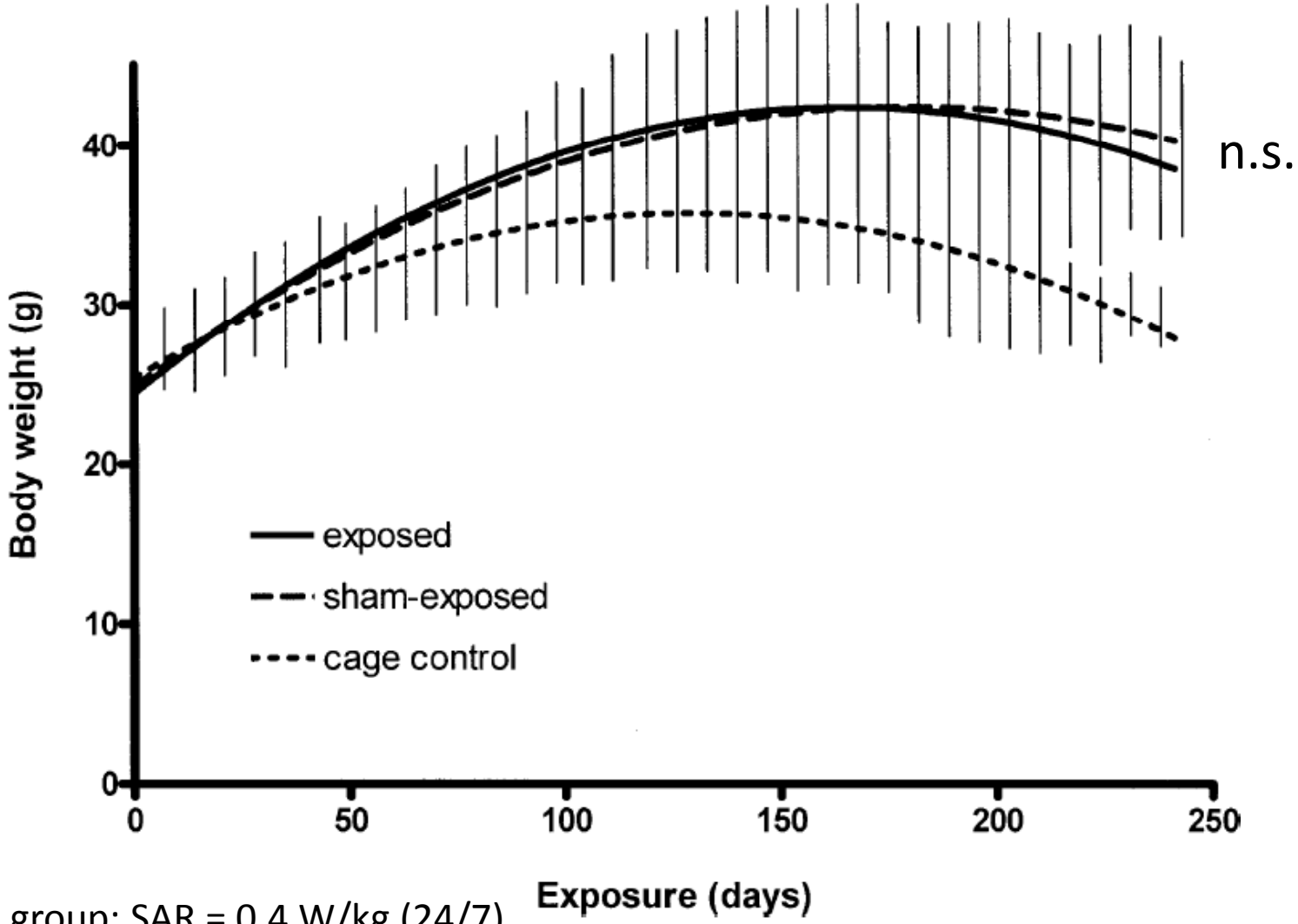
Studies in AKR/J Mice (1966 MHz; UMTS)



N=160 / group; SAR = 0.4 W/kg (24/7)
Blinded design

Sommer et al., Radiat Res 168 (2007): 72 - 80

Studies in AKR/J Mice (1966 MHz; UMTS)



N=160 / group; SAR = 0.4 W/kg (24/7)
Blinded design

Sommer et al., Radiat Res 168 (2007): 72 - 80

Mice Multigeneration Study (1966 MHz; UMTS)

N=32 pairs (2 females, 1 male) per group; 4 exposure groups (0, 0.08, 0.4, 1.3 W/kg); 4 generations; exposure 24/7; blinded design

Mice Multigeneration Study (1966 MHz; UMTS)

TABLE 2
Measures of Male Reproductive Function

Generation	Exposure	Testicular weight (g)	Accessory gland weight (g)	Total number of sperm/tubule	Number of malformed sperm/ tubule	Epididymis weight (g)
0	Sham	0.224 ± 0.017 (32)	0.347 ± 0.057 (14)	98.9 ± 11.1 (32)	5.7 ± 2.2 (32)	0.079 ± 0.007 (32)
	1.35 W/m²	0.222 ± 0.011 (32)	0.357 ± 0.064 (13)	97.5 ± 12.2 (32)	6.4 ± 2.7 (32)	0.080 ± 0.011 (29)
	6.8 W/m²	0.223 ± 0.020 (32)	0.360 ± 0.056 (11)	97.2 ± 10.3 (31)	6.1 ± 2.8 (31)	0.090 ± 0.023 (32)
	22 W/m²	0.214 ± 0.032 (32)	0.359 ± 0.063 (30)	96.0 ± 10.2 (31)	5.7 ± 2.8 (31)	0.076 ± 0.006 (32)
1	Sham	0.216 ± 0.015 (31)	0.368 ± 0.054 (31)	92.4 ± 9.5 (31)	4.7 ± 2.2 (31)	0.078 ± 0.007 (31)
	1.35 W/m²	0.209 ± 0.014 (31)	0.361 ± 0.032 (31)	92.6 ± 13.0 (31)	3.7 ± 2.6 (31)	0.079 ± 0.011 (31)
	6.8 W/m²	0.219 ± 0.014 (30)	0.344 ± 0.046 (30)	91.1 ± 12.4 (30)	4.5 ± 2.8 (30)	0.079 ± 0.008 (30)
	22 W/m²	0.210 ± 0.015 (32)	0.352 ± 0.036 (29)	92.2 ± 11.6 (32)	4.3 ± 2.2 (32)	0.074 ± 0.004 (32)[a]
2	Sham	0.221 ± 0.010 (31)	0.360 ± 0.050 (31)	92.2 ± 10.9 (31)	4.1 ± 2.6 (31)	0.077 ± 0.006 (31)
	1.35 W/m²	0.214 ± 0.012 (30)	0.378 ± 0.060 (30)	91.0 ± 10.2 (30)	4.3 ± 3.3 (30)	0.074 ± 0.006 (30)
	6.8 W/m²	0.216 ± 0.012 (32)	0.356 ± 0.063 (32)	91.1 ± 9.4 (32)	4.5 ± 2.1 (32)	0.077 ± 0.007 (32)
	22 W/m²	0.213 ± 0.015 (32)	0.357 ± 0.040 (31)	92.9 ± 12.1 (32)	4.9 ± 3.2 (32)	0.077 ± 0.007 (32)
3	Sham	0.226 ± 0.033 (32)	0.389 ± 0.043 (32)	89.8 ± 8.7 (32)	5.5 ± 2.7 (32)	0.083 ± 0.010 (32)
	1.35 W/m²	0.222 ± 0.013 (32)	0.383 ± 0.054 (31)	89.2 ± 8.6 (32)	5.8 ± 3.3 (32)	0.090 ± 0.012 (32)
	6.8 W/m²	0.224 ± 0.014 (32)	0.394 ± 0.046 (29)	90.8 ± 10.3 (32)	4.7 ± 2.3 (32)	0.090 ± 0.014 (32)
	22 W/m²	0.219 ± 0.015 (28)	0.405 ± 0.052 (27)	91.1 ± 8.6 (28)	5.9 ± 2.7 (28)	0.088 ± 0.011 (28)

Note. All data are given as means ± SD (*N*).
[a] $P < 0.05$ compared to sham.

Sommer et al., Radiat Res 171 (2009) 89-95

Mice Multigeneration Study (1966 MHz; UMTS)

TABLE 3
Measures of Female Reproductive Function in Mice that were Killed on Day 18 after Mating

Generation	Exposure	Uterus weight (g)	Number of corpora lutea	Number of resorptions	Number of fetuses	Weight of fetuses (g)	Number of malformed fetuses
0	Sham	8.4 ± 2.8 (32)	6.0 ± 2.7 (32)	1.1 ± 1.1 (31)	7.8 ± 1.8 (32)	0.7 ± 0.3 (31)	0.2 ± 0.5 (32)
	1.35 W/m²	8.2 ± 3.6 (32)	5.8 ± 2.0 (32)	0.7 ± 0.8 (30)	8.5 ± 1.6 (30)	0.6 ± 0.3 (30)	0.5 ± 0.6 (30)
	6.8 W/m²	6.8 ± 3.6 (32)	6.5 ± 1.8 (32)	0.4 ± 1.2 (32)	7.4 ± 2.3 (32)	0.6 ± 0.3 (30)	0.1 ± 0.3 (29)
	22 W/m²	6.4 ± 3.8 (32)	5.9 ± 1.8 (31)	0.9 ± 1.0 (28)	7.8 ± 2.0 (29)	0.6 ± 0.3 (28)	0.6 ± 0.7 (27)
1	Sham	7.3 ± 3.1 (31)	6.1 ± 1.9 (31)	1.1 ± 1.1 (30)	7.1 ± 1.7 (29)	0.7 ± 0.3 (29)	0.4 ± 0.6 (31)
	1.35 W/m²	8.0 ± 2.7 (32)	7.4 ± 1.8 (32)[a]	1.3 ± 1.0 (32)	6.9 ± 1.9 (32)	0.8 ± 0.3 (32)	0.5 ± 0.7 (32)
	6.8 W/m²	6.4 ± 3.0 (32)	5.9 ± 1.7 (32)	1.1 ± 1.1 (31)	6.7 ± 2.0 (32)	0.6 ± 0.3 (30)	0.6 ± 0.8 (31)
	22 W/m²	7.7 ± 2.6 (32)	5.9 ± 2.2 (32)	1.1 ± 1.2 (31)	7.2 ± 1.8 (32)	0.7 ± 0.3 (31)	0.7 ± 0.8 (31)
2	Sham	6.6 ± 2.5 (32)	6.5 ± 2.3 (32)	1.0 ± 0.9 (29)	7.1 ± 1.6 (31)	0.6 ± 0.2 (28)	0.7 ± 1.0 (29)
	1.35 W/m²	5.7 ± 2.6 (32)	6.1 ± 1.9 (30)	1.0 ± 0.9 (28)	7.2 ± 1.6 (29)	0.5 ± 0.3 (28)	0.8 ± 1.0 (26)
	6.8 W/m²	6.8 ± 3.0 (32)	6.7 ± 1.9 (32)	0.9 ± 0.9 (31)	7.0 ± 2.2 (31)	0.6 ± 0.3 (31)	0.6 ± 0.9 (29)
	22 W/m²	6.1 ± 3.4 (32)	6.0 ± 2.3 (30)	1.4 ± 1.2 (27)	7.2 ± 1.9 (27)	0.6 ± 0.3 (27)	0.6 ± 0.6 (27)
3	Sham	4.6 ± 3.1 (62)	5.4 ± 2.5 (63)	0.9 ± 0.9 (50)	7.5 ± 1.5 (54)	0.4 ± 0.2 (50)	0.6 ± 0.8 (50)
	1.35 W/m²	4.8 ± 3.8 (62)	5.6 ± 2.1 (61)	1.0 ± 1.2 (44)	7.3 ± 2.2 (48)	0.5 ± 0.3 (44)	0.8 ± 0.8 (44)
	6.8 W/m²	5.1 ± 4.1 (59)	5.3 ± 2.4 (64)	0.6 ± 0.8 (47)	7.3 ± 2.0 (47)	0.6 ± 0.2 (45)[b]	0.4 ± 0.7 (47)
	22 W/m²	3.6 ± 3.7 (56)	5.5 ± 2.5 (56)	0.9 ± 0.9 (35)	7.2 ± 2.1 (40)	0.5 ± 0.3 (34)	0.5 ± 0.8 (34)

Notes. For the weight of fetuses, the average weights of fetuses of each mouse were treated as one value. The higher numbers in generation 3 are due to the fact that all of these mice were killed at the end of the experiment. For details, see the text. In this last generation, weights of fetuses were comparatively low since not all females are pregnant at the same stage. All data are given as means ± SD (*N*).

[a] $P < 0.05$ compared to sham.

[b] $P < 0.01$ compared to sham.

Sommer et al., Radiat Res 171 (2009) 89-95

Mice Multigeneration Study (1966 MHz; UMTS)

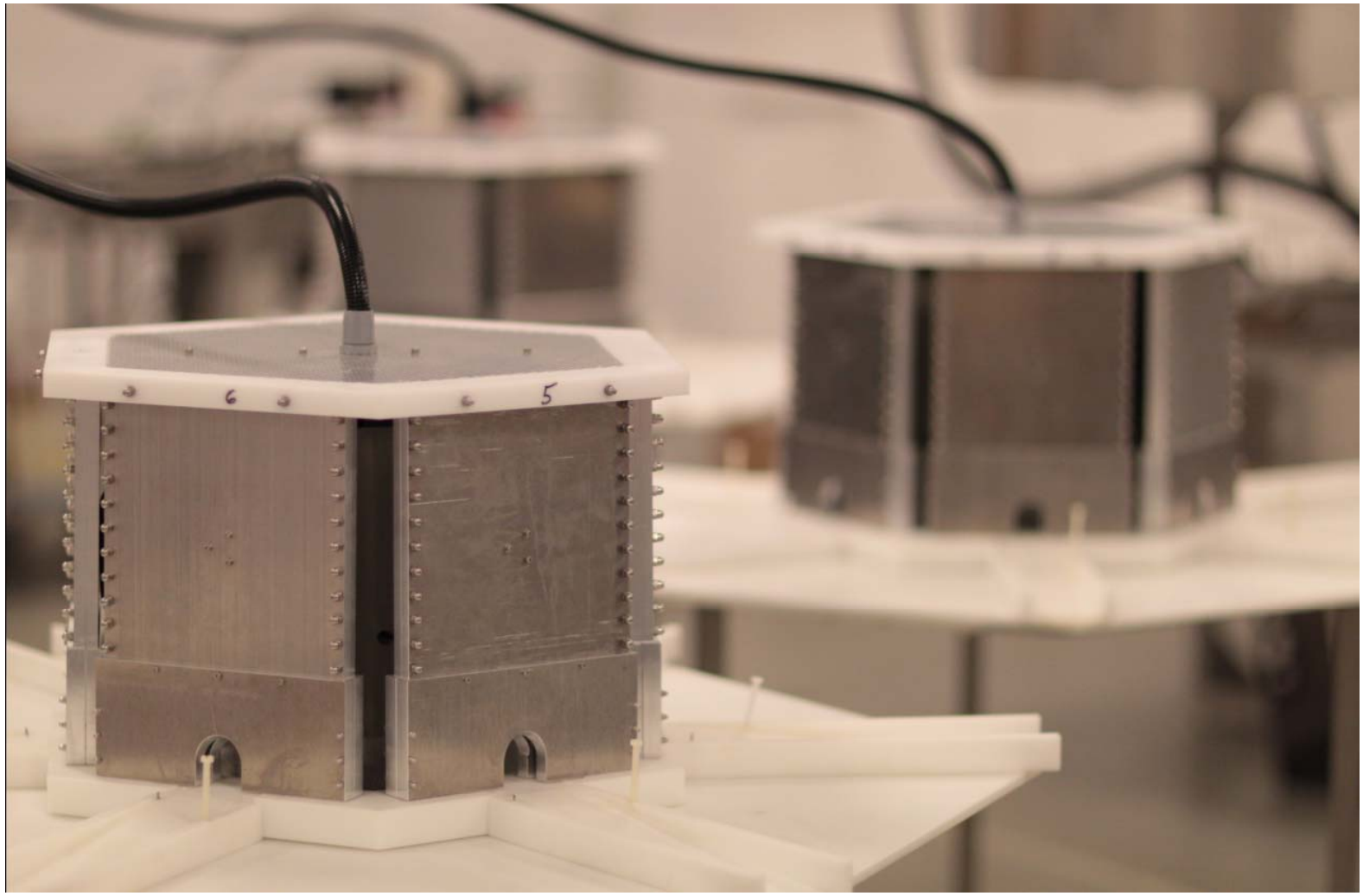
TABLE 4
Measures of Development of Pups

Generation	Exposure	Number of pups in the first litter	Weight of pups of the first litter (g)	Percentage of pups surviving until 21 days post partum	Number of pups in the second litter	Weight of pups of the second litter (g)	Percentage of pups surviving until 21 days post partum
1	Sham	7.4 ± 1.7 (32)	1.3 ± 0.08 (32)	38.8%	8.2 ± 2.5 (32)	1.28 ± 0.10 (32)	69.6%
	1.35 W/m²	7.2 ± 2.1 (31)	1.3 ± 0.11 (30)	41.1%	8.0 ± 2.1 (29)	1.29 ± 0.07 (29)	70.4%
	6.8 W/m²	7.1 ± 2.2 (32)	1.3 ± 0.09 (30)	41.2%	7.9 ± 2.4 (30)	1.31 ± 0.13 (29)	56.3%
	22 W/m²	6.9 ± 2.0 (31)	1.3 ± 0.10 (31)	36.5%	7.4 ± 2.6 (30)	1.31 ± 0.10 (30)	70.7%
2	Sham	6.3 ± 2.0 (31)	1.4 ± 0.10 (29)	31.6%	6.3 ± 2.0 (28)	1.37 ± 0.14 (27)	79.0%
	1.35 W/m²	5.8 ± 2.2 (32)	1.3 ± 0.15 (31)	37.0%	6.9 ± 2.3 (28)	1.34 ± 0.11 (27)	68.8%
	6.8 W/m²	5.3 ± 2.0 (31)	1.3 ± 0.13 (30)	27.9%	6.4 ± 1.9 (27)	1.30 ± 0.09 (27)	75.0%
	22 W/m²	5.8 ± 2.1 (32)	1.3 ± 0.10 (30)	37.5%	6.8 ± 2.6 (30)	1.32 ± 0.13 (30)	71.4%
3	Sham	6.3 ± 2.2 (29)	1.3 ± 0.10 (28)	30.6%	6.7 ± 2.9 (26)	1.35 ± 0.11 (26)	68.2%
	1.35 W/m²	6.2 ± 2.1 (26)	1.3 ± 0.17 (26)	21.3%	7.1 ± 2.1 (23)	1.35 ± 0.16 (23)	71.8%
	6.8 W/m²	5.9 ± 2.4 (31)	1.3 ± 0.12 (27)	35.9%	6.3 ± 1.8 (30)	1.36 ± 0.14 (30)	75.7%
	22 W/m²	6.1 ± 2.1 (29)	1.3 ± 0.10 (29)	24.3%	6.4 ± 2.2 (25)	1.34 ± 0.12 (25)	87.6%

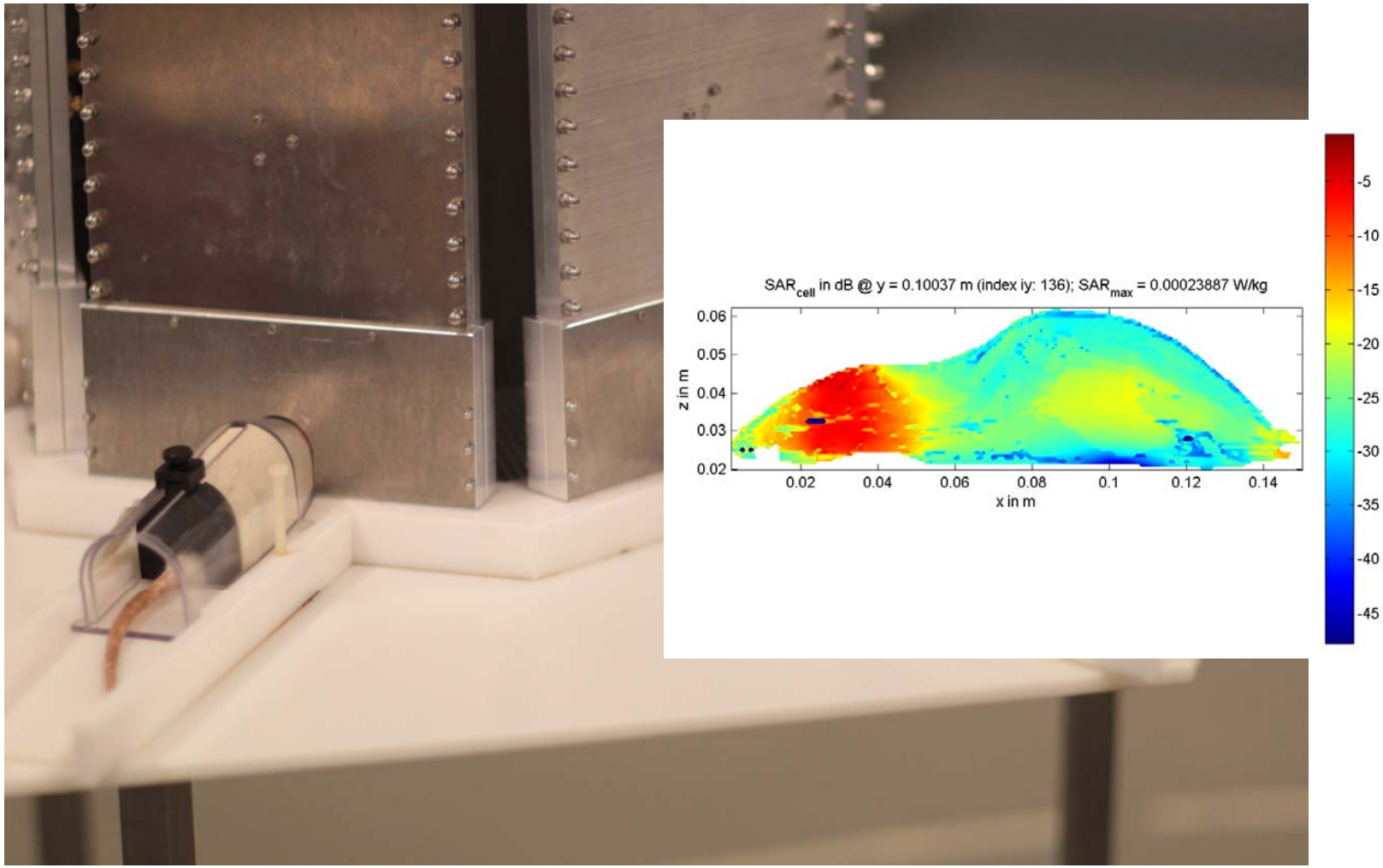
Notes. Numbers and weights of pups were recorded as the averages of all animals per individual litter. In cases where pups were found dead, their body weights were not recorded. All data are given as means ± SD (*N*).

Sommer et al., Radiat Res 171 (2009) 89-95

Effects of Head-Only Exposure (900 MHz) on Development, Learning and Memory in Rats



Effects of Head-Only Exposure (900 MHz) on Development, Learning and Memory in Rats



Effects of Head-Only Exposure (900 MHz) on Development, Learning and Memory in Rats

- N = 24 rats per group
- SAR (brain) = 0, 0.4, 2 and 10 W/kg (blinded)
- Exposure 2 h / day, 5 days / week
- Exposure started at an age of 14 days (!)
- Battery of behavioral tests:
  - 8-arm maze
  - Rotarod wheel
  - Open field
  - Water maze

} 3 times during experiment:
- juvenile (completed)
- adult
- pre-senile

Conclusions

- Relatively little is known about direct effects of RF-EMF exposure on hormones involved in development in untreated animals (mice or rats).
- Chronic exposure of AKR/J or normal mice (in a multigeneration study) revealed no adverse effects on health or development at rather high SAR values.
- „Sub“-thermal metabolic effects should be further investigated. Relation to EEG effects in humans???
- The ongoing study on rats (head-only exposure) will help to clarify effects of exposure in juvenile animals.

Acknowledgements

- Projects funded by the Bundesamt für Strahlenschutz (BfS), Germany
- Dr. Melanie Klose, Dr. Angela Sommer, Dr. Kirsten Schwarzpaul, Karen Grote, Thomas Ströhlein (Jacobs University)
- Nina Kloss (Jacobs University, 2nd year undergraduate, project on temperatures)
- Volkert Hansen, Joachim Streckert, Andreas Bitz (Universities Wuppertal and Essen)

Thank you for your attention!