



Mobile Telecommunications and
Health Research Programme

The Effect of Mobile Phone Radiation on Blood Pressure

A T Barker

RUM 7

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The effect of Mobile Phone Radiation on Blood Pressure

A T. Barker[†]

1 Executive Summary

Introduction

This double-blind study has investigated whether signals from GSM or TETRA handsets cause acute changes in the blood pressure of normal volunteers. The research was stimulated by a report of blood pressure changes of 5-10mm Hg following GSM exposure in a small, but high profile, study (Braune et al., 1998). The Stewart report recommended that a larger, better controlled study be carried out to investigate this phenomenon further.

Data has been collected from 120 normal volunteers, making this study three times larger than previous ones. The volunteers each attended six sessions between 1 and 4 weeks apart. At each session the volunteers were exposed, in a randomised order and for 40 minutes, to one of six configurations of the standard U.K. MTHR handset exposure system. Hence, at the end of their six visits, each subject had been exposed to one session of Modulated, Carrier Wave and Sham modes for both GSM and TETRA handsets.

The primary metric of the study was Mean Arterial Pressure (MAP). The design of the study enables changes of less than 1mm Hg in blood pressure to be detected, making it some five times more sensitive than previous studies. Secondary measures were adrenaline and nor-adrenaline levels in the blood, heart rate variability and 24 hour post-exposure ambulatory blood pressure measurements

Results

None of the secondary measures showed statistical differences as a function of the exposure type. Our primary measure, MAP, showed no differences between the groups which are attributable to their radiofrequency exposure. A small decrease in MAP of about 0.7mm Hg was observed in the group exposed to GSM Sham signals when compared to the other five groups. It is not thought that this represents an effect of the radiofrequency signals; the hypothesis that the other 5 MAPs were, in fact, actively raised by their exposures is not consistent with one of them being a TETRA handset in Sham mode. At present we have no well-founded explanation for this small decrease, but it may be linked to measurements which suggest that, when in GSM Sham mode, the MTHR handsets may run slightly warmer than in the other modes.

Conclusions

Despite being several times more powerful than previous studies, this work has shown no change in MAP due to a variety of radiofrequency exposures from GSM and TETRA handsets. This finding is consistent with those reported in other recent studies (Braune et al., 2002; Tahvanainen et al., 2004). Our results lead us to conclude that further studies of acute changes in blood pressure due to GSM and TETRA handsets are not required.

2 Study Aims and Objectives

The primary aim of this study was to investigate whether the radiofrequency signals from GSM or TETRA handsets cause acute changes in the blood pressure of normal volunteers. The research was stimulated by blood pressure changes of 5-10mm Hg reported following GSM exposure in a small, but high profile, study (Braune et al., 1998). The Stewart report recommended that a larger, better controlled study be carried out to investigate this phenomenon further. Secondary aims were to study heart rate variability and blood catechol concentrations as markers of sympathetic nervous system activity and to measure ambulatory blood pressure for 24 hours after exposure to determine the duration of any pressure changes which were observed.

3 Participants

Professor Anthony T. Barker - Consultant Clinical Scientist, Royal Hallamshire Hospital, Sheffield (Principal Investigator)

Dr. Peter R. Jackson - Reader in Clinical Pharmacology and Honorary Consultant Physician, University of Sheffield (Clinical Lead)

Miss Helen Parry - Senior Research Nurse, Royal Hallamshire Hospital, Sheffield

Dr. Leslie A. Coulton - Senior Research Scientist, University of Sheffield

Dr. Greg G. Cook - Senior Lecturer, University of Sheffield

4 Achievements

4.1 Study design

The study was a double-blind crossover study of 120 human volunteers, making it three times larger than all previous ones. The volunteers each attended six sessions between 1 and 4 weeks apart. At each session

the volunteers were exposed, in a randomised order and for 40 minutes, to one of six configurations of the standard U.K. MTHR handset exposure system. Hence, at the end of their six visits, each subject had been exposed to one session of Modulated, Carrier Wave and Sham modes for both GSM and TETRA handsets.

4.2 Metrics

The primary metric in this study was blood pressure, measured non-invasively using semi-automatic instrumentation during the exposure sessions. The study was initially designed to exclude a clinically insignificant temporary elevation of blood pressure of 2mm Hg with a high degree of certainty. However we were able to recruit more subjects than initially proposed (as discussed later) which, when coupled with repeat measurements of blood pressure, enabled changes of less than 1mm Hg to be detected in the final dataset.

Secondary measures were:

1. Heart rate recorded throughout the exposure sessions to investigate possible underlying changes in autonomic nervous system activity. As the change in low frequency spectral content due to variability of beat to beat heart rate is largely under sympathetic control (Guzzetti et al., 1988) this will add to information about sympathetic nervous system activity.
2. Catechols (adrenaline and nor-adrenaline) measured from blood samples taken before and after exposure were used as a metric of sympathetic nervous system activity. Mixed venous blood is not universally a good index of the activity of the sympathetic nervous system (Folkow, 1994). However, in the situation of an acute blood pressure change as described by Braune, which could only be achieved by generalised reflex vasoconstriction, spill over of catechols from muscles into mixed venous blood should provide a sensitive index of sympathetic activity.

- Blood pressure measured over the 24 hour period following exposure, using an ambulatory data logging system, to study the duration of any observed pressure changes.

4.3 Clinical Protocol

Participants were recruited by advertisement within the Royal Hallamshire Hospital and the University of Sheffield, and by word of mouth. At an initial screening visit full information was provided and informed consent requested. Those between 18 and 65 years of age were included; the only specific exclusion criteria were severe hypertension (BP > 200/120mm Hg), pregnancy, and any reason likely to prevent completion of the full 7 visits, so as to ensure as representative a population sample as possible. At the screening visit blood pressure was measured in standard fashion using the Omron 705CP semi-automated device, following American Society of Hypertension guidelines. After the screening visit participants attended on 6 further occasions each separated by at least 7 days. These later visits all had an identical structure, with standardised blood pressure measurements. Subjects remained seated throughout and refrained from eating, drinking or smoking for 1 hour prior to and during the visit. Following the fitting of the MTHR handset in the standard position against the left side of the head, a 20 minutes run-in period allowed parameters to stabilise. The handset was then switched on for a 40 minute exposure period. Figure 1 shows the timing of the blood pressure and other measurements made during each visit. In all a total of 23 blood pressure measurements were made at each visit.

Venous blood was sampled from the dominant arm using individual punctures, both at the end of run-in and at the end of the 40 minute exposure period. EGTA/glutathione preservative was added, the mixture immediately spun, and the separated plasma frozen at -80°C for subsequent analysis for catechols. Heart rate data was recorded in the form of R-R interval using a Polar S810 system which telemetered the data wirelessly to disk throughout the visit. Immediately following the final blood pressure reading of the exposure phase the Omron 711 cuff was replaced on the same arm by the cuff for a Spacelabs 90217 ambulatory blood pressure monitor which was programmed to take readings at 20 minute intervals between the hours 07.00 until 23.00 and at 30 minute intervals from 23.00 until 07.00. Participants returned their monitors the following day and the data was downloaded for analysis. On study days, and whilst the ambulatory monitor was in place, participants were asked to avoid lengthy mobile telephone conversations. At each visit, they were also asked to estimate a number of parameters relating to their mobile phone usage that day, the preceding day and since their previous visit. At the end of each exposure session subjects were asked whether or not they thought their handsets were transmitting, and why.

4.4 Interventions

There were six interventions, each delivered at a separate visit. Three different outputs of a standard MTHR GSM handset, namely GSM Modulated (GSM Mod), GSM Carrier Wave (GSM CW), GSM Sham (GSM Sham - defined as GSM CW delivered to an internal load rather than the antenna) and the equivalent

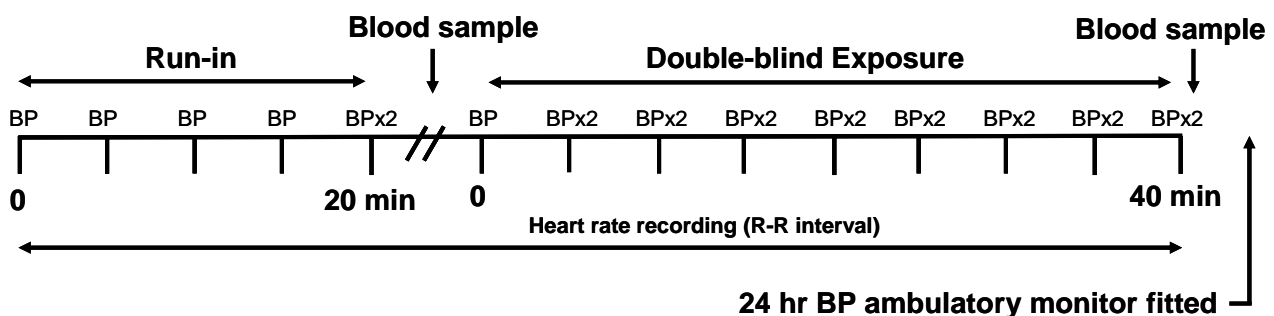


Figure 1. Timing of procedures within each visit

modes for a TETRA handset were used

The order of the interventions was determined by a balanced Latin square design and subjects were randomly allocated to a sequence within the squares.

4.5 Results

All data were analysed using SPSS 12.0 unless otherwise stated.

4.5.1 Demographics

Figure 2 shows the demographics of the study population Blood Catechols

Catechol concentrations were analysed using ANCOVA, with run in sample values as the covariant. Figures 3 and 4 show the estimated marginal means versus intervention groups for adrenaline and nor-adrenaline.

There were no significant differences between the groups ($p=0.22$ for adrenaline and $p=0.84$ for nor-adrenaline)

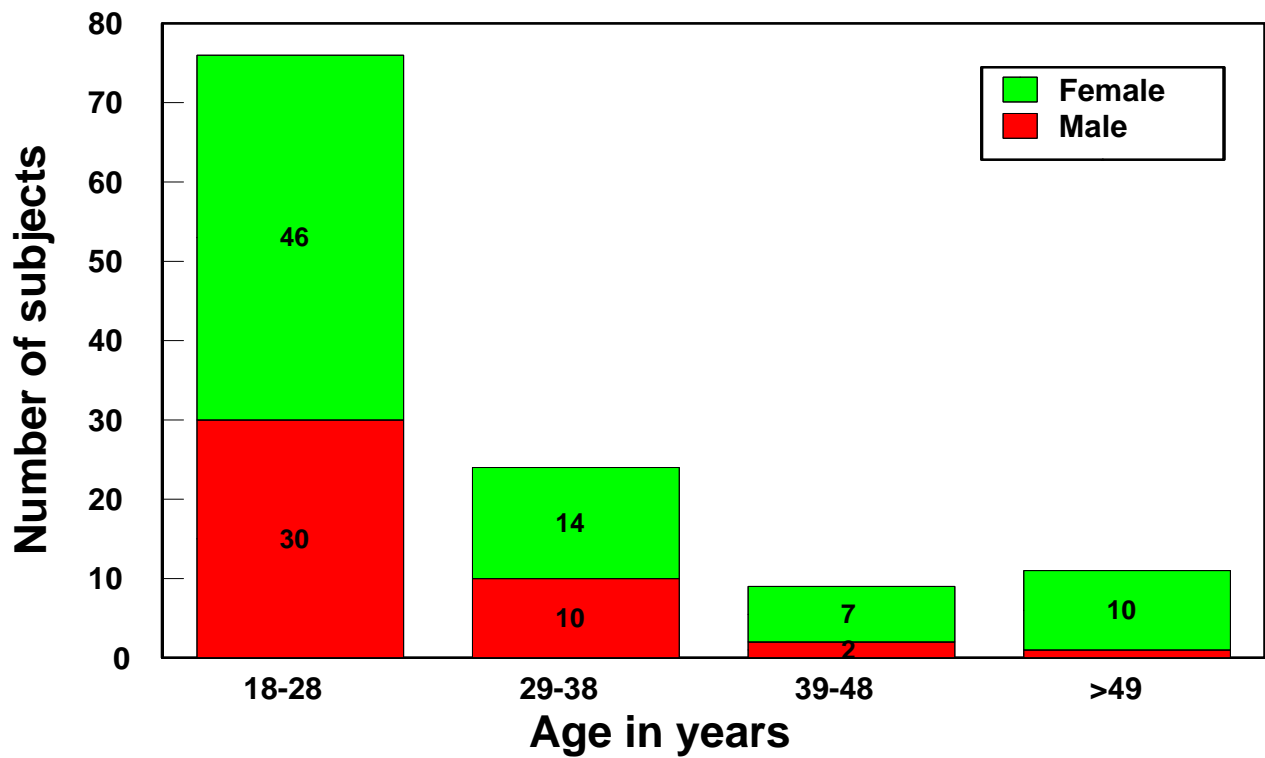


Figure 2. The demographics of the study population

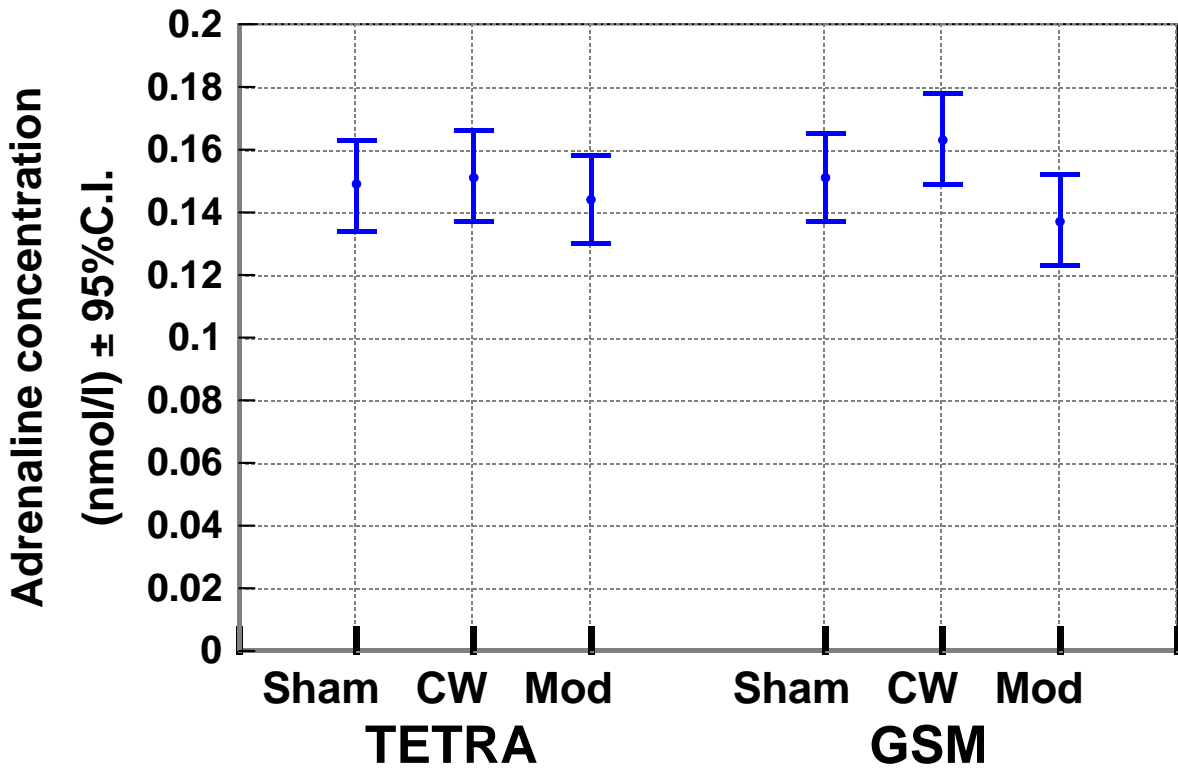


Figure 3. Estimated post-exposure marginal means for adrenaline

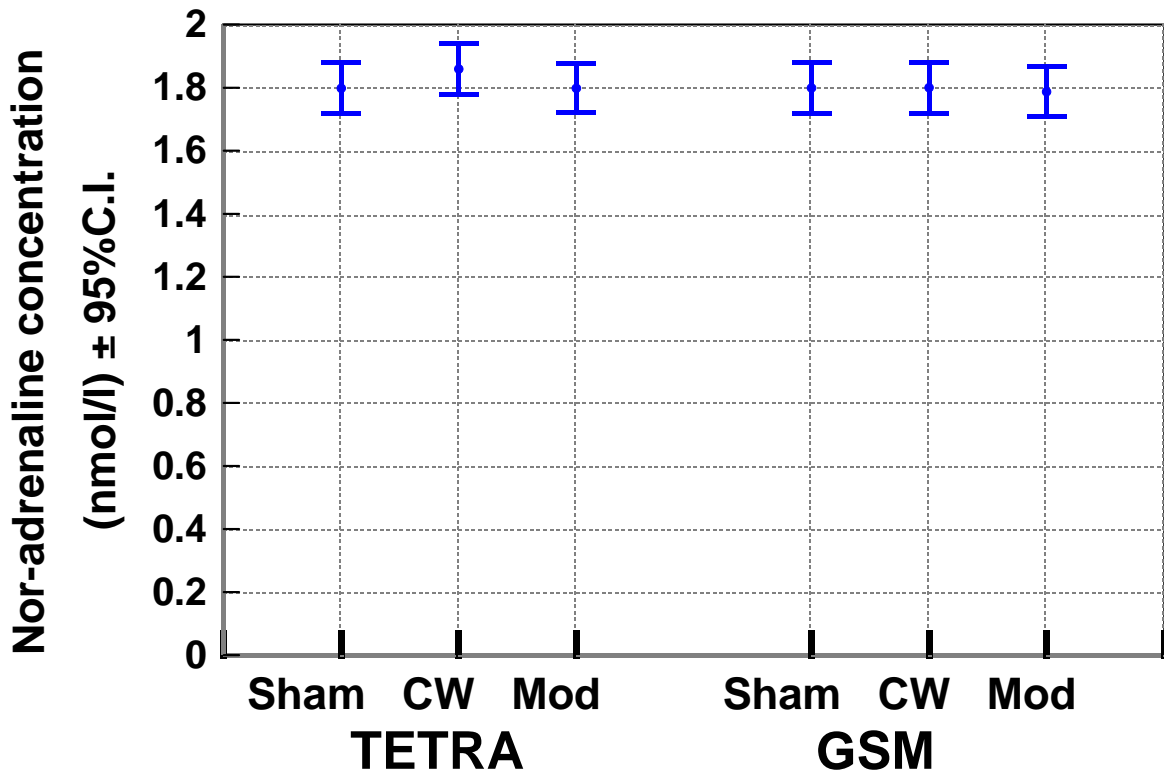


Figure 4. Estimated post-exposure marginal means for nor-adrenaline

4.5.2 Heart rate variability

Heart rate variability (HRV) was calculated using purpose developed software written in Matlab and based on the Lomb algorithm (Laguna et al., 1998). Correct functioning of the software was confirmed by analysing synthesised data for which the solution was known. The power density was calculated in two standard bands along with their ratio (European Society of Cardiology, 1996). ANCOVA has been used

to analyse the first 20 minutes of the exposure period, the second 20 minutes and the total 40 minutes of the exposure period, using the corresponding 20 minute run-in period data as the covariate. Figures 5 to 7 show, as examples, the estimated marginal means for the total 40 minutes of exposure. None of the nine measures showed any statistical association with exposure type ($p=0.22-0.64$).

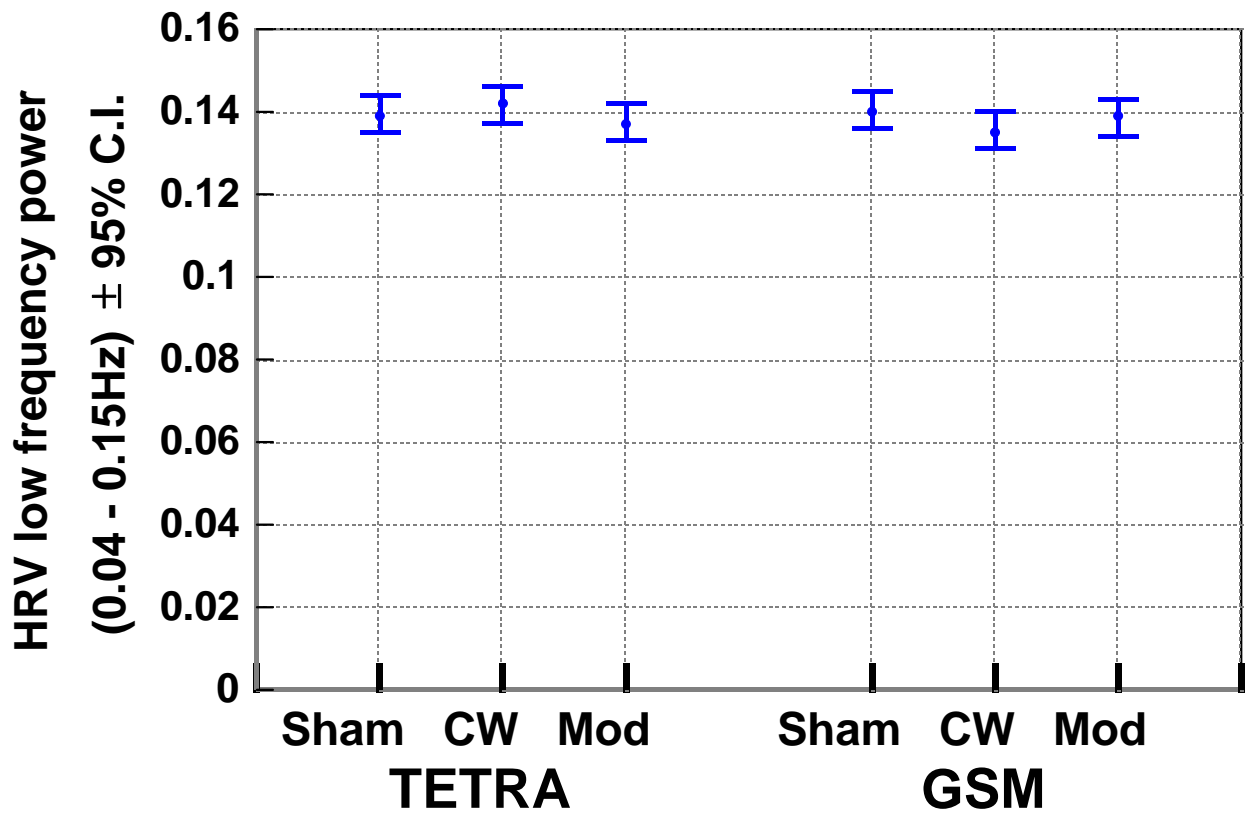


Figure 5. Estimated marginal means of the power in HRV low frequency band during the 40 min exposure period

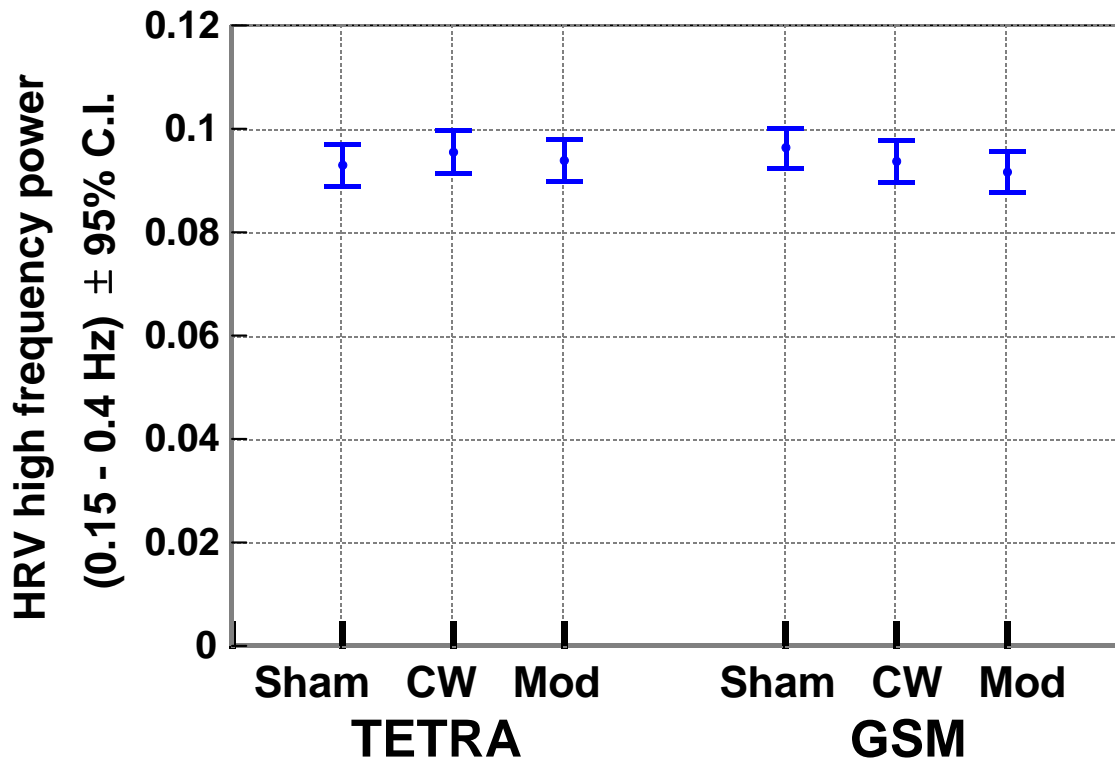


Figure 6. Estimated marginal means of the power in HRV high frequency band during the 40 min exposure period

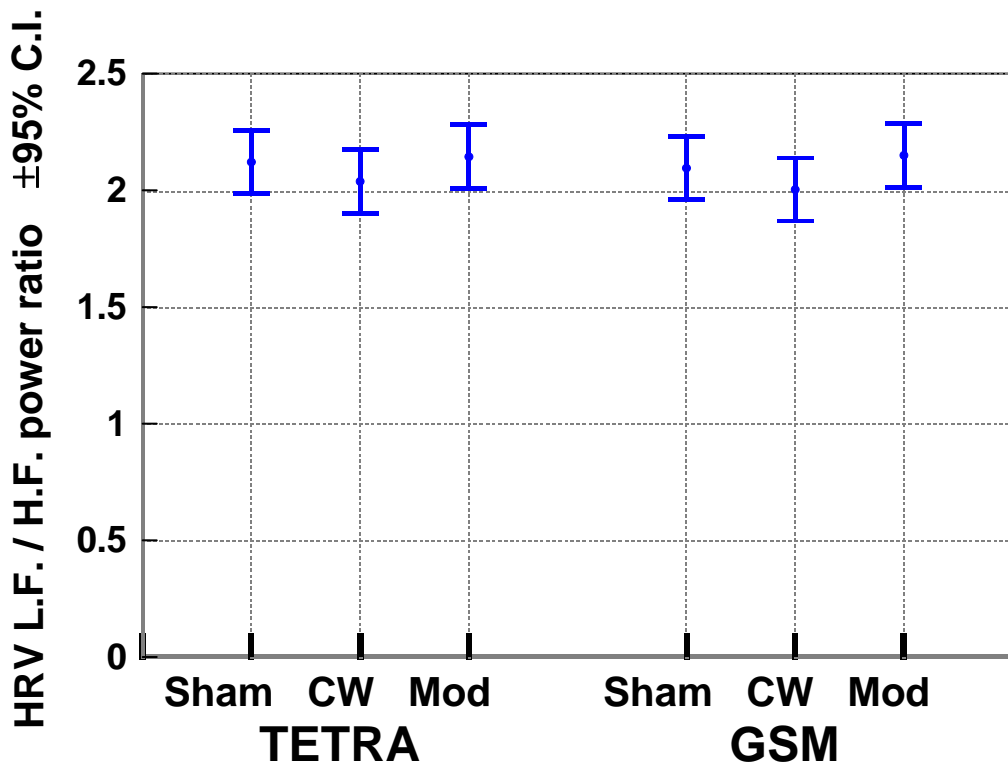


Figure 7. Estimated marginal means of the ratio of HRV low to high frequency band powers during the 40 min exposure period

4.5.3 Mean Arterial Pressure during exposure (the primary metric of the study)

MAP, averaged over the 40 minute exposure period, has been analysed with ANCOVA using the average MAP during the run-in period as the covariate and shows a difference between the treatment groups ($p=0.04$). In a *post hoc* analysis, just one of the six interventions appears to be statistically different from the others, namely GSM sham. This has a mean value of MAP 0.7mm Hg lower (95% confidence limits 0.3 - 1.2 mm Hg) than that of the other five exposures, which are all tightly grouped within a range ± 0.13 mm Hg. Figure 8 shows the estimated marginal means of MAP over the 40 minute exposure period versus intervention group. Figure 9 shows the time course of MAP during the exposure period. It can be seen that the MAP of the GSM sham group is consistently lower than that of the others throughout (the first data point being after 5 minutes exposure).

4.5.4 24 hour ambulatory blood pressure recordings

For each subject the data has been linearly interpolated to 10 minute epochs from the commencement of the recordings. This has then been analysed using repeated measures ANCOVA in three blocks, the first 12 hours of the recording, the second 12 hours and the full 24 hours, using run-in mean arterial pressure as the covariate. No statistical association with exposure type was seen ($p=0.12-0.53$). The estimated marginal means of MAP during the first 12 hours and the time course over the first 120 min of the ambulatory recording are shown, as examples, in figures 10 and 11 respectively.

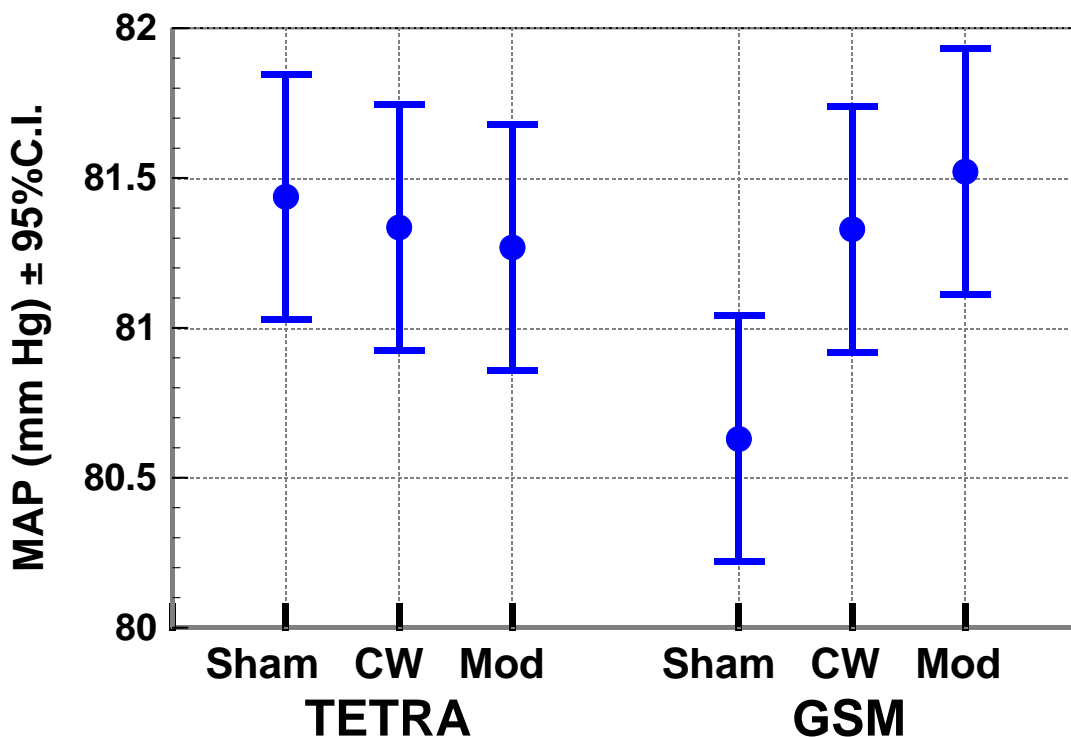


Figure 8. Estimated marginal means of MAP during the 40 min exposure period

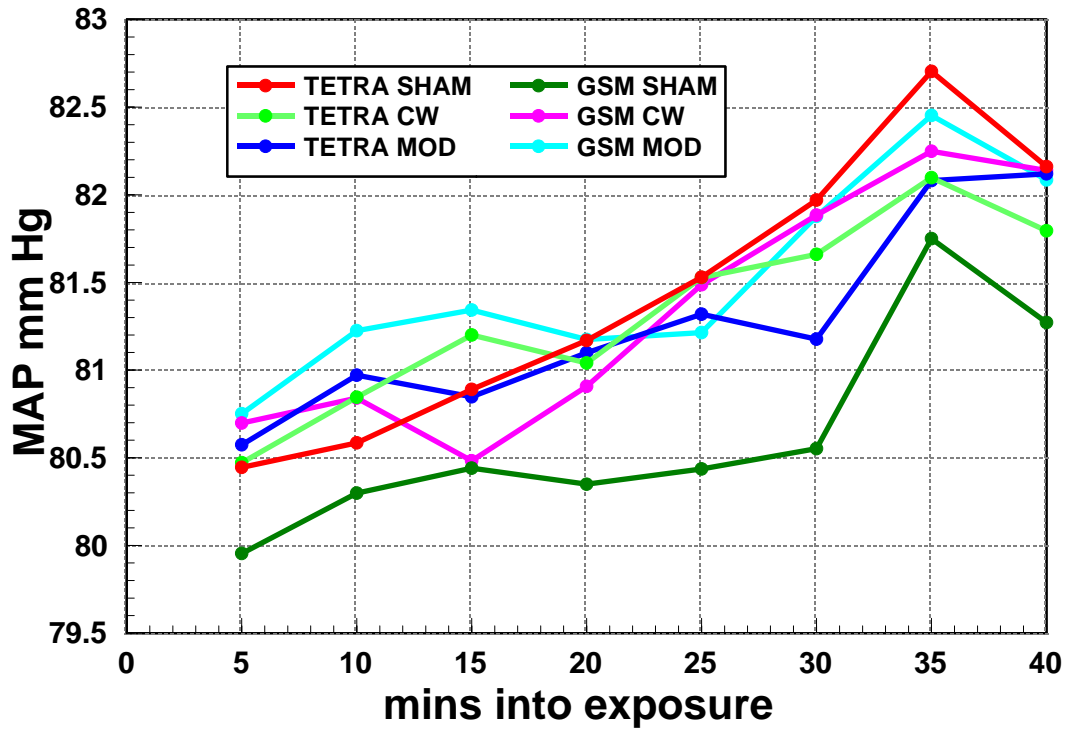


Figure 9. Estimated marginal means of MAP during the 40 minutes exposure period

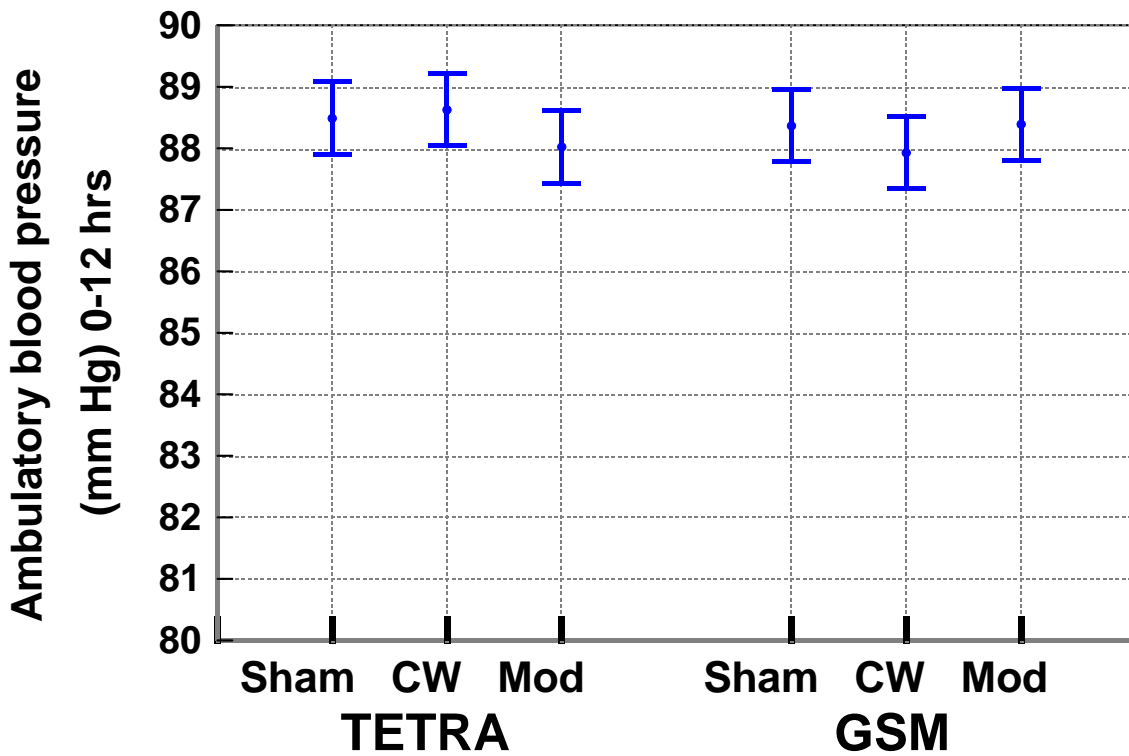


Figure 10. Estimated marginal means of ambulatory MAP during the first 12 hours of recording

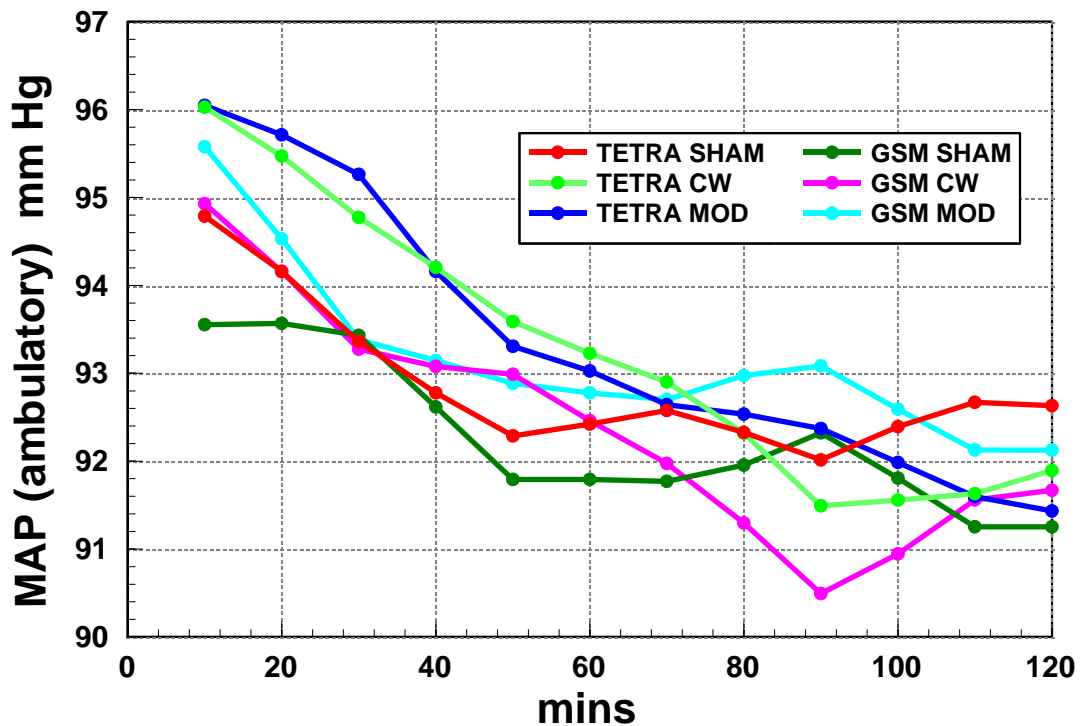


Figure 11. Estimated marginal means of ambulatory MAP during the first 120 min of recording

5 Analysis of Objectives Met

The project experienced no significant problems throughout its duration. At all stages it remained on schedule and to budget. We were able to collect data from 120 subjects, an increase over the 100 originally proposed, due to the remarkably low drop-out rate (5 subjects in total) which we encountered. Credit for this should go largely to our research nurse, Miss Helen Parry, who was responsible for both recruitment and the day-to-day running of the data collection phase of the study. The decision of the study team to collect data from additional subjects has increased the statistical power of the study at no additional cost to the MTHR programme. Additionally, in the early stages of the overall MTHR programme, we provided technical input into the design of the standard MTHR handset, in the form of infra-red thermal imaging and other temperature measurements following our observation that temperature differences between handsets in the various modes were readily detectable by subjects. We also developed a qualitative quality assurance procedure to check that the correct signals were

being emitted from the handsets in each of their six modes. We used this throughout the study and identified a number of hardware faults in the handsets that would otherwise have gone undetected. We recommend that similar checks should be incorporated into future protocols which use the MTHR standard exposure system.

6 Interpretation

Despite having the power to detect changes of mean arterial pressure of <1mm Hg, this study has demonstrated no effect of GSM and TETRA signals on blood pressure and related physiological parameters. Our analysis has identified a single statistically significant finding, which suggests that GSM handsets in Sham mode decrease MAP by -0.7mm Hg. It seems unlikely that this represents an effect of the radiofrequency signals; the hypothesis that the other 5 MAPs were, in fact, actively raised by their exposures is not consistent with one of them being a TETRA handset in Sham mode (figure 8). At present we have no well founded explanation for this finding, but we are of the view that it is likely to represent a

real effect rather than a chance occurrence. This is supported by the sham GSM data also being low (though not statistically significantly so) in the first two ambulatory data points shown in figure 11. Additionally, it can be seen from figure 9 that GSM Sham data is low, from the first measurement point at 5 minutes throughout the 40 minutes exposure period.

We have carried out comprehensive checks on our data to look for methodological errors, including the randomisation procedure, the mapping of exposure type onto our blinding code, and ambient temperature measurements made during the course of the exposure sessions, but these have revealed no anomalies. Based on the replies to our standard question set, subjects were not able in general to distinguish between the different exposure modes, although a minority of subjects correctly identified the GSM Mod intervention as transmitting (figure 12). The majority of these detected a faint buzzing sound

in a single handset which was only used for part of the study. Figure 12 provides no evidence that the GSM Sham mode could be consistently identified, either correctly or incorrectly.

In an attempt to throw light on this unexpected (but small) finding of an effect of GSM Sham exposure on MAP we have measured, as a surrogate for temperature, the power consumption of our handsets. Figure 13 shows the power taken by the handsets we have used in this study and which were available for retrospective measurement. The power has been calculated as the product of measured supply voltage and rms current when the handsets were powered by a mains adaptor (courtesy of Dr. Phil Chadwick) and placed against the head. It can be seen that the GSM Sham power consumption for a given handset is invariably higher than the corresponding GSM Mod and CW values.

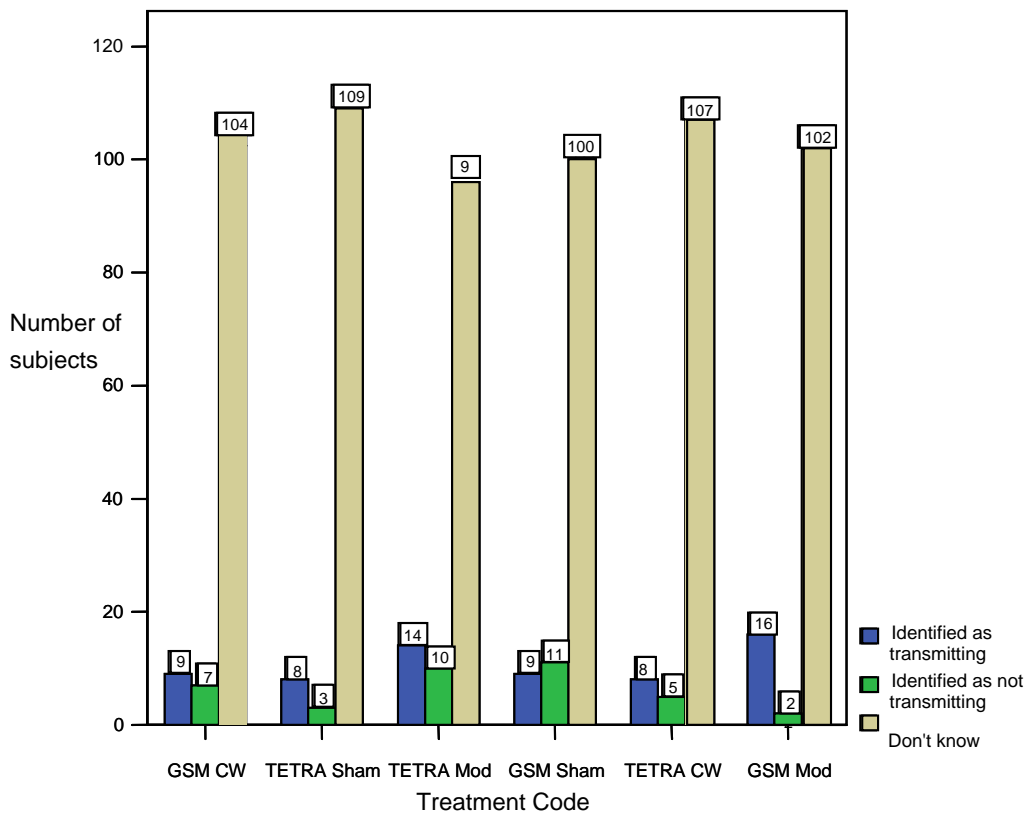


Figure 12. The ability of subjects to detect the intervention mode

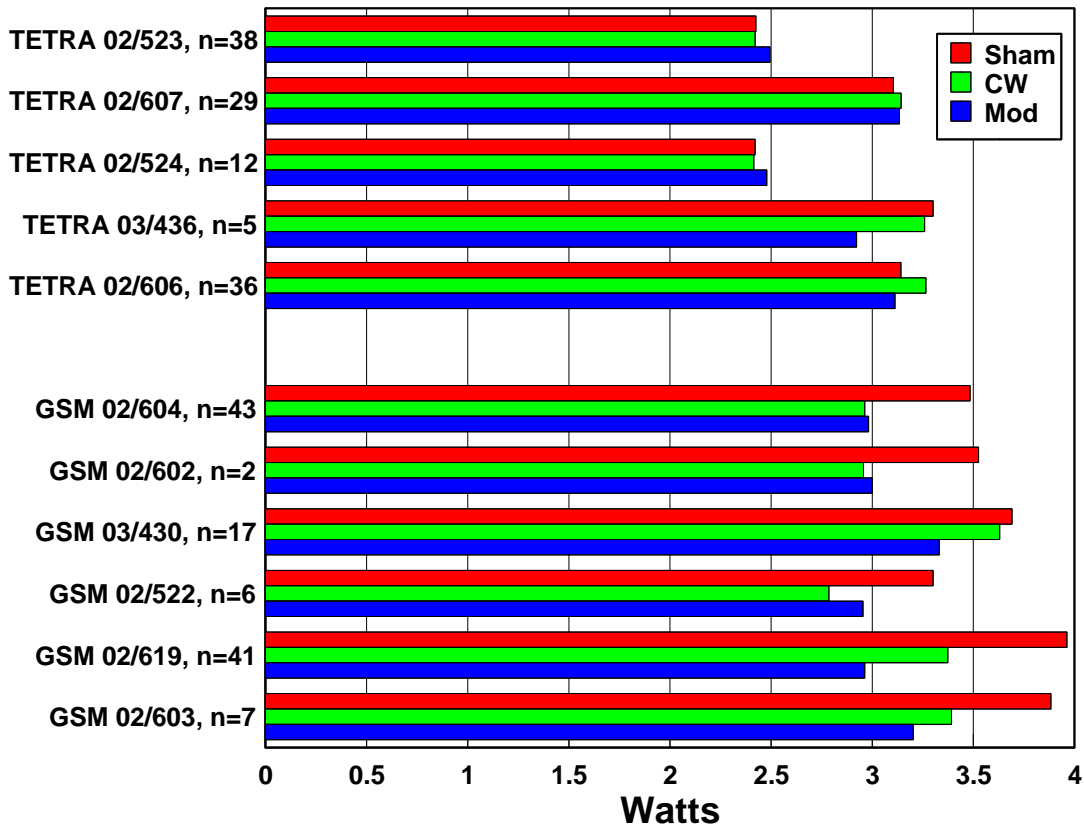


Figure 13. Power consumption of individual handsets when placed tilted against the head, n = the number of subjects for which that handset was used

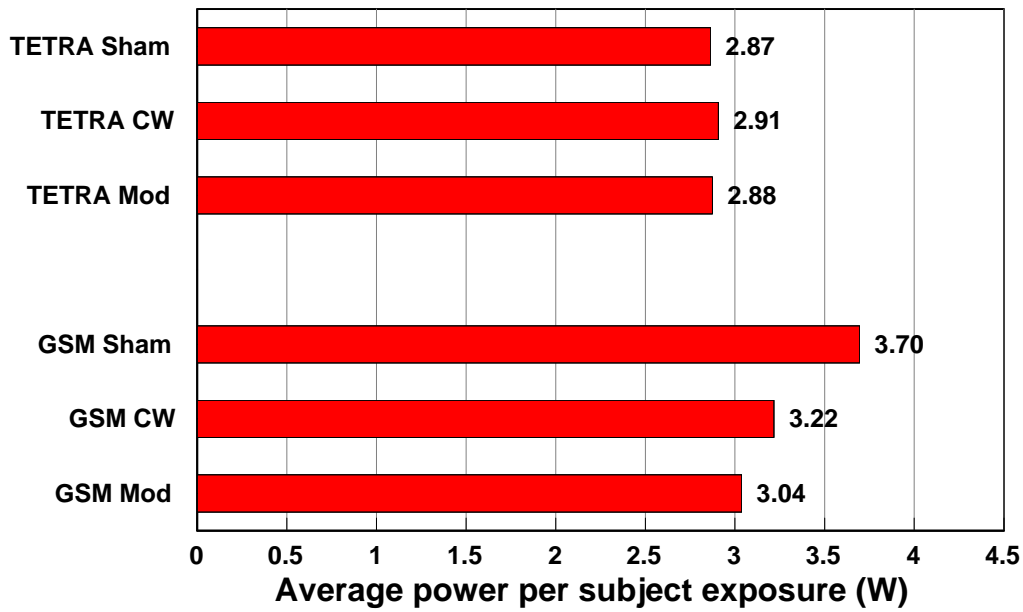


Figure 14. Handset power consumption weighted by number of volunteers for which each individual handsets was used

When measured with the handsets away from the head this imbalance does not occur. The effect appears to be due to the coupling between the head and the handset antennae when in an actively transmitting mode. In Mod and CW modes the power consumption of the GSM handsets drops by about 0.5W when close to the head, whilst the Sham power consumption is unaffected. This phenomenon does not occur in the TETRA handsets

Figure 14 shows the average power consumption during the study for each mode, calculated by weighting the data of figure 13 by the number of volunteers which used the individual handsets. It can be seen that the GSM Sham mode average is approximately 0.5W higher than the nearest other mode. When the power radiated in the active transmitted modes is also taken into account (estimated as -0.1W, Dr. Phil Chadwick, personal communication), the GSM handset in sham mode has, on average, higher internal power dissipation (by about 0.6W in 3W) than all the other GSM and TETRA modes. This would imply that they are slightly warmer in operation, but it is unknown whether this putative small increase in handset temperature would have a systemic effect on MAP. We have not made an attempt to quantify this temperature rise, but crudely estimate it to be about 1°C based on our previous measurements of skin temperature rise due to handsets applied to the side of the face in the standard exposure position. Measurements could be made, but would be quite difficult to carry out reliably. Issues that would need addressing if volunteer measurements were to be carried out would include inter and intra-subject variability, standardisation of the mechanical contact with the skin, ambient temperature control and a suitable measurement of temperature (either infra-red imaging or spot optical fibre measurements could be used but both have limitations). Alternatively a suitable phantom could be constructed, which would perhaps have less variability than subjects, but which would need appropriate dielectric and thermal conductivities, and be maintained internally at 37°C. Such a phantom-based approach would have similar

issues regarding the most appropriate temperature measurement technology.

Unfortunately, even if such measurements were made to identify this putative temperature increase, there remains no data in the scientific literature which quantitates a link between an applied temperature rise on one side of the face to systemic blood pressure changes. Hence our hypothetical explanation for our one significant finding remains unsubstantiated.

7 Future Priorities

In our opinion these findings, coupled with the two other recent studies, (Tahvanainen et al., 2004 and a failed self replication of the original study (Braune et al., 2002)) suggest that no further study of the acute effect of GSM and TETRA on blood pressure in normal subjects is required.

8 Publications

A paper based on this work has been accepted for platform presentation at the 2006 annual conference of the Bioelectromagnetics Society, and a paper to a refereed journal is planned.

9 Financial Summary

The project has stayed within budget at all times and has delivered a small overall underspend of £7,380.95

Breakdown by category	Grant	Expenditure
Total Grant	£363,535	£356,154.05
Consumables and other expenses	£67,936	£60,330.44
Equipment	£22,084	£22,308.61
Salaries and Overheads	£273,515	£273,515

10 Acknowledgements

We would like to gratefully acknowledge the assistance of Dr. Steven Wood who wrote the software implementation of the Lomb algorithm and the software for assembling and ordering the data prior to statistical analysis

11 References

- Braune, S., Riedel, A., Schulte-Monting, J., and Raczek, J. (2002). Influence of a radiofrequency electromagnetic field on cardiovascular and hormonal parameters of the autonomic nervous system in healthy individuals. *Radiat Res* 158, 352-356.
- Braune, S., Wrocklage, C., Raczek, J., Gailus, T., and Lucking, C. H. (1998). Resting blood pressure increase during exposure to a radio-frequency electromagnetic field. *Lancet* 351, 1857-1858.
- European Society of Cardiology (1996). Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. *Circulation* 93, 1043-1065.
- Folkow, B. (1994). Autonomic nervous system in hypertension. In *Handbook of hypertension: behavioural factors in hypertension*, J. S. a. B. D.R., ed. (Oxford, Blackwell Scientific Publications), pp. 431-432.
- Guzzetti, S., Piccaluga, E., Casati, R., Cerutti, S., Lombardi, F., Pagani, M., and Malliani, A. (1988). Sympathetic predominance in essential hypertension: a study employing spectral analysis of heart rate variability. *J Hypertens* 6, 711-717.
- Laguna, P., Moody, G. B., and Mark, R. G. (1998). Power spectral density of unevenly sampled data by least-square analysis: performance and application to heart rate signals. *IEEE Trans Biomed Eng* 45, 698-715.
- Tahvanainen, K., Nino, J., Halonen, P., Kuusela, T., Laitinen, T., Lansimies, E., Hartikainen, J., Hietanen, M., and Lindholm, H. (2004). Cellular phone use does not acutely affect blood pressure or heart rate of humans. *Bioelectromagnetics* 25, 73-83.

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