# TITLE: SLEEP QUALITY AND NOISE: COMPARISONS BETWEEN HOSPITAL AND HOME SETTINGS (10 words)

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**Key words**: Sound level, sleep quality, paediatric ward, environmental noise

**Abbreviations:**

dBA decibels

TST: Total Sleep Time

SE: Sleep Efficiency

**What is known on this subject** *(34/40 words)*

* Children and parents self-report poor sleep on paediatric wards, but the only objective measurements have been in oncology and intensive care settings
* Noise at night may contribute to an environment which is not conducive to sleep

**What this article adds** *(39/40 words)*

* Children and mothers experience over an hour less sleep and poorer sleep quality in hospital compared to when they sleep at home
* Hospital noise levels exceed World Health Organisation recommendations and are significantly louder than in children’s bedrooms at home

**Main paper 2499 words (figures separately)**

ABSTRACT **(246/250 WORDS)**

**Objective:** Children and their parents report poor sleep in hospital and complain about noise. We aimed to measure sleep quality and noise levels in hospital and compare these to the home environment.

**Design:** Observational within case controlled study.

**Setting:** Paediatric medical wards at Southampton Children’s Hospital and bedrooms at home.

**Participants:** Children aged 3-16 years and their co-sleeping parents.

**Interventions**: Sleep quality was measured using actigraphy for a maximum of 5 nights in each setting. Median sound levels at the bedside were monitored overnight in a sub-group in both settings.

**Main outcome measures:** Total sleep time, sleep efficiency, median sound levels overnight

**Results:** 40 children and 16mothers completed actigraphy in both settings. Children had on average 62.9 minutes, and parents 72.8 minutes per night less sleep in hospital than at home. Both children and parents had poorer sleep quality in hospital compared to home: mean sleep efficiency 77.0% v 83.2% children and 77.1%v88.9% parents respectively. Median sound levels in hospital measured in 8 children averaged 48.6 dBA compared to 34.7 dBA at home and exceeded World Health Organisation recommendations of 30dB.

**Conclusions:** Children and their mothers have poor quality sleep in paediatric wards. This may impact the child’s behavior, recovery and pain tolerance. Sleep deprivation adds to parental burden and stress levels. Sound levels are significantly elevated in hospital and may contribute to poor sleep. Reduction in noise level could therefore lead to an improvement in sleep impacting both parent and child quality of stay.

INTRODUCTION

In 2016 England’s children spent approximately 2.4 million nights (over 70,000 years) in hospital[1]. What is known about their sleep in hospital? Research using self-report sleep diaries, questionnaires and parental interview consistently indicates reduced sleep time, increased night waking and poor sleep quality in both children and co-sleeping parents.[2-4]. While self-report measures can be inaccurate,[5-7] two small studies in oncology in-patients using objective measures of children’s sleep, wrist watch accelerometry or ‘actigraphy’, support these assumptions. Linder et al studied 15 children aged 5-12yrs over 3 nights in the USA and reported reduced sleep quality on all nights compared to age normative data. [8, 9] Setyoma et al compared the sleep of 11 Japanese children (aged 2-12 years) over two consecutive nights of admission for chemotherapy to one night at home, allowing children to act as their own controls. Children took longer to fall asleep in hospital (42.1 v 26.5 minutes) but no differences in sleep quality or total sleep time were reported.[10, 11] Thus, convergent evidence suggests that hospital admission adversely effects sleep quality but this has not been measured objectively in a general paediatric ward setting.

We have previously identified noise levels as a significant cause of sleep disruption in paediatric medical wards.[3]. The World Health organisation (WHO) recommend that average noise levels at night in hospital wards should not exceed 30 decibels (dB) with peak levels not exceeding 45dB[12]. Oliveira et al measured sound levels greater than 45dB for 85% of the night in general paediatric wards in Portugal but no comparisons were available to the child’s usual sleep environment[13].

In this study, we aimed to objectively measure sleep quality in both children and their co-sleeping parents admitted to paediatric medical wards and compare this to their sleep at home. A secondary aim was to measure sound levels at the bedside in both environments.

# METHODS

**Participants**

Inpatients ages 3-16 years, and their resident parents, were recruited across 6 wards at Southampton Children’s Hospital, a regional centre in the south of England, between February 2012 and July 2014.

Exclusion criteria included: underlying neurological disorder or epilepsy likely to disrupt sleep; significant sleep disorders as reported by parents; surgical procedure during admission; patients likely to be admitted to the high dependency unit; and families that did not speak English.

The study was reviewed and approved by a UK National research ethics committee (*reference 10/HO502/82*). Parents completed a consent form on behalf of their child. Where appropriate children also completed an assent form.

**Measures:**

*Demographic data*: Data were collected on parent and child age and ethnicity. The child’s reason for admission was classified as either acute or chronic condition. Chronic conditions were defined as significant health problems with history of regular hospital admission and/or experience of ward attendance (e.g. cystic fibrosis, chronic renal disease). Location of hospital bed (4-6 bed open bays or single occupancy cubicle) was recorded for children recruited in the latter part of the study.

*Actigraphy*: Children and caregivers were monitored using a Basic Mini Motionlogger actigraph watch worn on their non-dominant wrist (Ambulatory Monitoring Inc., New York) for up to five consecutive nights in hospital, and up to five consecutive nights at home. This device has been validated against gold standard polysomnography for identifying sleep–wake patterns in children.[14] Watches were initialized to record in zero-crossing mode (number of times per one minute epoch that the activity signal level crosses zero i.e. a measure of frequency of movement.). A sleep diary was used to record ‘lights out’ and wake times.

*Sound levels*: For a sub-set of the children, sound levels were monitored overnight using an industry standard calibrated Bruel & Kjaer 2236 sound level meter at the patient’s bedside for up to two nights in hospital and two nights at home. This detected ambient sound levels, measured in A weighted decibels (dBA), these represent sound levels as perceived by the human ear[12]. The device was set to record during the child’s sleep. Median sound levels (LAeq) during the child’s sleep period are reported.

**Data analysis**

The lack of prior studies on which to base sample size calculation meant that sample size estimate was pragmatic with initial estimates of 20 child-parent dyads. This was re-assessed at the study mid-point and the sample size was extended.

*Actigraphy data*: These were analysed using ActionW2 software using the Sadeh algorithm validated for use with children.[15] Raw data were visually inspected to reject epochs where the watch had been removed. Primary outcome measures included

1. Total Sleep Time (TST): total minutes from sleep-onset time until final morning wakening
2. Sleep efficiency (SE): Percentage of minutes scored as sleep from sleep onset to morning wakening.

Data were analysed in SPSS version 21 (IBM) and examined for normality using Shapiro-Wilk test. Normally distributed data were analysed using paired or independent samples t-tests. Non-normally distributed data were analysed using Wilcoxon signed rank test for paired samples and Mann Whitney U test for independent samples. Change in sleep measures within a location over time were assessed using ANOVA with repeated measures or Friedman test for non-parametric data.

# RESULTS

**Participants**

55 children and 32 parents met the inclusion criteria and were recruited to the study (Figure 1). 40 children and 16 parents completed a minimum of one night of actigraphy both in hospital and at home. Attrition was due to children not tolerating the actiwatch, limitations of equipment availability and reluctance to continue the study after discharge. The 40 children (19 males) had a mean age of 9.3 years (SD 3.5.3), 87.5% were white and 65% were admitted with an acute condition. All 16 parents were mothers with an average age of 37.9 years (SD 6.1) Ages were missing for one child and two mothers. There were no significant differences in demographics, or reason for admission between the children recruited and the final sample.

Of the 8 children (5 males) who completed sound level monitoring, the average age was 9.0 years (SD 3.1) and a higher proportion (27.5%) were from black and ethnic minority backgrounds. No other significant differences were noted.

**Actigraphy children**

Children were monitored for a mean of 2.9 (SD 1.5) nights in hospital and 3.5 (SD 1.5) nights at home. TST was normally distributed, and SE was not normally distributed, means and confidence interval are reported for ease of reading. Both TST (mean 446.6 minutes hospital, 95% confidence interval (CI) 416.0-477.2, versus 509.5 minutes home, 95% CI 482.1-536.9, p<0.001) and SE (mean 77.0% hospital, 95% CI 73.2-80.9%, versus 83.2% home, 95% CI 80.1-86.4% p=0.002) were significantly lower in hospital compared to the home environment. There was an average reduction in TST of 63 minutes (SD 86.6, 95% CI 36.43-65.6) in hospital compared to home. (Figures 2&3)

**Actigraphy parents**

Parents were monitored for a mean of 2.6 nights (SD 1.5) in hospital and 3.6 nights (SD 1.2) at home. Both TST and SE were normally distributed. Both TST (mean 381.1 minutes hospital, 95% CI 320.5-441.7, versus 453.9 minutes home, 95% CI 414.0-493.7, p=0.004) and SE (77.1% hospital, 95% CI 71.1-83.1% versus 88.9% home, 95% CI 85.5-92.3%, p<0.001) were significantly lower in hospital than at home. There was an average reduction in TST of 72.8 minutes (SD 85.01, 95%CI 35.58-115.23). in hospital compared to home. (Figures 2&3)

**Differences in hospital sleep measures by type of admission and sleep location**

A larger group of 46 children and 24 parents completed one night of actigraphy in hospital. There was no significant difference in demographic characteristics or reason for admission in this subgroup as compared to the recruited sample. Data entry was incomplete in regards to location of sleep.

There was no difference in TST and SE during hospital stays between children admitted with acute or chronic conditions (acute mean TST 439.0 minutes (95% CI 402.6-477.3), chronic mean TST 471.4 minutes (95% CI 429.4-517.4), p=0.22, acute mean SE 75.9%, 95% CI 70.7-81.1%) chronic mean SE 79.1%, (95% CI 74.3-83.8%; p=0.661 n=46)

There was no difference in average TST between children sleeping in open bays compared to single occupancy cubicles (426.4 minutes open bay 95% CI 388.1-467.8 v 399.2 minutes single occupancy cubicle 95%CI 336.9-459.3 p=0.47 n=19 or average SE open bay mean 82.8% 95%CI 75.7-89.9%, cubicle mean 72.4%, 95% CI 61.3-82.1% p=0.17 n=19).

**Controlling for recovery night at home.**

As participants may have experienced a night of recovery sleep on returning home, differences between consecutive nights at home were assessed. [16, 17]. There was no recovery effect noted in TST and SE in either children or parents in a repeated measure analysis comparing the first night at home to the third night at home (children TST p=0.807, children SE p=0.984 Parents TST p=0.249 Parent SE p=0.607)

S**ound level monitoring**

Sound level monitoring was completed at the bedside for at least one night in 10 children during their hospital admission of whom 5 had 2 nights of measurement. The average median sound level LEeq recorded was 48.24 dB with a trend level difference between the 7 children sleeping in open bays versus those sleeping single occupancy cubicles (n=3). (open bay mean 50.35 dBA, 95% CI 38.7-62.0, single occupancy cubicle mean 42.27 dBA, 95% CI 33.3-51.2, p=0.077).

Eight children were monitored both in hospital and at home. Median sound levels were significantly higher in hospital than at home than at home, LAeq 48.6 dBA hospital (95% CI 42.3-54.8 dBA) compared with 34.7 dBA home (95% CI 27.9-41.5; p=0.017). (Figure 4)

# DISSCUSSION

This is the first report of poor sleep quality in both children and mothers in a paediatric medical ward environment using objective measures. Children lost over one hour of sleep in hospital compared to sleep at home, averaging just under 7.5 hours of sleep, while mothers experienced almost an hour and quarter less sleep, averaging only 6 hours and 20 minutes in hospital. Not only did children and mothers have shorter sleep in hospital but their sleep quality was also relatively poor.

Does this matter? Growing evidence supports the role of sleep in behavioural and emotional regulation across life[18]. School-aged children deprived of 54 minutes of sleep (less than in the present study) over five nights had restless-impulsive behaviour and poorer emotional regulation.[19-21]. A study of mothers caring children with eczema found that only 39 minutes of sleep deprivation correlated with increased maternal anxiety and depression[22]. Having a child in hospital is a stressful experience[3, 23], even during a short admission 90% of parents report feeling upset, and 52% mentally exhausted[24]. Sleep loss may compound parental stress and anxiety, and emotionally dysregulated children will be less likely to comply with treatment.

Sleep loss in hospital may have other physiological consequences. An association between lack of sleep and increased pain sensitivity is well established in adults[25]. While experimental studies are lacking in children, it is reasonable to assume the same is true.[26, 27] Better sleep could, in theory, improve children’s ability to cope with pain and reduce the need for analgesia. There is also good evidence that sleep regulates immune function, although it is not known the extent to which sleep loss impacts on this[27-29]. As infection is the leading cause of hospital admission it makes little sense to further risk impairment of immune function through sleep loss.[30]. In PICU, there is growing interest into the impact of large physiological insult such as burn or mechanical ventilation on a child’s sleep, and the impact this has on the child’s outcome[31].

Our study was not designed to explain why children and their parents experienced poor sleep. In a US paediatric oncology setting sound, light, medication dose, pain and nausea accounted for 57% of the variance in total sleep time between patients.[32] Parents in our previous research had identified noise as a modifiable source of sleep disruption.[3] Median bedside sound levels in this present study (48.2 dBA) exceeded WHO guidelines of 30 dBA, and were similar to levels in a Portuguese general paediatric ward (43.4 -54.9dB) and oncology wards in the USA (49.5 dB).[12, 13, 33]

While we did not measure the inter-relationship between sleep quality and noise levels it is reasonable to infer that noise will have affected sleep. The sleeping brain is highly attuned to sound, an important evolutionary defence to potential threat. Nocturnal noise events can induce changes in sleep stage and awakening resulting in fragmentation of sleep architecture.[34] Electronic sounds such as IV pump alarms are particularly likely to induce arousal.[35] Furthermore, the autonomic arousal associated with such repeated noise exposure does not show the acclimatisation that occurs when awake. Our findings that noise levels in children’s bedrooms (34.7 dBA) also exceeded WHO recommendation of 30 dBA LAeq were interesting and underline the importance of home measures.[12] Traffic noise in urban settings can impact on children’s sleep and traffic noise exposure has been linked to increased frequency of emotional symptoms and hyperactivity and may impact blood pressure.[36, 37] Are WHO guidelines unrealistic for modern society, or are some children chronically over-exposed to night time noise?

Limitations

No record was kept of the families who declined participation, or who were not approached, so there may have been sampling bias in our original sample of 55 children. However, families of sicker children were likely to refuse to take part at the outset, therefore selection bias would be towards children with less disrupted sleep. Of the 55 children recruited to the study only 73% completed sleep measures in both settings, however, the lack of demographic differences between the original and final samples suggests no systematic bias.

Importantly these data represent the largest series of children with objective sleep measures in hospital. That each child acted as their own control with measures both in hospital and in their home environment is a further strength.

Expert consensus is that five nights of actigraphy is optimal for reliable interpretation[38]. In this study on average children were studied for 2.9 nights and mothers for 2.6 nights. This was a necessary compromise as the average length of admission to paediatric units was 2.1 days in 2012/2013[39]. Indeed previous research using this approach has reported data including only one night actigraphy.[11]

Limited data were recorded for other variables that could have impacted on sleep. Future studies could usefully explore how child factors (treatment, observation schedules, pain, fever, primary diagnosis) and environmental factors (light, temperature, noise) relate to children’s sleep.

Finally, each hospital ward has a unique and fluctuating environment dictated by physical design, resident children and parents and by staff behaviour. Generalisability of our findings cannot be assumed although our data do confirm a growing literature in this field.[3, 4, 13, 40]

**Conclusion**

Children and their mothers in this study had significantly less sleep at night in hospital compared to at home. Furthermore, they were exposed to significantly higher noise levels that exceeded WHO recommendations. Despite 150 years of medical progress we have forgotten the basic lessons of patient care,

 “Unnecessary noise is the cruellest absence of care.” Florence Nightingale 1859.

Sleep is one aspect of care that can be freely delivered and future research should evaluate interventions which promote sleep for children and parents alike.

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