Effects of Sleep on Speech and Language Outcomes in Stroke Rehabilitation

Ian Kim, Tayler Simonds, Michelle Swanson

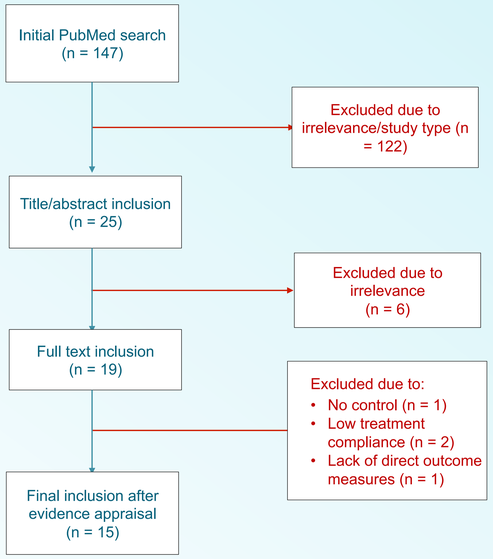
University of North Carolina at Chapel Hill, Division of Speech and Hearing Sciences

Introduction

Sleep disturbance is prevalent among patients who have suffered from stroke, and poor sleep may have an impact on stroke recovery. Suboptimal sleep has been linked to poor cognition and memory in those with neurodegenerative disease, and even normal adults. This relationship may carry clinical implications about the sleep needs of stroke patients who are receiving speech and language therapy during their rehabilitation.

Studies that explicitly address the effects of sleep on speech and language outcomes post-stroke are scarce, though we came across a variety of studies which measured multiple outcome domains that are closely linked to speech and language processes. These included measures of overall cognition, memory, attention, executive function, reaction time, vigilance, and motor learning.

Methods



- All three reviewers independently decided to include or exclude at the title/abstract and full text level.
- Evidence levels were established by independent double appraisal and reviewer discussion of discrepancies in order to reach consensus.

Results

Figure 1: Summary of quality appraisal findings by author. Key: Good quality: Green, Adequate: Yellow, Poor: Red

First Author & Year	Group(s)	Limitations
Aaronson 2015	OSA (n = 80) and non-OSA (n = 67).	Study evaluated language but omitted subjects with severe aphasia
Aaronson 2016	4 weeks of CPAP treatment (n = 20) or treatment as usual (n = 16).	CPAP compliance low (11/20 subjects, note that ITT was used in their analysis)
Gao 2008	Mice with ischemic surgery/GHB (n = 7), ischemic surgery/saline (n = 6), sham surgery/saline (n = 6), and sham surgery/GHB treatment (n = 6).	Might not translate to humans
Gomez 2008	Patients with prefrontal lesions (n=14), parietal lesions (n=5), healthy controls (n=15)	Duration of study, sleep deprived control would perhaps have been preferable
Hodor 2014	Ischemic rats (Bac treatment vs. control)	Might not translate to humans
Kim 2015	Patients post-stroke (n = 80)	Nature of study allows for numerous confounders
Lefevre-Dognin 2014	SAS+ (n = 28) and SAS- (n = 15) as defined by AHI ≥ 10 respectively.	Significant age differences between SAS+ and SAS- groups (p = 0.004); irregular administration time of BAWL
Ryan 2011	CPAP vs. no CPAP treatment (n=22,22)	12% CPAP noncompliance
Sandberg 2001	Patients post-stroke (n = 133) who fulfilled criteria for sleep apnea (n = 78), defined by AHI ≥ 10.	Sleep apnea group had significantly higher rates of previous cerebral infarction and ischemic heart disease
Siccoli 2008	Patients with first ever acute stroke (n=11). Compared to 5 age-matched controls	Small sample size and variation in time of follow-up examinations performed during recovery phase (ranged from 3 to 12 months)
Siengsukon 2008	Post-stroke individuals (n = 18) vs. age-matched neurologically intact controls (n = 18), divided into sleep (n = 9) and no-sleep (n = 9) subgroups	Pseudo-randomized, time-of-day effect confounder, sleep quality not assessed
Siengsukon 2009	Stroke pts assigned to test in the evening and retest in the morning (after sleep) vs. test in the morning and retest in the evening (no sleep)	Pseudo-randomized, time-of-day effect confounder, sleep quality not assessed
Siengsukon 2009	Post MCA stroke individuals (n = 15) vs. age and sex matched controls (n = 15), divided into sleep (n = 8) and no-sleep (n = 7) subgroups	No effect size given; SEM error bars overlapped between stroke-sleep and stroke-nosleep groups: not likely to be clinically significant
Siengsukon 2015	Post-stroke individuals >6 months following stroke (n = 20) vs. neurologically intact controls (n = 10)	Small sample size
Zunzunegui 2011	Ischemic rats with sleep vs. sleep deprivation	Might not translate to humans
Baumann 2014	Post-stroke patients	Data is not presented in a way that shows the relationship between sleep and outcomes (confounders not accounted for)
Hsu 2006	Post-stroke patients with AHI ≥ 30 receiving CPAP (n = 15) vs. those not receiving CPAP (n = 15)	Low CPAP treatment compliance: mean of 1.4 h/night, median of 0.16 h/night; mean exceeded 6h in only two patients
Kim 2010	Post-stroke patients with insomnia treated with hypnotics (n = 15) vs. post stroke patients w/o insomnia (no treatment, n = 15)	No appropriate control
Sandberg 2001	Post-stroke patients with AHI >= 10 (n = 78) and post-stroke patients with AHI < 10 (n = 55)	Low CPAP treatment compliance: mean of 4.1 +/- 3.6 h/night (range 0-10.9h), 15/31 patients used for <4 h/night

Figure 2: Summary of study findings by domain. Key: Significant: Green, Non-significant: Yellow

Domain	Article	Measures	Results
Overall Cognition	Aaronson 2015	Canadian Neurological Scale (CNS)	Significant difference in CNS total score between SA+ and SA- groups (p = 0.01, d = 0.47)
	Ryan 2011	Canadian Neurological Scale (CNS) – total score and cognitive subscale	Significant differences between control and CPAP groups in change in CNS total score (p = 0.001) and CNS cognitive subscale score (p = 0.01) over 1-month period.
	Sandberg 2001	Mini-Mental State Examination (MMSE)	No significant difference between SA+ and SA- groups (p = 0.206).
	Siccoli 2008	Mini-Mental State Examination (MMSE)	MMSE scores correlated with WASO scores (r = -0.855; p = 0.003), sleep efficiency measures (r = 0.818; p = 0.007), and amount of REM sleep (r = 0.708; p = 0.033).
	Siengsukon 2009 "Sleep enhances…"	Mini-Mental State Examination (MMSE)	SA+ group scored 15.9±8.5 while SA- group scored 17.8±8.3. No significant difference (p = .209).
Language	Aaronson 2015	Category Fluency Test for verbal fluency	No significant difference was found between OSA and non-OSA stroke patients (p = 0.41).
	Aaronson 2016	Category Fluency Test for verbal fluency	No significant difference was found between stroke patients in CPAP treatment and control groups (p = 0.11).
Attention	Aaronson 2015	D2 Test of Attention	OSA patients had significantly lower attention scores than non-OSA controls (p < 0.01).
	Aaronson 2016	D2 Test of Attention	OSA patients with CPAP performed significantly better than controls (p = 0.05, partial eta squared = 0.09).
	Ryan 2011	Sustained attention response time	No significant difference found between CPAP treated patients and controls (p=0.32).
	Siccoli 2008	D2 Test of Attention	Attention positively correlated with sleep efficiency (r = 0.850, p = 0.004) and negatively correlated with wake after sleep onset (r = -0.864, p = 0.003).
Memory	Aaronson 2015	Rey Auditory Verbal Learning Test	OSA patients did not perform significantly better than controls (p=0.39).
	Aaronson 2016	Rey Auditory Verbal Learning Test	CPAP patients did not perform significantly better than controls (p=0.32).
	Gomez 2008	Rey Auditory Verbal Learning Test, Rey-Osterreith Complex Figure Test	No significant improvement after a night of sleep.
	Siccoli 2008	CVLT and Rey Visual Design Learning Test	Wake after sleep onset correlated significantly with poor performance on tests of verbal memory (p<0.05) and figural memory (p<0.01) while sleep efficiency improved performance significantly (p<0.05). REM sleep correlated significantly with more memory measures than slow-wave sleep.
Working Memory	Aaronson 2015	WAIS-III Letter-Number Sequencing	OSA patients did not perform significantly better than controls (p=0.10).
	Aaronson 2016	WAIS-III Letter-Number Sequencing	CPAP patients did not perform significantly better than controls (p=0.16).
	Gomez 2008	"2-back" (Modified N-back)	No significant improvement after a night of sleep.
	Ryan 2011	Digit span backwards (visuo-spatial span for aphasic patients)	CPAP patients showed significant improvement on digit (or V.S.) span backward, while those without CPAP did not. However, the between-group difference was not significant.
Motor	Aaronson 2015	Finger Tapping Test	OSA patients had significantly lower psychomotor ability than non-OSA patients (p < 0.01).
	Aaronson 2016	Finger Tapping Test	CPAP patients did not perform significantly better than controls (p = 0.45).
	Gomez 2008	Serial Reaction Time Task (SRTT)	Patients with prefrontal lesions improved overnight on a motor learning test (p<0.001) while parietals did not show significant learning.
	Kim 2015	Hand strength test, Purdue Pegboard, 9-hole peg test	Good sleepers did not show significantly different performance on any of the motor outcomes compared to poor sleepers.
	Lefevre-Dognin 2014	Fugl Meyer score	SAS patients were not significantly different from non-SAS patients, neither at baseline (p = 0.76) nor after 2 months (p = 0.20).
	Ryan 2011	6-minute walk distance, Berg Balance Scale, CNS motor subscale	CPAP patients showed a significant increase in 6-minute walk distance after 1 month (p = 0.02) and CNS motor subscale (p = 0.001), whereas control patients did not improve. Both groups showed significant improvement in Berg Balance Scale score over baseline (p = 0.001 for controls, p = 0.01 for CPAP group).
	Sandberg 2001	Organic Brain Syndrome Scale (OBS) – confusion subscale	Psychomotor slowing was not significantly different between post-stroke patients with AHI ≥10 and those with AHI < 10 (p = 0.225).
	Siengsukon 2015	Motor learning – continuous tracking task	After 3 consecutive days of sleep after baseline, post-stroke individuals demonstrated a significant improvement in tracking (p = 0.006) while the neurologically intact controls did not (p = 0.816).
	Siengsukon 2008	Motor learning – continuous tracking task	Post-stroke individuals who slept exhibited a significant improvement in tracking (p = 0.018, effect size = 0.764). Post-stroke individuals who did not sleep did not (p = 0.467). Neither control group showed improvement (p = 0.702 for sleep group, p = 0.458 for no-sleep group).
	Siengsukon 2009 "Sleep to learn after stroke…"	Motor learning – continuous tracking task	Post-stroke individuals who slept exhibited a significant improvement in tracking over stroke patients who did not sleep (p = 0.006). Controls who slept did not show a significant improvement over controls who did not (p = 0.816).
	Siengsukon 2009 "Sleep enhances…"	Motor learning – continuous tracking task	Post-stroke individuals who slept exhibited significant temporal motor learning (p = 0.036) and spatial learning (p = 0.014) while post-stroke individuals who did not sleep did not exhibit either (p = 0.962 for temporal, p = 0.556 for spatial). Spatial tracking did not improve in either of the control groups (p = 0.578 for sleep, p = 0.776 for no-sleep).
Motor-Animal Studies	Gao 2008	Grip strength	Post-stroke mice given GHB (a slow-wave sleep promoting drug), showed significant grip-strength restoration compared to controls at 3 weeks, but the effect was no longer significant at 5 weeks.
	Hodor 2014	SPR (single-pellet reaching task)	Post-stroke rats given baclofen, a non-REM sleep promoting drug, performed significantly better on SPR task than controls. (only significant in rats with right-hemisphere lesions).
	Zunzunegui 2011	SPR	Post-stroke rats were sleep-deprived and performance on SPR was significantly worse than sleeping counterparts starting at 2 weeks.
Vigilance	Aaronson 2015	Psychomotor Vigilance Task (PVT)	No significant difference was found between OSA and non-OSA stroke patients in PVT score (p = 0.08).
	Aaronson 2016	Psychomotor Vigilance Task (PVT)	No significant differences were found between stroke patients in CPAP treatment and control groups in PVT score (p = 0.34).
Executive Function	Aaronson 2015	Tower of London	A significant difference was found between OSA and non-OSA stroke patients on Tower of London test (p = 0.02, d = 0.42).
	Aaronson 2016	Tower of London	A significant difference was found between stroke patients in CPAP treatment and control groups in Tower of London test (p < 0.01, partial eta-squared = 0.26).
Intelligence	Aaronson 2015	WAIS-III Matrix Reasoning	A significant difference was found between OSA and non-OSA stroke patients in WAIS-III Matrix Reasoning score (p = 0.01, d = 0.44).
	Aaronson 2016	WAIS-III Matrix Reasoning	No significant difference in WAIS-III Matrix Reasoning Score was found between stroke patients in CPAP treatment and control groups (p = 0.33).

Conclusions

- There is mixed evidence for a positive effect of sleep on stroke outcomes related to speech and language.
- CPAP non-compliance is a major barrier to evaluating its effect on stroke outcomes.
- Most studies were limited by small sample size.
- Only two studies directly investigated language outcomes, and these authors excluded patients with severe aphasia. Therefore, we need studies that specifically address this population.
- A few studies looked for differences in MMSE among high-functioning patients, and ceiling effects likely came into play.
- Animal studies were consistent but the results need to be replicated in humans.
- 7 out of 12 human studies showed significant effects on motor outcomes, while less than half of those showed significant differences in cognitive measures.

Acknowledgements & Disclosure

This systematic review was completed as a project for SPHS 701 Introduction to Research Methods under the guidance of Dr. Linda Watson & Dr. Jessica Steinbrenner.

The authors declare no financial or intellectual conflicts of interest.

References are available upon request:

Tayler Simonds: tayler_simonds@med.unc.edu
Ian Kim: ian_kim@med.unc.edu
Michelle Swanson: michelle_swanson@med.unc.edu

UNC SCHOOL OF MEDICINE