# Behavioral Sleep of Geriatric Squirrel Monkeys (*Saimiri boliviensis*) in Amami Oshima, Japan

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## ABSTRACT

***Objective:*** **Although native to Neo-Tropical countries, squirrel monkeys are reared in captivity in zoos, amusement parks, primate research labs conducting clinical vaccine research for malaria parasite, space physiology and as exotic pets in Japan. We quantitated behavioral sleep-activity data among captive-reared (in a group cage), geriatric squirrel monkeys.**

***Methods:*** **Five captive born, female geriatric monkeys (aged 20-26 yr), reared in one group cage at the University of Tokyo's Amami Laboratory facility premises were used. Quantitation of the behavioral sleep activity was performed by non-invasive actigraphy (Actiwatch AW-64, Mini Mitter Co.) for 13 consecutive days in 2013. Activity count, total sleep time (TST)/ 24 h circadian cycle and sleep episode length (SEL) during 12 h resting phase of the 24 h circadian cycle were measured.**

***Results:*** **The mean TST/ 24 h circadian cycle for 5 monkeys ranged between 6 hr 39 min and 10 hr 9 min. These TST values are noticeably higher than the mean TST/24 h of 4 h 47 min, previously recorded 4 younger adult monkeys (aged 7-14 yr) living under similar condition. The SEL during the 12 h resting phase ranged between 5 – 14 min. for all five monkeys.**

***Conclusion:*** **The findings of this study may form a baseline of activity-behavioral sleep quantitation for geriatric squirrel monkeys.**

## KEY WORDS

**actigraphy, activity, captivity, 'Miss Baker', *Saimiri*, total sleep time**

## INTRODUCTION

Though the Rowe's indispensable reference book on primates[1)] reported that the life span of Bolivian squirrel monkey (*Saimiri boliviensis*) is 'not available' in 1999, the life expectancy of squirrel monkeys (*Saimiri species*) in the wild is now estimated to be around 15 years; under optimal captive conditions, their life span may exceed up to 30 years[2,3)]. Although native to Neo-Tropical countries, squirrel monkeys are reared in captivity in zoos[4)], amusement parks[5)], primate research labs conducting clinical vaccine research for malaria parasite[6,7)], space physiology[8)] and as exotic pets in Japan.

As such, a need to determine and suggest reasonable daily sleep time for squirrel monkeys under captivity exist.

Most of the previously reported sleep data for squirrel monkeys using polysomnography were based on the model of either a restrained single monkey[9,10)] or unrestrained single monkey[11,12)] in a cage. This mode of experimental protocol distorts the natural pattern, where *S. boliviensis* monkeys live in a group size of 45-75 with a polygamous mating system[13)]. Thus, collecting reliable data from a group of monkeys is vital to quantitate the sleep activity and vigilance behavior of squirrel monkeys.

The objective of this study was to quantify behavioral sleep-activity data among captive reared (in a group cage), geriatric squirrel monkeys.

## MATERIALS AND METHODS

Five captive born, female geriatric monkeys (aged 20-26 yr), reared in one group cage at the University of Tokyo's Amami Laboratory facility premises were used in this study. Data collection for this study was carried out between Feb.19, 2013 and March 5, 2013. The guidelines set for care and use of laboratory primates by the Institute of Medical Science, University of Tokyo were followed, and approval for this study from the Animal Welfare and Animal Care Committee of the University of Tokyo was obtained. Monkeys had *ad libitum* access to food and water.

Quantitation of the behavioral sleep activity was performed by non-invasive actigraphy (Actiwatch AW-64, Mini Mitter Co., Fig.1) for 13 consecutive days, as described previously[14,15)]. Activity count, total sleep time (TST)/ 24 h circadian cycle and sleep episode length (SEL)

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**Figure 1: Bolivian Squirrel monkey, with a tagged actiwatch in the neck. (photo by Sachi Sri Kantha)**

**Table 1: Activity and Behavioral Sleep Parameters measured in 5 geriatric female Squirrel Monkeys**

| Squirrel Monkey (code ID) | Age (yr) | Activity Counts/ 24 h (AU)* | TST/ 24 h (min)* | SEL/ resting 12 h (min)* |
|---|---|---|---|---|
| 187009 | 26 | 87 ± 11 | 403 ± 82 | 5 ± 2 |
| 290007 | 23 | 274 ± 51 | 457 ± 87 | 5 ± 2 |
| 291002 | 22 | 175 ± 14 | 609 ± 74 | 14 ± 6 |
| 291008 | 22 | 207 ± 15 | 469 ± 65 | 5 ± 1 |
| 293005 | 20 | 202 ± 25 | 399 ± 94 | 6 ± 6 |

*Mean ± SD for 12 complete days of data. AU = arbitrary unit, TST = Total Sleep Time, SEL = Sleep Episode Length.

during 12 h resting phase of the 24 h circadian cycle were measured.

## RESULTS

The mean daily activity count for these 5 female monkeys ranged between 87 and 274 activity unit (AU). As expected, the oldest 26 yr old monkey had the lowest activity count of 87 AU. But other four monkeys in the age range between 20 and 23 years were highly active, for their age. The mean TST/24 h circadian cycle for 5 monkeys ranged between 6 hr 39 min and 10 hr 9 min. These TST values are noticeably higher than the mean TST/24 h of 4 h 47 min for 4 chronologically younger adult monkeys (aged 7-14 yr) previously reported by us[14]. The SEL during the 12 h resting phase ranged between 5 ─ 14 min. for all five geriatric monkeys. Contrastingly, the SEL/12 h resting period values for these geriatric monkeys was similar to the mean SEL/12 h resting period reported for the chronologically younger monkeys[15].

## DISCUSSION

Though sleep quantification purists hold polysomnographic (PSG) or electroencephalograhic (EEG) criteria as authentic in preference to behavioral quantification of sleep, empirical data in humans have been reported as early as 1970 that behavioral estimation of wake-sleep states was in agreement with EEG criteria 93% of the time[16]. As such, considering other meritorious features including non-invasiveness, and relatively low cost, actigraphy has become a preferential objective method for sleep quantification in children and primates[17-24].

Among the 5 geriatric monkeys studied one of the 22 year old monkeys (No. 291002) appears to be an outlier to other four monkeys, in terms of TST and SEL parameters. It's TST/24 hr. was over 10 hours, compared to the TST range of other four monkeys between 6 ─ 8 hours. In our interpretation, previously reported polysomnographic TST values of either 9.9 hr (from 12 hr record)[9] or 8.2 ─ 8 10.0 hr (from circadian day record)[13] appears to be those of exhausted monkeys sleeping alone in a cage. While the SEL/12 hr of rest time for four monkeys ranged between 5-6 min, the outlier monkey's (No. 291002) was 14 min. It could be that, this particular monkey had developed aging related infirmities, earlier than other four.

When comparing the two sleep parameters TST and SEL between the geriatric monkeys (in this study) and the younger adult monkeys (our previous study[15]), we noted that while the total sleep time increased for geriatric monkeys, the sleep episode length remained almost identical to younger adult monkeys. As sleep episode length is a specific indicator of vigilance function during sleep, we interpret that even when monkeys aged and became geriatric, they retained their vigilant attention.

**Table 2: Previous reports on Geriatric Squirrel Monkeys**

| Description | No. of squirrel monkeys studied | Age (yr) | Reference |
|---|---|---|---|
| senile plaques | 4 | 20 and above | Walker *et al*.[25] |
| amyloid in brain | 6 | 20-27 | Walker *et al*.[26] |
| β-amyloid angiopathy | 6 | 20-23 | Elfenbein *et al*.[27] |
| ovarian aging | 1 | 20 | Walker *et al*.[28] |
| β-amyloid in brain and amyloid angiopathy | 7 | 20-26 | Murakami *et al*.[29] |

Table 2 provides a compilation of previous studies on specific aspects of brain and ovary aging in geriatric squirrel monkeys, aged 20 years and above[25-29]. Walker *et al*.,[26] had analyzed the deposition of amyloid in neocortex and meningeal blood vessels of the 27 year old geriatric monkey (named 'Miss Baker'). This particular *S. sciureus* monkey from Peru, born in 1957, gained news recognition and fame for its 15 min suborbital flight on May 28, 1959 in the NASA program. She also became a non-human primate celebrity, tagged as 'America's First Lady in Space', appearing in the *Life* magazine's cover of June 15, 1959, and was receiving hundreds of letters from school children, after her suborbital flight[30,31]. We don't have any published information on whether activity-sleep profiles of 'Miss. Baker' were recorded, after her 'retirement' from the NASA program. She died on Nov. 29, 1984, after more than 25 years in captivity[26,31]. Five among the 7 monkeys used in the study by Murakami *et al*.[29] belonged to our sample from Amami Oshima.

A primary limitation of this study was that other than visual observation of thinning hair density and wrinkling in these studied monkeys, other clinical parameters of aging were not evaluated. A secondary limitation was that, we were prevented from continuing a longitudinal study, due to the needs of fellow researchers[29] that resulted in the death of these monkeys.

While studies on geriatric Old World monkeys, especially rhesus monkeys[32-34] have gained prominence in the past 25 years, available data on geriatric New World monkeys seems limited. As such, though the activity-behavioral sleep data presented in this study for geriatric squirrel monkeys seems limited in scope, we infer they are of value to the laboratories and zoos which rear squirrel monkeys under captive conditions.

## CONCLUSION

The findings of this study may form a baseline of activity-behavioral sleep quantitation for geriatric squirrel monkeys.

## CONFLICT OF INTEREST

None

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