Department of Environment System

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2019

Master's thesis

Gender-based sleep disturbance prediction in the 2050s of Jakarta
（2050 年代のジャカルタにおける性別を考慮した睡眠障害の予測）

Submitted August 16, 2019

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1. Introduction

1.1. Climate change

1.1.1. Global warming

In the past 50 years, as the average global temperature has increased at the fastest rate in recorded history, global warming is widely accepted that have happened. The evidences that approve global warming are not only restricted to global temperature rise (the planet's average surface temperature has risen about 0.9 °C since the late 19th century, a change driven largely by increased carbon dioxide emission and other human-made emissions into the atmosphere) (Figure 1) [1]. Rising ocean temperature (the top 700 meters of ocean showing warming of more than 0.4 degrees Fahrenheit since 1969 [2]), and faster sea level rising (8 inches in the last century, doubled rating than that of last century [3]) are considered to highly connect to global warming as well. It is now strongly called for controlling the global warming below 2°C, or not it may possibly lead to destructive damage to the earth[4].

In accordance with the Fifth Assessment Report of IPCC (the Intergovernmental Panel on Climate Change), scientists attribute the global warming trend observed to the human expansion of the greenhouse gas emission that result in greenhouse effect that is leading the atmosphere to trap heat radiating from earth toward space (Figure 2)[6]. They concluded there was a more than 95 percent probability that human activities over the past 50 years have warmed the earth. Anthropogenic GHG emissions are mainly decided by population size, economic activity, energy use etc. The Representative Concentration Pathways (RCPs), predict four different 21st century pathways of greenhouse gas emissions and atmospheric concentrations, and air pollutions. Multi-model results show that the increase of global mean surface temperature by the end of 21st century (2081-2100) relative to (1986-2005) may reach to 4.8 °C, which suggesting that it is essential to limit total cumulative CO_2 emissions from anthropogenic sources below 2900 $GtCO_2$ [5].
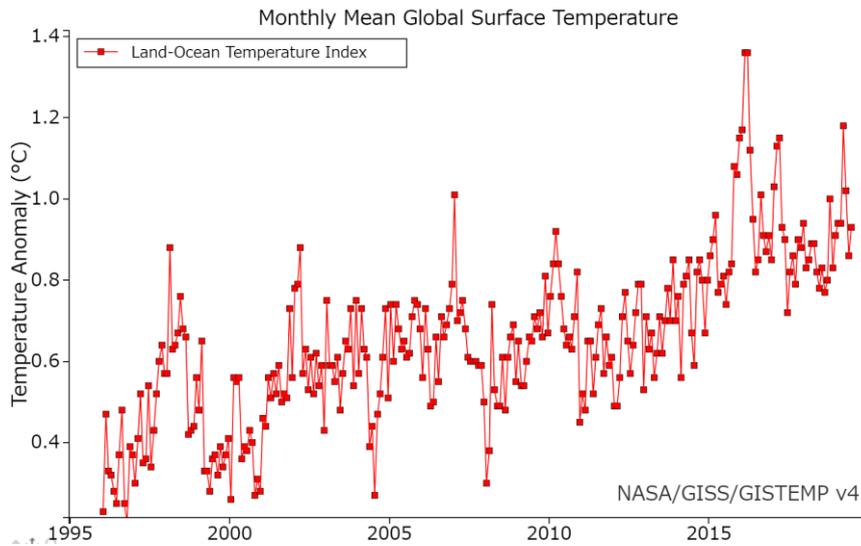
Figure 1 Global surface temperature [1]
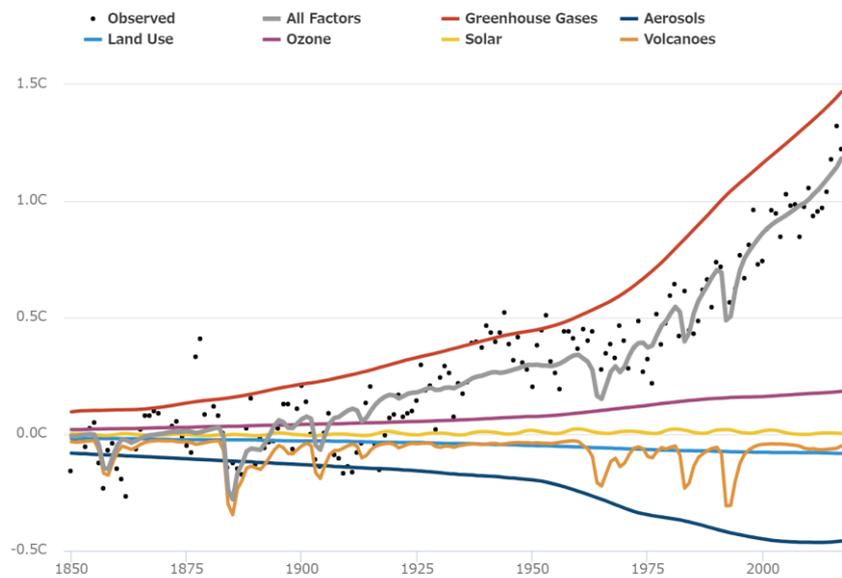
Figure 2 the estimated role of each different climate forcing in changing global surface temperatures since records began in 1850 [6]

1.1.2. Urbanization and human population growth

1.1.2.1. Urbanization

Cities are the manifestation of human society accelerating developments. Urbanization refers to the human population turn from rural areas to urban areas, the gradual rise in the proportion of residuals living in urban areas, and the ways where each society adapts to the change. Primarily it is the process that towns and cities are becoming larger and larger as more people gathering to live in

central areas. The United Nations predicted that by 2050 about 64% of the developing world and 86% of the developed world would be urbanized area. That is nearly 3 billion urban population in 2050s, the most of which will occur in Africa and Asia. Notably, the United Nations has also recently projected that nearly all global population growth from 2017 to 2030 will be by cities, about 1.1 billion new urbanites over the next 13 years[7].
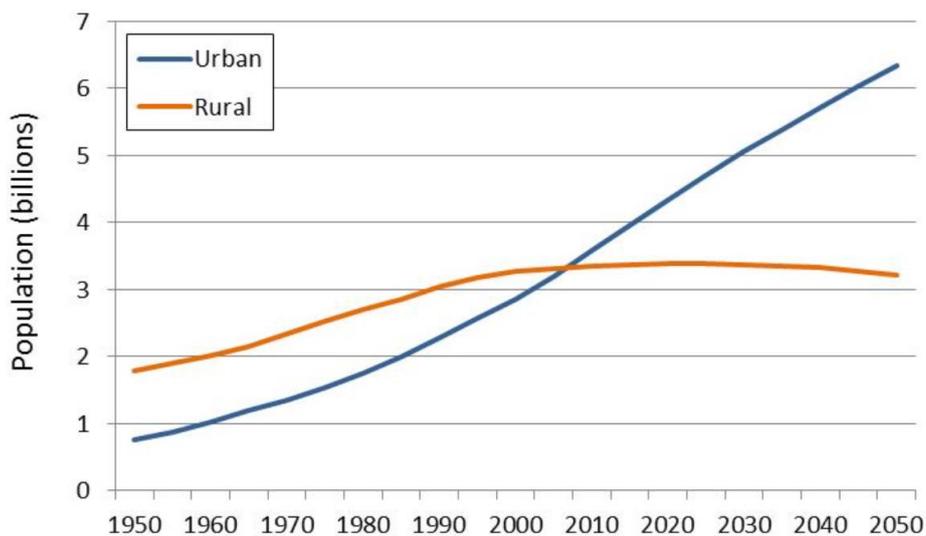
Figure 3 Urban population and rural population in 1950-2050 [7]

In terms of Asia region, the United Nations projects that Asian urbanization rate could rise to 56% in 2030, and further to 64% in 2050. South-East Asia is inferior in its urbanization with its urban population having increased from 32% to 42% between 1990 and 2010. Malaysia's urban population grown from 50% to 72%, while that of Indonesia population increased from 31% to 44%. South Asia is further behind, with its urban population only increasing from 28% to 33%. Urban area rate in India grown from 26% to 30%. There are 12 of the world's 21 mega-cities are indeed in Asia such as Tokyo, Delhi, Mumbai, and Shanghai[7].

1.1.3. Human population growth

The world population is prospected from 7.3 billion to 8.6 billion by the end of 2030, 9.8 billion in 2050 (95% prediction interval)[8] as is reported in a new United Nations report. And in 2030, Asia is predicted to reach 5 billion population level in total that takes about 58% in the whole world, so Asian urbanization problem will be distinct and should concentrate more.
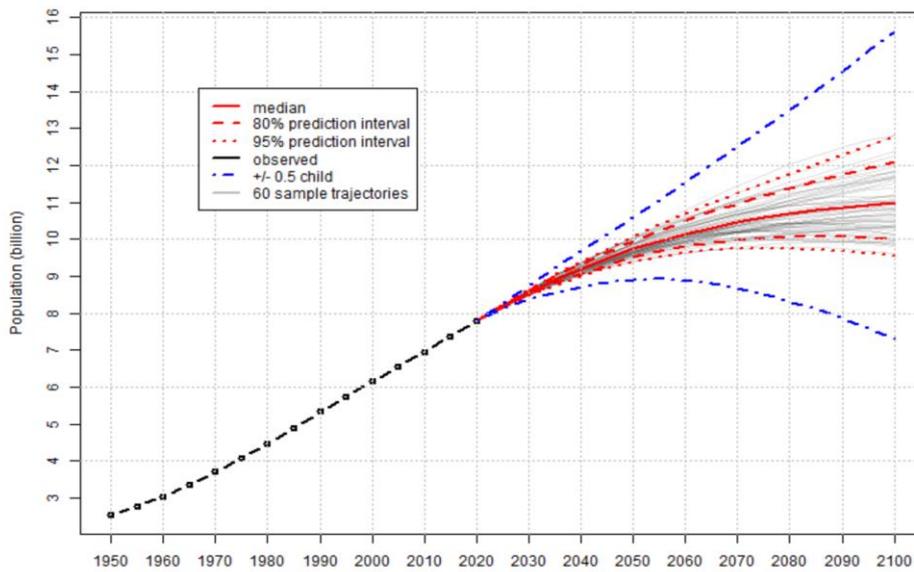
Figure 4 World population prediction [7]
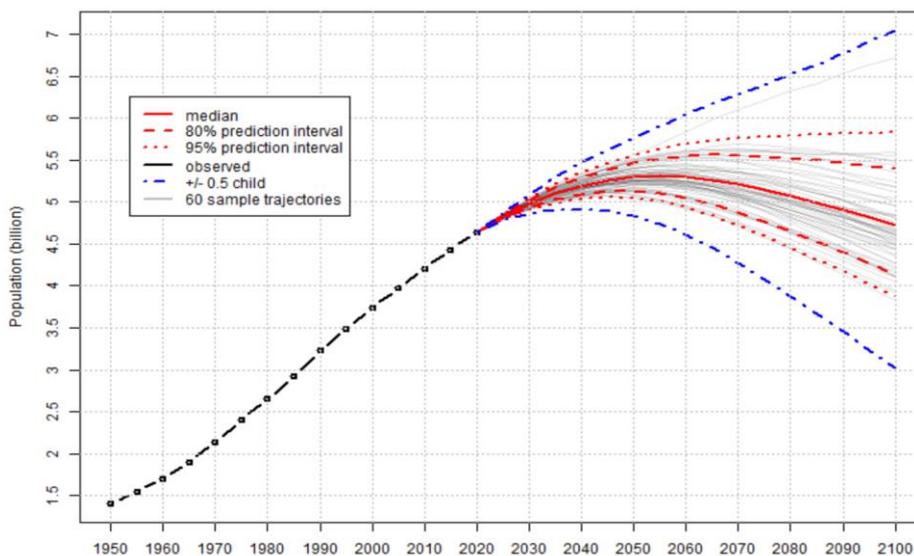
Figure 5 Asia total population [7]

1.1.4. Indonesia urbanization and population growth

Indonesia is a country in Southeast Asia with large population. With over 261 million people, it is the world's 4th most populous country as well as the most populous Muslim-majority country and the urban population of Jakarta is prospected to rapidly grow up in 2050s[9].
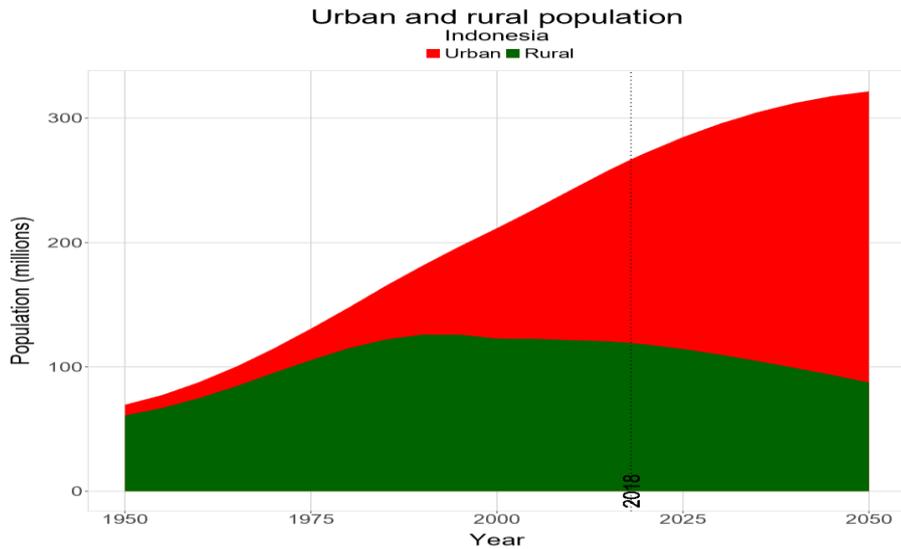
Figure 6 Indonesia urban and rural population [9]

1.1.4.1. Jakarta population growth

Tokyo is predicted to become the second largest urban area in the world when Jakarta in Indonesia will take the first by 2030 according to Euromonitor International expectation[10]. In the light of the Euromonitor International report, Jakarta's population will increase by 4.1 million from 2017 to 2030[9](Figure 7). Figure 8 shows the visualized land use change of Jakarta, it can be visualized that urbanization has progressed extensively in 14 years from 2001 to 2014. Tremendous urban area increased where is easily accumulate solar radiation heat and rises urban temperature [10]
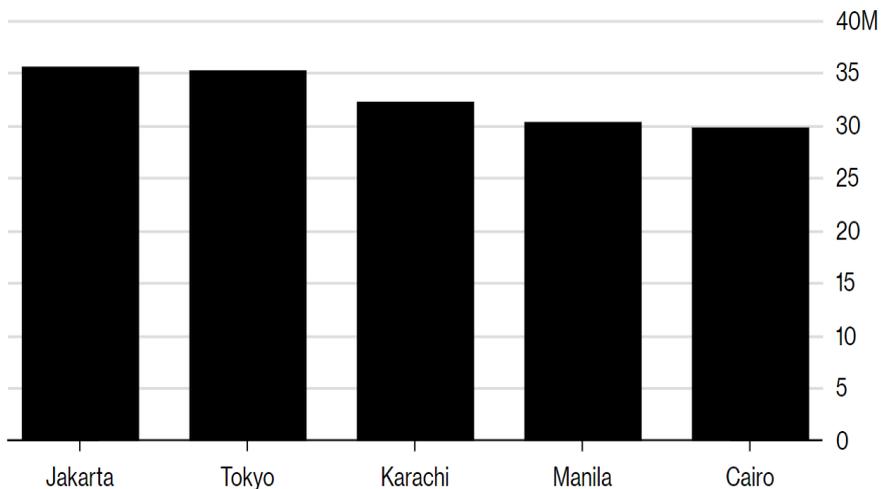
Figure 7 Population of five largest megacities in 2030 [9]

LEFT VIEW ....
Platform: Landsat 7
Sensor: ETM+
Acq. Date: 17-SEPT-2001
Dimension: 75 x 75 km
S.Resolution: 30 m
Data Type: Land Cover
City: Jakarta (Indonesia)

RIGHT VIEW ....
Platform: Landsat 8
Sensor: OLI/TIRS
Acq. Date: 13-SEPT-2014
Dimension: 75 x 75 km
S.Resolution: 30 m
Data Type: Land Cover
City: Jakarta (Indonesia)

Category	L	R
Urban Dense	L: 37,865.16 ha. (6.73%)	R: 79,120.89 ha. (14.05%)
Urban Sparse	L: 41,956.20 ha. (7.45%)	R: 63,766.17 ha. (11.33%)
Bare Land	L: 5,969.07 ha. (1.06%)	R: 7,135.65 ha. (1.27%)
Cropland	L: 215,103.87 ha. (38.21%)	R: 185,951.61 ha. (33.03%)
Grassland	L: 64,491.93 ha. (11.46%)	R: 39,220.20 ha. (6.97%)
Forest	L: 56,802.42 ha. (10.09%)	R: 48,516.12 ha. (8.62%)
Water	L: 140,761.44 ha. (25%)	R: 139,239.45 ha. (24.73%)
Others	L: 0.00 ha. (0%)	R: 0.00 ha. (0%)

Figure 8 Land coverage rate of Jakarta in 2001 and 2014 (left: Sep, 2001; right: Sep, 2014) [10]

The accelerating urbanization and growing population of Jakarta will trigger many new urban problems accompanying with the high-rise and high-density buildings that altered surface coverage of city. The most prominent problem is urban heat island phenomenon appearance that beget energy consumption increase and residential health problem. It can be previewed that critical challenge existing in Jakarta squaring up its expiditous urbanization progress.

1.1.5. Urban heat Island

The exaggerative global environmental changes, where the deforestation, breakage in biodiversity and desertification are following, are driven mostly by the rapid human population growth accompanying with urbanization process. Cities take the major sources of anthropogenic CO_2 emissions from fossil fuels for

heating, transportation, industrial manufacturing process, and so forth[11]. While the city GHG affecting climate at a global scale is still uncertain, its local impact on the urban climate has been descried long ago. With the construction and function of cities changing, buildings, roads, and other infrastructure changes the morphology of the surface and airflow, combining with increasing anthropogenic emissions of heat, carbon dioxide, there finally bring about evident urban climate change [11].

Urban heat island (UHI) is considered to be one of the major problems in the 21st century as the result of urbanization of human civilization[5]. Urban development commends the use of significant amounts of cement and asphalt for roofing purposes and for paving sidewalks and roads. These ranges of urban surface cause the local temperature to rise higher than the ambient rural areas. The introduction of new surface materials coupled with the emission of heat, pollutants dramatically change city's radiative, urban surface instruction, and atmosphere above. Many urban areas also lack green coverage that cause the poor evapotranspiration which plays an important role of the water cycle. The green coverage provides with cooling shade and reduced removal of CO_2 that contributes to increasing temperatures[13].
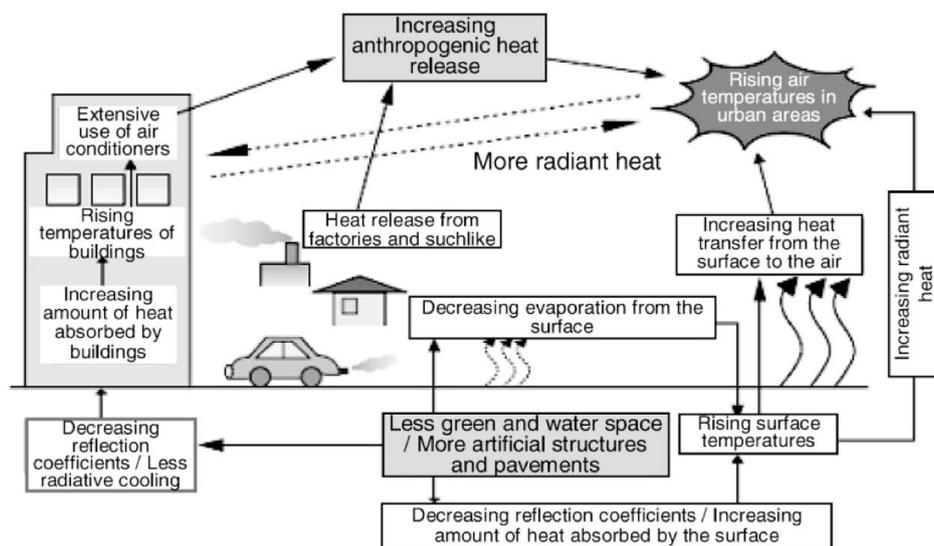
Figure 9 How the urban heat island happens – image sourced from Yamamoto [13]

UHI has spatial diversity that includes the temperature difference between the urban area and least developed area. For example, Urban Heat Island Intensity (UHII) of magnitude as low as 0.4 °C and as high as 1.5 °C within and in between

three housing estates in Hong Kong was reported[13]. Maximally around 4°C temperature difference was detected in Singapore Central Business District(CBD) area [14].Values range from −3.6 to 5.2 °C during the day and −0.2 to 7.5 °C during the night in London (20:00–07:00) [15]. The differences between the forest land surface temperature versus those of developed and agricultural lands approximate an UHI potential of 5 °C in Kathmandu[16]

Also UHI varies from day to night and from summer to winter. The surface urban heat island intensity (SUHII) averaged in Northwest China was significantly lower in the day than at night (annual mean ranging from −0.1 ± 1.3 °C at 10:30 local solar time to 3.3 ± 0.9 °C at 1:30 local solar time)[17]. There was the highest intensities recorded in the spring and summer (±12 °C), and the lowest in the winter in a small urban agglomerate in Brazil[18]. Although different geographic factors may lead to different performances of UHI, UHI has been reported more or less in urbanization, which suggesting that UHI has actually become into an urban climate problem nowadays.

1.1.5.1. Urban heat island effects on sleep quality

Urban heat islands, particularly during the summer, have multiple impacts and contribute to atmospheric urban heat islands. In cities, particularly after sunset, air temperatures can be as much as 12°C warmer than the air in neighboring, less developed regions[19]. The UHI effects may be positive, such as warming temperature in winter and lengthening the plant-growing season, however most of them are negative and economically and environmentally harm to human society.

When exaggerating heat wave can lead to lethal heat-stress disease, it will diffusely bring out moderate heat-related disease such as sleep disturbance, fatigue as well, though these related researches are less than heat-stress disease researches now. In an epidemiological survey implement in Osaka in summer and winter[20], there were more than 40% in summer and 24% in winter of sleep disturbance suffers in residential respectively due to nocturnal outdoor temperature variation triggered by urban heat island. There was 48.8% sleep disturbance prevalence in Tokyo and expending 3.44×10^8 yen loss per degree per day[22]. Referring to Ihara[21] assessment result, sleep disturbance takes the most part of moderate diseases and will cost 3.60×10^9 yen damage in 2070s. Studies indicate that moderate heat-related diseases bring about a tremendous economic loss however these researches are limited in developed countries that is of scarcity in developing country.
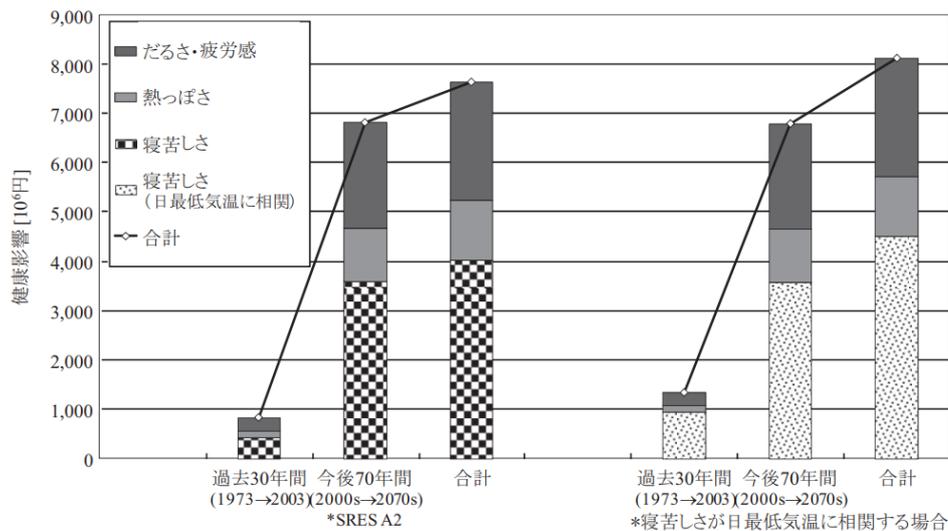
Figure 10 life cycle impact assessment due to moderate heat-related disease in 1973-2003 and 2000-2070 in Tokyo[21]

1.1.6. Mitigation and Adaptation

Climate change, as one of the most complex problems facing human nowadays, it includes many fields such as economics, society, environment and politics which will be continuing for decades and centuries. It is necessary for controlling greenhouse gas emitted. For example, the 21st Conference of Parties under the UN Framework Convention on Climate Change (COP21) was held in Paris in December 2015. The Paris Agreement[23] is an epoch-making framework, in which all the major emitters of developed, emerging and developing countries make commitment on tackling global warming.

To approach greenhouse gas emission reduction and sustainable development, climate policies provides a basis for countermeasures. Limiting the effects of climate change is essential to reach sustainable development. Local mitigation and adaptation vary in different countries.

1.1.6.1. Mitigation

Scientific research on climate change mitigation has grown rapidly science the first IPCC assessment report[24]. The target of mitigation is to control or decrease the emission of air pollutants that affect the climate by designing policies. Mitigation including managing the global principle and requires measures of international cooperation, while the actual countermeasures leading to control air pollutants and greenhouse emissions will applicate at local level combining local situations. There are many countermeasures for supporting climate change

mitigation efforts[23] such as utilizing renewable energy to application, developing sustainable transportation in cities, Improving energy efficiency and decreasing waste emissions.

1.1.6.2. Adaptation

Even if climate change mitigations control the greenhouse emission, it would take years to effect and some may not work enough, as well as global warming and its effects should last for decades of years itself. Adaptation is a kind of countermeasures responding to global warming, seeking for pathways to reduce the vulnerability of social and biological systems to relatively sudden change and eventually contribute to the effects of global warming. Adaptation is considered to be more essential for developing countries since those countries are prospected to bear more brunt of the impacts of global warming as their population increasing rapidly[25]. However, the capacity and potential for residential to adapt is unevenly distributed among disparate regions and populations when developing countries are generally capable to adapt[25]. Because doing so depends on such factors as wealth, technology, education, infrastructure, access to resources, management capabilities, acceptance of the existence of climate change and the consequent need for action, and sociopolitical will.

The IPCC[26] group also pointed out that climate change adaptation measures can reinforce and can be reinforced by efforts to promote sustainable development and reduce poverty. With regard to the relationship between mitigation and adaptation, mitigation advocates to reduce greenhouse gas emissions or enhance the removal of these gases from the atmosphere. However, even the most effective reductions in emissions would not stop future climate change impacts that makes the necessity for adaptation unavoidable.

1.2. Life cycle impact assessment

In LCA studies, environmental impacts are characterized due to the methodology used to assess it. The methods applicated for life cycle impact assessment (LCIA) quantify the relationship between each stage of the life cycle inventory and the corresponding environmental impacts. The objective of Life Cycle Impact Assessment is to figure out and estimate the magnitude and significance of the potential environmental impacts of the objective system. The process includes accounting, assessing, and interpreting the potential environmental impacts drive by the product through categorization and characterization of the flows. A distinction must be clarified between midpoint and

endpoint, where endpoint indicators are quantified at the level of the areas of protection (natural environment, human health, and natural resources), and midpoint indicators indicate impacts somewhere between the emission and the endpoint[27].

1.2.1. Life-cycle impact assessment method based on Endpoint modeling (LIME)

Life-cycle impact assessment methods on Endpoint modelling (LIME) was developed as a method for supporting Life Cycle Assessment with high precision. It has been used into many fields' products of LCA process in various companies, such as electric and electronic equipment. As with the accumulation of such studies, researcher found that some points to be improved were clarified concerning the assessment method. The arranges and improved issues were sorted out and published as LIME2[28].
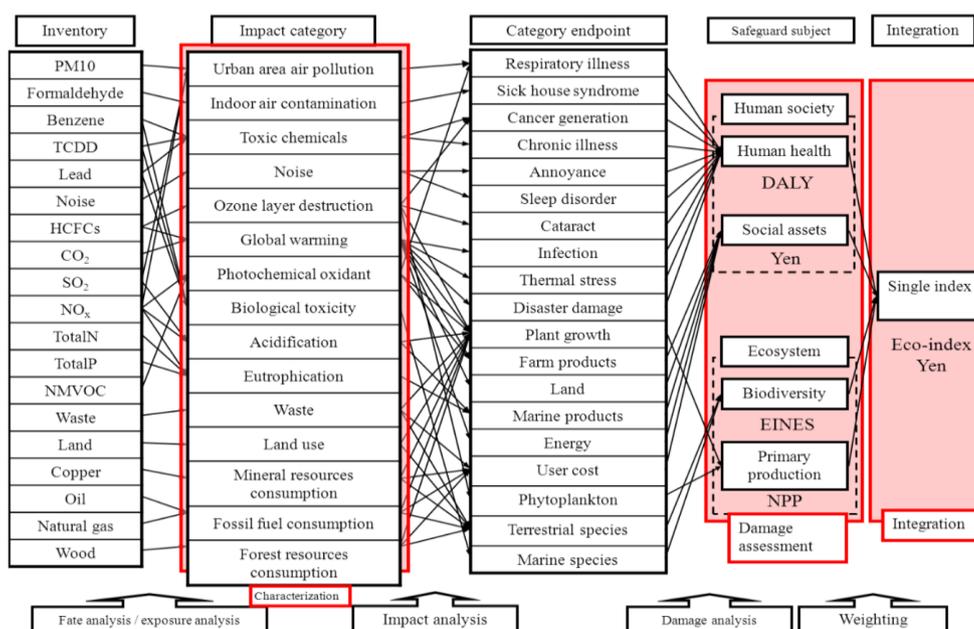
Figure 11 Concept map of LIME2 and the range of objects of assessment[28]

The assessment of environmental impact under this method consists of the five following steps. (1) Fate analysis (2) Exposure analysis (3) Impact analysis (4) damage analysis (5) Integration. To assess the total damage of environmental burden and to integrate environmental impact by epidemiology, ecology, toxicology and other natural science among the endpoints, assess environmental impact using social science analysis such as economics, psychology and so on[28].

Damage analysis is the step that integrate each object protection damage happened. The objects of protection were decided as four items: human health;

social assets; biodiversity and primary production that obtained few agreements though it is one of the LCIA research areas that have being drawing the most attention. Damage indexes were defined to suggest total amount damage on objects protection from environmental changes then. On human health impact assessment, the Disability Adjusted Life Year (DALY) was decided as damage indicator. In Japan version LIME, social assets use an economic index to thoroughly measure the impact on various components among agricultural products, forest, marine products and resources. All of damage index will be converted into single index that is monetary indicator (Yen).

LIME-1 and LIME-2 were not suitable for assessing the environmental impacts in other countries/regions because they are representing the environmental conditions in Japan and the Japanese value. To expand LIME utilization scale to the world, LIME-3 was developed in 2016. 9 impact categories and 4 endpoints were chosen that is the same with LIME2 but the conjoint analysis for weighting can be applied into whole G20s[29].

In whole, urban heat island accompanying with urbanization can drive many negative impacts on Earth's environments and has considerable research by scientists. Associations and governments set up basis policies to systematically stipulate concrete measures to retard urban island phenomenon even though it will be going on for decades of years probably. Human health, as one of the most heat-related problem that causes tremendous economic loss about which related studies have been implemented in development countries plenty while developing countries such as Jakarta are in shortage. Started from rapid urbanization and population prospection, urban heat island may possibly bring about enormous complexed problems in developing countries, which requires opportune complementary study.

1.3. Sleep disturbance

1.3.1. Sleep mechanism

Sleep occurs in everyone indicating that its essential physiological and mental importance to human being growing process. Sleep function can be prescribed as multiple effects in many physiologic and mental aspects including human growth, brain mechanism or immune system and other psychological conditions[29]. While abundant breakthroughs in human understanding of the basic mechanisms of sleep regulation has been gained in the past 100 years, however, sleep is generated by multiple pathways and molecule effects that contribute to other physiological functions as well, that have made human understanding of the effects of sleep onerous[30]. Hereinafter, sleep mechanism will be recounted in global mechanism rather than molecular function squaring up the sleep molecular mechanism has few correlations to this study.

Usually, the sleep is defined basing upon physiological characteristics observed in mammals including decreased body movement and electromyographic activity, relatively inhibited sensory activity, reduced muscle activity and inhibition of nearly all voluntary muscles during rapid eye movement (REM) sleep, reduced interactions with ambient environments and brain wave architecture assessed by polysomnography[31]. On the whole, the mammalian sleep definition is decided on activity and metabolism relating to the electrical brain signals obtained in the electroencephalogram (EEG). Muscle activity in the electromyogram (EMG) and electroencephalogram (EEG) characteristics determined the sleep states in animals when human being sleep states are more discernible than animals by more distinguished characteristics of EEG constructions[32]. In human sleep states, sleep is divided into two broad types: non-rapid eye movement (non-REM or NREM) sleep and rapid eye movement (REM) sleep. The NREM is divided in to three stages: N1, N2, and N3, N4 (Table1). NERM and REM sleep have disparate performance in body behaviors. During NREM stages, body temperature and heat rate fall and less energy is cost by brain.

Non-REM sleep occurs first and after a transitional period is called slow-wave sleep or deep sleep. During this phase, body temperature and heart rate fall, and the brain uses less energy[32]. REM sleep, also called paradoxical sleep, represents a smaller part of whole sleep process.

Table 1 Sleep staging criteria[31]

Sleep Stage	Scoring Criteria
Waking	>50% of the page (epoch) consists of alpha (8-13 Hz) activity or low voltage, mixed (2-7 Hz) frequency activity.
Stage 1	50% of the epoch consists of relatively low voltage mixed (2-7 Hz) activity, and <50% of the epoch contains alpha activity. Slow rolling eye movements lasting several seconds often seen in early stage 1.
Stage 2	Appearance of sleep spindles and/or K complexes and <20% of the epoch may contain high voltage (>75 µV, <2 Hz) activity. Sleep spindles and K complexes each must last >0.5 seconds.
Stage 3	20%-50% of the epoch consists of high voltage (>75 µV), low frequency (<2 Hz) activity.
Stage 4	>50% of the epoch consists of high voltage (>75 µV) <2 Hz delta activity.
Stage REM	Relatively low voltage mixed (2-7 Hz) frequency EEG with episodic rapid eye movements and absent or reduced chin EMG activity.
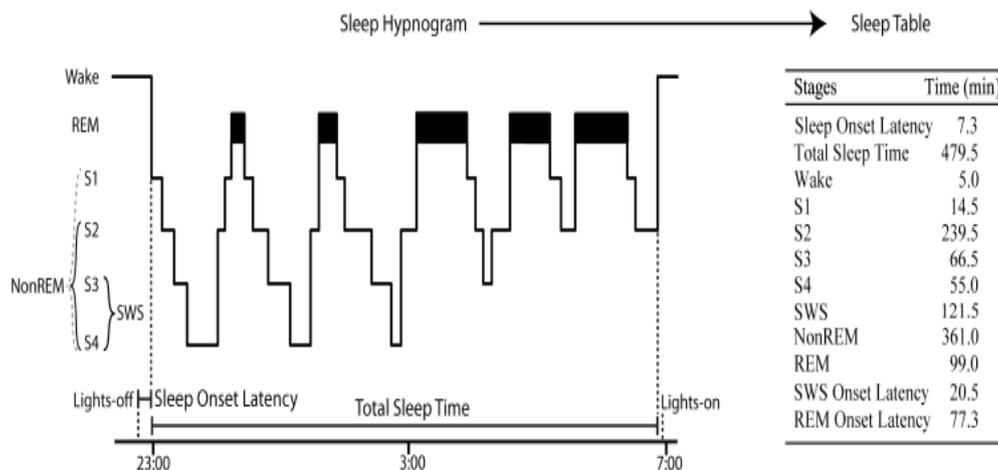
Figure 12 Sleep stages duration[32]

1.3.2. Sleep disturbance and sleep disorder

Sleep disorder is a medical sleep patterns disorder. Sleep disorder may be impacted by physical, mental, social factors when they are serious enough. In epidemiological tests, polysomnography and actigraphy are utilized to order for some sleep disorder.

The classification of sleep disorder is arduous, and it is necessary to differentiate from disorders and to explain an understanding of symptoms and

pathophysiology that capable for apposite treatment. There exist many classifications published from association. 81 sleep disorder diagnosis are listed in the International Classification of Sleep Disorders (ICSD) edition3[33] and these items are categorized into 8 items showing in table 2. Some detailed description of insomnia, obstructive sleep apnea, circadian rhythm sleep disorders, all of whom were mention frequently in sleep disorder diagnosis will be given.

Table 2 the International Classification of Sleep Disorders (ICSD) Edition[35]

Items	Category
Item 1	Insomnias
Item 2	Sleep-related breathing disorders
Item 3	Central disorders of hypersomnolence
Item 4	Circadian rhythm sleep-wake disorders
Item 5	Parasomnias
Item 6	Sleep-related movement disorders
Item 7	Other sleep disorders

Sleep disorder is a type of mental illness diagnosed by psychiatrist's criteria. In another, subjective sleep disturbance distinguished from sleep disorder. PSQI is a self-administered questionnaire, the disturbed sleep judgement result is considered to correlate with sleep disorder. Hereinafter, the disturbed sleep is described as sleep disturbance.

1.3.3. Sleep disturbance diagnostic tools

Many diagnostic tools are available that may allow a better understanding of what the problem may be for sleep disturbance suffers. The diagnostic tools are developed accompanying with clinical and epidemiological medicine acknowledged to sleep disturbance since last century. Nowadays, the diagnostic tools of sleep disturbance are usually categorized into objective sleep measures and subjective assessment measures.

1.3.3.1. Objective sleep measures

Polysomnography (PSG)

Polysomnography (PSG) is widely regarded as the standard device for the sleep disorder diagnosis[36]. Various physiological parameters are controlled when objects sleeping, such as an Electroencephalogram (EEG), Electrocardiogram (EKG). Sleep disturbances from obstructive sleep apnea to legs syndrome to parasomnias can be diagnosed through PSG.

Actigraphy

Actigraphy is a portable device to record sleeping and wakening patterns and circadian rhythms by human body activities. The recorded data including: total sleep time (TST), total wake time (TWT), sleep efficiency (SE), sleep latency, and frequency and duration of wake episodes after sleep onset are evaluated based on the periods of activity and indolence of body movements[36]. Studies have shown that actigraphy is in high correlation with PSG for total sleep time (TST). Comparison showed over 90% agreement in 20-30 years healthy adults, in which actigraphy was valid for estimating rates in the young people[38]

1.3.3.2. Subjective assessment measures

Pittsburgh Sleep Quality Index

The Pittsburgh Sleep Quality Index (PSQI) is a self-report questionnaire that assesses sleep quality over past 1-month time interval. The measure consists of 19 individual items, creating 7 components that produce one global score. The PSQI is intended to be a standardized sleep questionnaire for clinicians and researchers to use easily and is used for multiple populations. The questionnaire has been used in many clinic situations, including research and clinical activities, and has been used in the diagnosis of sleep disturbances. There are numerous clinical studies that have found the PSQI questionnaires results to be reliable and valid in the assessment of sleep problems to some extent.[39]

Among 19 items, the PSQI measure several different elements of sleep quality, consisting 7 components and one composite score. The 7 component scores consist of subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Every item is weighted on a 0-3 scale, and the global PSQI score is then estimated by adding the seven component scores, providing a total score ranging from 0 to 21, in which the lower scores suggest a better sleep quality. Each item varies on a 0–3 interval scale. The global PSQI score is then calculated by totaling the seven component scores, providing an overall score ranging from 0 to 21, where lower scores denote a healthier sleep quality. A PSQI global score >5 resulted in a sensitivity of 98.7 and specificity of 84.4 as a marker for sleep disturbances in insomnia patients versus controls. A cut-off point >6 in the PSQI global score thus resulted in a slightly lower sensitivity of 93.4% and a specificity of 100%[40].Traditionally, the items from the PSQI have been summed to create a total score to measure overall sleep quality.

Table 3 Pittsburgh Sleep Quality Index (PSQI)[39]

Pittsburgh Sleep Quality Index (PSQI)						
C1	C2	C3	C4	C5	C6	C7
Subjective sleep quality	Sleep latency	Sleep duration	Habitual sleep efficiency	Sleep disturbance	Use of sleeping medication	Daytime dysfunction

There are also some other sleep quality questionnaires and sleep diaries that designed by clinical and epidemiological research. Both the two methods cost very low cost and can be self-administered. What is more, as it has been shown in recent studies, their accuracy specificities are compared high, which can be trust to study in a wide scale.

1.3.4. Gender sleep differences

Gender differences cause men and women to possess different sleep patterns and may possibly underlie different risk for sleep disturbances[41]. Usually gender differences point to biological and physiological differences mainly resulting by the sex chromosomes and the gonadal hormones that embodying at cellular, organ and metabolism system levels. In previous studies, female predispose sleep disturbance than male and a risk ratio of 1.41 [95% confidence interval: 1.28-1.55] for female versus male was found[41]. Women with all adult age groups complain more sleep problems than men such as inadequate sleep time and insomnia. While women have better sleep quality than men among young adults[42]. There is a female predisposition of idiopathic hypersomnia while narcolepsy and REM behavior disorder have a few men predisposition[43][44]. About clinical symptoms, gastroesophageal reflux disease which was related to obstructive sleep apnea (OSA), was found to have connection with African American male sleepiness, female insomnia and Caucasians female restless legs symptoms. Sleep latency defined as the minutes it takes to fall asleep is longer in women than men, what is more, there were inconsistent between subjective and objective measures of sleep quality between women and men. Women who complain poor sleep quality while the quantitative analysis of their polysomnographic sleep does not support women complain[44]. This suggests that women are either more sensitive to sleep clinical symptoms and are more likely to report symptoms in clinical survey. Gastroesophageal reflux disease (GERD) was associated with sleepiness in males and African Americans,

insomnia in females, and restless legs symptoms in females and in Caucasians[45]. In all, gender differences of sleep quality are widely existing in the whole world and divers in countries and regions.

Gender differences are frequently mentioned in human sleep quality and indicating geographic variance due to men and women respective sex chromosomes and gonadal hormones levels. Air temperature are effective on sleep quality by interacting with human body temperature and circadian rhythm. Another study indicates that

1.3.5. Other sleep effective factors

Age is another factor that continuously described effecting on sleep quality besides sex. Subjective and objective sleep quality deteriorate with age. Older women have higher sleep complaints rate than older men that is not found in children and adolescent[46][49].

Several epidemiological studies have been conducted to evaluate sleep disturbance prevalence in different countries, it cannot drop consistent conclusion precisely of sleep quality throughout various global regions. Chevalier et al. used a survey of some insomnia and its impact on life quality and healthcare cost among five Northern European countries referring to a 4-iterm questionnaire, there were 4%-20% prevalence of insomnia of subjective[47]. Another study using a standardized questionnaire and sleep diaries studied the geographic difference in sleep quality appraise sleep risk factors for sleep disturbances in 2202 subjects selected middle-aged adults (20-45 years) from Sweden, Iceland Belgium, reporting different performance of sleep complaints of these three regions[48]. A report developed by OECD[50] suggests that there are regional and country various on sleep time (Figure13). Hence, the regional and cultural factors are inevitable when inspect residual's sleep quality.
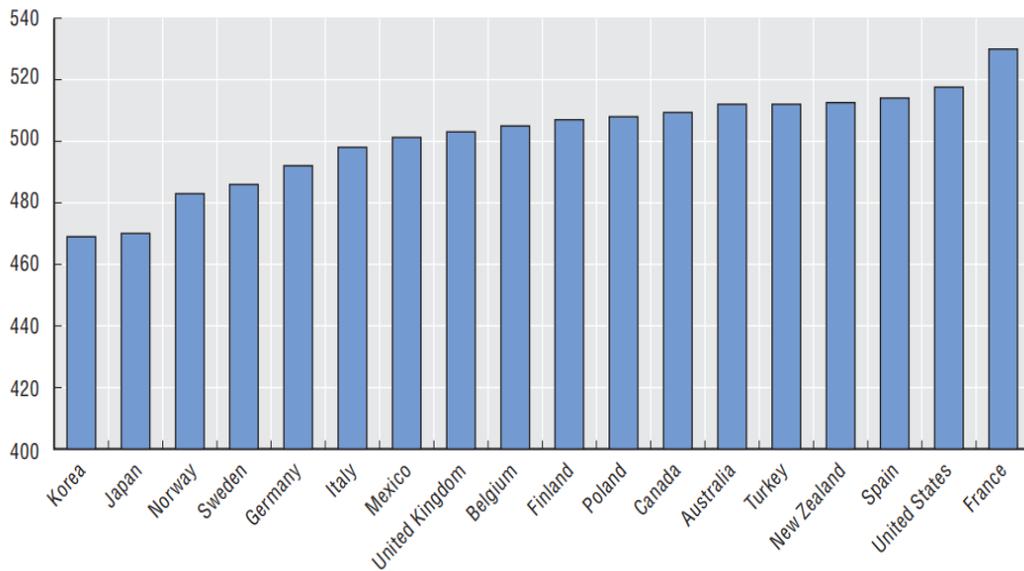
Figure 13 residential sleep time in world countries[50]

What's more, environmental and cultural influences interweave on sleep quality. thermal environmental affection on sleep quality through interacting with human body core thermal regulation in bedroom. Air temperature higher or lower than the thermal neutral temperature (29℃) have been concluded to rise the rate of wakefulness and decrease REM and SWS in semi-nude subjects[51]. Heat-related sleep disruptions do not disappear even tile after 5 continuous daytime and nocturnal heat exposure[52]. With high air temperature, human can increase activity in day and night, suggesting that air temperature has effects on REM and that daily air temperature variation may be an important input to the human body circadian clock[53].

2. Objectives

Air temperature has risen nearly 0.9°C since the last 19th century due to CO_2 emission increased, which may highly be because of human activities. As the high speed of urbanization, urban population will explosively grow up that will result in more climate change in which air temperature rising is visualized. Human health impact, as one of the most affected object, will bring about stupendous economic loss and magnify continuously with population growth, in which the developing countries perform the most obviously. It is necessary to assess the impact of temperature rise on human health in developing countries and the effectiveness of thermal countermeasures.

Comparing with heat stress mortality, there are few studies concentrate on sleep disturbance, whose impact is slight but widely diffusely exists in residential and, in all, bring about enormous pressure on human health. Gender differences are frequently mentioned in human sleep quality and indicating geographic variance due to men and women respective sex chromosomes and gonadal hormones levels. Air temperature affects sleep quality by interacting with human body temperature and circadian rhythm. Air conditioner, as is considered as one of the most effective adaptation to thermal environment, its performances on men and women are not well understood yet. Further more, there were few studies that concentrate on gender different reacting to air temperature variation and sleep studies are centralized more on developed countries than developing countries. Hence, it will be meaningful to assess the air temperature impact on developing countries residential sleep quality.

This study is aimed to (1) quantify the relationship between air temperature variation and sleep disturbance prevalence of men and women in Jakarta, Indonesia. (2) assess the impact of temperature on sleep disturbance of men and women and the air conditioner function on sleep disturbance. (3) predict the sleep loss of Jakarta in 2050 due to air temperature increasing to understand the global sleep disturbance impact among society.

3. Methodology

Sleep disturbance was selected as human health assess item impacted by urban heat island. In spit that sleep disturbance is not lethal, it widely exists among residential that also leading to stupendous impact on human health. Epidemiological survey was conducted in Jakarta. Residential sleep disturbance was determined referring to Pittsburgh Sleep Quality Index (PSQI) and Sleep Quality Index for Daily Sleep (SQIDS). Relationship between residential sleep quality and daily minimum temperature was quantified by use of Generalized Additive Models (GAMs). In another, men and women age impact was also considered and compared in quantifying model validity. Sleep disturbance function was applied to speculate 2006 and 2050 sleep disturbance morbidity, sleep disturbance impact of 2006 and 2050 was evaluated by the disability-adjusted life year (DALY)

3.1. Epidemiology survey

An overview of the epidemiological survey in Jakarta conducted by the Ihara laboratory is shown in Table 4. The composition of each subject's attributes is shown of February and October in Table 5 and Table 6.

Table 4 Epidemiology Survey Summary

Study period	(First time) February, 2016	Tuesday, Wednesday, Thursday
	(Second time) October, 2016	
Subjects	Men and women aged 20 and over living in Jakarta First time: N=263; Second time: N=264	
Subjects with chronic diseases	First time: N=16; Second time: N=16	
Remaining samples	First time: N=247; Second time: N=248	
Methodology	Visiting investigation	
Main items	Demographic attribute: sex, age, social economy class; Daytime activity schedule, air conditioning pattern; Sleep disorder survey; Fatigue survey	

Table 5 Summary of subjects (February)

	Total	N	Male[%]	Female[%]
		263	50.6	49.4
	Male	133	100	0
	Female	130	0	100
Age	20–29	101	50.5	49.5
	30–39	84	51.2	47.6
	40–49	58	50.0	50.0
	50~	20	50.0	50.0
SEC	A1(more than Rp 6,000,001)	60	46.7	53.3
	A2(Rp 4,000,001 – Rp 6,000,000)	50	46.0	54.0
	B(Rp 2,500,001 – Rp 4,000,000)	79	51.9	48.1
	C1(Rp 1,750,001 – Rp 2,500,000)	52	57.7	42.3
	C2(Rp 1,250,000 – Rp 1,750,001)	22	50.0	50.0

Table 6 Summary of subjects (October)

	Total	N	Male[%]	Female[%]
		264	51.1	48.9
	Male	135	100	0
	Female	129	0	100
Age	20–29	100	51.0	49.0
	30–39	86	52.3	47.7
	40–49	58	50.0	50.0
	50~	20	50.0	50.0
SEC	A1(more than Rp 6,000,001)	61	65.6	34.4
	A2(Rp 4,000,001 – Rp 6,000,000)	50	52.0	48.0
	B(Rp 2,500,001 – Rp 4,000,000)	80	48.8	51.3
	C1(Rp 1,750,001 – Rp 2,500,000)	52	40.4	59.6
	C2(Rp 1,250,000 – Rp 1,750,001)	21	42.9	57.1

3.2. Sleep Quality Questionnaire

PSQI questionnaire

PSQI evaluate subjects' sleep quality by 18 questions in four stages of 0-3 points each, and the total score (0-21 points) is calculated. The higher the overall score, the worse the sleep quality. It showed that 5.5 points (between 5 points and 6 points) and the diagnostic criteria of sleep disturbance coincided at a high level.

Table 7 Pittsburgh Sleep Quality Index[40]

Pittsburgh Sleep Quality Index (PSQI)						
C1	C2	C3	C4	C5	C6	C7
Sleep quality	Sleep latency	Sleep duration	Habitual sleep efficiency	Sleep disturbance	Use of sleeping medication	Daytime dysfunction

SQIDS questionnaire

PSQI evaluates the past month's sleep, so its evaluation results may are not affected by the daily temperature. Therefore, PSQI Sleep disturbanceed people are unrelated to nighttime high temperature. Meanwhile, to assess the deterioration of sleep due to daily temperature, it is necessary to investigate the quality of sleep every day. SQIDS was developed referring to PSQI. The criteria for determining sleep disturbances with SQIDS are consistent with PSQI.

Table 8 Sleep Quality Index for Daily Sleep[54]

Sleep Quality Index for Daily Sleep (SQIDS)						
C1	C2	C3	C4	C5	C6	C7
Sleep quality	Sleep latency	Sleep duration	Habitual sleep efficiency	Sleep disturbance	Use of sleeping medication	Daytime dysfunction

3.3. Generalized Additive Models (GAMs)

A generalized additive model (GAM)[55]is a generalized linear model (GLM) in which the linear predictor is given by a user specified sum of smooth functions of the covariates plus a conventional parametric component of the linear predictor. The GAMs can be written as:

$$g[E(Y)] = \beta_0 + \sum_{j=1}^{p} f_j(x_{ij}) + \epsilon_i$$
$$= \beta_0 + f_1(x_{i1}) + f_2(x_{i2}) + \ldots + f_p(x_{ip}) + \epsilon_i$$

$\beta 0$ is the intercept, ϵi is the random error, $f(x)$ here is the smoothing function, $g[E(Y)]$ is link function that selected as logistic regression. GAMs can be modeled non-parametrically in addition to linear and polynomial terms for other predictors. Smoothing terms automatically estimated by R.i386.3.5 mgcv package, and smoothing terms were chosen by using the Generalized Cross Validation (GCV) criterion or an Un-Biased Risk Estimator (UBRE) criterion. Sleep disturbance prevalence was measured to dummy variable and satisfy the binomial distribution (No sleep disturbance=0; Sleep disturbance=1), regression analysis selects logistic regression.

3.4. Jakarta Gender Population

The total population data of Jakarta present and in 2050 was engraft from Kuwayama[57]. Male and female population were calculated referring to sex ratio of total population in World Population Prospects 2019[58].
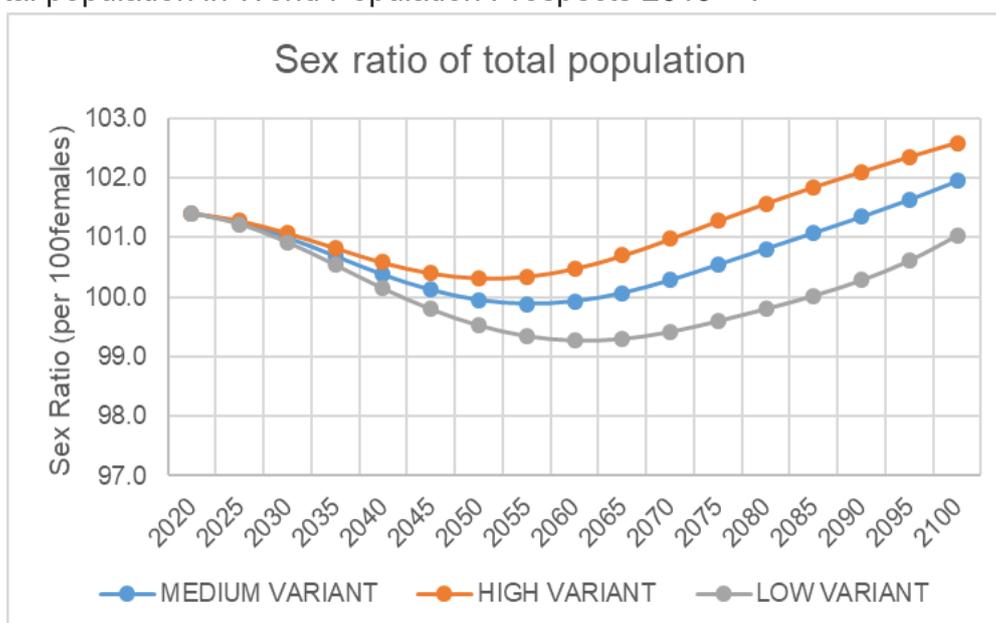
Figure 14 Sex ratio of total population of Jakarta

3.5. Jakarta temperature

Jakarta daily minimum temperature were approached from OGIMET[60] three stations(Tanjung Pri, Observatory, Soekaron-Ha). August Temperature of 2006 and 2050 were approached from the CM-BEM simulation that estimating the temperature and building energy consumption in consideration of the artificial exhaust heat emitted from a building or an outdoor unit of air conditioner, which, can reproduced a situation close to an actual environment[57].
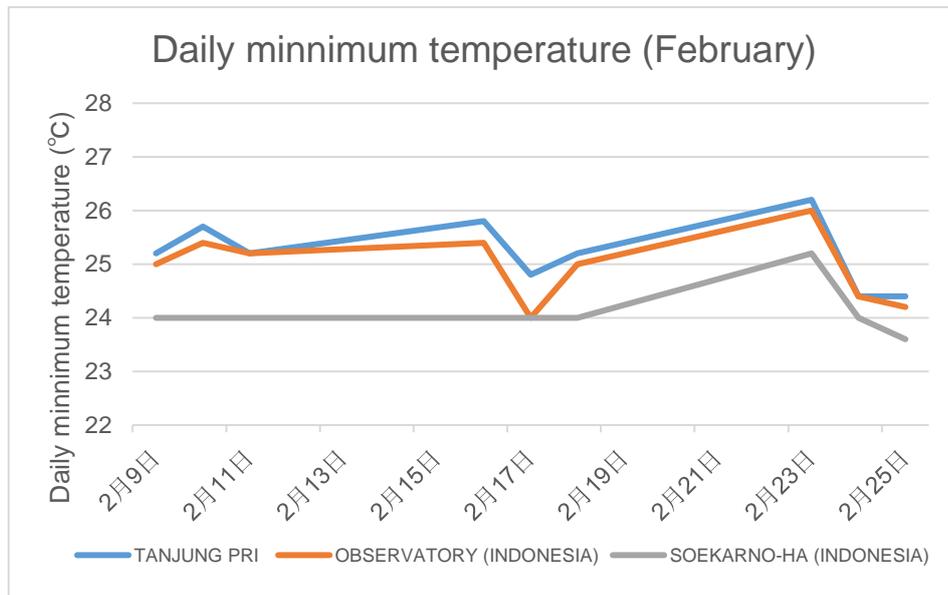
Figure 15 Daily minimum temperature in February
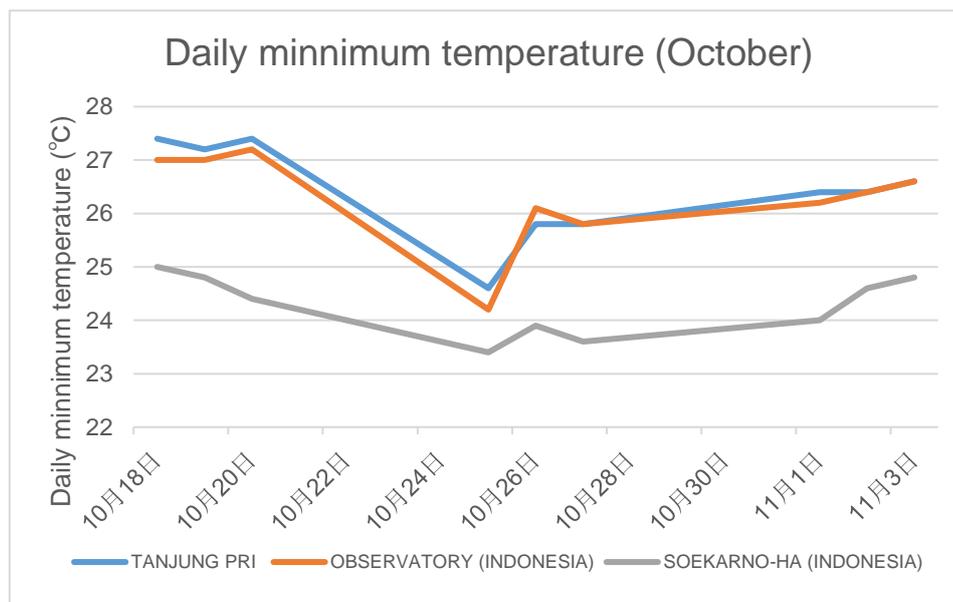
Figure 16 Daily minimum temperature in October

3.6. The Disability-adjusted Life Year (DALY)

The disability-adjusted life year (DALY)[56] is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. DALYs are calculated by combining life expectancy measures as well as the adjusted quality of life during a burdensome disease or disability for a population. DALYs are related to the quality-adjusted life year (QALY) measure; while it only measures the benefit with and without medical intervention and therefore do not measure the total burden. DALY is global calculated by toe parts YLL and YLD. The years of life lost (YLL) due to dying early. A medical condition that did not result in dying younger than expected was not counted. The years lost due to disability (YLD) component measures the burden of living with a disease or disability. Sleep disturbance is not lethal that DALYs were only calculated by YLD. One DALY is equal to one year of healthy life lost. Sleep disturbance weighted 0.1[57], period is 1/365 year because sleep disturbance is assessed every day in this study.

$$DALY = YLL + YLD$$

$$YLD = I \times DW \times L$$

I = number of incident cases in the population
DW = disability weight of specific condition
L = average duration of the case until remission or death (years)

$$YLL = N \times L$$

N = number of deaths due to condition
L = standard life expectancy at age of death

4 Results

4.1 Study subjects

According to survey results, respondents with diseases may give huge impact on human sleep, so respondents who had diseases were excluded out of sample sizes in this study(Table 9).

Table 9 Subjects with diseases in February and October

February		October	
First time	263	First time	264
Two weeks later	263	Two weeks later	264
total	526	total	528
February		October	
heart disease	1	mental disease	1
respiratory disease	5	respiratory disease	1
connective tissue disease	1	rheumatism	5
rheumatism	1	sleep disorder	4
sleep disorder	2	other disease	5
other disease	6		
total	16	total	16
February		October	
First time	247	First time	248
Two weeks later	247	Two weeks later	248
Samples	494	Samples	496

4.2 Descriptive analysis

4.2.1 PSQI scores and sleep disturbance prevalence

PSQI evaluated past one month sleep quality of objects. Both February and October the first time PSQI score and prevalence were higher than the second time, this may because people might evaluate their situations more strictly when they first got to know this survey. October scores and prevalence were higher than February scores, it may because ambient temperature and humidity variation or object samples changed. There were objects who's sleep quality were seriously bad (scores >8). In total, there was 11.1% in February and 14.7% in October of sleep disturbance prevalence. There was totally 12.9% of sleep disturbance prevalence in Jakarta, which was much lower than Tokyo's prevalence 46.6%, Jakarta residential may have better sleep quality than Tokyo residential in whole[61]. In C4 habitual sleep efficiency, all subjects' efficiency were higher than 80% that the scores were 0 scores. C3 sleep duration and C5 sleep disturbance got relatively higher scores.
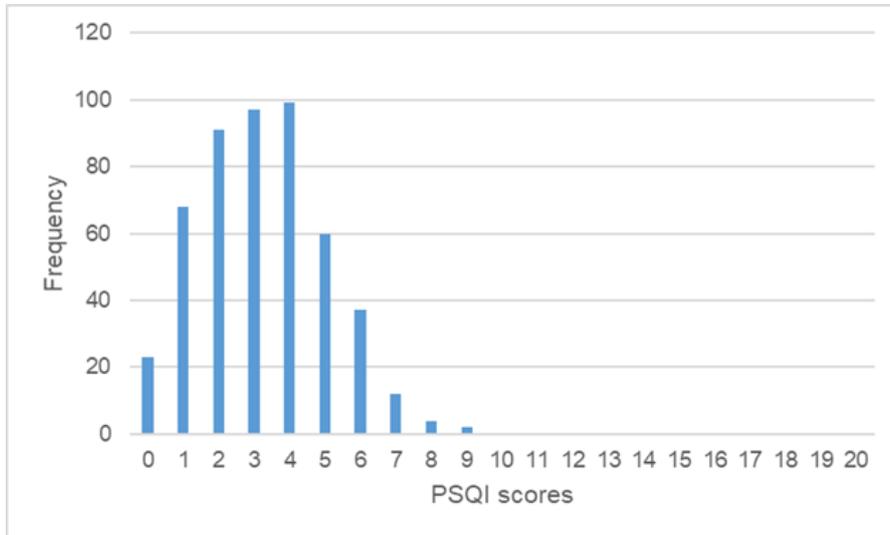
Figure 17 PSQI scores in February
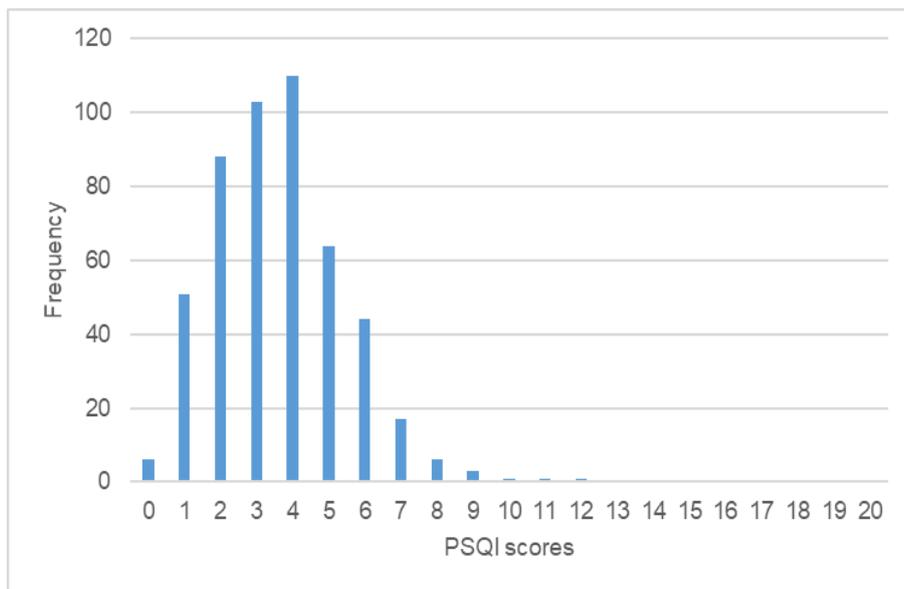
Figure 18 PSQI scores in October
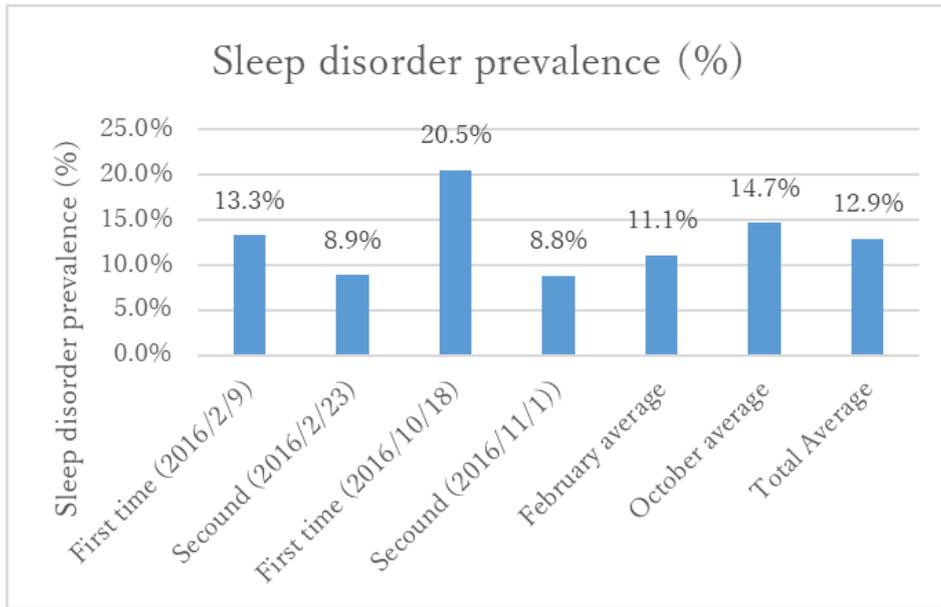
Figure 19 Sleep disturbance prevalence of PSQI

Table 10 Component average scores of PSQI

Component	First time (2016/2/9)	Secound (2016/2/23)	First time (2016/10/18)	Secound (2016/11/1))
C1	0.65	0.64	0.81	0.79
C2	0.77	0.58	0.69	0.49
C3	0.84	0.87	0.83	0.65
C4	0	0	0	0
C5	0.77	0.71	1.04	0.96
C6	0.01	0.02	0.02	0.06
C7	0.29	0.31	0.45	0.44
total	3.32	3.14	3.84	3.38

4.2.2 SQIDS scores and sleep disturbance prevalence

In SQIDS scores, C4 habitual sleep efficiency and C6 use of medication got nearly 0 scores, C1 sleep quality and C7 daytime dysfunction got relatively high scores, who's scores structure was different as PSQI.

About every day's sleep disturbance prevalence (%), there were 8.1% in February and 5.9% in October respectively of subjects who were suffering from sleep disturbance. What is more, in study periods, the first day usually took the first position of prevalence in 3-day periods (except 2/23) correspondent to PSQI scores, suggesting that it may be over weighted at the first time survey by respondents.

Table 11 Component average scores of SQIDS

| Date	C1	C2	C3	C4	C5	C6	C7	Total	Prevalence
2016/2/9	0.83	1.48	0.78	0.00	0.24	0.00	0.98	3.49	14.1%
2016/2/10	0.83	0.63	0.89	0.00	0.14	0.00	0.94	3.44	12.5%
2016/2/11	0.75	0.50	0.87	0.00	0.12	0.00	0.89	3.40	10.1%
2016/2/16	0.75	0.48	0.83	0.00	0.14	0.00	0.97	2.91	7.7%
2016/2/17	0.79	0.47	0.56	0.00	0.13	0.00	0.87	3.05	6.9%
2016/2/18	0.78	0.43	0.88	0.00	0.14	0.01	0.83	3.07	6.5%
2016/2/23	0.79	0.45	0.50	0.00	0.13	0.00	0.89	3.10	4.8%
2016/2/24	0.77	0.43	0.51	0.00	0.13	0.00	0.87	3.02	5.2%
2016/2/25	0.73	0.46	0.84	0.01	0.10	0.00	0.82	2.96	5.2%
2016/10/18	0.78	0.44	0.78	0.00	0.18	0.00	0.89	2.80	6.9%
2016/10/19	0.73	0.43	0.75	0.00	0.16	0.02	0.87	2.97	6.0%
2016/10/20	0.75	0.45	0.74	0.00	0.13	0.01	0.86	2.69	6.0%
2016/10/25	0.78	0.44	0.75	0.00	0.18	0.02	0.90	2.81	8.9%
2016/10/26	0.73	0.38	0.74	0.00	0.14	0.02	0.84	2.85	4.8%
2016/10/27	0.78	0.37	0.77	0.00	0.15	0.02	0.84	2.93	6.5%
2016/11/1	0.81	0.35	0.70	0.00	0.15	0.00	0.84	2.61	7.3%
2016/11/2	0.76	0.33	0.81	0.00	0.11	0.00	0.81	2.81	4.0%
2016/11/3	0.76	0.30	0.78	0.00	0.12	0.00	0.84	2.45	2.8%
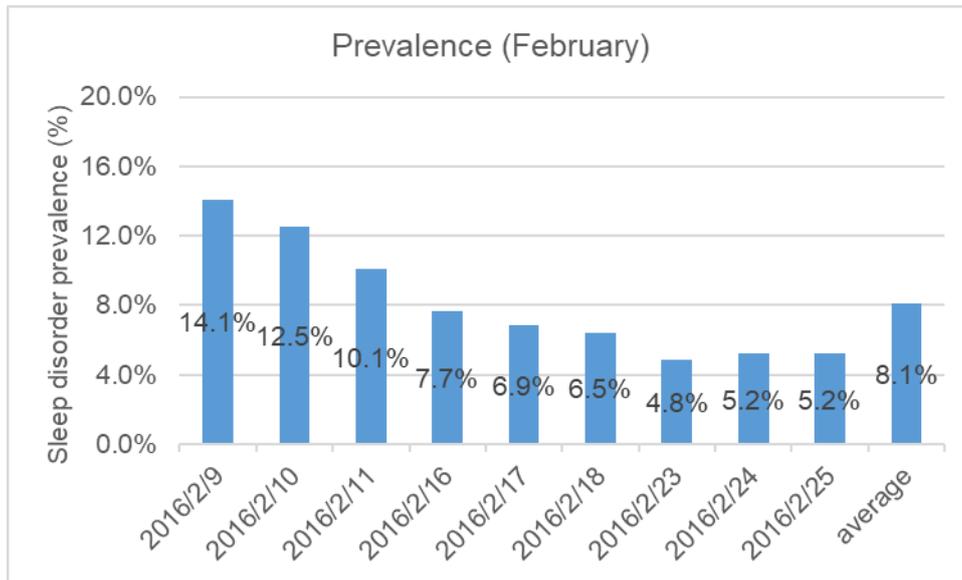
Figure 20 Everyday sleep disturbance prevalence in February
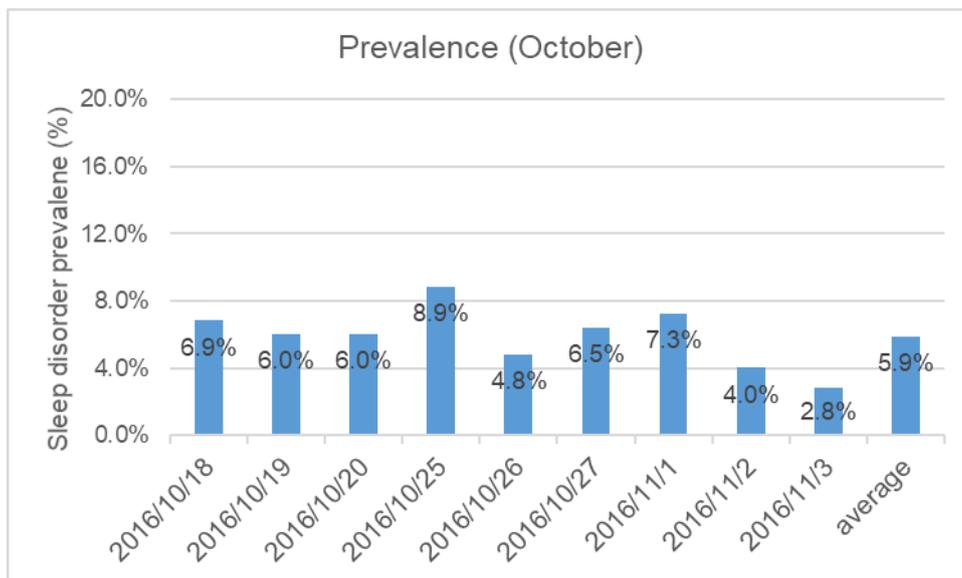

Figure 21 Everyday sleep disturbance prevalence in October

4.3 Gender differences in sleep disturbance

4.3.1　Gender comparison of PSQI scores results

Men and women scores were collected and gender differences tested by student-test. In total, men got higher global scores than women (t=2.01, P=0.045). C3 sleep duration had apparent gender differences (t=3.42, P=0.001). In February, C1 respondents sleep quality (t=2.24, P=0.04) and C3 sleep duration (t=2.04, P=0.04) had statistical differences in men and women when only C3 sleep duration was found to be gender different in October (t=2.79, P=0.01).

Table 12 PSQI average scores of total subjects

	Total	Men	Women	t	p
C1	0.72±0.50	0.75±0.51	0.70±0.48	1.56	0.118
C2	0.63±0.71	0.65±0.72	0.61±0.69	1.01	0.311
C3	0.80±0.82	0.88±0.87	0.71±0.75	3.42	0.001
C4	0.01±0.03	0.00±0.00	0.00±0.05	-1.03	0.301
C5	0.87±0.50	0.86±0.5	0.88±0.49	-0.48	0.630
C6	0.03±0.17	0.03±0.17	0.03±0.16	0.01	0.989
C7	0.37±0.51	0.36±0.52	0.38±0.51	-0.72	0.473
Total	3.42±1.82	3.53±1.93	3.3±1.68	2.01	0.045
Prevalence	12.9%±12.21%	15.1%±15.63%	10.8%±8.79%	1.65	0.007

Table 13 PSQI average scores of February and October subjects

	February				October			
	Men (n=258)	Women (n=238)	t	p	Men (n=254)	Women (n=242)	t	p
C1	0.69±0.5	0.59±0.49	2.24	**0.03**	0.8±0.51	0.8±0.45	0.04	0.97
C2	0.68±0.7	0.66±0.7	0.33	0.74	0.62±0.74	0.55±0.68	1.07	0.29
C3	0.93±0.89	0.78±0.74	2.04	**0.04**	0.84±0.86	0.64±0.75	2.79	**0.01**
C4	0±0	0±0.06	-1.05	0.3	0±0	0±0	65535	—
C5	0.74±0.54	0.74±0.49	-0.11	0.91	0.99±0.42	1.01±0.45	-0.51	0.61
C6	0.01±0.11	0.02±0.14	-0.84	0.4	0.04±0.22	0.03±0.18	0.56	0.57
C7	0.28±0.47	0.32±0.49	-0.99	0.32	0.44±0.55	0.44±0.52	-0.02	0.98
total	3.33±1.85	3.12±1.71	1.31	0.19	3.74±1.98	3.48±1.63	1.59	0.11

4.3.2 C3 Sleep duration

In terms of sleep duration, there was apparent gender differences in both February and October of PSQI scores. Compared with men, women had 0.2h longer sleep duration in total and October sleep duration was longer than February of men and women (total: t=-2.54,P=0.01; October: t=-2.94, P=0; February: t=-0.67, P=0.51).

Table 14 Gender sleep duration of PSQI

|	Men	Women	t	p
February	7.07±1.34	7.15±1.04	-0.67	0.51
October	7.11±1.18	7.42±1.17	-2.94	0.00
TOTAL	7.09±1.27	7.29±1.11	-2.54	0.01
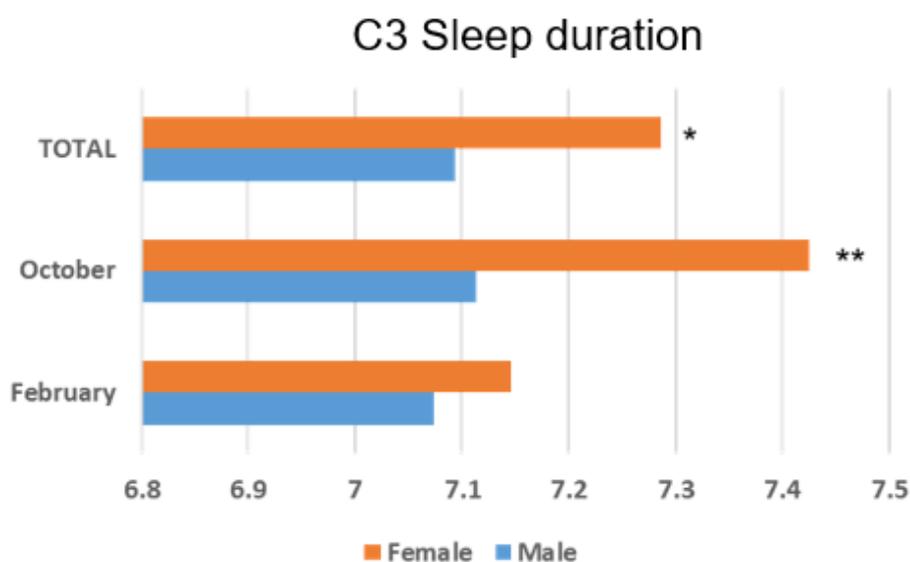
Figure 22 Gender sleep duration of PSQI

Taking age into account, 40s' got the shortest sleep duration while 20s' got the longest of men and women. Only 30s' had gender differences (t=-2.43, P=0.02). The 50s' sleep duration was relatively shorter than the younger generations', indicating that the sleep duration may possibly affected decreased with aging however there was no statistical difference between age group.

Table 15 Age sleep duration of PSQI

	Men	Women	t	p
20 (Nma=196, Nfe=186)	7.43±1.24	7.59±1.12	-1.29	0.2
30(Nma=166, Nfe=152)	6.95±1.37	7.29±1.11	-2.43	0.02
40(Nma=110, Nfe=106)	6.79±1.1	6.86±0.94	-0.52	0.61
50(Nma=40, Nfe=36)	6.86±0.98	6.94±1.06	-0.37	0.71

According to sleep study, sleep duration is associated with bedtime rather than waketime[62]. Bedtime has negative impact on sleep duration among countries or regional residuals. American, Canadian got better sleep than others. In this study of Jakarta, women went to bed 30min earlier than men (t=7.94, P=0)(Table 16), and both men and women had converse performances on bedtime and sleep duration, which corresponding with world country study results. However, comparing existing results, Jakarta residuals got earlier bedtime while the average sleep duration were inferior to most countries. This may because Jakarta samples were limited that was inaccuracy to describe the residuals' sleep, or the present study was almost concentrate on high latitude countries that people receive shorter sunshine time and daylight time than tropical residuals that may affect sleep durations.
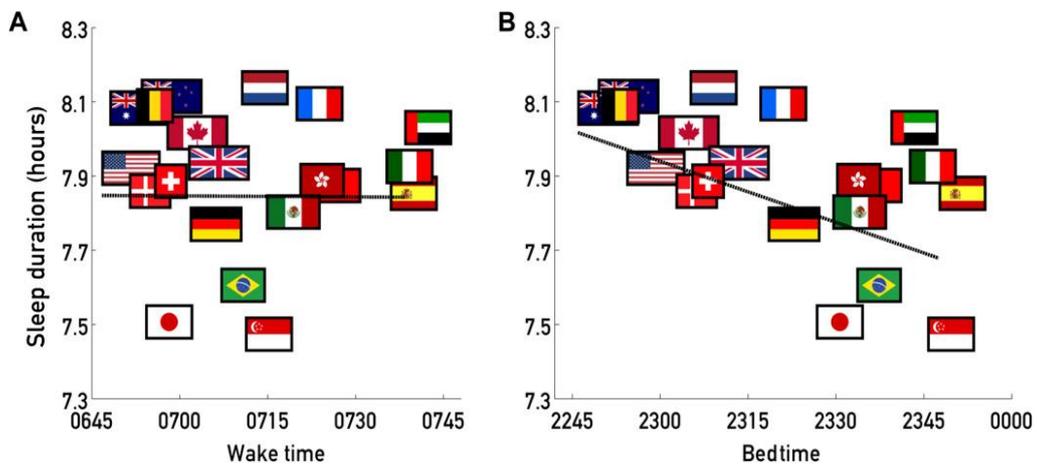
Figure 23 Country effects on sleep duration act through bedtime[62]

Table 16 Gender bedtime of Jakarta

|	Men	Women	T	P
February	22.68 ± 1.07	22.14 ± 0.93	5.68	0
October	22.37 ± 0.99	21.89 ± 0.88	5.61	0
Total	22.52 ± 1.07	22.01 ± 0.93	7.94	0
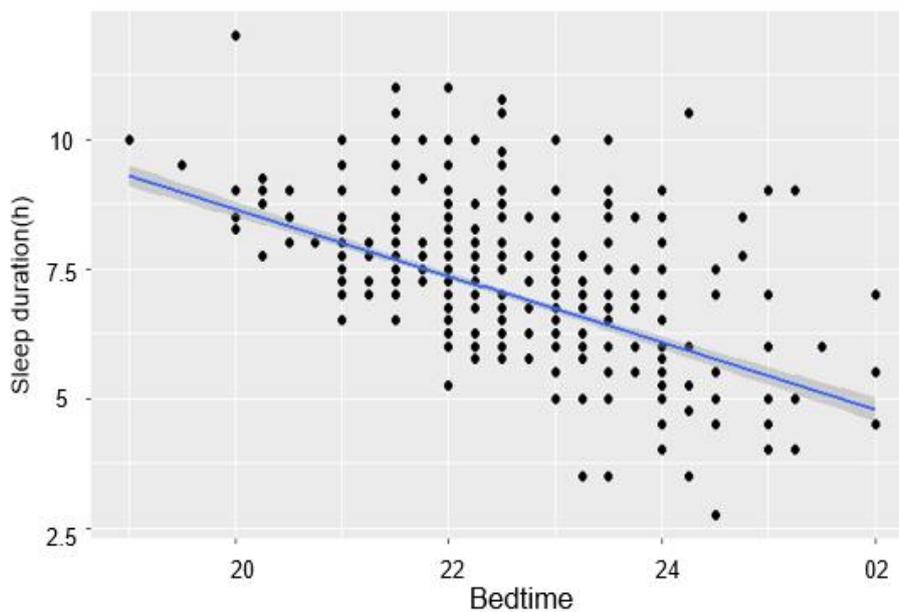


Figure 24 Bedtime and sleep duration in Jakarta
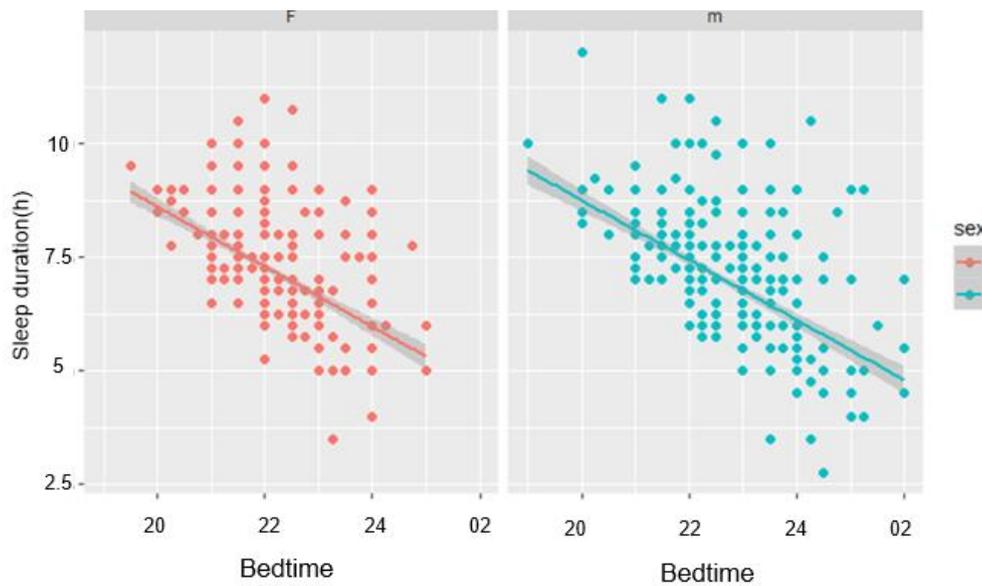
Figure 25 Men and women bedtime and sleep duration in Jakarta

4.3.3 Gender sleep disturbance prevalence of PSQI

About sleep disturbance prevalence of PSQI, men had got higher prevalence than women in all study periods(February: Male=13.9%, Female=9.6%; October: Male=16.3%, Female=12%; Total: Male=15.1%, Female=10.8%). October prevalence was higher than February.
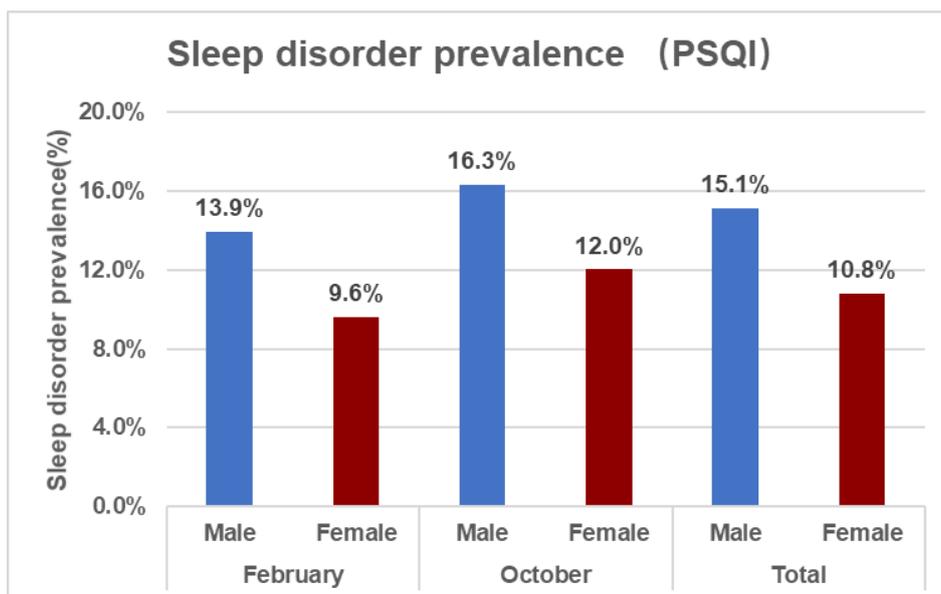

Figure 26 Sleep disturbance prevalence of PSQI

4.3.4 Gender differences of SQIDS results

SQIDS is developed to assess every day's sleep quality. In terms of Jakarta residential everyday sleep quality, gender difference was tested by t-test. C2 sleep latency, C3 sleep duration, C7 daytime dysfunction and total scores had gender differences (C2: t=2.53, P=0.01; C3: t=9.1, P=0; C7: t=-4.15, P=0; total scores: t=2.96, P=0). Men got higher scores than women in C2, C3, total scores while women got higher scores than men in C7, which had the same trend with PSQI scores.

Table 17 SOQIDS average scores of total subjects of men and women

	Male	Female	t	p
C1	0.77±0.5	0.78±0.52	-0.89	0.37
C2	0.46±0.66	0.41±0.62	2.53	0.01
C3	0.93±0.87	0.71±0.76	9.1	0
C4	0±0.03	0±0.03	-0.06	0.95
C5	0.13±0.38	0.16±0.42	-1.86	0.06
C6	0±0.07	0.01±0.12	-1.62	0.11
C7	0.84±0.62	0.92±0.68	-4.15	0
total	3.13±1.72	2.98±1.67	2.96	0

4.3.5 C3 sleep time

Sleep duration had decreased with aging of both men and women. Sleep duration decreased with bedtime becoming later that was consistent with PSQI C3. There were extremely long and short sleep duration of respondents. Suggesting these extremely short sleep duration respondent may possibly got worse sleep quality than others.
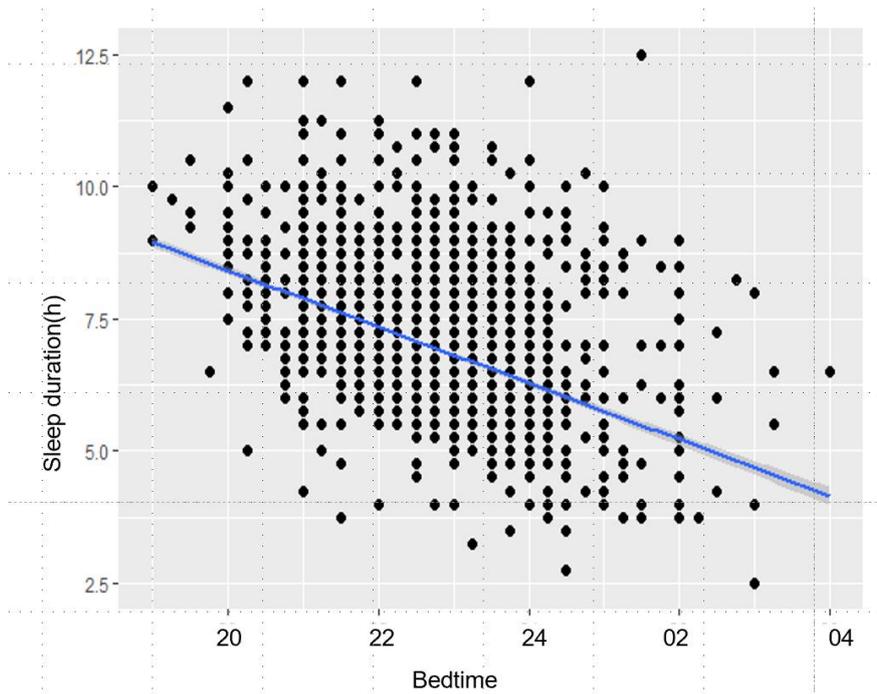
**Figure 27 bedtime and sleep duration of SQIDS**
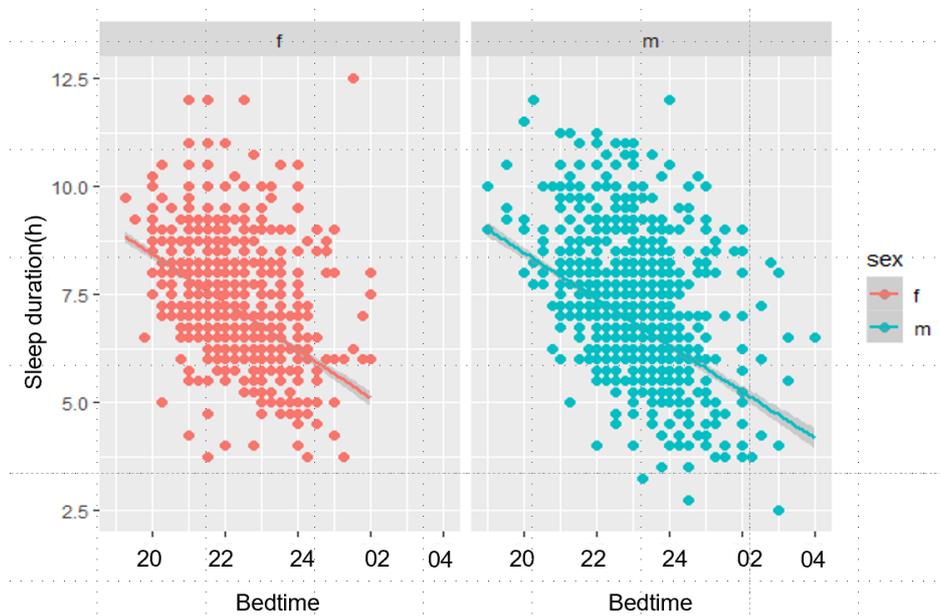
Figure 28 Men and women bedtime and sleep duration of SQIDS

In terms of age impact, though age may have huge impact on sleep quality, there was not so much variation between age groups and no statistical relationship between age and sleep duration of respondents here.
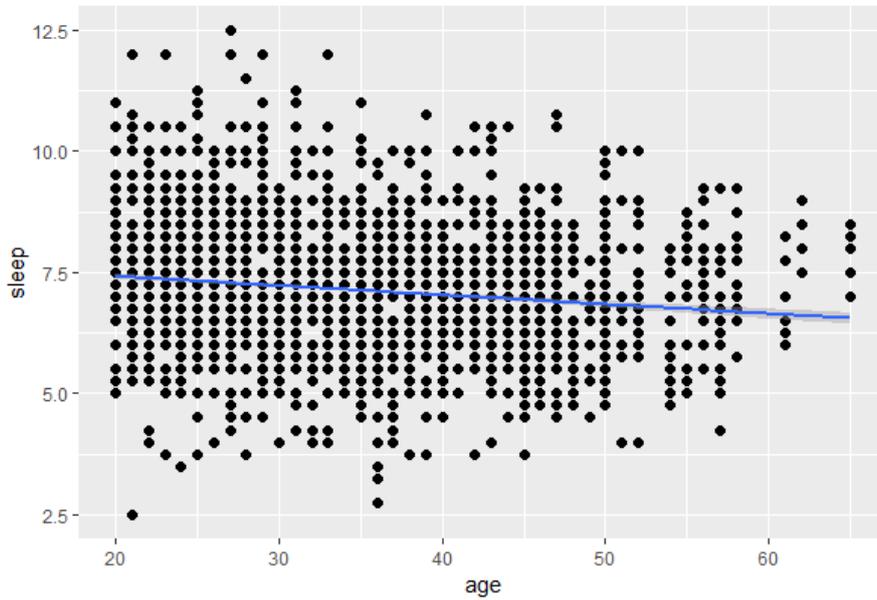
Figure 29 age variation and sleep duration

Figure 30 Men and women age variation and sleep duration

Everyday sleep duration and daily minimum temperature relationship showed no connection, suggesting that air temperature variation may had no impact on residential sleep duration.
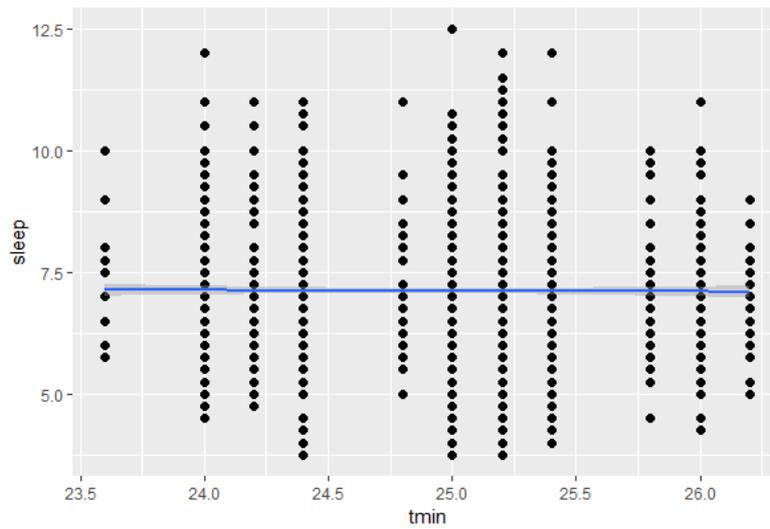
Figure 31 daily minimum temperature and sleep duration

4.3.6 Sleep disturbance prevalence of SQDIS

About sleep disturbance prevalence, man had higher prevalence than women in total(February: Male=6.0%, Female=4.8%; October: Male=5.6%, Female=5.5%; Total: Male=5.8%, Female=5.2%). Men in October prevalence was higher than February prevalence, while women's was higher than in October.
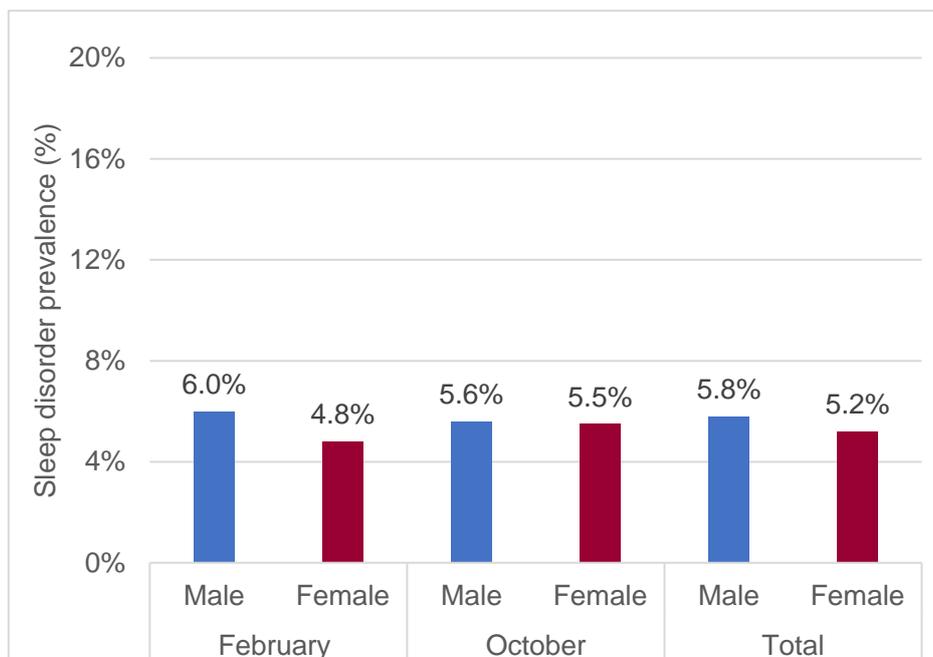

Figure 32 Gender sleep disturbance prevalence of SQIDS

4.4 Statistical regression analysis

4.4.1 Total sleep disturbance prevalence

Sleep disturbance prevalence was predicted by use of generalized addictive models(GAMs) through measured data. People's prevalence was measured as dummy variable in regression analysis (healthy objective = 0, sleep disturbance sufferers =1), to incarnate the GAMs' consistency with measured data (All intercept measures were significant that will be omitted in this study), measured data average of each temperature were displayed in figure . First raw data were performed (February = 2367, October = 2376, Total = 4743) for the first time. And it showed no significant relationship between daily minimum temperature and sleep disturbance prevalence except total model ($P<0.05$)
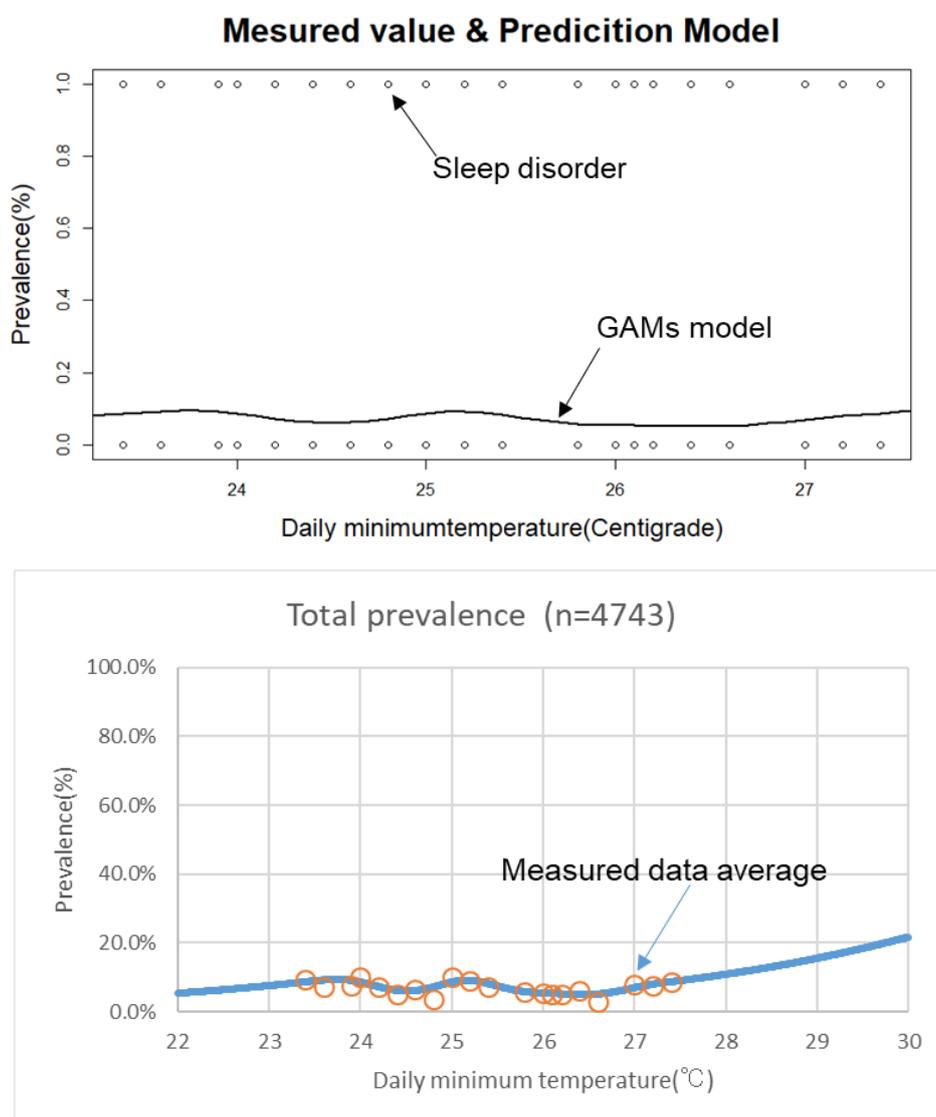

Figure 33 Generalized additive model (GAMs)

Mesured value & Predicition Model
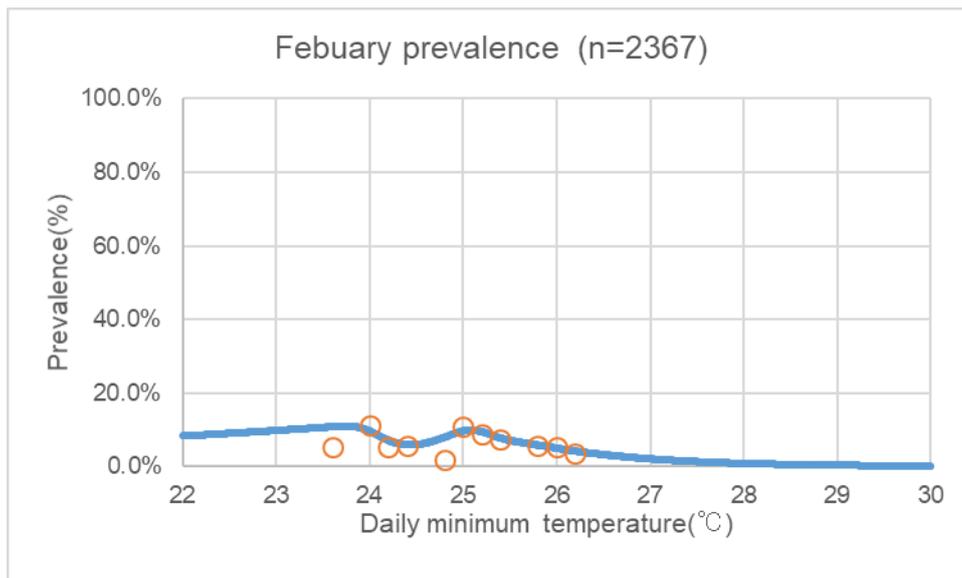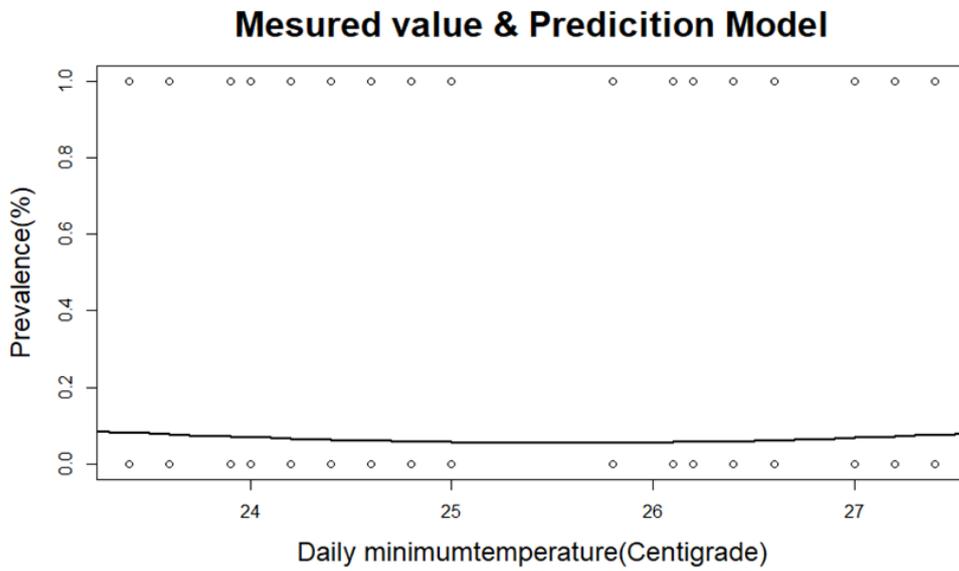
Figure 34 Generalized additive model (GAMs) in February

Mesured value & Predicition Model


October prevalence (n=2376)
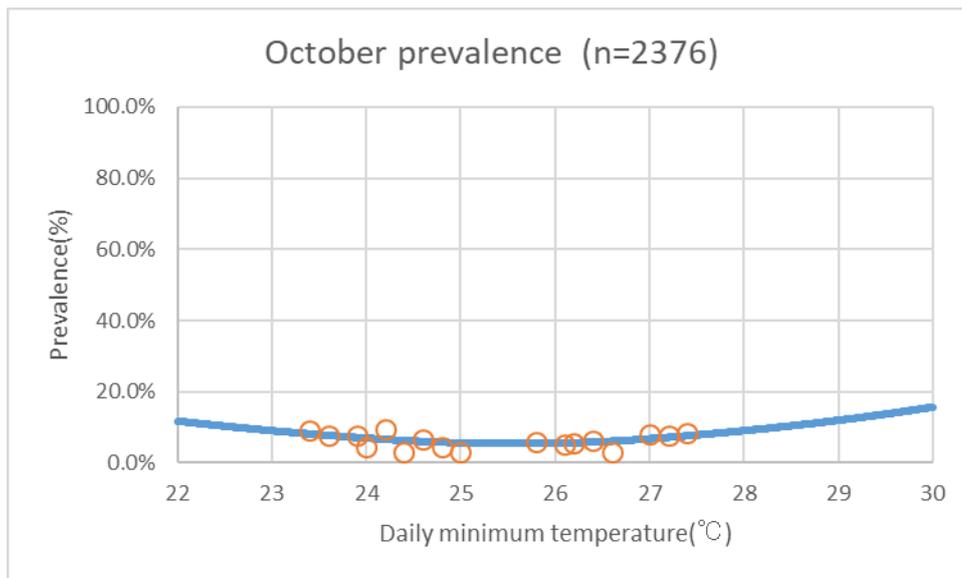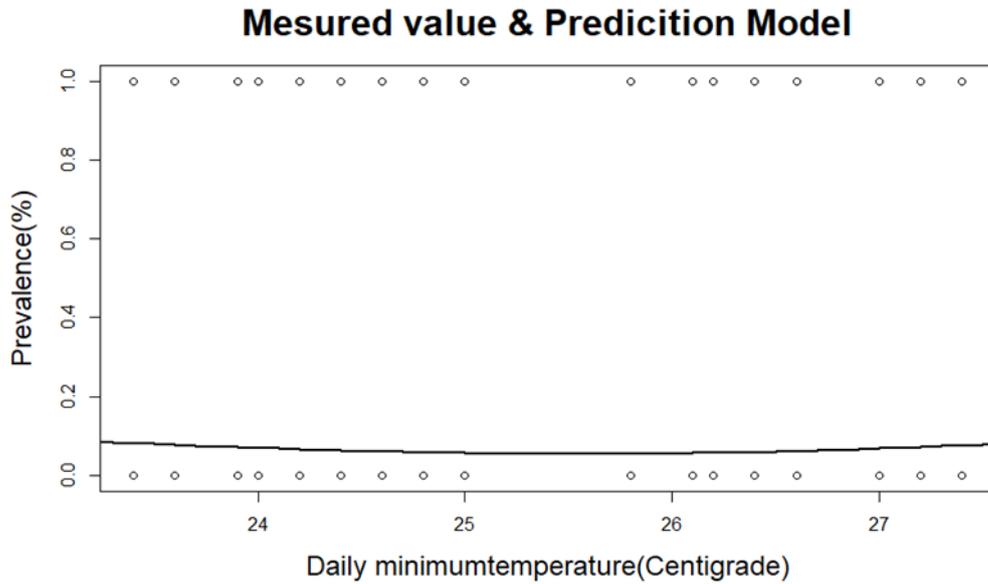
Figure 35 Generalized additive model (GAMs) in October

To exclude other factors that would affect sleep quality, data that excluding disease were performed for the second time (February = 2232, October = 2232, Total = 4464), in total healthy residuals, there would be a little increase as the daily minimum temperature rising, while the February would decrease with temperature rising. However, among all models, only total prevalence smoothing terms were calculated significantly (Table 19), it was calculated that sleep disturbance prevalence would increase with temperature rising, which means that Jakarta residuals sleep quality may deteriorate with temperature rising. Tri HarsoKaryono[62] studied thermal comfort and building energy in Jakarta, residuals' thermal comfort would varied a little in (-1~1) considered as neutral thermal comfort in 23 ~ 30 ℃(neutral temperature = 26.4 ℃), indicating that residentials habitual thermal comfort temperature intervals, means that in this temperature interval, thermal comfort may slightly be affected by temperature thus sleep quality also will be affected limitedly.

Mesured value & Predicition Model
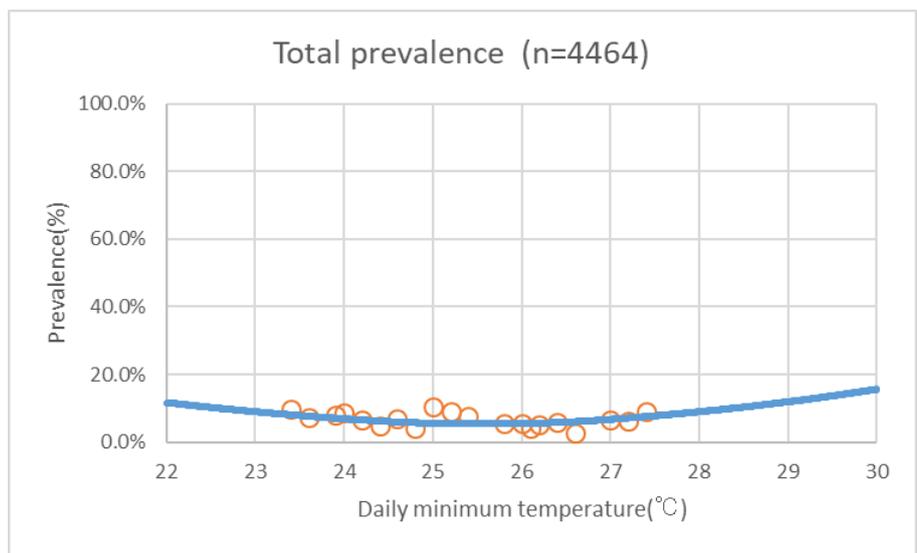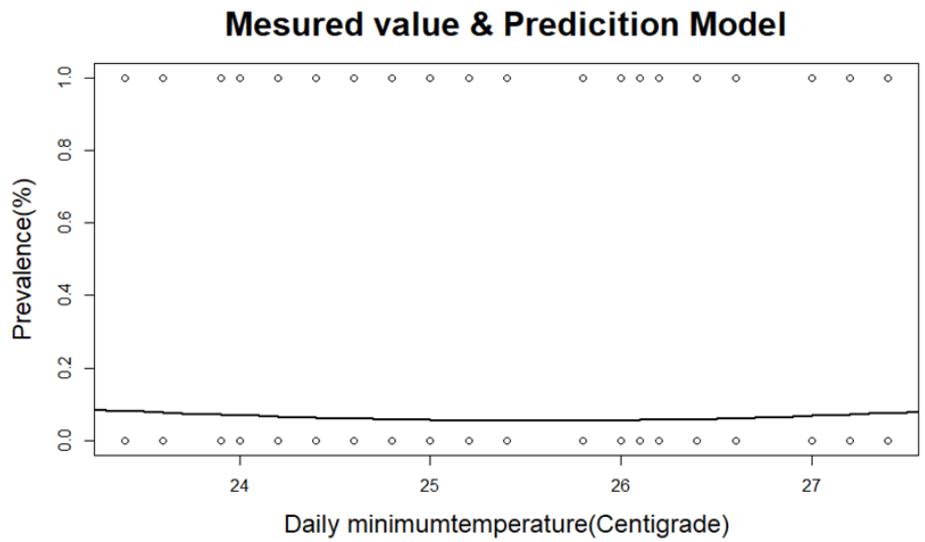
Figure 36 Generalized additive model (GAMs)

Mesured value & Predicition Model
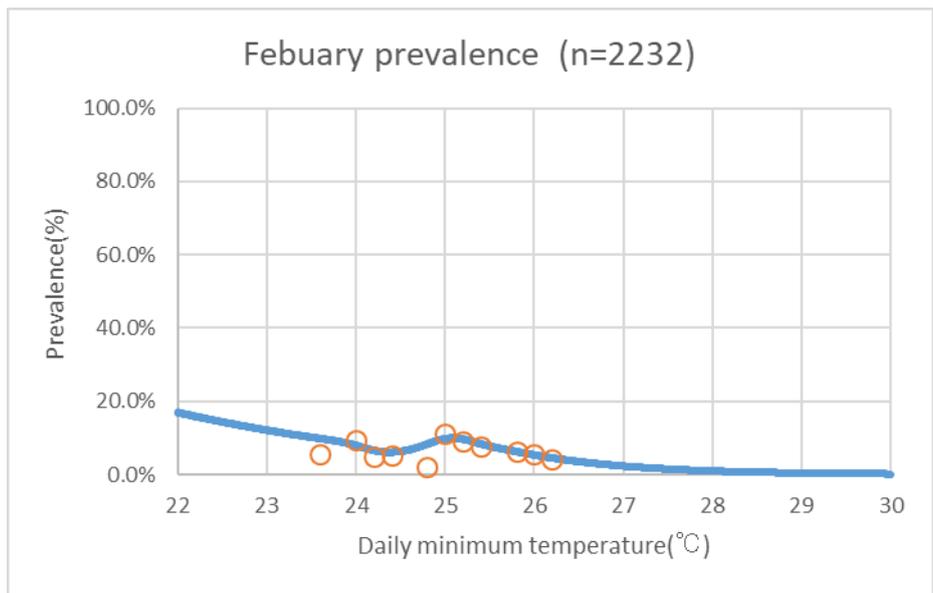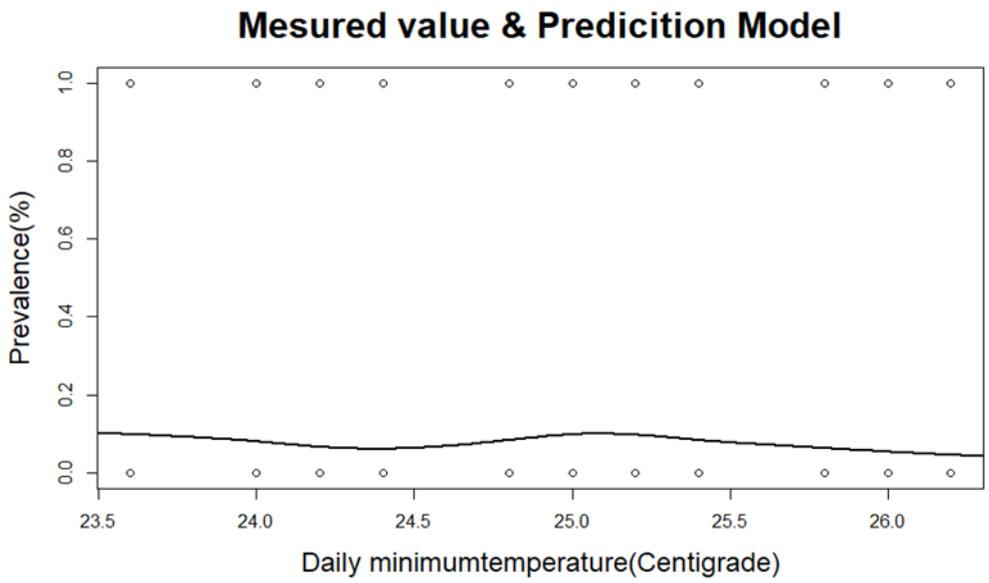
Figure 37 Generalized additive model (GAMs) in February

Mesured value & Predicition Model

Prevalence(%) vs Daily minimumtemperature(Centigrade)

October prevalence (n=2232)

Prevalence(%) vs Daily minimum temperature(℃)
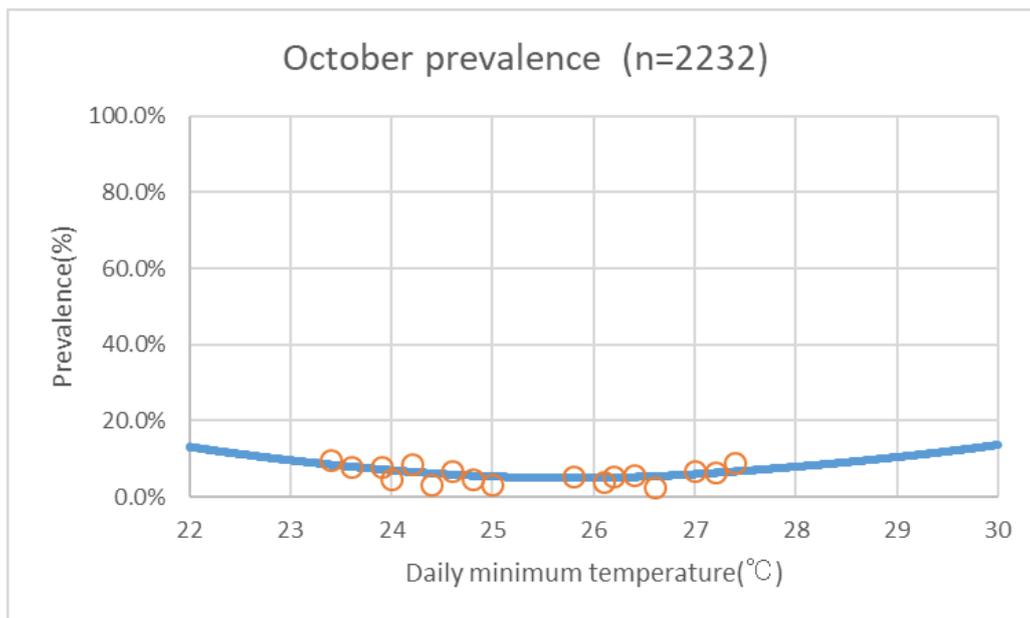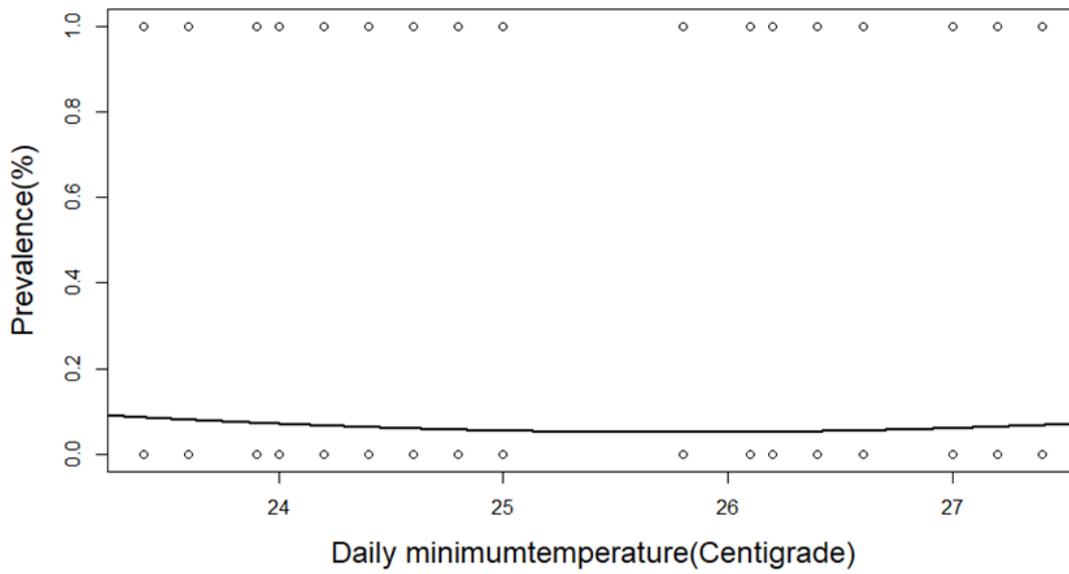
Figure 38 Generalized additive model (GAMs) in October

Table 18 Edf of smoothing terms of GAMs

	n	s(tmin)	intercept
Total prevalence	4743	6.42*	-2.57***
February prevalence	2367	4.7	-2.44***
October prevalence	2376	1.92	-2.7***
Total prevalence (without diseases)	4464	6.04	-2.57***
February prevalence (without diseases)	2232	3.97	-2.5***
October prevalence (without diseases)	2232	1.93	-2.78***

Signif. codes: '***' P<0.001 ; '**' P<0.01 ; '*' P<0.05

In total prevalence, the daily minimum temperature were significantly related to sleep disturbance prevalence, there was an increase after 25.8℃ with daily minimum temperature rising.

4.4.2 Component scores analysis

Each component score was predicted respectively by using generalized addictive models (GAMs) with the daily minimum temperature rising. Models are calculated by measured data of respective temperature group. Among all respondents, C1, C2, C5, C7 scores were predicted to increase with the daily minimum temperature rising. The majority of respondents had more than 80% sleep efficiency and did not take sleep medication so C4 Sleep efficiency and C6 Use of sleep medication had very small variation. C3 had decreased perform suggesting that sleeping time decreases with daily minimum temperature rising. In terms of total score, it varied from 2.6-3.3 scores in 22-30 ℃, smoothing terms table are showed in Table 4. Only C3 have significant calculated smoothing terms.

C1 Subjective sleep quality


C1 Subjective sleep quality


C1 Subjective sleep quality prediction
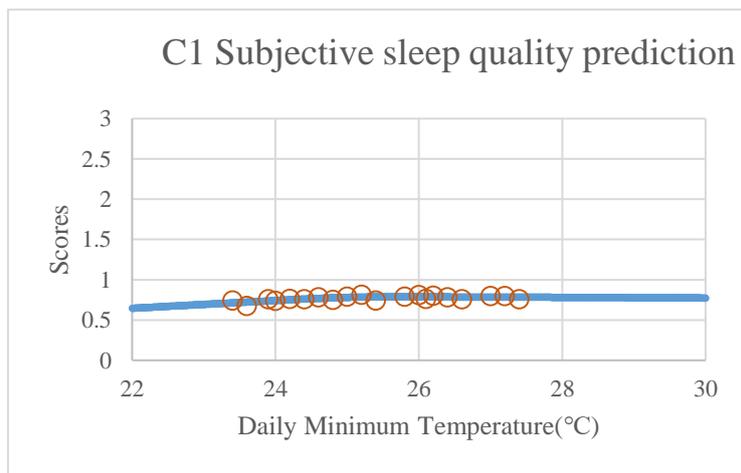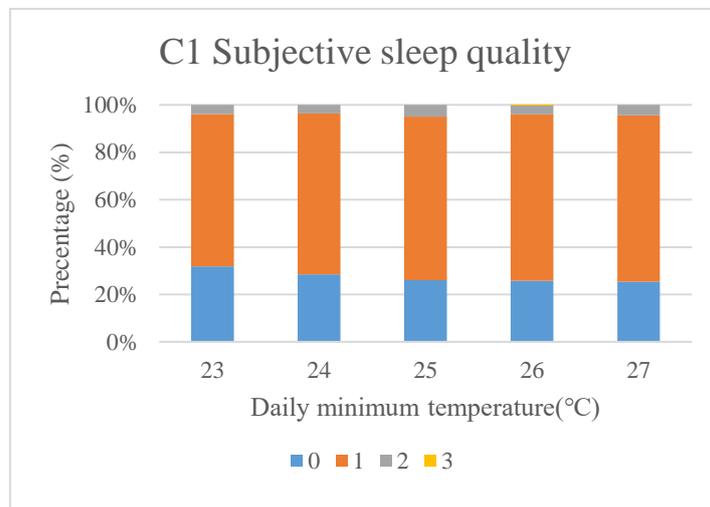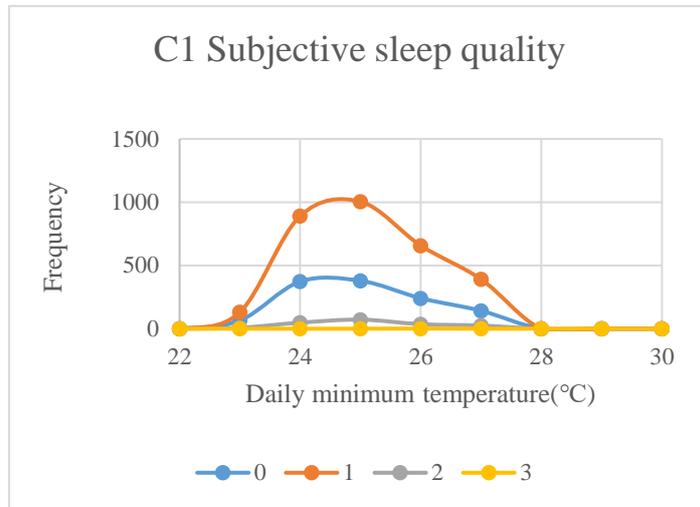
Figure 39 Smoothing spline of C1
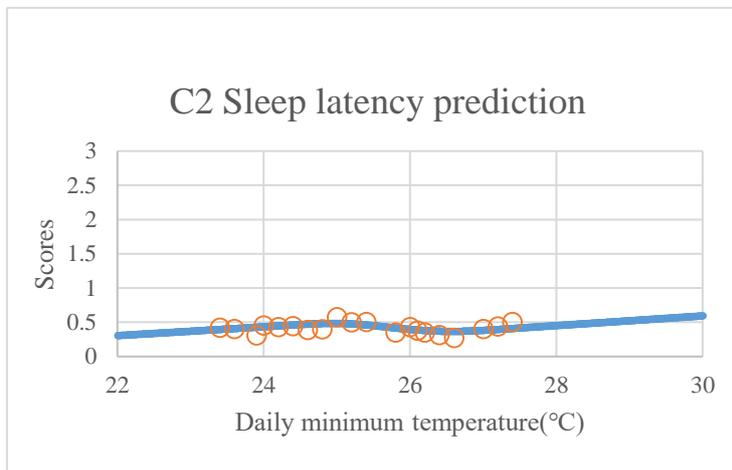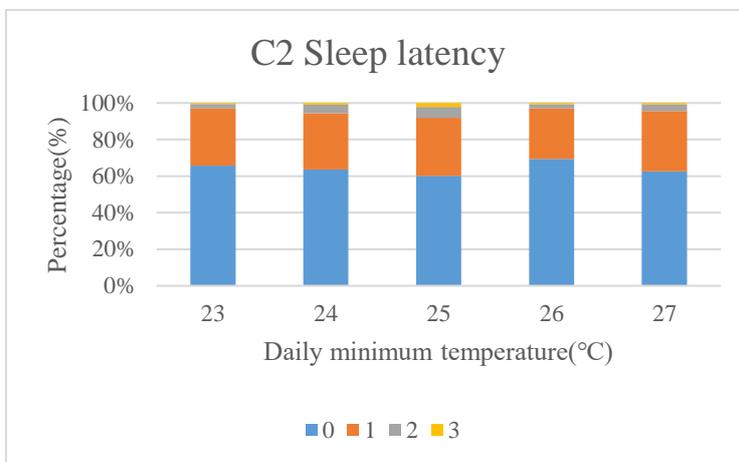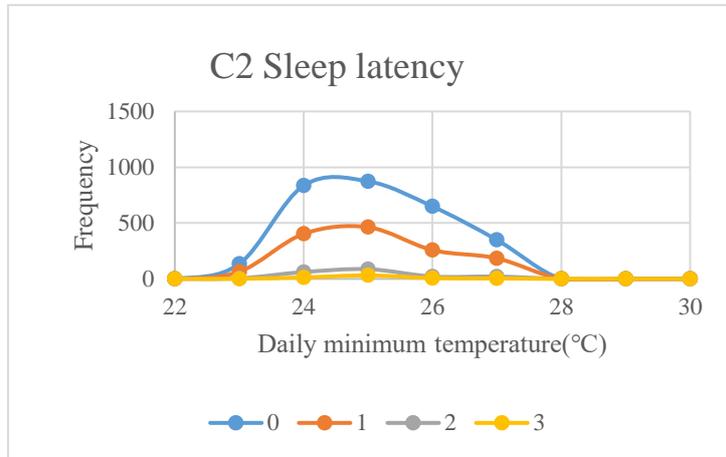
Figure 40 Smoothing spline of C2
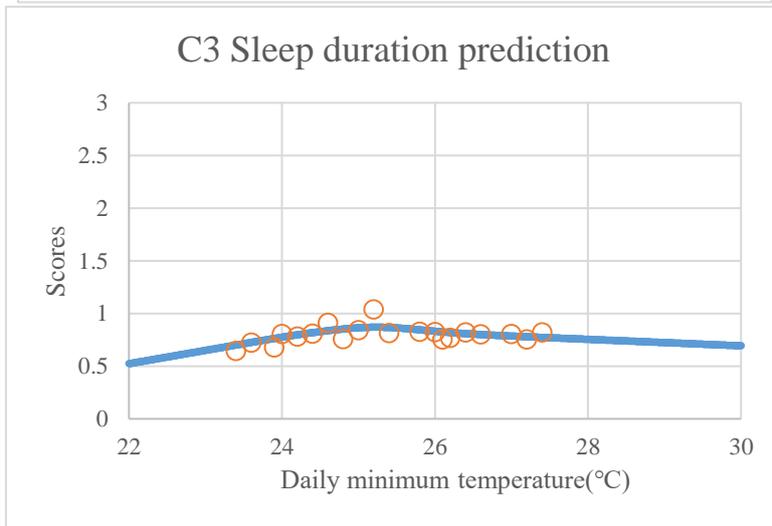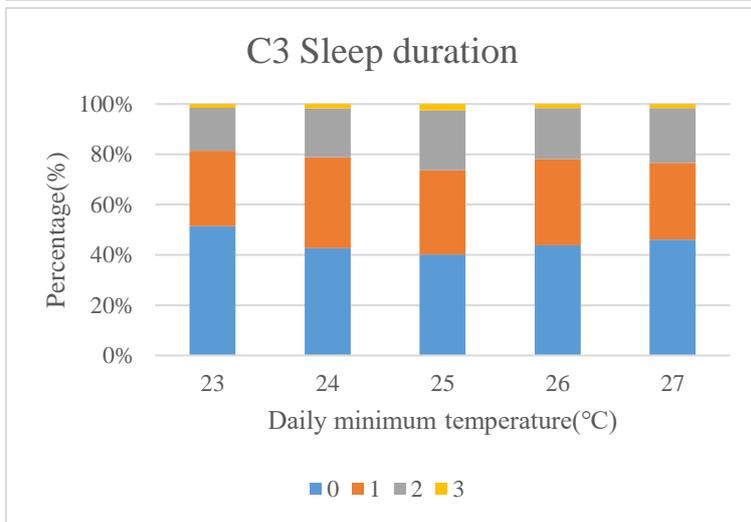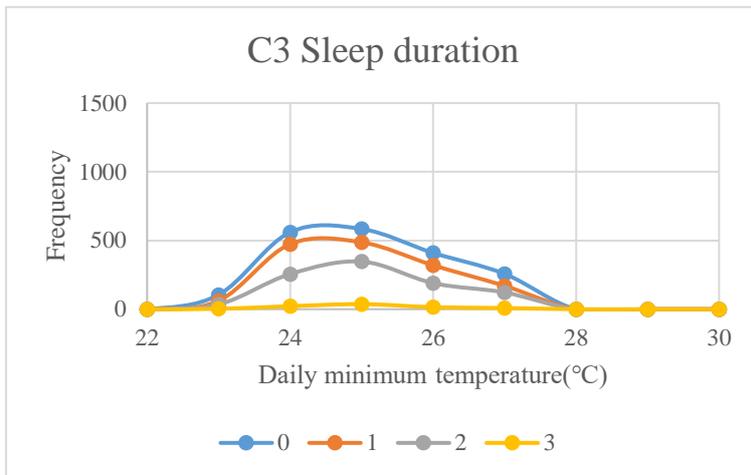
Figure 41 Smoothing spline of C3
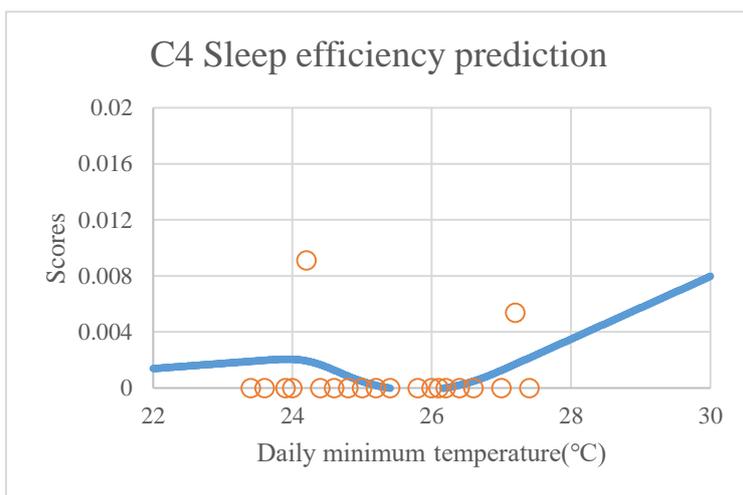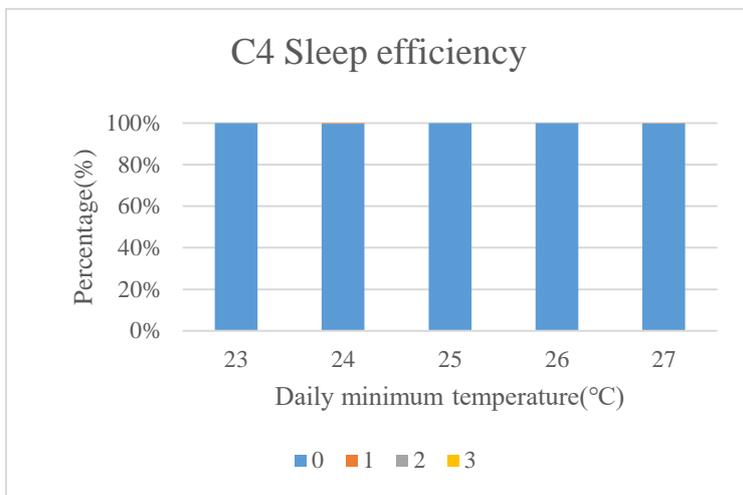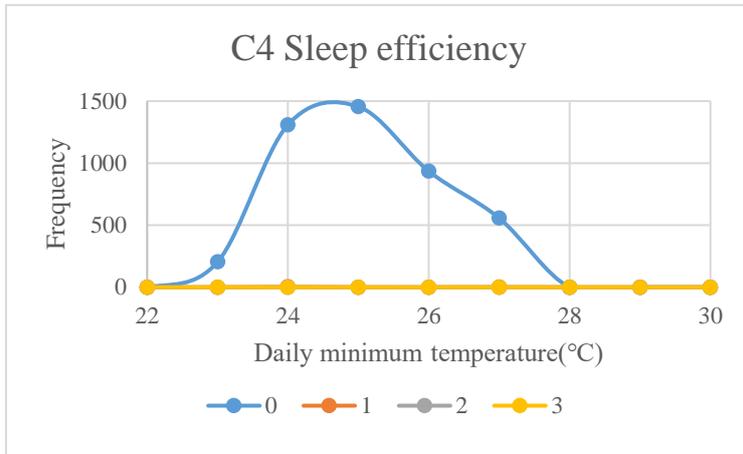
Figure 42 Smoothing spline of C4
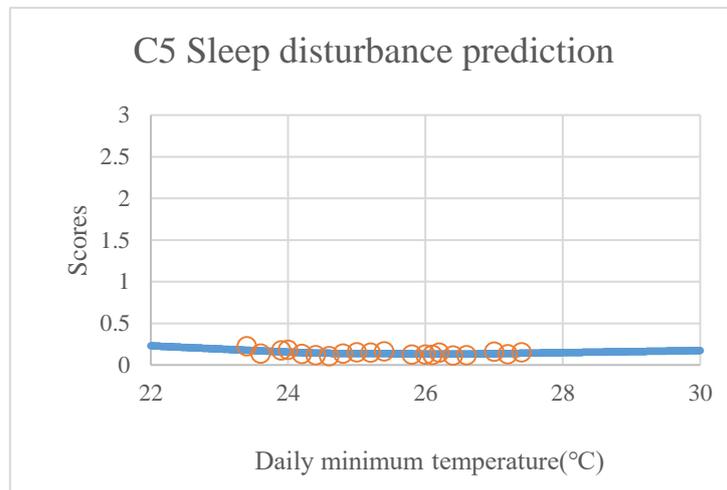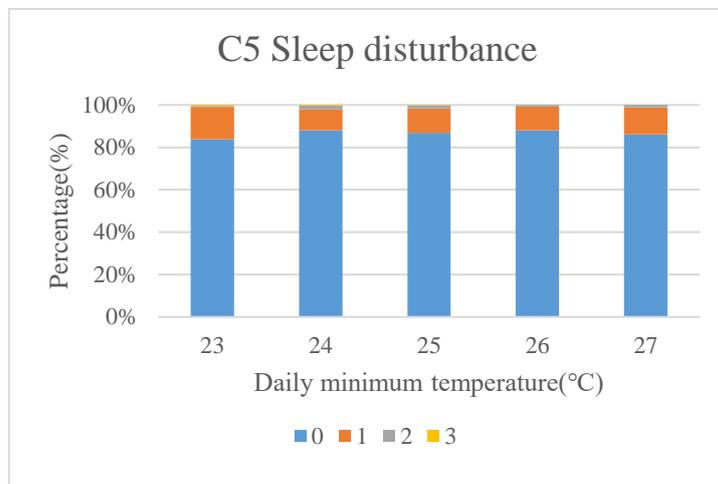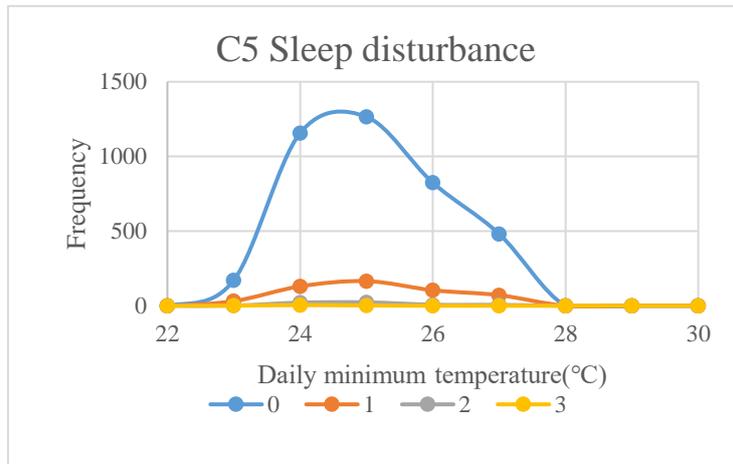
Figure 43 Smoothing spline of C5
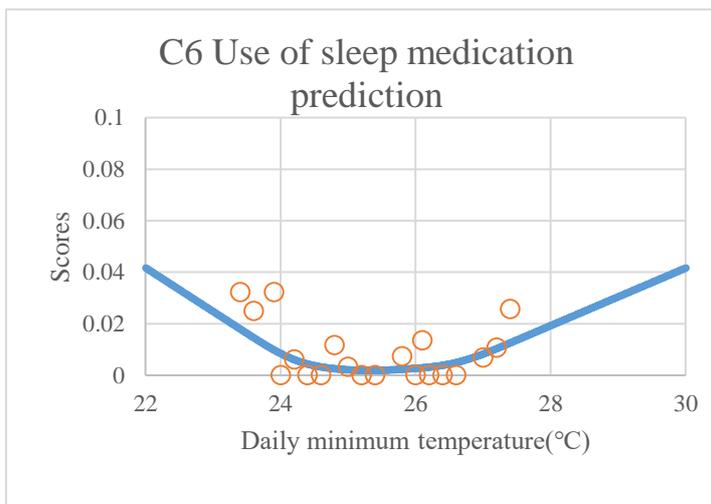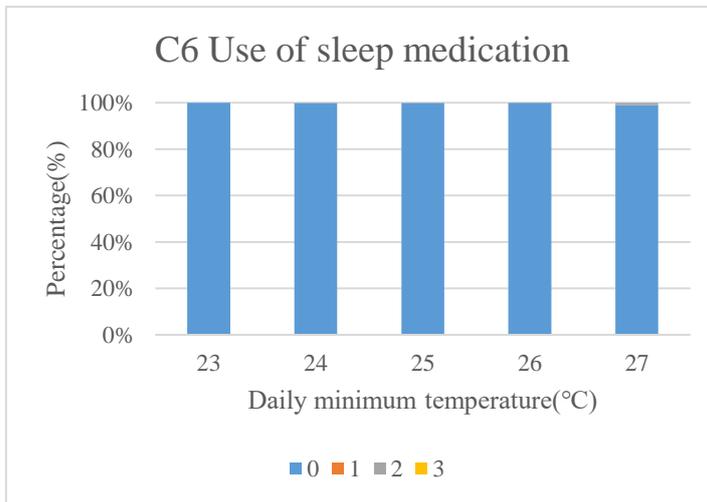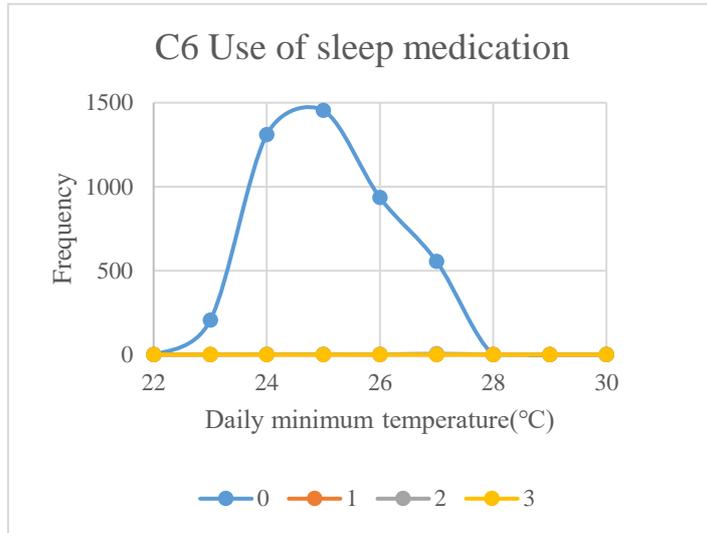
Figure 44 Smoothing spline of C6
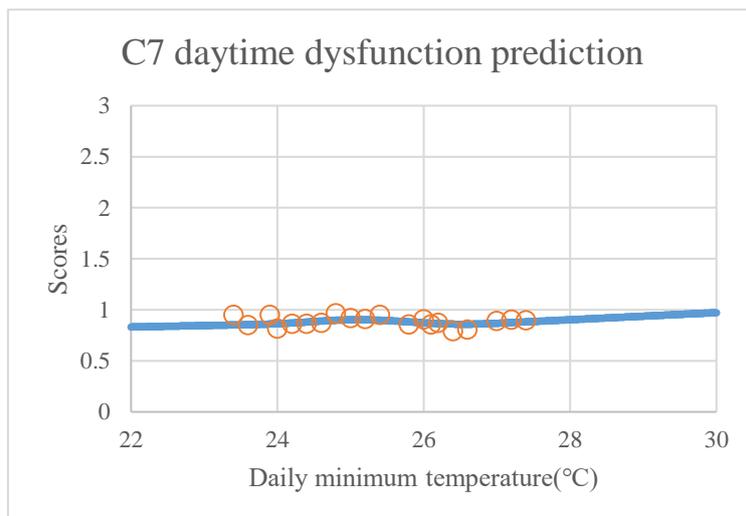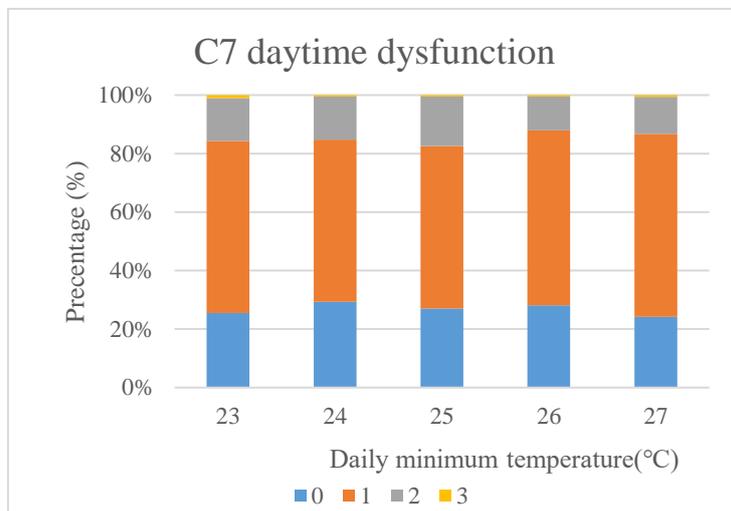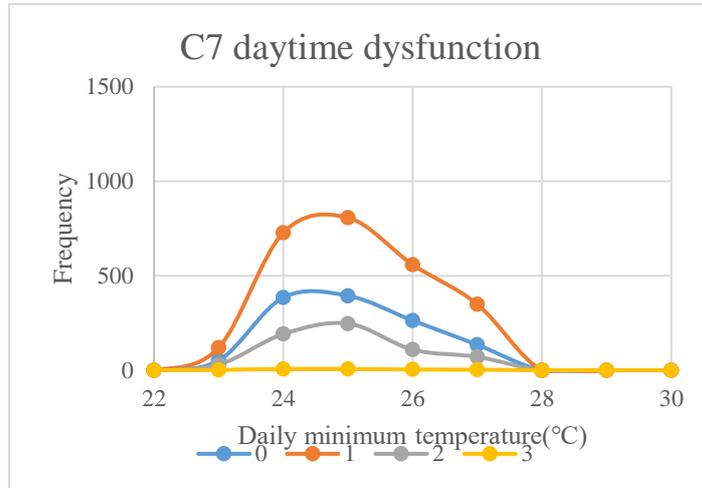
Figure 45 Smoothing spline of C7
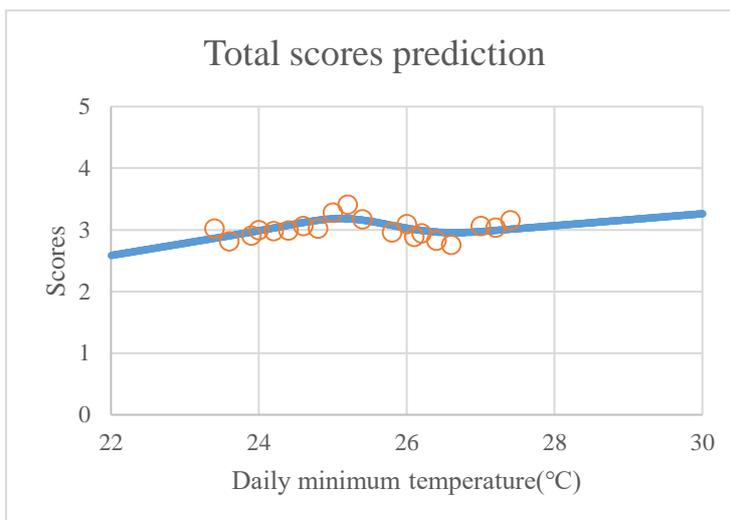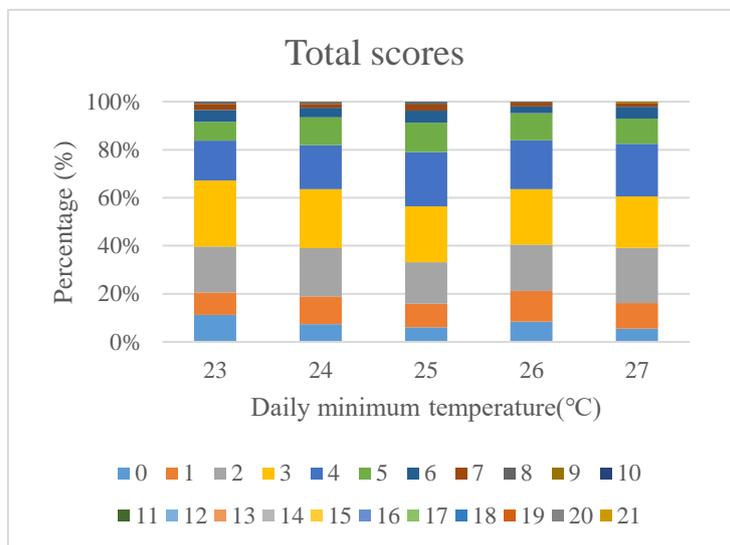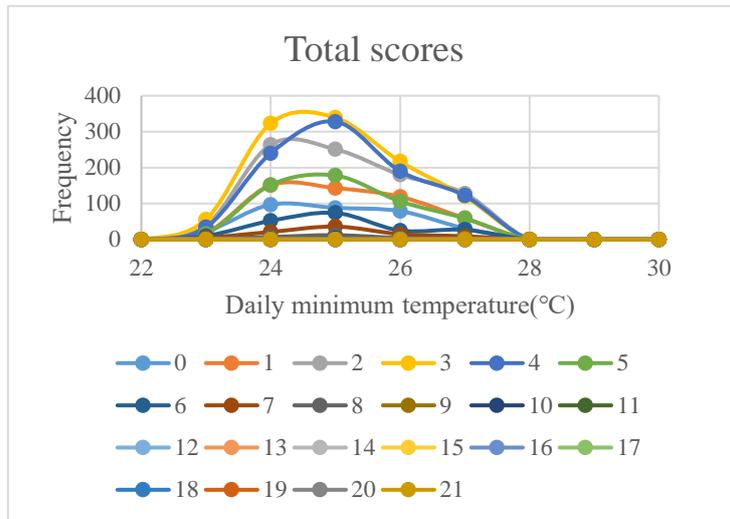
Figure 46 Smoothing spline of total scores

Table 19 Edf of smoothing terms of componets

Component	n	s(tmin)	intercept
C1	4464	2.8	0.77***
C2	4464	2.8	0.43***
C3	4464	2.8*	0.82***
C4	4464	2.8	0*
C5	4464	2.8	0.14***
C6	4464	2.8	0***
C7	4464	2.8	0.88***

Signif. codes: '***' P<0.001 ; '**' P<0.01 ; '*' P<0.05

4.4.3 Gender comparison on sleep disturbance prevalence

In total, the sleep quality was significantly affected by daily minimum temperature (P=0.01). Men and women were estimated to have inverse performance on sleep disturbance prevalence, while there were no significant function estimated of men and women sleep prevalence on daily minimum temperature variance.
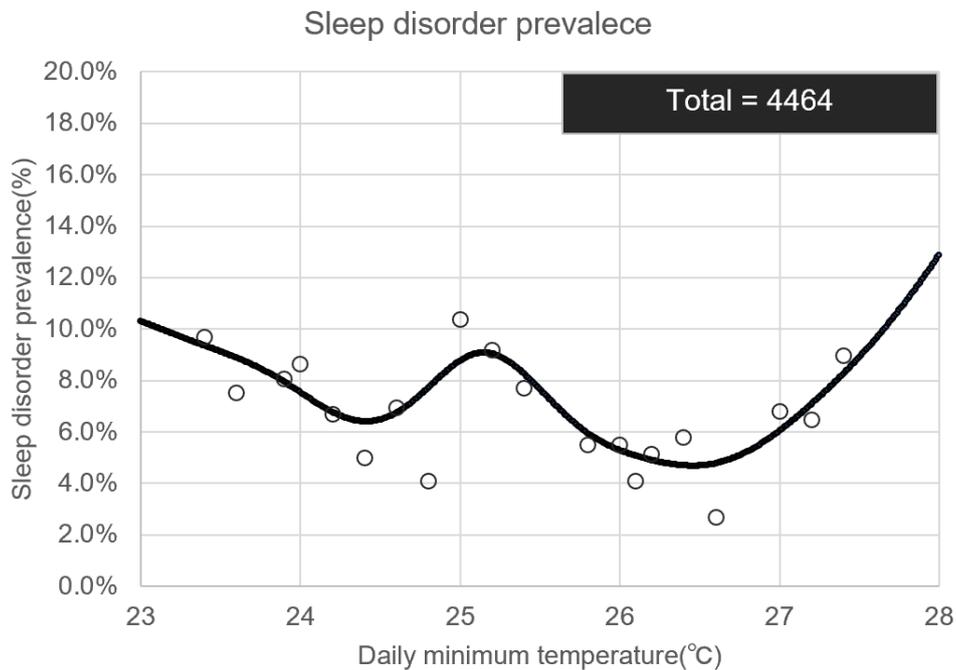

Figure 47 Smoothing spline of total subjects
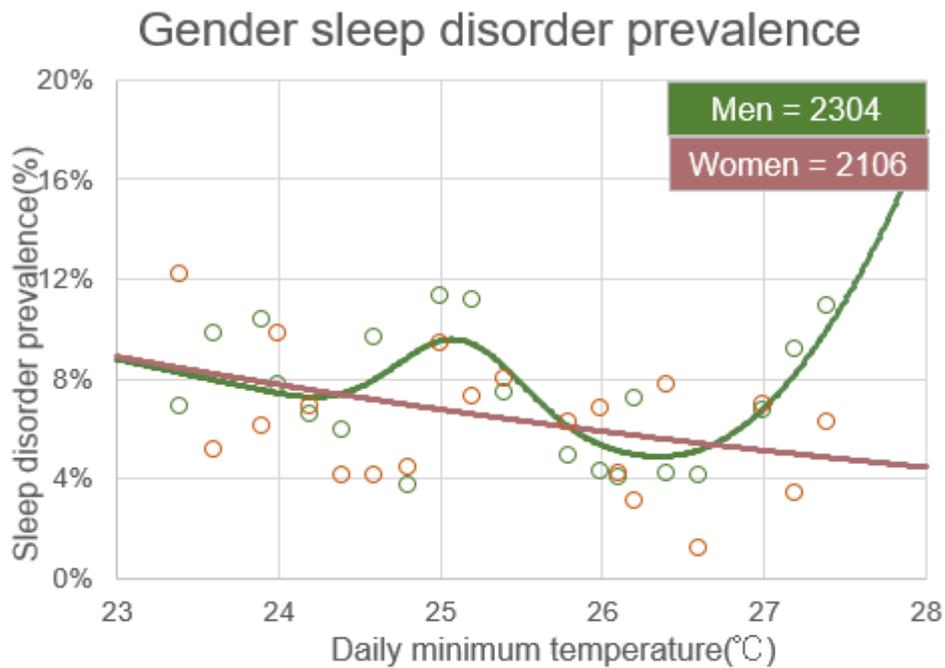
Figure 48 Smoothing spline of men and women

Table 20 Significant of smoothing terms

S(temp)	edf	chi.sq	p-value	UBRE
total	5.32	17.4	0.01	-0.49
men	4.29	10.68	0.07	-0.47
women	1	2.97	0.08	-0.52

4.4.4 The relationship between PSQI and SQIDS

Comparing SQIDS and PSQI results, SQIDS prevalence may underestimate the percentage of suffers referring to PSQI results, in total there was 5.8% of men and 5.2% of women who suffering from sleep disturbance. The average of daily sleep disturbance suffers that took 44.4% of PSQI results, as PSQI is reliable and valid, SQIDS may possibly have chance to underestimate daily sleep disturbance prevalence. As PSQI has high level of validity and precision on in judging sleep disturbance, SQIDS may have possibly underestimated sleep disturbance prevalence. Therefore, men and women SQIDS sleep disturbance prevalence was revised by PSQI. SQIDS was conducted to assess the same periods as PSQI by utilizing temperature-sleep disturbance function.(February: period1 1/9~2/9, periods 2 1/23~2/23; October: period1 9/18~10/18, period2 10/1~11/1).

In total, SQIDS could assess 48.0% in total who suffering from sleep disturbance judged by PSQI.(Men: 53.5%; Women: 42.0%).

Table 21 Estimating Periods

	Period 1	Preiod 2
February	2016/1/9~2016/2/9	2016/1/23~2016/2/23
October	2016/9/18~2016/10/18	2016/10/1~2016/11/1
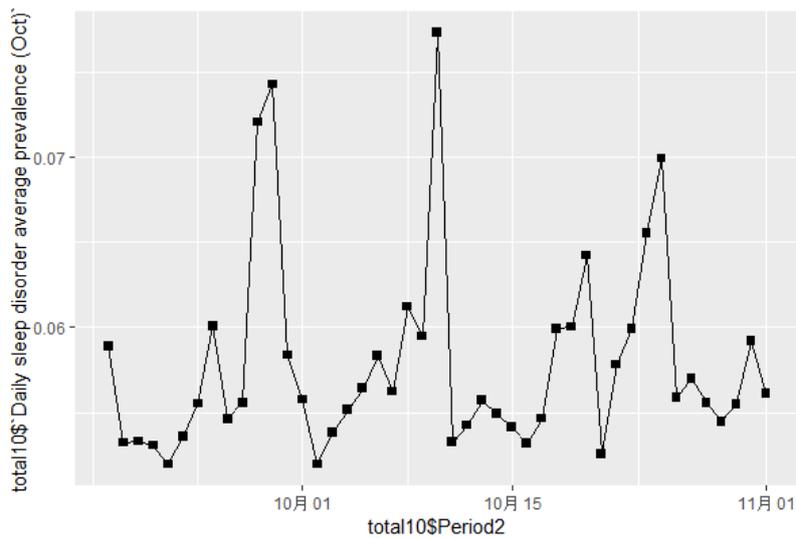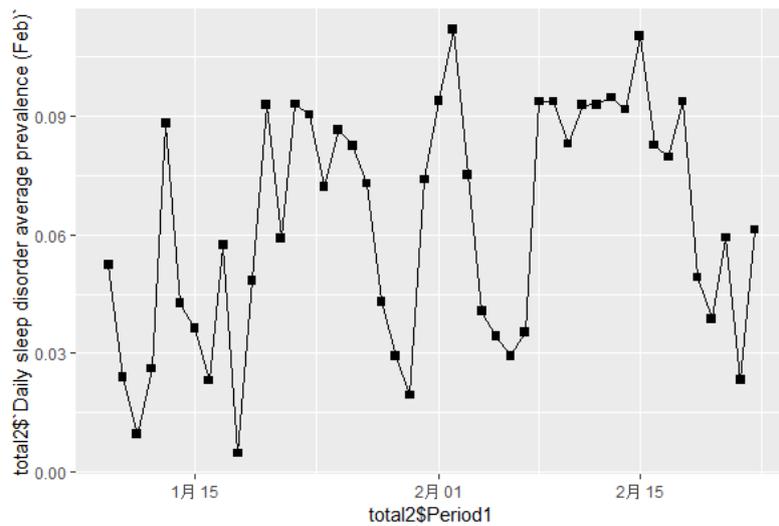
Figure 49 Estimated daily average sleep prevalence of total subject
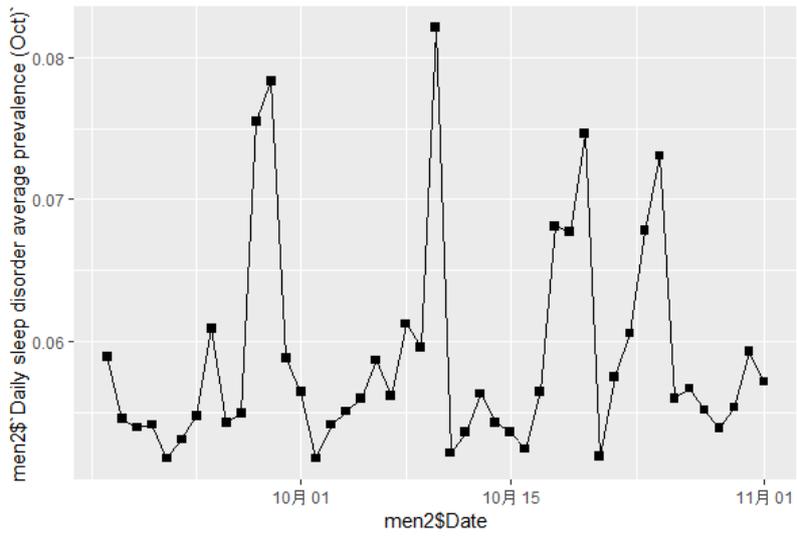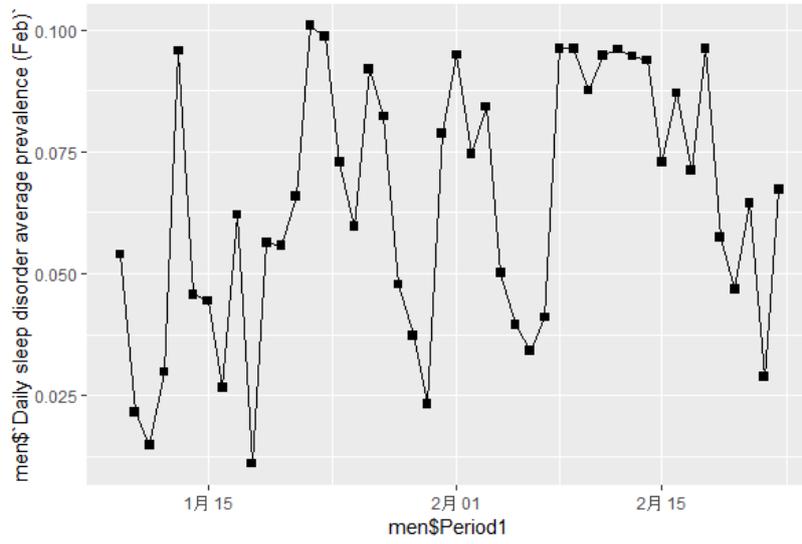
Figure 50 Estimated daily average sleep prevalence of men
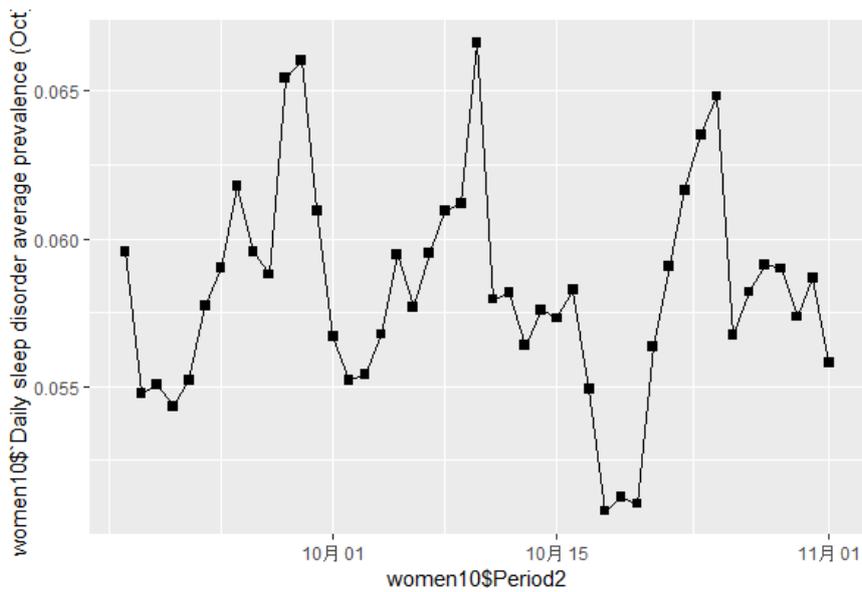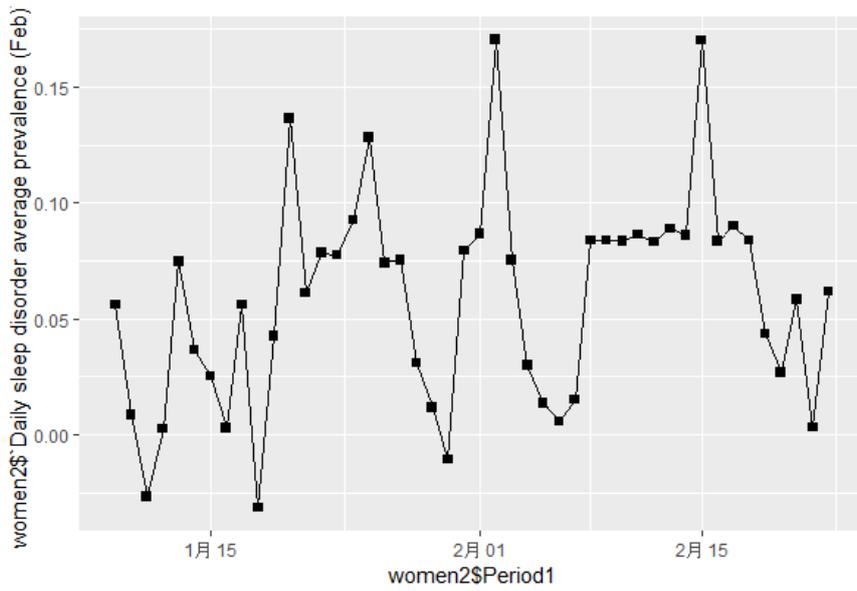
Figure 51 Estimated daily average sleep prevalence of women

Table 22 SQIDS and PSQI results estimating the same periods

		SQIDS	PSQI	SQIDS/PSQI	Average
Men	February	6.4%	13.9%	0.46	0.535
	October	5.9%	9.6%	0.61	
Women	February	5.9%	16.3%	0.36	0.420
	October	5.8%	12.0%	0.48	
Total	February	6.3%	15.1%	0.42	0.480
	October	5.8%	10.8%	0.54	

4.5 Countermeasure – air conditioning

It was widely recognized that sleep quality was generally impacted by mental and physical factors of sleeping objectives and the ambient environmental factors in bedroom. The sleep noise, lightening, and thermal environment have been considered as environment factors in sleep environment on the sleep quality. Previous study results have revealed that when the bedroom thermal environment diverge largely from a 'thermal comfort zone', sleep quality can be impacted or even deteriorated as soon as thermoregulatory responses were present[63]. Nowadays, it is essential to use air conditioner during sleep to maintain a thermally comfortable sleep environment. A study on the sleep thermal environment and the use of air conditioner in bedrooms in Hong Kong. It showed that more than 65% of the respondents would leave their air conditioner on throughout the sleep duration and the rest would use their air conditioners for certain hours during sleep[64].

To understand air conditioner effects on sleep quality of Jakarta residential, the air conditioner use was asked and data were evaluated by air conditioner / No air conditioner situations respectively.

4.5.1 Total Air conditioning utilization

In February, Jakarta residential mainly use electric fans (65%) and air conditioner cooling pattern (27%). In October, there were 78% using electric fans and air conditioner cooling pattern (14%) and air conditioner dehumidifying (2%). There was no survey about Jakarta residential air conditioner possession, so the residential staying schedule was checked, [Q9: Please chose the stay place today every time (office outside and moving, by a car or train, are included "outside"), AC means air conditioned]. By period of 11:45~12:00 PM, there was more than 98% objectives answering staying at home, in February there was 27% objectives using air conditioner and 15% in October. If we assuming it that home air conditioner use equals air conditioner possession, the air utilization almost equals air conditioner possession, suggesting that air conditioner owners all would like to use air conditioner as thermal countermeasure as sleep environment controlling.
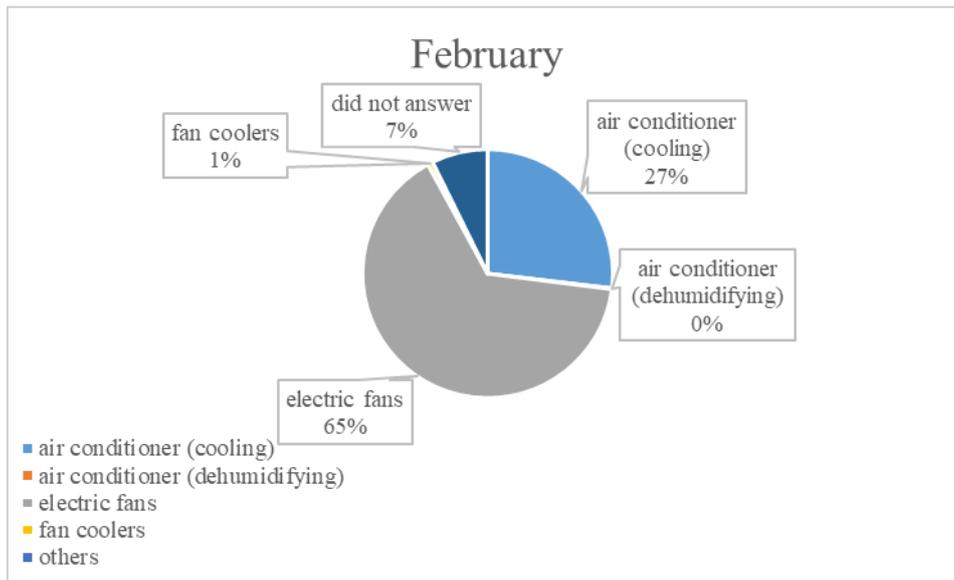
Figure 52 Thermal environment countermeasure in February
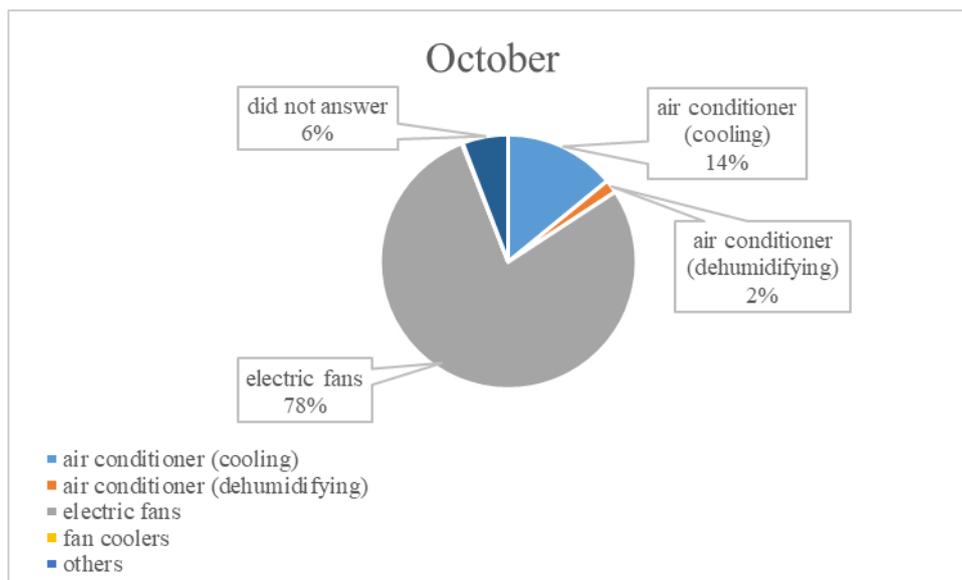
Figure 53 Thermal environment countermeasure in October

PM	Home		Office (in the building)		In the building excl. home & office		Outdoor	
	AC room	Non AC room	AC room	Non AC room	AC room	Non AC room	AC	Non AC
0:00								
0:30								
1:00								
1:30								
2:00								
2:30								
3:00								
3:30								
4:00								
4:30								
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8:00								
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9:00								
9:30								
10:00								
10:30								
11:00								
11:30								
12:00								

Figure 54 Question 9: Please chose the stay place today every time
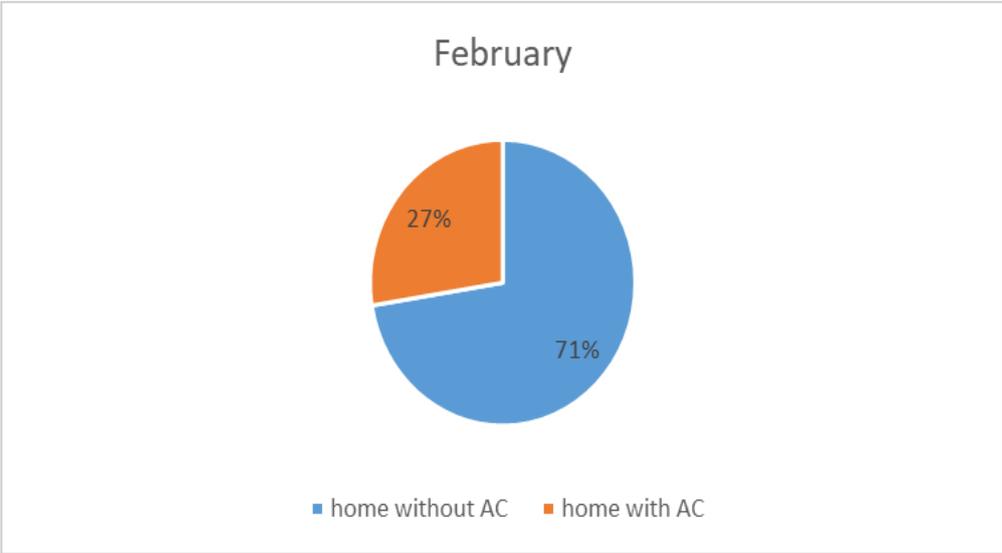
Figure 55 Air conditioner in bedroom in February
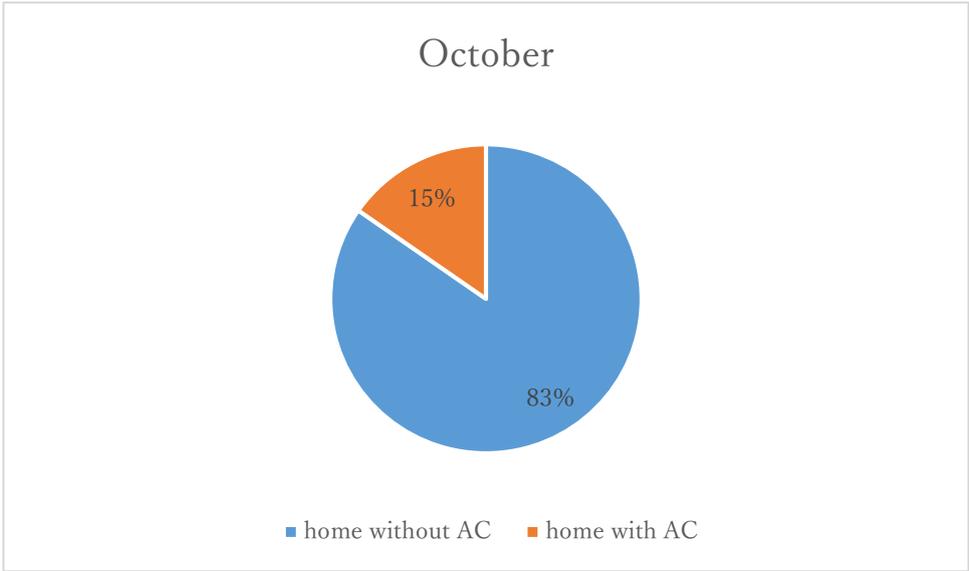
Figure 56 Air conditioner in bedroom in October

4.5.2 Gender differences on air conditioner use

In terms of gender and age differences on air conditioning utilization, there was 17.2% in men and 25.8% in women that using air conditioner. The elderly possessed the lowest air conditioning utilization percentage among age groups (men=10%, women=25.8%) suggesting that the elderly may be more sensitive to thermal temperature variation and low willingness to use air conditioner. There were previous studies that investigated the thermal comfort connecting with the indoor microclimate. Studies on Japanese population indicating that the elderly reported less discomfort to warmth in the cold season and to coldness in hot season than younger people when comparing the satisfaction of thermal comfort between the elderly and the younger subjects in a controlling air temperature[65]. R.L. Hwang and C.P. Chen(2010)[66] found a temperature range corresponding to 80% thermal acceptability were found to be 23.2–27.1°C in the summer and 20.5–25.9°C in the winter of the elderly as a rang interval described by Cheng et al (2008)[67], 23.0–28.6°C, of the non-elderly in summer. Demonstrating that the elderly reacting to thermal comfort is distinct to the young people did even though be in the same indoor ambient environment, it is possible that the elderly and the young people selection of thermal countermeasures also vary differently.
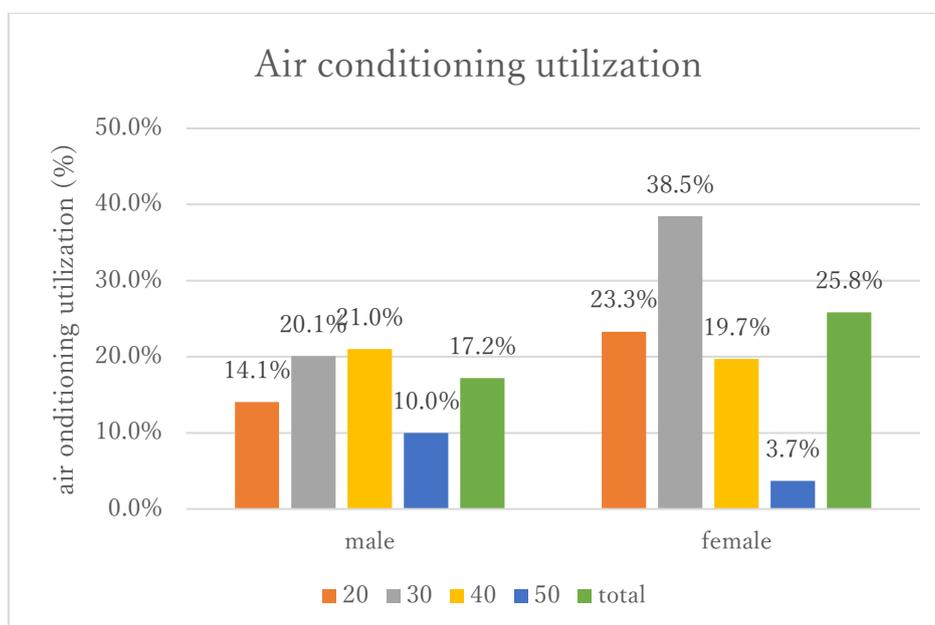
Figure 57 Air conditioner gender utilization

In all, there was 5.6% sleep disturbance suffers of air conditioning utilizers and no 7.4% air conditioning utilizers. However, it could not drop conclusion that the air conditioner utilizer may got lower sleep disturbance prevalence than no air conditioning sleep utilizers when referring to the controversial results of sleep disturbance prevalence of men and women air conditioning utilizers. K. Tsuzuki et al (2008)[69] studied the male subjects wearing short pajamas slept on a bed covered with a cotton blanket in various air conditioning environments. Giving a result that when sleeping in an ambient environment having a suitable air velocity inside, it would be helpful to reduce wakefulness duration by protecting from the skin and rectal temperatures decreasing and the body mass loss under a warm and humid sleep condition.
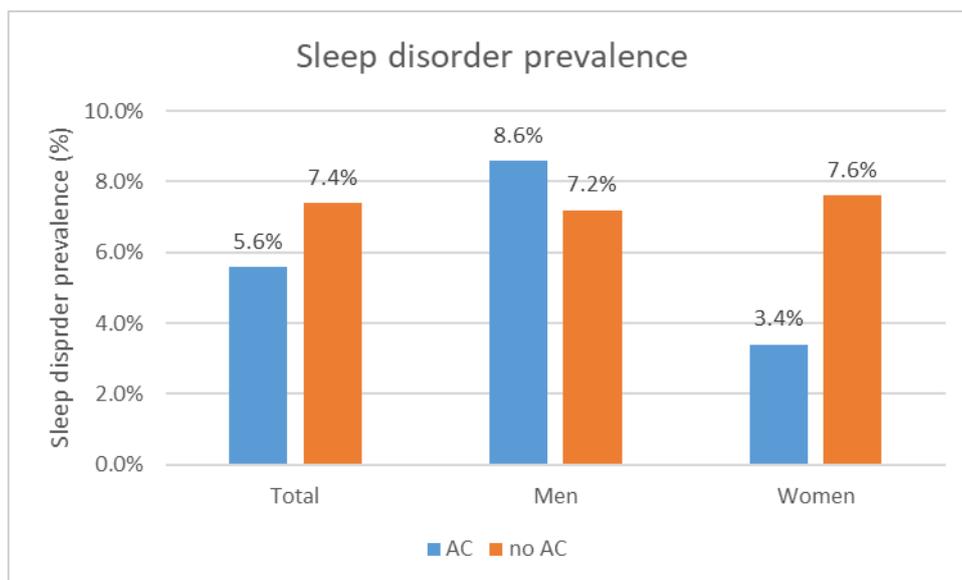
Figure 58 Sleep disturbance prevalence in AC/No AC bedroom

In terms of gender and age impact, the young men (20s, 30s) who used air conditioning got higher prevalence than who did not, which was opposite to the elder men (40s, 50s), there was no statistical differences between age group of men (df = 3, P= 0.39). Women who did no use air conditioning while sleeping got higher sleep disturbance prevalence than who did, indicating that air conditioner may effect on women rather than men. Women of 30s' who did not use air conditioning got the highest prevalence (9.5%) and 50s' got the lowest 0%. However, 50s' sample were limited (n=9), it may be very possible that women air conditioning utilizer who suffered from sleep disturbance were not included in survey. There were no significant differences between age groups of women (df = 3, P= 0.39).
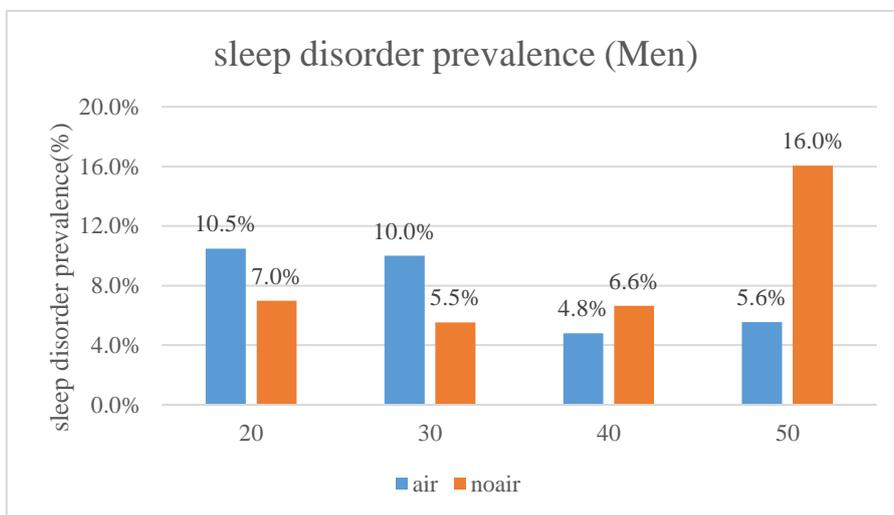
Figure 59 Sleep disturbance prevalence in AC/No AC bedroom of Men
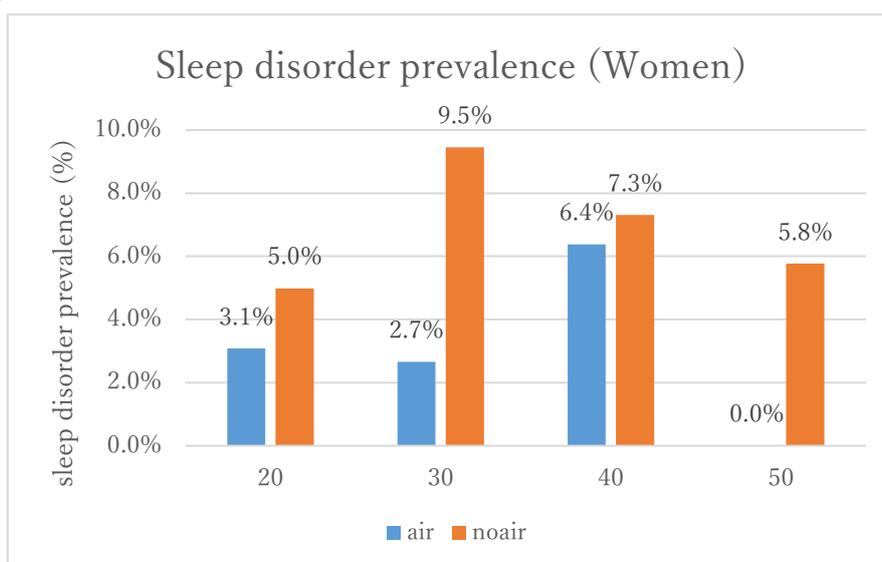
Figure 60 Sleep disturbance prevalence in AC/No AC bedroom of Women

4.5.3 Air effects on sleep disturbance prevalence

In terms of air conditioning utilization on sleep disturbance prevalence, data was divided by air conditioning/No air conditioning ($N_{air\ conditioning}$ =954, $N_{no\ air\ conditioning}$ =3510), as is showed in Figure , people who use air conditioner was predicted to get lower sleep disturbance prevalence than people who did not. Disparity performed in lower temperature threshold (23~24℃) and higher temperature threshold (27℃), indicating that air conditioning may effect in lower and higher temperature on sleep quality. Total no air conditioner group smoothing term was significantly calculated indicating that people who did not use air conditioner was affected by temperature(P=0.04). After 26℃ there was apparent increase of sleep disturbance prevalence, explaining that the sleep quality deteriorate with temperature rising higher, when people who use air conditioner would not be impacted by outdoor temperature, supporting the opinion that air conditioner may effect on indoor temperature that protecting people sleep quality from high temperature.
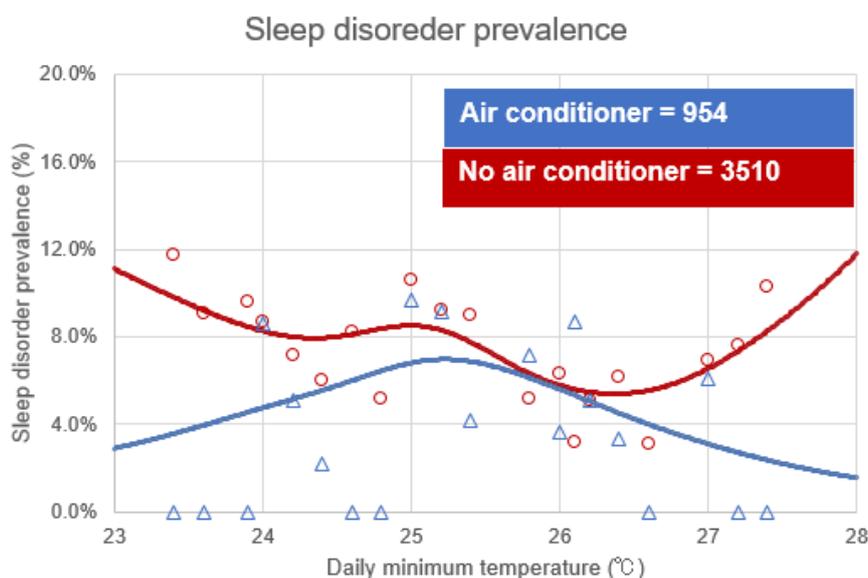
Figure 61 Air conditioner effect on sleep disturbance

Men who used air conditioning were predicted to have decreasing on sleep disturbance with daily minimum temperature when no air conditioning group would not have much variation accompanying with temperature rising. Men Air conditioning group prevalence was almost 8%. In women, the performance was opposite with men. Women who used air conditioner got better sleep quality than women who did not use. Sleep prevalence of air conditioner group would increase with daily temperature rising, while it decreased with temperature rising of no air conditioner group. Among these models, smoothing terms were not significantly estimated excluding women no air conditioner group(P=0.03), suggesting that women who did not use air conditioner was affected by daily temperature, and women sleep quality who use air conditioner was not statistically related to daily minimum temperature, suggesting that women who use air conditioner may possibly would not be affected by daily outdoor temperature.
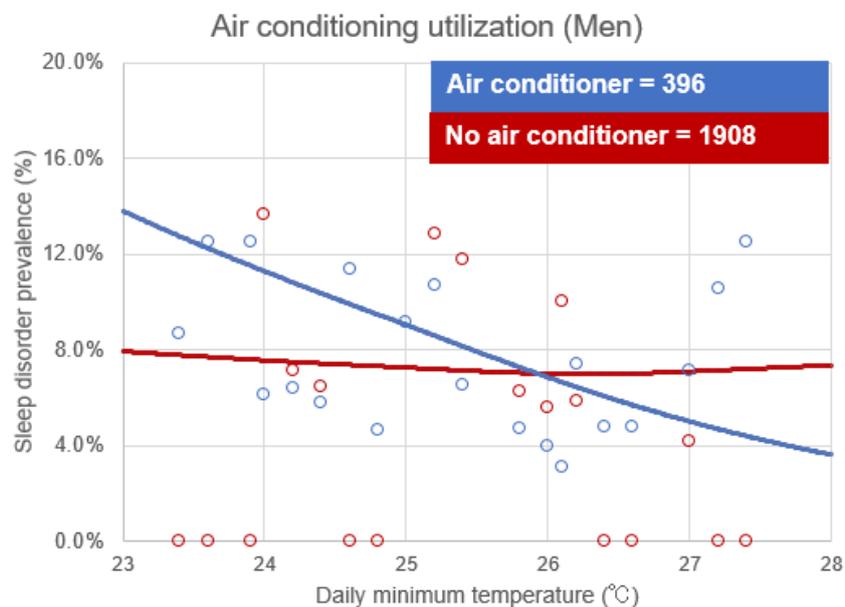
Figure 62 Air conditioner effect on sleep disturbance of Men
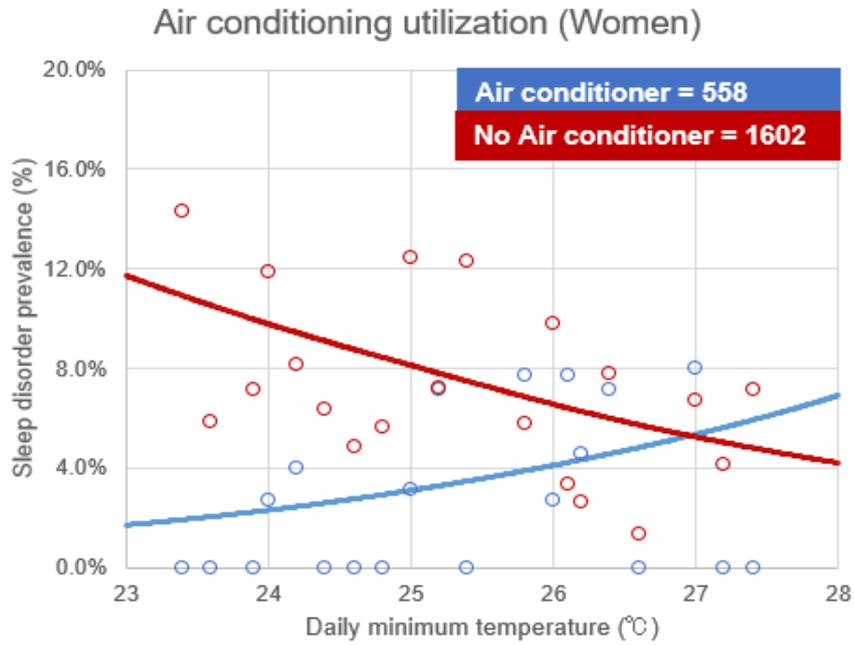
Figure 63 Air conditioner effect on sleep disturbance of Women

Table 23 Significant of smoothing terms

S(temp)	edf	chi.sq	p-value	UBRE
total-air conditioner	2.17	3.71	0.25	-0.57
total- no air conditioner	3.47	10.41	0.04	-0.47
men-air conditioner	1.05	2.75	0.14	-0.41
men- no air conditioner	1.22	0.24	0.83	-0.48
women- air conditioner	1.03	1.33	0.25	-0.7
women- no air air conditioner	1.2	6.4	0.03	-0.46

In regard to residential, it may be possible that there were some people that using air conditioner continuously and had get used to air conditioner, resulting that air conditioner may not effect on those, also those that did not use air conditioner may get use to high temperature that sleep quality would withstand temperature variation. To enlarge the influence of air conditioner on subjective, those who using air conditioner continuously and who do not use air conditioner during survey periods were excluded, and remaining data were estimated to general additive models again. Results were showing in figure 61 and figure 62. Men and women sleep qualities were predicted to have converse performance on air conditioner use. Men and women models smoothing terms were not significant, indicating that men and women sleep disturbance prevalence had no statistical correlation with daily temperature variation on air conditioner use. This may also because subjective data were limited that models could not developed precisely. Smoothing terms were showed in Table 24.
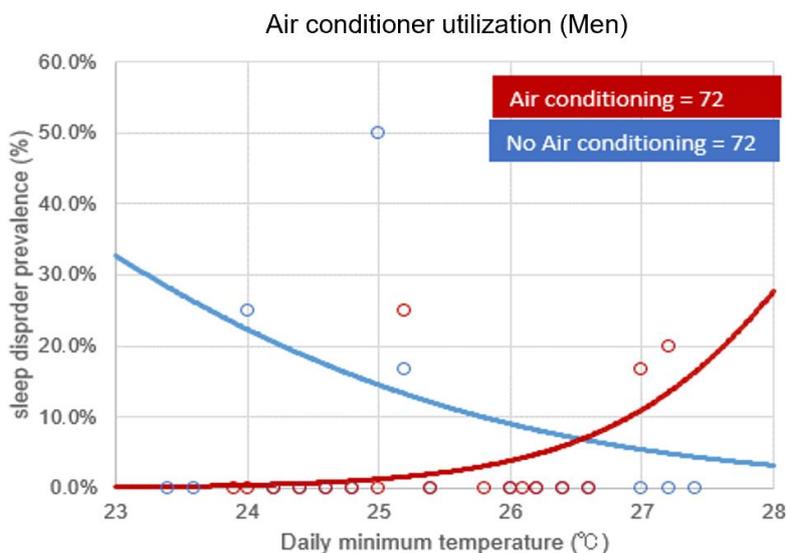
Figure 64 Air conditioner effect on sleep disturbance of Men

Air conditioner use (Women)
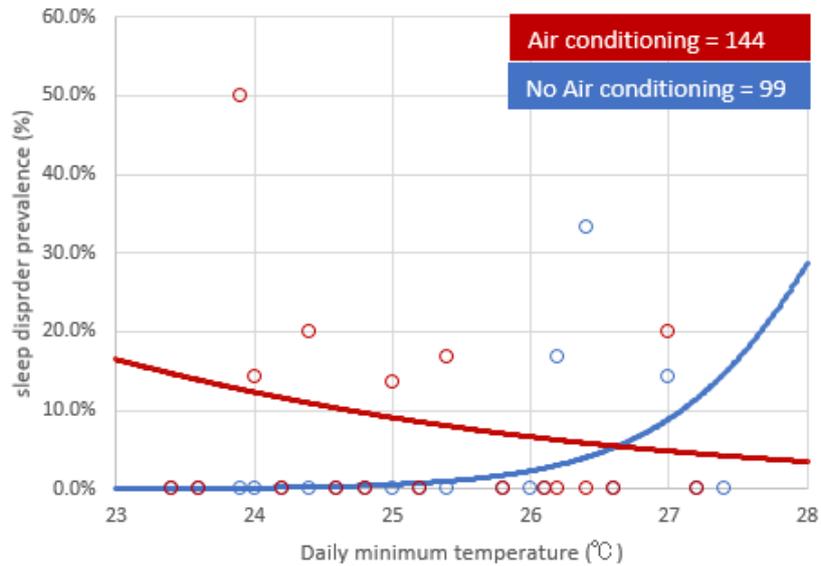
Figure 65 Air conditioner effect on sleep disturbance of Women

Table 24 Significant of smoothing terms

S(temp)	edf	chi.sq	p-value	UBRE
men-air conditioner	1.01	2.21	0.14	-0.23
men- no air conditioner	1.00	1.92	0.17	-0.63
women- air conditioner	1.00	3.73	0.06	-0.80
women- no air air conditioner	1.01	0.72	0.397	-0.36

4.6 Age effect on sleep quality

Besides gender differences on sleep quality, age is another foremost factor that effect sleep mechanism. In previous study, slow-wave sleep has significantly negatively correlated with age in children and adolescents. REM sleep, slow-wave sleep, and REM latency significantly decreased with age in adults, when sleep efficiency decreases in the elderly[69]. Adding age effect into consideration, results were showed below. Models were compared by AIC. In total, sleep disturbance prevalence was significantly possibly correlated with age (P=0.02), and it was significant related to temperature as well (P=0.01), while it showed no linear correlation. Sleep quality deteriorated with aging, suggesting that the elderly sleep was worse than the young. Daily minimum temperature had not significant correlation with sleep disturbance prevalence. It may because that sleep quality may be affected by indoor temperature instead of outdoor temperature.
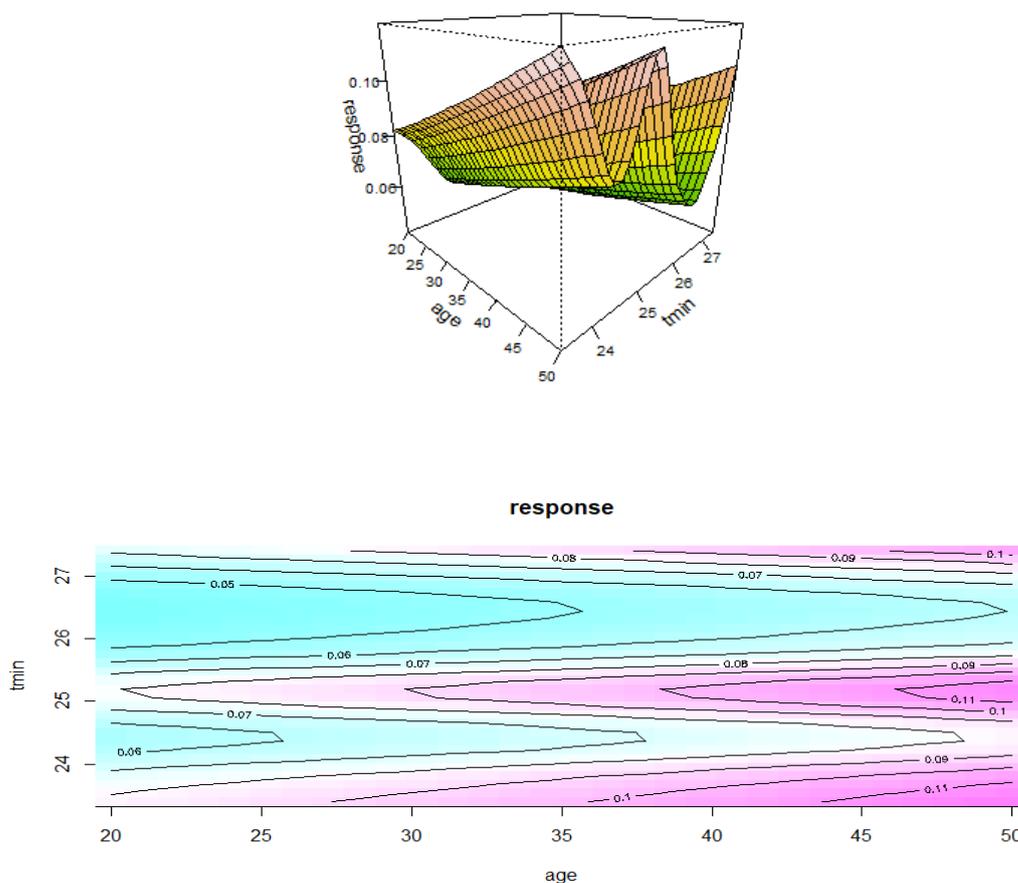
Figure 66 Age and daily minimum temperature effect on sleep disturbance

In terms of gender comparison, air conditioner/No air conditioner models were developed. In terms of men sleep quality, those who did not use air conditioner sleep disturbance prevalence had significantly possible relationship with age (P=0.01), suggesting that men sleep quality was impacted by age rather than temperature. In no air conditioner situation, the elder men would get worse sleep quality than the young, it may because that the elderly body weakness such as muscle and bone loss which would impact body thermal regulation resisting to ambient thermal environment variation. Women who used air conditioner their sleep quality had no connection with age and temperature. Those who did not use air conditioner their sleep quality were impacted by temperature rather than age, indicating that women all were weak to ambient thermal environment, and with temperature rising sleep quality deteriorated. Comparing women with air conditioner, it may be concluded that air conditioner is effective on women than men. Model's precise were compared by AIC (Table 25).
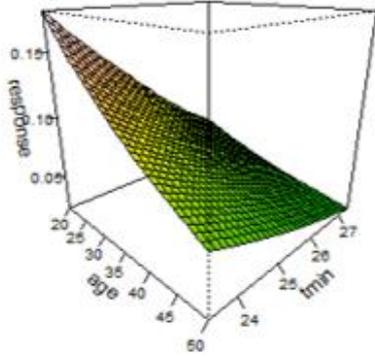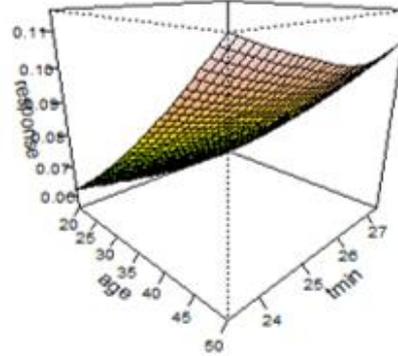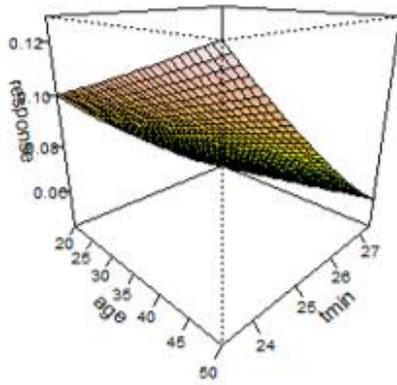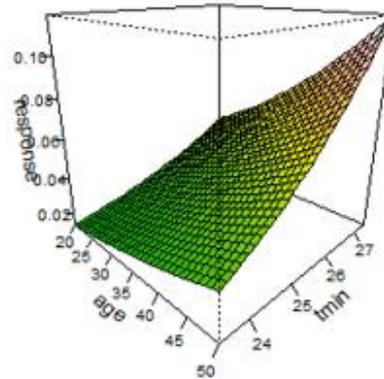
Figure 67 Age and daily minimum temperature effect on sleep disturbance

Table 25 Significant of smoothing terms

	S(temp)				Age		
	edf	chi.sq	P-value	UBRE	estimate	z	P-value
total	5.43	17.7	0.01	-0.50	0.01	2.3	0.02
men-air conditioner	1.05	3.28	0.11	-0.41	-0.04	-1.67	0.09
men- no air conditioner	1.22	0.25	0.83	-0.48	0.02	2.55	0.01
women- air conditioner	1.03	1.53	0.22	-0.7	0.03	1.06	0.29
women- no air conditioner	1.2	6.61	0.02	-0.46	0.01	1.03	0.3

Table 26 AIC of smoothing spline models

Smoothing spline	AIC
total ~ s(tmin)	2258.9
total ~ s(tmin) + age	2255.7
men air ~s(tmin)	232.9
men air ~s(tmin) + age	231.9
men noair ~s(tmin)	994.4
men noair ~s(tmin) + age	990
women air ~s(tmin)	168.4
women air ~s(tmin) + age	169.3
women noair ~s(tmin)	860.8
women noair ~s(tmin) + age	861.7

In all, men got higher sleep disturbance prevalence than women of Jakarta by accounting PSQI and SQIDS results. Total sleep disturbance prevalence showed statistical relationship between daily minimum temperature and sleep disturbance prevalence. Component scores had different performances, C1, C2, C5, C7 scores were predicted to increase with the daily minimum temperature rising. The majority of respondents had more than 80% sleep efficiency and did not take sleep medication so C4 Sleep efficiency and C6 Use of sleep medication had very small variation. C3 had decreased perform suggesting that sleeping time decreases with daily minimum temperature rising. Only C3 scores had significant connection with daily minimum temperature. Both men and women elderly had the lowest air conditioner use rate, indicating that the elderly was weak to air conditioner. In Jakarta subjects, the air conditioner utilizer had lower sleep disturbance prevalence than no air conditioner subjects suggest that the air conditioner may be effective on the temperature impact on sleep disturbance, while there was no consistent with men and women performance. Total no air conditioner group smoothing term was significantly calculated indicating that

people who did not use air conditioner was affected by temperature(P=0.04). After 26℃ there was apparent increase of sleep disturbance prevalence, explaining that the sleep quality deteriorate with temperature rising higher, when people who use air conditioner would not be impacted by outdoor temperature, supporting the opinion that air conditioner may effect on indoor temperature that protecting people sleep quality from high temperature. In terms of gender differences, smoothing terms were not significantly estimated excluding women without air conditioner group(P=0.03). This suggesting that women who did not use air conditioner was affected by daily temperature, and women sleep quality who use air conditioner was not statistically related to daily minimum temperature, suggesting that women who use air conditioner may possibly would not be affected by daily outdoor temperature, when male sleep quality was more impacted by age factors rather than temperature.

4.7 Sleep disturbance impact assessment
4.7.1 Assessment scenarios
To assess the impact of sleep disturbance, the disability-adjusted life years (DALY) were calculated under three scenarios below (Table 27). Current scenario 2006, Future scenario 2050(Air conditioner popularity rate 15%) and Future scenario that with increased air conditioner popularity rate 60% in 2050. The 2006 and 2050 temperature was simulated by CM-BEM simulation that estimating the temperature and building energy consumption in consideration of the artificial exhaust heat emitted from a building or an outdoor unit of air conditioner[57], which, can reproduced a situation close to an actual environment. Specific calculation conditions was approached by a climate scenario that encompasses a wide range of impacts (RCP8.5) combined with SSP-based socio-economic scenarios(SSP3) which context across multiple scales against which robustness of the human and natural systems within the deltas were tested.

Table 27 three scenarios

	Scenario A	Scenario B	Scenario C
Period	2006 Aug	2050 Aug	2050 Aug
Scenario Condition	Present	RCP8.5 + SSP3	RCP8.5 + SSP3
Air conditioner rate	15%	15%	60%
Monthly minimum temperature	25.81	27.29	27.34
Population	26,582,770	47,640,698	47,640,698
Male/Female	100.8/100	99.9/100	99.9/100

Scenario gender population

The population prospection was estimated by utilizing a result from Kanda laboratory, Tokyo Institute of Technology Kanda laboratory. Population of male and female was developed by sex ratio of total population in World Population Prospects 2019[58].
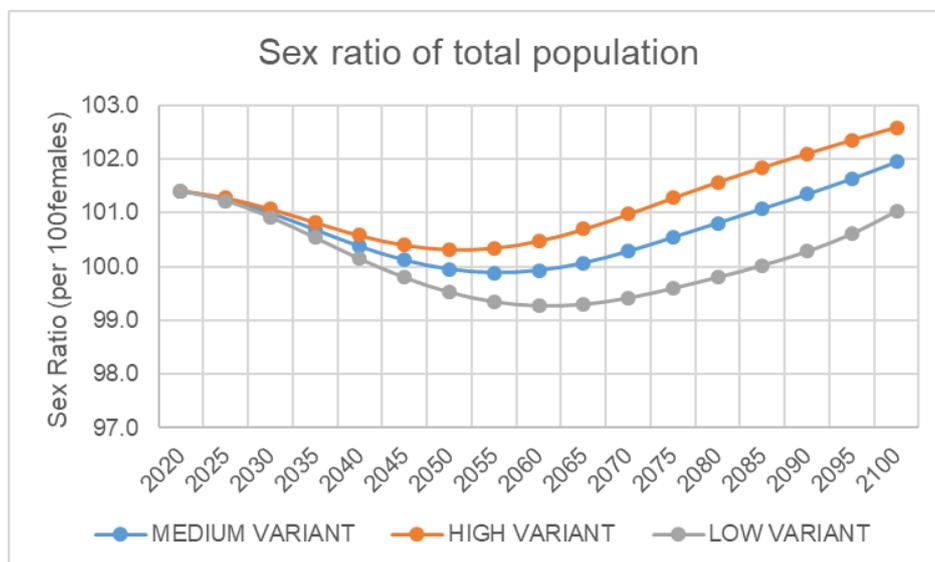
Figure 68 Sex ratio of total population of Jakarta

PSQI prevalence in 2006 and 2050 would be predicted by SQIDS respectively referring to Table 28.

Table 28 PSQI and SQIDS

		SQIDS	PSQI	SQIDS/PSQI	Average
Men	February	6.4%	13.9%	0.46	0.535
	October	5.9%	9.6%	0.61	
Women	February	5.9%	16.3%	0.36	0.420
	October	5.8%	12.0%	0.48	
Total	February	6.3%	15.1%	0.42	0.480
	October	5.8%	10.8%	0.54	

4.7.2 PSQI sleep disturbance impact assessment

In current scenario, there was 342.6×10^3DALY happened due to sleep disturbance, in which residential without air conditioner took the most part of DALY. In future scenario(2050), there was 109% increased comparing with 2006, in which residential increased as many as 372.4×10^3DALY. Thus 1℃ rising would bring about 251.6×10^3DALY impact in total Jakarta with 15% air conditioner popularity rate. When air conditioner popularity rate increased from 15% to 60%, there was 32.8%(234.3×10^3DALY) decreased, that is 1% air conditioner popularity rate increase brought about 5.21×10^3DALY reliving among Jakarta residential(2.44×10^{-4}DALY per person per month).
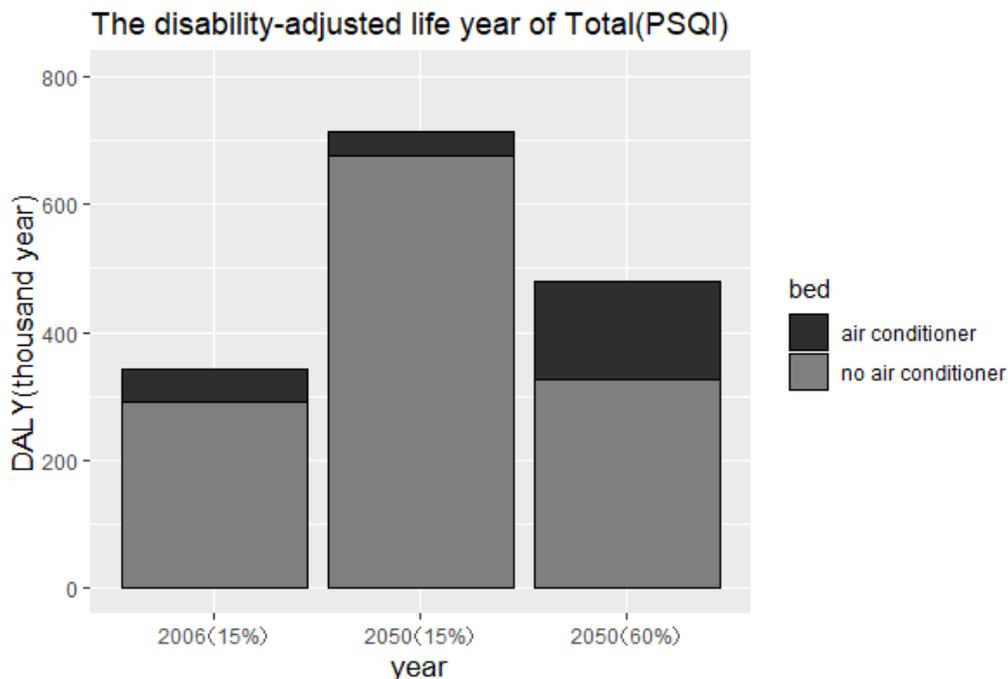
Figure 69 Total DALY of Sleep Disturbance

Table 29 the DALY of total residential

DALY of Total Residents[10^3 years]

Condition	Air conditioner	No air conditioner	Total DALY	Comparison
2006 (15%)	50.7	291.9	342.6	-
2050 (15%)	38.7	676.3	715	+109%

DALY of Total Residents[10^3 years]

Condition	Air conditioner	No air conditioner	Total DALY	Comparison
2050 (15%)	38.7	676.3	715	-
2050 (60%)	154.8	325.9	480.7	-32.8%

In men of Jakarta, In current scenario, there was 179.3×10^3DALY happened due to sleep disturbance, in which residential without air conditioner took the most part of DALY. In future scenario, there was 23.9%(42.9×10^3DALY) increased comparing with 2006, that is 1℃ rising would bring about 29.0×10^3DALY impact in male residential of Jakarta with 15% air conditioner popularity rate. When air conditioner popularity rate increased from 15% to 60%, there was 22.8%(50.6×10^3DALY) increased, that is 1% popularity rate increase brought about 1.12×10^3DALY increasing among male Jakarta residential(1.05×10^{-4}DALY per person per month).
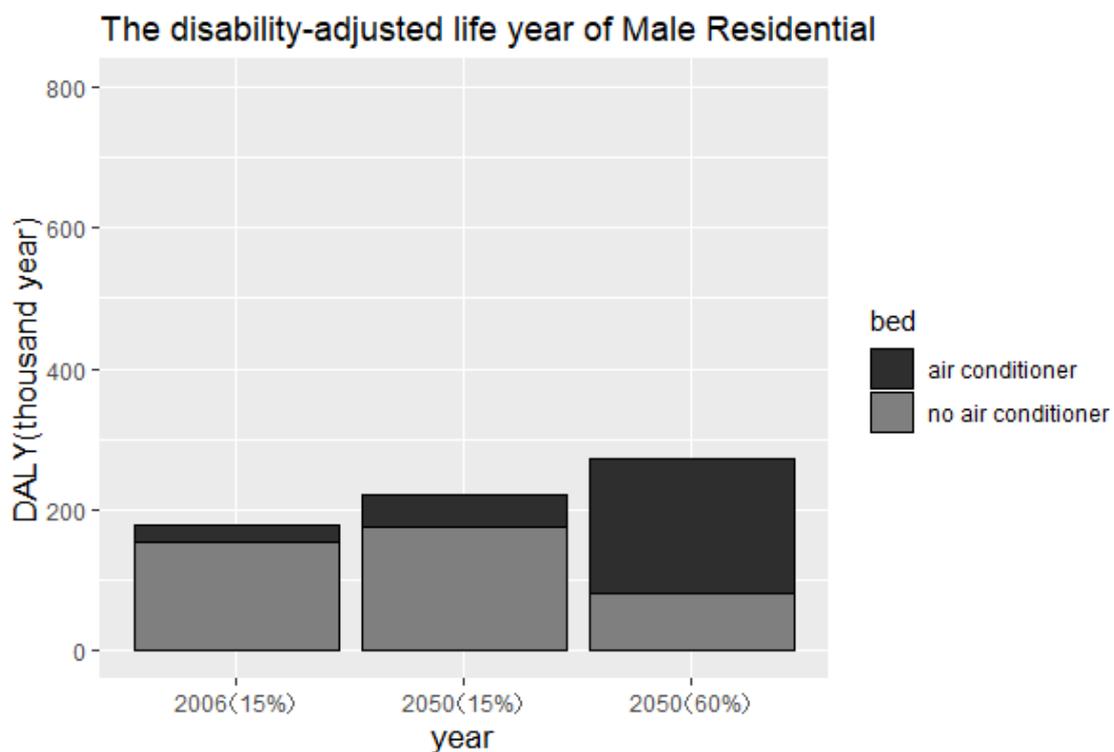
Figure 70 Male DALY of Sleep disturbance

Table 30 the DALY of male residential

Condition	Air conditioner	No air conditioner	Total DALY	Comparison
2006 (15%)	26.2	153.1	179.3	-
2050 (15%)	48.2	17	222.2	+23.9%

Condition	Air conditioner	No air conditioner	Total DALY	Comparison
2050 (15%)	48.2	17	222.2	-
2050 (60%)	192.8	80	272.8	+22.80%

In women of Jakarta, In current scenario, there was 203 $\times$ 10^3DALY happened due to sleep disturbance, in which residential without air conditioner took the most part of DALY. In future scenario, there was 41%(83.3 $\times$ 10^3DALY) increased comparing with 2006, that is 1℃ rising would bring about 56.3 $\times$ 10^3DALY impact in male residential of Jakarta with 15% air conditioner popularity rate. When air conditioner popularity rate increased from 15% to 60%, there was 25.4 $\times$ 10^3DALY increased, that is 1% popularity rate increase brought about 0.56 $\times$ 10^3DALY increasing among male Jakarta residential(5.22$\times$ 10^{-5}DALY per person per month).
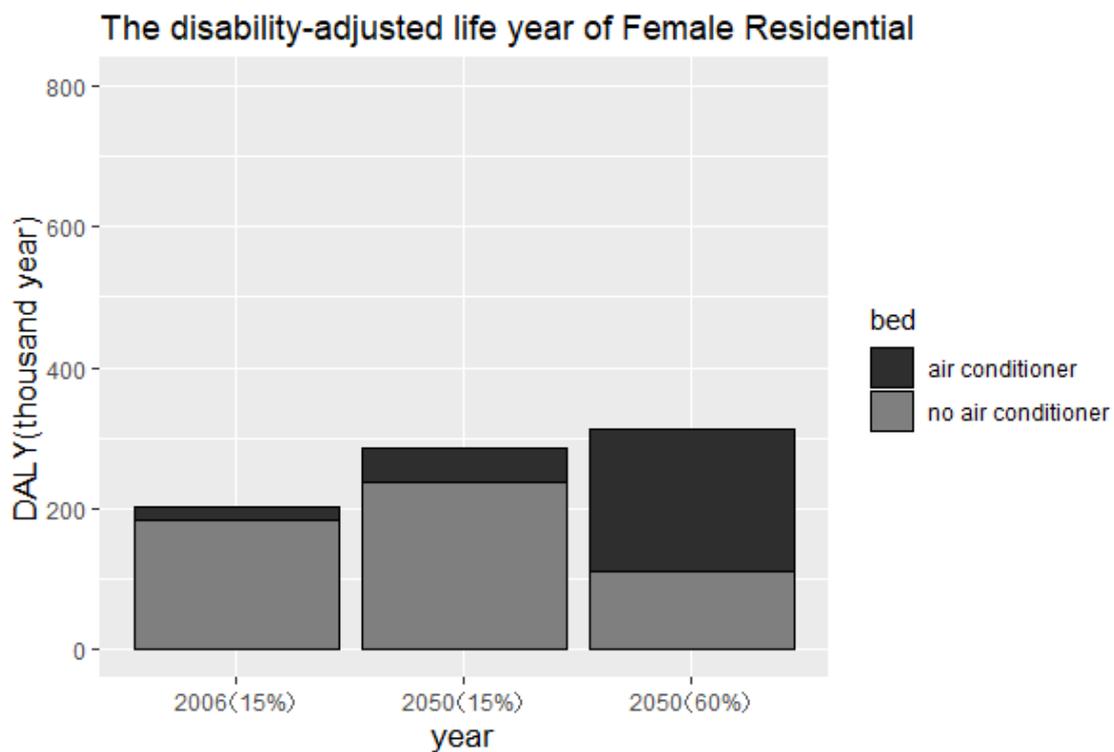
Figure 71 Female DALY of PSQI

Table 31 the DALY of female residential

Condition	Air conditioner	No air conditioner	Total DALY	Comparison
2006 (15%)	18.5	184.5	203	-
2050 (15%)	49.3	237	286.3	+41.0%

Condition	Air conditioner	No air conditioner	Total DALY	Comparison
2050 (15%)	49.3	237	286.3	-
2050 (60%)	200.2	111.5	311.7	+8.9%

Both men and women got increase DALY when air conditioner popularity rate increased. Men's DALY was predicted by the function between daily minimum temperature and sleep disturbance prevalence that was not statistically significant may possibly leading to an inadequate DALY. On the other hand, women got significant smoothing spline, and the prevalence of air conditioner utilizer was higher than that of those who did not use air conditioner after 27 ℃, this may because women are weak to air conditioner and air conditioner may bring about negative effect for sleep quality of women.

5　Conclusion

5.1　There was 12.9% sleep disturbance morbidity for one month sleep and 7% sleep disturbance sleep prevalence for everyday sleep in Jakarta. SQIDS valued 0.535 of the PSQI sleep disturbance.

5.2　Jakarta men got worse sleep quality than Jakarta women. There was gender differences on sleep duration that women sleep longer than men, which may be a reason for better sleep quality. Sleep duration had negative connection with bedtime of men and women, while other developed countries got longer sleep duration at the same sleep time. This may have connection with regional sunshine duration that effecting sleep duration a lot.

5.3　C3 sleep duration, total scores and sleep disturbance had gender differences in monthly sleep quality.

5.4　Daily minimum temperature was effective on sleep disturbance prevalence (P=0.01) when it showed no simple linear relationship.

5.5　In whole, respondents who using air conditioner got lower sleep prevalence than those who did not use air conditioner. No air conditioner in total and women can be predicted by temperature variation effectively, while male sleep in Jakarta would not.

5.6　Men and women got contrary performances on the relationship between sleep disturbance and daily minimum temperature. Men sleep quality deteriorated with daily minimum temperature while women sleep got better.

5.7　In air conditioner use, men did not get significant function. Women who use air conditioner sleep quality will deteriorate suggesting that women may be weak to air conditioner.

5.8　The elderly had lowest air conditioner use rate that may because of the elderly weakness of air conditioner.

5.9　Male sleep quality affected more by age instead of air temperature, while women was conversed.

5.10　In total, 2050 DALY had 109% increased comparing with 2016, when air conditioner popularity rate increased from 15% to 60%, there was 32.8% DALY decreased.

5.11　In men, there was 23.9%(42.9 × 103DALY) increased comparing with 2006 in male residential of Jakarta with 15% air conditioner popularity rate. When air conditioner popularity rate increased from 15% to 60%, there was 22.8%(50.6 × 103DALY) increased.

5.12   In women, there was 41%(83.3 × 103DALY) increased comparing with 2006 in female residential of Jakarta with 15% air conditioner popularity rate. when air conditioner popularity rate increased from 15% to 60%, there was 8.9%(25.4 × 103DALY) increased among female Jakarta residential.

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7 Acknowledgements

I would like to express my deepest gratitude first and foremost to my supervisor, Associate Professor Ihara, who has walked me through the whole stage of my thesis writing and has offered me valuable suggestions in my academic studies. The thesis would not have been completed without his patient instruction and expert guidance.

Secondly, I would like to thank to my sub-supervisor Professor Oshima. He provides me excellent guidance and a great idea of my thesis that has complete my thesis inadequate.

I also would like to owe gratitude to all members of my laboratory and my friends, who also help me a lot in my study and daily life in Japan, which making me a great time for studying in Japan.

I would finally like to express my gratitude to my beloved parents who have always been supporting my decision without a word of complaint and helping me to walk through difficulties.