

Evaluation for Fatigue and Accident Risk of Korean Commercial Bus Drivers

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Many Korean bus drivers work long hours, which causes fatigue and increased risk of accidents during driving. Their fatigue due to long working hours may cause a significant accident accompanied by injuries of the general population. The present study aimed to evaluate the fatigue and accident risk in Korean commercial bus drivers. The subjects were 16 city and express bus drivers with various work schedules: 2 shifts (2 shifts in a day), WR (duty-off), W2R (duty-duty-off), and W4R2 (duty-duty-duty-duty-off-off). We measured the subjects' heart rate in their workplace during their work and calculated relative heart rate (RHR) and maximum acceptable work time (MAWT), the maximum amount of time for which workers can sustain their workload without physical fatigue. Fatigue and risk index, which is a tool for assessing the risk from fatigue in the safety critical workers, was calculated using the subjects' work schedule. RHR ranged from 9.7 to 21.8% and MAWT was shorter than each subject's actual work hours. Fatigue (45.2-54.4) and risk indices (1.8) were high in WR schedule, which were higher than recommended value (30-35 for fatigue index and < 1.6 for risk index). According to these findings, Korean bus drivers worked long hours beyond their physical abilities, and the fatigue and risk indices were high, especially in WR schedule. It is necessary to prepare the policies to reduce the fatigue and accident risk in the Korean bus drivers including regulation for bus drivers' driving time restriction.

Keywords: bus; drivers; driving time; fatigue; working hours

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Introduction

Long working hours are considerable problem in the workplace that could have a negative impact on workers' health. The health conditions associated with long working hours include obesity (Jang et al. 2014; Kim et al. 2016), cardiovascular diseases (Holtermann et al. 2010; Kivimäki et al. 2011; Virtanen et al. 2012), sleep disturbances (Virtanen et al. 2009; Amagasa and Nakayama 2013; Kim and Lee 2015), mental illnesses such as depression and anxiety (Virtanen et al. 2011; Bannai and Tamakoshi 2014), and occupational injuries (Nakata 2011; Caruso 2014).

In 1979, International Labour Organization (ILO 1979) recommended the work conditions through the convention No.153: hours of work and rest periods (road transport) convention. According to this convention, the maximum total driving time, including overtime, shall exceed neither 9 hours per day nor 48 hours per week. Furthermore, no driver shall be allowed to drive continuously for more than 4 hours without a break, and drivers shall be entitled to a break after a continuous period of 5

hours of work. According to Korean Labor Standards Act (Korea Legislation Research Institute 2018), work hours shall not exceed 8 hours a day nor 40 hours a week. In addition, work hours may be extended up to 12 hours per week where there exists an agreement between employers and employees. Therefore, the legal work hours in Korean workers are 52 hours a week. Whereas, an employer of specific businesses may have workers in excess of 12 hours per week of extended work hours, if an employer has entered into any written agreement with the labor representative. The specific businesses mentioned above included transportation business. In other words, it was legally allowed for Korean commercial bus drivers to work long hours contrary to ILO convention No.153. Recently, bus drivers have been excluded from the specific businesses, but their working hours are still long.

Korean bus drivers' working hours are different according to the type of work. Some bus drivers work 8 hours a day, but others work up to 17 hours a day. Most bus drivers are complained of fatigue, poor concentration, sleep disturbances, gastrointestinal problems, and others.

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Commercial bus drivers are responsible for the safety of the public. So, their fatigue due to long working hours may cause a significant accident accompanied by injuries of the general population, as well as their health problems.

Work conditions such as long working hours (McCartt et al. 2000; Stutts et al. 2003), sleep deprivation (Leechawengwongs et al. 2006), and fatigue (Smith 2016) were reported to be associated with traffic accidents of drivers. Therefore, it is important to evaluate the fatigue and risk of accidents in commercial bus drivers to prevent the significant traffic accidents and ensure the safety of the public. This is also important for health management of bus drivers. The present study aimed to evaluate the fatigue and risk of accidents in Korean commercial bus drivers, and provide a basis for the policy for preventing commercial bus drivers' fatigue and ensure a safety of the public.

Methods

Subjects

There are many types of shift work in Korean bus drivers. Among them, most common 4 types are 2 shifts a day (2 shifts schedule), work every other day (WR schedule), 2 workdays followed by 1 resting day (W2R schedule), and 4 workdays followed by 2 resting days (W4R2 schedule). According to the statistics in 2017, the numbers of bus drivers engaged with 2 shifts, WR, and W2R or W4R2 schedule were 39,224 (46.9%), 23,320 (27.9%), and 21,168 (25.3%), respectively (Federation of National Bus Transport Business Associations 2017). For 2 shifts schedule, 2 drivers are responsible for whole day driving of a bus. In this schedule, one bus driver works from early morning to afternoon (e.g., 05:00 a.m. to 02:00 p.m.), and other driver works from afternoon to midnight (e.g., 02:00 p.m. to 01:00 a.m.). For WR schedule, one bus driver should be responsible for whole day driving of a bus. In this schedule, he (or she) works from early morning (about 05:00 a.m.) to midnight (about 12:00 or 01:00 a.m.). Thus, daily work hours are very long, which are 16 to 18 hours a day. For W2R and W4R2 schedule, one bus driver should be responsible for whole day driving of a bus. He (or she) works 2 consecutive days and rests next one day (W2R schedule) or works 4 consecutive days and rests next two days (W4R2 schedule). Work hours in W2R and W4R2 schedules are very long, which are 14 to 17 hours a day.

There are several bus types including city bus, regional bus, and express bus. City bus circulates inside a city, and regional bus circulates between a city and nearby satellite cities. Express bus travels cities of long distances, and intercity bus travels between a city and rural areas with long distance. City bus and regional bus drivers operate their bus routes from 4 times to 8 times a day. Bus drivers have about 10 to 30 minutes between each bus driving. They should perform tasks such as a simple bus cleaning and maintenance and rest in the spare time. If they do not have enough time, they should start next bus driving without resting.

We visited the bus company to explain the purpose of the study to the bus drivers, and selected bus drivers who agreed to participate in the study. Subjects with a history of heart disease or cerebrovascular disease were excluded. The subjects included 2 city bus drivers engaged with 2 shifts schedule, 4 city bus and 4 regional bus drivers engaged with WR schedule, 4 express bus drivers engaged with W2R schedule, and 2 intercity bus drivers engaged with W4R2

schedule. All subjects were men aged from 43 to 61. The present study was approved by the Institutional Review Board of Catholic University of Korea, Seoul St. Mary's Hospital (approval ID: KC15OISI0398). Informed consents were obtained from all study subjects.

Methods

We interviewed the subjects to get information including their demographic characteristics, work duration, daily working hours, and monthly working days. And we measured ambulatory heart rate with ActiGraph (wGT3X-BT, Shalimar, FL, USA) and H7 heart rate sensor (Polar®, Kempele, Finland). Heart rate was measured continuously for 48 hours including resting day and workday. Subjects were asked to avoid drinking and intensive exercise during the measurement. We interviewed them to obtain the information for their work schedule, work hours, rest breaks, and so on.

We calculated actual work hours using the interview data. The average heart rate was calculated during work, and maximal heart rate was estimated as following equation suggested by Tanaka et al. (2001):

$$\text{Maximal heart rate} = 208 - 0.7 \times \text{Age}.$$

$$\text{Relative heart rate (RHR)} \text{ was calculated as following equation:}$$

$$\text{RHR} = (\text{HR}_{\text{work}} - \text{HR}_{\text{rest}}) / (\text{HR}_{\text{max}} - \text{HR}_{\text{rest}}) \times 100 (\%),$$

where HR_{work} was average heart rate during work, HR_{rest} was resting heart rate, and HR_{max} was maximal heart rate. Maximum acceptable work time (MAWT), which means the maximum amount of time for which workers can sustain their workload and work hours without physical fatigue was estimated using a formula suggested by Wu and Wang (2002). We defined overwork index, which was the ratio of actual work hours and MAWT. Overwork index greater than 1.0 means the subjects worked beyond their physical ability.

Fatigue and risk index is a tool for assessing the risk arising from fatigue associated with work patterns for safety critical workers, which was developed by Health & Safety Executive in 2006 (HSE, Health & Safety Executive 2006). Greubel et al. (2010) reported that they did not find the sufficient evidence for a mandatory use of the fatigue and risk index, but it might be beneficial in designing work schedule. Fatigue and risk index includes six factors associated with fatigue: the length of the shift, the interval between shifts, the number of rest days, the quality of the rest breaks, the variability of the shifts, and the time of day. Fatigue index means the average probability of being sleepy on duty, which takes a value between 0 and 100. Higher fatigue index means the worker would have high possibility of sleepy on duty. Risk index means the relative risk of the occurrence of an accident during working. Risk index of 1.0 represents the average risk on a typical two-day, two-night, four-off schedule, involving 12-hour shifts starting at 08:00 a.m. and 08:00 p.m. High risk index means the workers would have high risk of accidents on duty. Fatigue and risk index calculator can be freely downloaded from HSE homepage (HSE 2013). We calculated fatigue and risk index using the subjects' work schedule derived from the interview.

Results

The subjects were all men aged from 43 to 61. Their work duration for bus driving was ranged from 3 to 24 years. Average daily working hours and monthly working days of the subjects engaged with 2 shifts schedule were 8.0

hours and 21.4 days, respectively. Average daily working hours of WR, W2R, and W4R2 schedule were extremely long, which were 17.5, 14.6, and 15.0 hours, respectively. The subjects worked 3 (WR and W2R schedule) or 5 (W4R2 schedule) consecutive days 1 or 2 times in a month, so their monthly working days were 16.5, 21.5, and 21.5 days, respectively (Table 1).

Table 2 shows RHR, actual work hours, and MAWT. RHR ranged from 9.7 to 21.8%, and MAWT estimated from RHR ranged from 9.1 to 16.4 hours. Actual work hours of the subjects engaged with 2 shifts schedule were 7.8 and 8.2 hours respectively, which were both shorter than their MAWT, their overwork indices were below 1.0. Whereas, actual work hours of the subjects engaged with WR, W2R, and W4R2 schedule were longer than MAWT and their overwork indices were greater than 1.0.

Figs. 1 and 2 show calculated fatigue and risk index of the subjects during 20 workdays. Fatigue index of WR schedule ranged from 45.2 to 54.4, which was highest among all schedules. Fatigue index of other schedules was not different significantly each other (Fig. 1). Risk index of WR schedule was 1.8, which was highest among all subjects. Risk index of W2R and W4R2 schedule ranged from 1.0 to 1.53, and increased with workdays. Risk index of W2R and W4R2 schedule was higher than that of 2 shifts

schedule (Fig. 2).

Discussion

There are two main results in the present study. First, the actual working hours in WR, WR2, and W4R2 schedule were longer than MAWT, which means the subjects worked longer hours beyond their physical abilities. Second, fatigue and risk index of WR schedule was very high, which means the subjects with WR schedule had high possibility of sleepy and high risk of accidents on duty.

Working hours over 48-60 hours were associated with high blood pressure (Hayashi et al. 1996; Iwasaki et al. 1998) or death from acute myocardial infarction (Landsbergis 2004). In the recent meta-analysis, the relative risk of coronary heart disease for long working hours was 1.59 (95% confidence interval 1.23-2.07) (Virtanen et al. 2010). According to another meta-analysis showed dose-response relationship between working hours and cardiovascular disease; the relative risks for weekly working hours of 49-54 hours and ≥ 55 hours were 1.27 (95% confidence interval 1.03-1.56) and 1.33 (95% confidence interval 1.11-1.61), respectively (Kivimäki et al. 2015). According to these studies, long working hours may increase the risk for cardiovascular disease. Nevertheless, long working hours are not equal to physical overwork. In other words,

Table 1. General and work-related characteristics of the subjects.

1	56	2 shifts	16	City bus	8.0	21.4
2	57	2 shifts	20	City bus	8.0	21.4
3	51	WR	13	City bus	17.5	16.5
4	49	WR	24	City bus	17.5	16.5
5	56	WR	7	City bus	17.5	16.5
6	49	WR	5	City bus	17.5	16.5
7	47	WR	23	Regional bus	17.5	16.5
8	43	WR	7	Regional bus	17.5	16.5
9	51	WR	12	Regional bus	17.5	16.5
10	56	WR	26	Regional bus	17.5	16.5
11	52	W2R	18	Express bus	14.6	21.5
12	50	W2R	20	Express bus	14.6	21.5
13	47	W2R	3	Express bus	14.6	21.5
14	45	W2R	14	Express bus	14.6	21.5
15	61	W4R2	20	Intercity bus	15.0	21.5
16	44	W4R2	15	Intercity bus	15.0	21.5

2 shifts, WR, W2R, and W4R4 means 2 shifts a day, working every other day, 2 workdays followed by 1 rest day, and 4 workdays followed by 2 rest days. City bus circulates inside a city, regional bus circulates between a city and nearby cities, express bus travels cities of long distances, and intercity bus travels between a city and rural areas of a long distance.

Table 2. Maximal acceptable work time of the subjects.

No	Work schedule	Work time		Work hours	RHR (%)	MAWT (hours)	Overwork index
		Start	End				
1	2 shifts	04:08 a.m.	11:55 a.m.	7.8	17.7	11.2	0.70
2	2 shifts	06:38 a.m.	02:48 p.m.	8.2	13.1	13.9	0.59
3	WR	05:35 a.m.	11:18 p.m.	17.7	12.5	14.3	1.24
4	WR	07:10 a.m.	10:40 p.m.	15.5	11.3	15.2	1.02
5	WR	05:15 a.m.	10:20 p.m.	17.1	12.8	14.1	1.21
6	WR	07:25 a.m.	00:30 a.m.	17.1	17.6	11.2	1.53
7	WR	07:07 a.m.	01:40 a.m.	18.6	17.6	11.2	1.66
8	WR	06:40 a.m.	00:47 a.m.	18.1	21.8	9.1	1.98
9	WR	07:17 a.m.	00:30 a.m.	17.2	17.9	11.0	1.56
10	WR	07:10 a.m.	01:53 a.m.	18.7	12.6	14.3	1.31
11	W2R	12:00 p.m.	01:30 a.m.	13.5	16.6	11.8	1.15
12	W2R	03:20 p.m.	06:00 a.m.	14.7	15.0	12.7	1.16
13	W2R	06:40 a.m.	19:00 p.m.	12.3	17.2	11.4	1.08
14	W2R	09:10 a.m.	04:00 a.m.	17.8	21.6	9.3	1.92
15	W4R2	07:30 a.m.	22:15 p.m.	14.8	17.0	11.5	1.28
16	W4R2	08:30 a.m.	23:30 p.m.	15.0	9.7	16.4	1.10

2 shifts, WR, W2R, and W4R4 means 2 shifts a day, working every other day, 2 workdays followed by 1 rest day, and 4 workdays followed by 2 rest days. RHR and MAWT means relative heart rate and maximal acceptable work time. Overwork index is the ratio of work hours and MAWT.

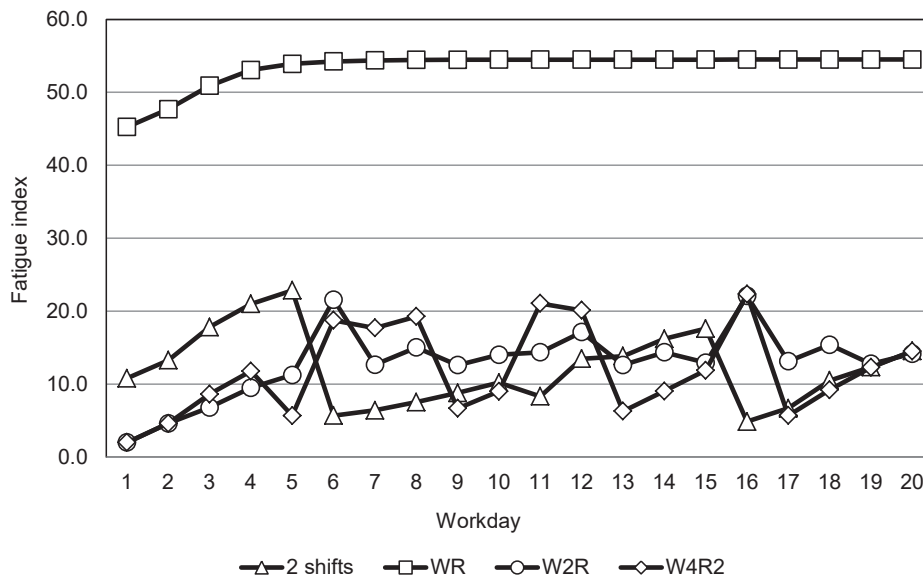


Fig. 1. Fatigue index of Korean bus drivers according to work schedule.

Fatigue index means the average probability of being sleepy on duty, which takes a value between 0 and 100. The value represents accumulated fatigue in each workday, and fatigue index in the rest day was not included in the figure. 2 shifts, WR, W2R, and W4R2 means 2 shifts a day, working every other day, 2 workdays followed by 1 rest day, and 4 workdays followed by 2 rest days, respectively.

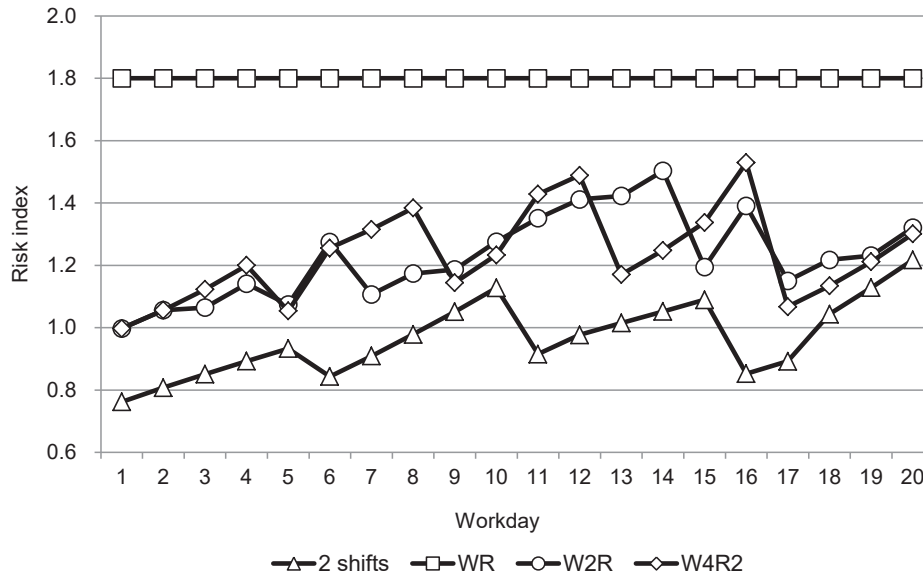


Fig. 2. Risk index of Korean bus drivers according to work schedule. The risk index means the relative risk of the occurrence of an accident during working. Risk index of 1.0 represents the average risk on a typical two-day, two-night, four-off schedule, involving 12-hour shifts starting at 08:00 a.m. and 08:00 p.m. The value represents the risk of an accident on duty due to accumulated fatigue in each workday, and risk index in the rest day was not included in the figure. 2 shifts, WR, W2R, and W4R2 means 2 shifts a day, working every other day, 2 workdays followed by 1 rest day, and 4 workdays followed by 2 rest days, respectively.

physical load of heavy physical work such as construction workers is different from light physical work such as office work. Recently, some researchers have considered physical demand in the study of cardiovascular disease (Clays et al. 2013; Allesoe et al. 2015; Holtermann et al. 2016). According to these studies, high physical demand from work may increase the risk for cardiovascular disease.

As described above, both long working hours and physical demand of work may increase the risk for cardiovascular disease. In other words, overwork would be derived from both long working hours and high physical demand of work. So we should have considered both of them for investigating the bus drivers' physical fatigue from work. RHR is good index to represent physical workload, and can be used as an indicator for physical workload associated with dynamic muscular work (Shimaoka et al. 1998; Christensen et al. 2000). During work, lactic acid accumulates in the blood, and at some point accumulated lactic acid causes an excessive burden on the cardiovascular system, resulting in a sudden increase in heart rate (Wu and Wang 2002). A marked increase of heart rate is a sign of physical fatigue, which was applied to determine the acceptable workload and work hours (Saha et al. 1979). Some researchers have performed the studies about the MAWT and RHR. Ariza and Idrovo (2005) investigated the MAWT using RHR, and 43% of workers did not have fulfilled the MAWT. Lunde et al. (2016) evaluated cardiovascular load in male construction workers using the MAWT and RHR, and reported that working hours in 19% of the subjects had been exceeded their MAWT. In the present study, only 2 subjects engaged with 2 shifts

schedule worked shorter hours than their MAWT, and all other subjects worked longer hours than their MAWT (overwork indices were higher than 1.0). In addition, overwork indices were higher in WR schedule than in W2R or W4R2 schedule (mean overwork index was 1.44 and 1.28, respectively). This finding means the physical workloads in the subjects with 2 shifts schedule was suitable for their physical abilities, and the WR schedule caused considerable overwork in the subjects.

Safety critical worker is defined as "Where the ill health of an individual may compromise their ability to undertake a task defined as safety critical, thereby posing a significant risk to the health and safety of others" (Constructing Better Health 2016). Safety critical workers' health conditions affect the safety of the public, as well as themselves. The fatigue of commercial vehicles drivers including bus drivers may cause critical accidents which threaten the safety of the public. Fatigue and risk index developed by HSE (2006) is a tool for evaluating the fatigue and the risk of accidents in safety critical workers. Fatigue index means the probability of being sleepy on duty, which is recommended to be less than 30-35 for day shifts and 40-45 for night shifts to minimize the risk of fatigue (Health and Safety Laboratory 2008). Risk index means the relative risk of the occurrence of an accident on duty, which is recommended to be less than 1.6 to minimize the risk of an accident (European Commission 2006). In the present study, fatigue indices in 2 shifts, W2R, and W4R2 schedule were less than 30, whereas fatigue index in WR schedule was 45.2-54.4, which was higher than the threshold for night shifts. The results of risk index showed

similar pattern to those of fatigue index. Risk indices in 2 shifts, W2R, and W4R2 schedule were less than 1.6, whereas fatigue index in WR schedule was 1.8, which was higher than the threshold for night shifts. In addition, the fatigue and risk index other than WR schedule increased with consecutive working days and decreased after resting days. This might be because the fatigue was accumulated on consecutive working days and recovered somewhat on resting days, whereas the fatigue and risk index of WR schedule showed plateau and did not decrease after resting day. This represents that the subjects with WR schedule did not recover from fatigue after resting day. These findings meant that WR schedule did not allow the recover from fatigue during resting day, which might increase the risk of an accident on duty.

ILO and many countries have regulations that restrict bus drivers' driving and working hours. ILO (1979) recommended the maximum driving time should not exceed neither 9 hours per day nor 48 hours per week. European Union (EU) recommended daily and weekly driving time should not exceed 9 hours and 56 hours (average 45 hours per week) via Regulation (EC) No. 561/2006 (European Commission 2006). The United States recommended daily driving time should not exceed 10 hours (passenger-carrying drivers) or 11 hours (property-carrying drivers) via Hours of Service Regulations (Federal Motor Carrier Safety Administration 2017). Canada recommended daily driving and working hours should not exceed 13 hours and 14 hours via Commercial Vehicles Drivers Hours of Service Regulations (Ministry of Justice of Canada 2009). In Korea, regulation for working hours is stipulated in the Labour Standards Act in Korea. Statutory working hours regulated in the Labour Standards Act is 40 hours and 5 days a week. This Act has allowed extended working hours up to 12 hours a week. But transportation, sales, finance and insurance, telecommunications, advertising, medical, and other sectors are exception of this regulation. The workers in these sectors are allowed to work more than 12 hours of extended hours a week. In other words, there is no regulation for restriction of bus drivers' working or driving time in Korea. This is one of the causes for Korean bus drivers' long working and driving hours. As observed in the present study, most bus drivers' working hours engaged with WR, W2R, and W4R2 schedule were longer than their MAWT. In addition, the fatigue and risk indices of the bus drivers engaged with WR schedule exceeded the recommended threshold. So, it is necessary to prepare the polices to reduce the fatigue and risk for accidents in the Korean bus drivers.

There are some limitations in the present study. First, MAWT was designed to evaluate the physical workload in the dynamic muscular work. Bus driving is somewhat different from the dynamic muscular work, so the MAWT in the bus drivers may not be accurate. Second, the number of the subjects was not sufficient for statistical analysis. So, the findings of the present study may not be generalized to

other Korean bus drivers. Researches with sufficient subjects should be conducted in the future.

According to the findings of the present study, Korean bus drivers may work long hours beyond their physical abilities. The fatigue and risk indices were very high in WR schedule, so bus drivers with WR schedule may have high possibility of sleepiness and high risk of accidents on duty. The fatigue related with long working and driving time may cause significant accidents threatening the public's safety. In order to prevent the accidents caused by commercial bus drivers, it is necessary to prepare the polices to reduce the fatigue and risk for accidents in the Korean bus drivers including regulation for bus drivers' driving and working time restriction.

Conflict of Interest

The authors declare no conflict of interest.

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