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Field Report

A Field Study on the Physiological Workload of Garbage Collectors in the Japanese Summer

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Abstract: A field study designed to reveal the physiological workload on garbage collectors (GC) was conducted in Japan. Three drivers who only operated a garbage truck, three loaders who actually collected as a team, three solo collectors, and one clerical worker, totaling 10 male workers participated in this study. The ambient temperature and the relative humidity, activity intensity, and heart rate were measured on the three days in July. The mean heart rate of the workers, excluding the clerical worker, was 97.5 bpm. There were cases in which the heart rate limit, as defined by ACGIH, was exceeded, including a case in which the loader sustainably exceeded this limit for over an hour. There were 10 worker-days in which the 58%HRmax level (corresponding to the permissible limit specified in the Netherlands) was exceeded based on the findings of the 18 worker-days for the loaders and solo collectors. There were many cases in which the energetic load of GC in the humid summertime in Japan exceeded the permissible limits as established in the U.S.A. and the Netherlands. The careful inspection of the actual work conditions and improvements in the work environment should be implemented for the occupational safety and health of GC.

Key words: Garbage collectors, Physiological workload, Heart rate, Hot and humid environment

Introduction

Garbage collection is performed outdoors whether it is hot, or cold, rainy. It is physically demanding work and various hazardous materials are among items handled. Various studies have been conducted inside and outside of Japan regarding the safety and health of garbage collectors (GC). There are several study reports on respiratory symptoms caused by dust, mites, and bacteria in Europe[1–3]. Furthermore, besides gastrointestinal symptoms[4] such as nausea and diarrhea from bad odors, *etc.*, studies on musculoskeletal symptoms and body injuries have also been reported[5]. Regarding energetic load, Kuijer *et al.*[6] exhibited that the percentage of the maximal oxygen uptake (%$\dot{V}O_{2max}$) of workers when collecting garbage bags exceeded the energetic acceptable peak load of 50%$\dot{V}O_{2max}$ for 1 h in the Netherlands. From heart rate measurement results of the GC, Kemper *et al.*[7] and Luttmann *et al.*[8] clarified that breaks of sufficient time and frequency are necessary, allowing GC to recover until their heart rate is not considered problematic. Anjos *et al.*[9, 10] also revealed the actual conditions of the workload by measuring the heart rate of GC, and appealed to set a limit on working hours in order to protect the health of workers in developing countries. In Japan, the Ministry of Labour issued a notice for disaster prevention to cleaning businesses in 1993[11]. There are also a great number of past reports on musculoskeletal symptoms, especially lumbar symptoms[12–16], and on actual fatigue conditions from field

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work research on GC[17].

In one city in Japan, the workload of municipal employees engaged in garbage collection, especially under the harsh conditions during the summer is severe, and this was considered to be an urgent issue which needed to be addressed for the safety and health of GC. However, the actual conditions of these risks and workload were not objectively understood. Consequently, we were commissioned by this particular city to conduct a field study with the purpose of revealing the physiological workload on GC in midsummer.

Methods

Outline of the municipality

The municipality in Japan directly operates the garbage collection business, with full-time employees engaged in such operations. In districts other than housing complexes, a procedure is employed in which the worker accompanying the collection vehicle collects garbage bags left in front of each residence with his bare hands, providing good service to citizens. Moreover, solitary residents are approached and garbage is taken out from inside their home in some cases, for welfare services as well. This particular city is a large urban city that is densely populated, with downtown areas and regions crowded with small residences. The traffic is generally heavy on roads in the residential district, requiring workers to quickly gather up and load garbage so that the collection vehicle does not disturb the residential traffic and cars. Therefore, it was thought that workers have a high risk of falling, suffering garbage-related injuries, and back pain. Furthermore, the workload under conditions of both high temperatures and high humidity during the East Asian summer monsoon is severe. In order to prevent heat stroke, the municipal authorities of the city therefore took specific measures, such as encouraging water intake and distributing wet scarves to cool down the neck as well as "salt candies" for salt supplementation.

Participants

Workers engaging in garbage collection for the city in question (Field Workers) were divided into three specialized occupational categories. In this report, workers only operating the garbage truck are referred to as DRIVERs, and workers travelling to the collection site by garbage truck and collecting garbage bags with their bare hands upon arrival at that site while accompanying the garbage truck are referred to as LOADERs. These workers generally perform collection with 1 DRIVER and 2 LOADERs as a crew. Besides these, there is an occupation in which one person drives a small garbage truck, gathering up and loading garbage bags by themselves; these workers are referred to as SOLOs.

There are dozens of garbage collection offices in this particular city. Among these, a request to conduct a field study in one office considered to have a standard workload for garbage collection was submitted to the municipal authorities. The subjects of the study were set to be a total of 10 men, one person each by age (thirties/forties/fifties) and by occupation (LOADERs/SOLOs/DRIVERs), as well as one clerical worker (CLERK) as a comparison subject. The managerial personnel of the office where the investigation was performed asked workers corresponding to the conditions as subjects to participate in the research, and 10 workers for whom permission was granted (the CLERK was in his fifties) participated in the study.

This study protocol was approved (approval number: 21–25) by the Human Research Ethics Committee of Shiga University of Medical Science (Otsu, Japan). After the details of the study were explained, each of the participants provided his informed consent in writing.

Measurement

The investigation was conducted during the final week of July, which are generally include conditions of high temperatures and high humidity based on usual yrs data, in 2009. Three different dates were selected for the investigation, including 3 separate days, consisting of Monday, Wednesday, and Friday in the belief that multiple days with different loads should be investigated. The ambient temperature (°C) and the relative humidity (%RH), activity intensity (Mets), and heart rate (beat per min: bpm) were measured from before starting to the completion of collection work. Regarding the ambient temperature and humidity, data was obtained every 10 s by installing a hygrothermograph (AZ8829, AZ) to the waist belt of participants. Regarding activity intensity, data was obtained every 10 s by installing a 3-axis acceleration-measuring activity gauge (HJA-350IT, OMRON Corp.) to the waist belt of participants. Regarding heart rate, the detection part of a heart rate recorder (RS400, Polar Electro Oy) was installed to the chest and the recording part was installed to the wrist of participants, respectively, with a belt, and data was obtained every 5 s. A high-performance scale with a resolution of 50 g (BC-305, TANITA Corp.) was used to measure the weight of participants in their underwear before and after the collection work. The body mass index

(BMI) of participants was calculated from the weight measured before the collection work on the first measurement day and the height based on an interview with the subject.

Data analyses

Working hours: The work process of garbage collection was: Workers left the garage adjacent to the office building at the beginning of the morning or afternoon (9 o'clock in the morning or 13 o'clock in the afternoon) in a garbage truck, and collected garbage from several collection regions (3 regions each in the morning and afternoon, representatively). Garbage was carried to an incineration plant when the storage space of the garbage truck was full, and workers came back to the office when the garbage collection of the scheduled region was complete. The amount of time combining the time it took the Field Workers from leaving the office to returning to the office building in both the morning and afternoon was defined as the work period of garbage collection, P_{work}. The work starting time of the CLERK was determined to be the same as the Field Workers, with the finishing time determined to be when duties were finished, immediately before taking off the measuring apparatus. Regarding the LOADER, the time spent actually gathering up and loading the garbage bags into the garbage truck after getting off the garbage truck was determined to be the actual loading period, P_{act}. The LOADER participants were asked to provide the amount of time spent doing this, and the start and end time of each P_{act} was estimated from activity intensity.

Thermal environment: The temperature at each hour of the city on the day of investigation announced by the meteorological agency was examined in order to evaluate the thermal environment, and was compared to the ambient temperatures of the participants. The temperature times subject to comparison were 10, 11, 14, and 15 o'clock, and the compared ambient temperature was the mean temperature 30 minutes before and after this time, totaling one hour.

Activity intensity: The mean and 95%ile value at P_{work} and P_{act}, respectively, were calculated from the activity intensity measured every 10 s. Moreover, the percentage of the total P_{work} time exceeding 3 Mets, which is the activity intensity corresponding to walking at normal speed[18] (3 Mets overtime rate) was calculated.

Heart rate: The mean and standard deviation (SD) at P_{work} and P_{act}, respectively, were calculated from the heart rate recorded every 5 s. Moreover, the time periods in which the measured heart rate exceeded the sustained heart rate threshold limit value, TLV (=180-age), of the heat load determined by the American Conference of Governmental Industrial Hygienists, ACGIH[19] were selected out, and the number, the median as well as the maximum continuous-time for these periods were all calculated. The heart rate was converted to a percentage of the maximal heart rate (=220-age)[20] estimated from the age of each person (%HR_{max}). Subsequently, the mean %HR_{max} and 95%ile value at P_{work} and P_{act}, respectively, were calculated. Moreover, the percentage of the total P_{work} time exceeding 70%HR_{max}[21], which is considered as "slightly heavy exercise"[22] (70%HR_{max} overtime rate), was calculated. The permissible limit of 8 h per day for GC in Netherlands, 30%$\dot{V}O_{2max}$, is calculated as 58%HR_{max} when the result of Kemper *et al.*[6] is used, so the worker-days in which the mean %HR_{max} at P_{work} exceeded 58%HR_{max} was counted for each occupation.

Weight change: The percentage of weight change per day obtained by subtracting the weight before starting work from the weight after finishing work, relative to the weight before starting work was calculated.

Statistical analyses: The total P_{work} time of participants over the three measurement days excluding the CLERK was compared by one-way analysis of variance, ANOVA. The results were compared using multiple comparisons by the Tukey's HSD test when a significant difference was observed. The activity intensity and heart rate data at P_{work} were compared by one-way ANOVA between the three measurement days, for each participant. The mean and 95%ile value of activity intensity, and 3 Mets overtime rate; the mean and 95%ile value of %HR_{max}, and 70%HR_{max} overtime rate were evaluated by two-way repeated measures ANOVA (3 occupations excluding the CLERK × 3 measurement days as the repetitive element). The results were compared using multiple comparisons by the Tukey's HSD test when a significant difference was observed. The significant level for all statistical analyses was set to 0.05. JMP release 6.0.0 (Statistical Discovery ™) was used for statistical analyses.

Results

Working hours

Participant attributes, working hours on the 3 measurement days, and the ambient temperature and humidity around the body are shown in Table 1. The BMI ranged from 21 to 31, including one participant with a value of greater than 30. The total P_{work} time was 4:35 (hour:minute) to 6:18 for the LOADERs, 5:04 to 6:20 for the SOLOs, and 5:37 to 7:00 for the DRIVERs. SOLOs and DRIVERs

Table 1. Participant attributes, working hours, the ambient temperature and the relative humidity on the three measurement days

Occupation	Age	BMI	Working time (h:min)			Mean ambient temp. (°C)			Mean difference of the ambient temp.† (°C)			Mean ambient humidity (%RH)		
			Mon	Wed	Fri	Mon	Wed	Fri	Mon	Wed	Fri	Mon	Wed	Fri
LOADER (Actual collecting periods)	30's	25	4:45	5:05	4:44	28.7	32.5	31.2	2.5	0.9	0.8	75	65	62
	40's	27	6:18	5:31	5:40	29.8	31.5	31.6	4.0	0.5	2.0	84	74	67
	50's	23	6:00	4:35	5:54	28.0	31.4	30.0	2.4	−0.4	−0.5	93	61	50
	30's	25	2:11	2:15	2:59	29.8	33.5	32.1	–	–	–	78	64	63
	40's	27	3:01	2:07	3:07	29.4	31.9	32.5	–	–	–	85	78	68
	50's	23	4:16	1:49	2:58	28.2	31.6	31.0	–	–	–	92	67	56
SOLO	30's	22	6:20	5:27	5:25	31.7	33.0	32.7	6.1	1.5	2.4	67	63	56
	40's	31	5:46	5:13	5:33	29.8	31.6	31.7	4.4	0.5	1.7	69	66	68
	50's	26	6:05	5:04	6:08	29.5	32.1	31.6	4.1	0.9	1.3	69	70	64
DRIVER	30's	21	7:00	5:40	6:20	29.5	31.3	31.5	3.7	−0.4	0.9	52	55	46
	40's	23	5:45	6:10	5:37	29.9	33.3	31.6	4.3	2.0	1.4	83	80	58
	50's	24	6:35	6:00	6:05	28.6	31.6	32.1	2.7	0.2	1.7	52	75	58
Mean (n=9)			6:03*	5:25	5:42									
CLERK	50's	22	7:00	6:49	6:18	27.1‡	29.8	29.0	1.2‡	−2.4	−1.2	61‡	60	59

*There is a significant difference to Wednesday. †Mean difference of the ambient temperature around one's body from atmospheric temperature in the city. ‡He went out of business trip for several hours.

cleaned the storage space of the garbage truck after returning to the garage, so the time they returned to the office building was late compared to the LOADERs. The total P_{act} time of the LOADERs was 1:49 to 4:16, which was approximately half of the total P_{work} time. The mean total P_{work} time of 9 Field Worker participants was the longest on Monday (6:03), with a significant difference observed compared to Wednesday (5:25), which was the shortest.

Thermal environment

In this city, the weather on the Monday under investigation was cloudy followed by rain, with the weather on Wednesday and Friday being mostly clear. The atmospheric temperature of said city at 9 o'clock and the maximum atmospheric temperature and humidity during the investigation was: 24.7 °C, 28.2 °C, 90% on Monday, 30.3 °C, 32.9 °C, 67% on Wednesday, and 27.2 °C, 31.5 °C, 64% on Friday. The atmospheric temperature on Monday was generally low compared to Wednesday and Friday, and the mean measured ambient temperature around the body was also low. However, because the Field Workers were wearing a raincoat on Monday, the mean difference between the ambient temperature around the body and the atmospheric temperature was greater on Monday compared to other measurement days, and the ambient humidity of the LOADERs was higher on Monday compared to other measurement days. The ambient temperature of the Field Workers was generally higher than the atmospheric temperature, but the ambient temperature of the CLERK was lower than the atmospheric temperature, excluding Monday, in which the worker went out on a business trip.

Activity intensity and Heart rate

The time series plot of the heart rate, activity intensity, and ambient temperature of the workers in their thirties on Wednesday, which was mostly a clear day, is shown as an example in Fig. 1, by occupation. A large increase in activity intensity and heart rate at P_{act} was observed in the LOADER. An increase in activity intensity and heart rate was observed intermittently within approximately 10 minutes in the SOLO (the periods of actual work collecting garbage are shown by double-headed arrows in Fig. 1.). It was supposed that the workers got out of the garbage truck and collected garbage bags by walking or running. The activity intensity and heart rate barely increased in the DRIVER during P_{work}. On the other hand, an increase was observed in the latter half of the lunch hour. The reason for this is due to the fact that he had been playing basketball at that time based on an interview with the subject.

As a result of comparatively examining the time series data of the activity intensity and heart rate of each participant between the 3 measurement days, a significant difference was observed in 8 of 10 participants (excluding the SOLO and DRIVER in their fifties) regarding activ-

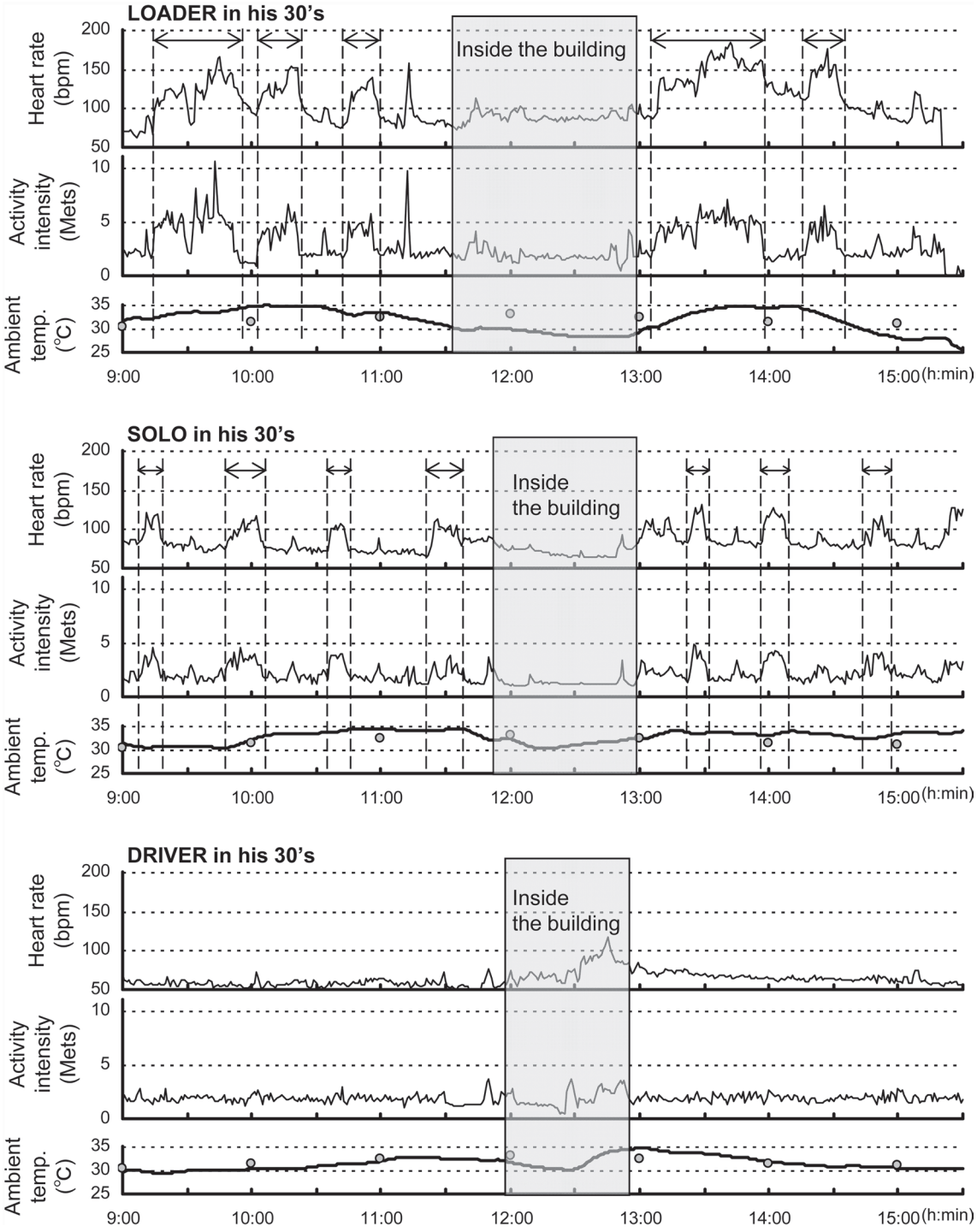

Fig. 1. Heart rate, activity intensity and ambient temperature around the body on the time series plot of the workers on mostly sunny Wednesday (The period indicated by a double-headed arrow is actual gathering up and loading period of the LOADER or the SOLO. Gray-colored circle shows atmospheric temperature in the city.)

ity intensity. A significant difference was observed in all participants regarding heart rate. The amount of various types related to activity intensity is shown in Fig. 2 by the 3 measurement dates. The mean heart rate (bpm), and the number, the median as well as the maximum value of each continuous-time, of the periods in which the measured heart rate exceeded the TLV is shown in Table 2 by the 3 measurement dates. The amount of various types related to

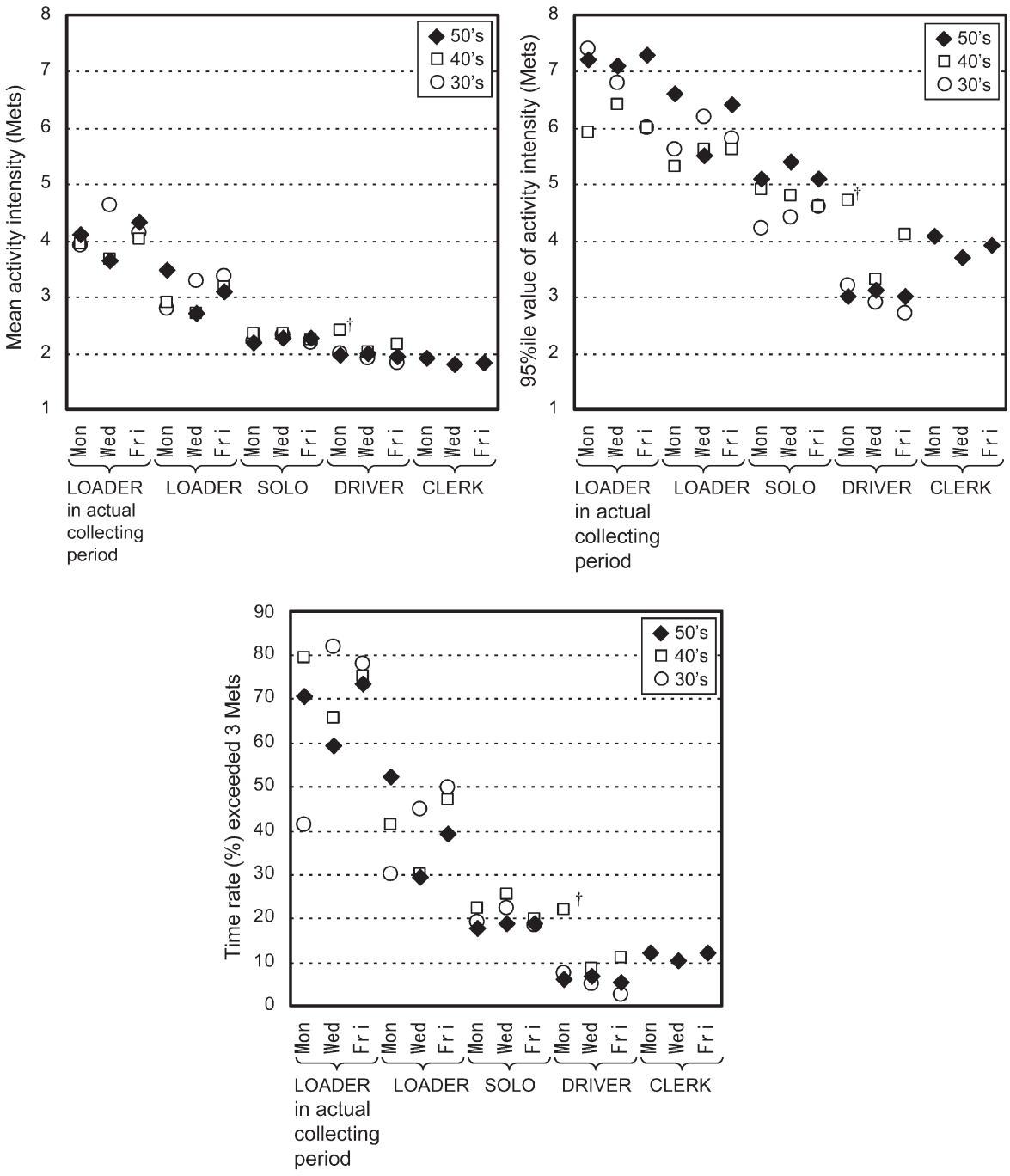

Fig. 2. Activity intensity on the three measurement days (upper left: mean, upper right: 95%ile value, lower: time rate; †: The driver helped with gathering up and loading.)

$\%HR_{max}$ is shown in Fig. 3 by the 3 measurement dates.

The mean activity intensity (Mets) at P_{work} was 2.7 to 3.5 for the LOADERs, 2.2 to 2.3 for the SOLOs, 1.8 to 2.1 for the DRIVERs (excluding the data from a worker in his forties that helped gather up and load garbage on Monday), and 1.8 to 1.9 for the CLERK (Fig. 2). The mean activity intensity at P_{act} was 3.6 to 4.6 for the LOADERs (Fig. 2). There were no interactions in any when two-way repeated measures ANOVA was carried out on the mean and 95%ile value of activity intensity, and the 3 Mets overtime rate of the 3 occupations excluding the CLERK and 3 measurement days as a factor. A significant difference of LOADER > SOLO > DRIVER was observed among the 3 occupations.

Table 2. Absolute heart rate on the three measurement days

Occupation	Age	Analysis time (h:min)			Heart rate (bpm) Mean [SD]			No. of period exceeded TLV†			Continuous-time for the periods exceeded TLV† (min)					
											Median			Maximum		
		Mon	Wed	Fri	Mon	Wed	Fri	Mon	Wed	Fri	Mon	Wed	Fri	Mon	Wed	Fri
LOADER (Actual collecting periods)	30's	4:04	5:05	4:44	108 [23]	112 [29]	113 [24]	16	23	24	0.7	0.8	0.8	5.8	19.5	5.9
	40's	6:18	5:31	5:40	107 [16]	108 [17]	118 [21]	27	19	20	0.5	1.9	1.0	2.7	7.3	63.3
	50's	6:00	4:35	5:54	100 [14]	85 [15]	93 [17]	5	3	4	0.9	1.6	0.2	3.3	2.3	1.5
	30's	2:02	2:15	2:59	126 [18]	135 [23]	127 [18]	16	22	24	0.7	0.8	0.8	5.8	19.5	5.9
	40's	3:01	2:07	3:07	120 [10]	122 [16]	132 [16]	27	17	20	0.5	1.8	0.9	2.7	7.3	62.8
	50's	4:16	1:49	2:58	107 [11]	97 [17]	107 [10]	5	3	4	0.9	1.6	0.2	3.3	2.3	1.5
SOLO	30's	6:20	5:27	5:25	84 [17]	88 [16]	83 [16]	1	0	0	0.3	–	–	0.3	–	–
	40's	5:46	5:13	5:33	101 [11]	103 [13]	102 [11]	1	12	7	0.5	0.2	0.2	0.5	1.2	0.3
	50's	6:05	5:04	6:08	86 [16]	82 [14]	82 [13]	22	1	8	0.3	0.1	0.3	8.5	0.1	1.0
DRIVER	30's	7:00	5:40	6:20	67 [12]	61 [6]	63 [5]	0	0	0	–	–	–	–	–	–
	40's	5:45	6:10	5:37	86 [11]‡	80 [9]	83 [8]	0	0	0	–	–	–	–	–	–
	50's	6:35	6:00	6:05	83 [9]	83 [7]	81 [7]	0	0	0	–	–	–	–	–	–
CLERK	50's	7:00	6:49	6:18	87 [12]	84 [10]	87 [10]	5	0	2	45	–	85	2.3	–	2.1

†TLV: Threshold Limit Value (=180-age) defined by ACGIH. ‡The driver helped with gathering up and loading.

The mean heart rate at P_{work} was 85 to 118 for the LOADERs, 82 to 103 for the SOLOs, 61 to 86 for the DRIVERs, and 84 to 87 for the CLERK. The mean ± SD of the mean heart rate of the 3 days was 97.5 ± 11.8 at P_{work} for the 6 workers (3 LOADERs and 3 SOLOs) who were gathering up and loading garbage, and 119.3 ± 12.0 at P_{act} (mean total time was 165 min). When compared to TLV, the DRIVERs did not exceed this value, but there were cases in which the value exceeded that for the SOLOs and LOADERs. Regarding the LOADER in his forties, in particular, there was a case in which TLV was sustainably exceeded for over an hr (Table 2).

There were no interactions in any when two-way repeated measures ANOVA was carried out on the mean and 95%ile value of $\%HR_{max}$, and $70\%HR_{max}$ overtime rate of the 3 occupations excluding the CLERK and 3 measurement days as a factor. There were no significant differences between the 3 measurement days, but a significant difference of LOADER > SOLO > DRIVER was observed among the 3 occupations. When cases in which 58%HR was exceeded as extracted from the 9 worker-days (3 worker-days only for the CLERK) measured per occupation, it was 7 worker-days for the LOADERs, excluding the 2 days for the worker in his fifties, and was 3 worker-days only for the worker in his forties for SOLOs, with none for the DRIVERs or the CLERK (Fig. 3).

Weight change

The percentage of body weight change at each measurement date is shown in Fig. 4. The weight change was negative on all 3 measurement days in the LOADER and SOLO in their fifties, and for the LOADER, there were 2 days in which the body weight decreased by almost 2%, and for the SOLO, there were 3 days in which the body weight decreased by 1% or more. A positive weight change was measured at least one day for the other participants.

Discussion

Activity intensity

This study evaluated the physiological workload on GC using measured activity intensity and heart rate. An acceleration-measuring activity gauge installed on the waist was used to measure activity intensity. The activities of walking and running were undoubtedly reflected in these measured values[23], making it possible to determine the period of actual loading work without us accompanying the participants during the collection work. On the other hand, upper limb activities such as lifting objects and/or bending and twisting of the trunk of the body were not sufficiently reflected in the measured values. Therefore, the measured activity intensity value of the LOADERs mainly reflects the load of walking and running, and thus should be interpreted to underestimate the load of lifting garbage bags and loading them into the garbage truck. The workload of walking and running approximately 4 Mets, which is comparable to "fast-walking,"[18] became evident

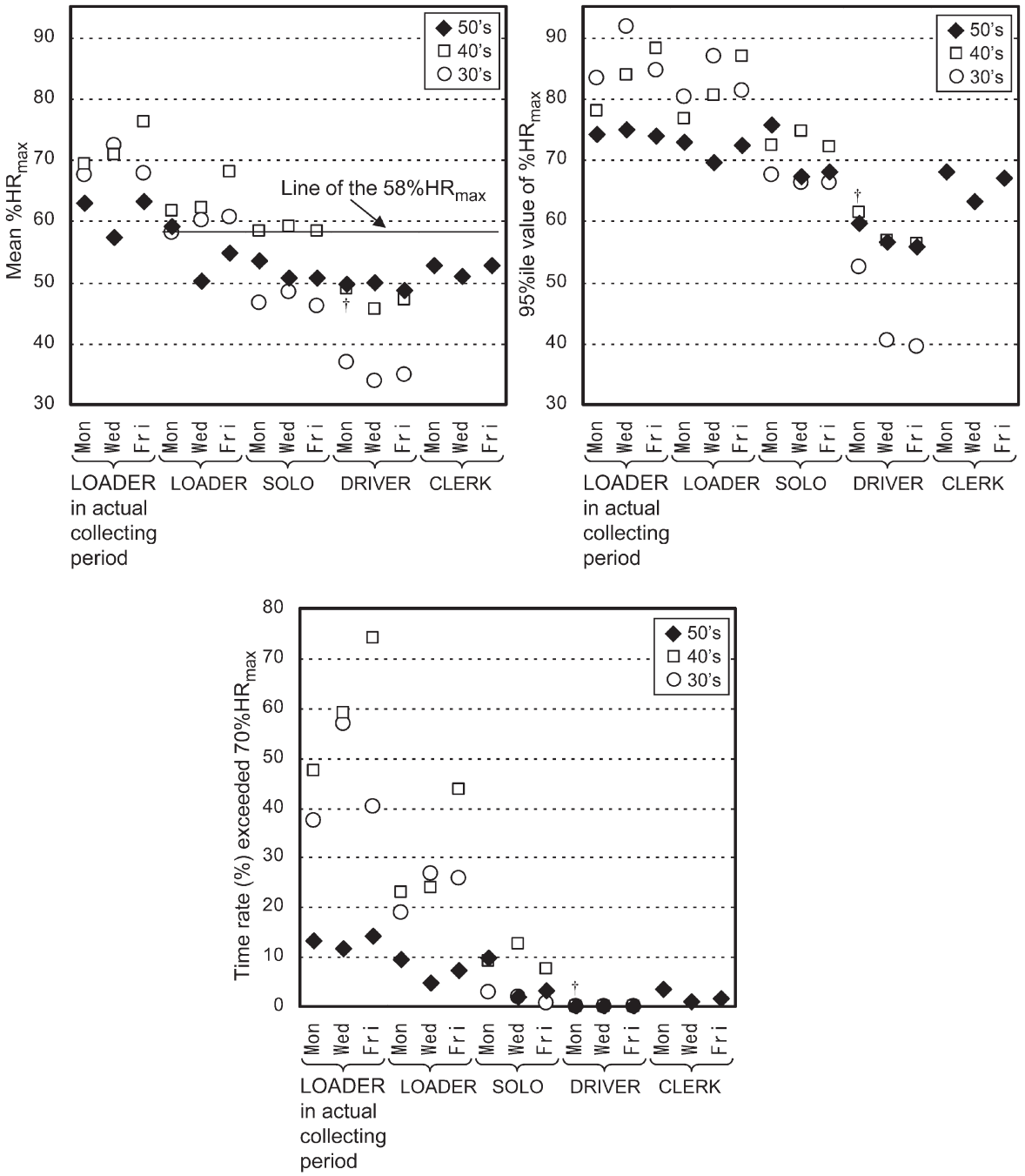

Fig. 3. Percentage of maximal heart rate (%HR_{max}) on the three measurement days (upper left: mean, upper right: 95%ile value, lower: time rate ; †: The driver in his 40's helped with gathering up and loading.)

during the actual loading period of the LOADERs. However, it can be considered that a load from lifting garbage bags and loading them into the garbage truck was actually involved.

Heart rate

Heart rate is used as an index that reflects the entire physiological workload in a more adequate manner, because the workload evaluation by activity intensity measured using an accelerometer is limited, as mentioned earlier.

The mean ± SD obtained from the mean heart rate per day of 10 GC workers reported in Netherlands in 1990 was 99.7 ± 7.2 when loading polyethylene bags with garbage

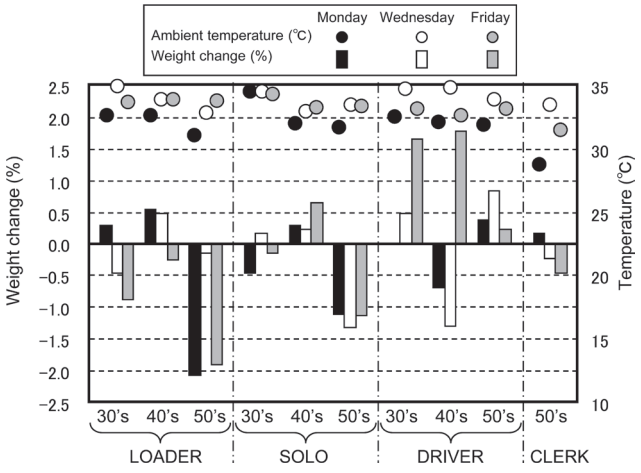

Fig. 4. Percentage of weight change (shown as bar chart) and ambient temperature around the body (shown as circle plot) on the three measurement days

inside by bare hands, which is the same method used for garbage collection work in this study[6]. The value from the mean heart rate per day for 314 GC worker-days measured in the winter of 1996 in Brazil (from June to November) was 97.6 ± 10.6, and the value from an mean heart rate for 308 GC worker-days at P_{act} (mean time: 293 min) was 104.0 ± 11.7[10]. The value computed from the mean heart rate per day of 3 LOADER and 3 SOLO workers over 3 days in this study was 97.5 ± 11.8, approximately the same value as the results in the above 2 studies. Moreover, The value from the mean heart rate of 3 LOADERs over 3 days at P_{act} (mean time: 165 min) in this study was 119.3 ± 12.0, a shorter P_{act} time than the result obtained by GC in Brazil, but with a heart rate that was higher by about 15 bpm. The workload was not small compared to the results obtained in 2 overseas countries over 10 yrs ago, due to the fact that the result of this study was data obtained under a harsh thermal environment.

ACGIH indicates that '180-age' bpm (TLV) should not be sustainably exceeded and that the heart rate should return to 120 bpm after a minute break as a limit value for heart rate, which is the physiological index under thermal environments[19]. In this study, the heart rate of LOADERs at P_{act} often exceeded the TLV. Regarding the work on Friday of the LOADER in his forties, in particular, there was a time in which the TLV was sustainably exceeded for over an hr, and it can be surmised that the circulatory system was under a heavy workload.

A permissible limit of 30%$\dot{V}O_{2max}$ is specified for GC workload when working 8 h a day in Netherlands[24]. Kemper *et al.*[6] measured the heart rate and oxygen uptake during collection work as simulated with garbage collection workers as the subject. 58%HR_{max} corresponded to 30%$\dot{V}O_{2max}$ when we calculated from these results. In this study, 58%HR_{max} was exceeded in 7 of 9 worker-days (78%) for the LOADERs.

The heart rate of the SOLOs was generally lower than the LOADERs, and cases exceeding 58%HR_{max} were smaller than the LOADERs on 3 of 9 worker-days. The fact that it is an intermittent operation with a short period of actual collecting work, the fact that a "certain amount of rest" was taken at a high frequency, and the fact that workers can work at their own pace were thought to be the cause for this. Increased activity intensity and heart rate during work were barely observed in the DRIVERs. The occasional sudden increase in heart rate may be due to various experiences, such as an accident almost occurring[25]. The psychological stress of DRIVERs is considered to be high because they need to be cautious so as not to cause traffic accidents, but from the measured heart rate and activity intensity, it was thought that this has no impact on physiological workload.

Weight change

The municipal authorities of the city specifically encouraged water intake to prevent heat stroke for Field Workers. Nevertheless, approximately 1 kg calculated from one's weight, close to 1 l when converted to volume, of water loss occurred in the LOADER and SOLO in their fifties. The sensitivity of the thirst center in humans decreases with age, making them less sensitive to thirst[26], so it is possible that the workers in their fifties participating in this study became substantially deficient for water intake as a result of relying on voluntary hydration from thirst. Enhancing awareness and education on the intake of water and salt as well as improving the environment so Field Workers can frequently take water and salt, taking into consideration the properties of workers due to age, is important for preventing heat stroke.

Difference among the three measurement days

In this particular city, there is generally more garbage the day after holidays, with many garbage bags having earth and sand mixed in. Indeed, in the outcome, the mean working hours of 9 Field Workers was longest on Monday, with Monday estimated as having had the most amount of garbage to be collected during the investigation week. In addition, Field Workers worked wearing raincoats on Monday, which had a high humidity from rain, increasing the perception of it being more humid, and the overall

workload was thought to be great from the additional weight of the raincoat and difficulty in moving. The workload of participants, the amount of garbage collection, and environmental conditions varied to some extent, but there were no striking differences between the 3 measurement days in terms of the activity intensity and heart rate per day of the 9 Field Workers.

Representation of subjects

An investigation could only be performed at one office because the investigation period was limited in order to evaluate the actual workload under harsh thermal environmental conditions. There are offices in charge of many districts with crowded small residences in this particular city, but the office subject to this study was asked to select a place in which such regions of heavy workload for garbage collection were not concentrated. There was no significant difference observed between offices upon health investigation of all workers at all garbage collection offices in the city as subjects[27] or regarding health conditions and/or fatigue in a questionnaire investigation on subjective fatigue symptoms using Field Workers from 3 offices (including the office subject to this study), which were thought to have a standard workload for garbage collection[28]. Consequently, it was thought that the representation by the examined office in this particular city was generally satisfied.

The participants and the investigation date

One worker who participated in this study was categorized into "Obesity class 2"[29], as defined by Japan Society for the Study of Obesity, based on his BMI. The worker was not excluded from this investigation, because no abnormalities were detected during an annual health check in their workplace, and he performed the physically demanding work in comparison to office work on a daily basis.

The end of the rainy season came late in the yr of the investigation compared to normal yrs, and was not measured under fierce heat as in the same period of normal yrs (the maximum atmospheric temperature of common yrs is 33.4 °C). However, because it was raining and humid on one measurement day and the maximum atmospheric temperature exceeded 30 °C on 2 measurement days, it was thought that the investigation was carried out under the intended environment of high temperature and high humidity.

Conclusion

There were many cases in which the workload of GC in the humid summertime in Japan exceeded the permissible limit enacted in the U.S.A. and the Netherlands. It is important to start by having the field workers and managerial personnel understand these facts, in order to advance initiatives for occupational safety and health. Further, it is necessary to immediately consider measures to reduce the workload on GC such as setting up garbage collecting points to be used by several residences, a transition to a so-called station type, and/or introducing mechanical loading in garbage trucks at garbage collection points for housing complexes. There was a case in which the workload exceeded the permissible limits regarding the SOLOs peculiar to this particular city. Moreover, because SOLOs work by themselves, considerations including a rescue system in the event of traffic accidents or sudden physical deconditioning are required.

Inspection of the actual work conditions and improvements in the work environment should therefore be carried out to improve the occupational safety and health of GC.

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