

Heart rate and energy expenditure during garbage collection in Rio de Janeiro, Brazil

Frequência cardíaca e gasto energético durante a coleta de lixo domiciliar no Rio de Janeiro, Brasil

Luiz A. Anjos ^{1,2}
João A. Ferreira ³
Jorginete J. Damião ⁴

Abstract

Physiological workload is used to estimate the physical demand of tasks in the workforce, but limited information is available for the various work activities in developing countries. Eighty-three randomly selected male workers participated in the present study, aimed at assessing the physiological workload of garbage collection (GC) in Rio de Janeiro, Brazil. Heart rate (HR) was obtained on four consecutive workdays. Energy expenditure (EE) was extrapolated from heart rate data based on individual laboratory-established heart rate/oxygen consumption curve in 70 workers. Mean HR during GC was 104.0 ± 11.7 bpm (\pm SD), representing $56.9 \pm 7.5\%$ of maximum heart rate. EE was 1608.3 ± 738.5 kcal for an average of 293.1 ± 103.9 minutes of work per day. Based on all measurements, work in garbage collection in Rio de Janeiro can be considered excessively heavy. These data emphasize the need to develop appropriate classification of workload to be used in health-related research and in the development of maximum acceptable work time in association with the physiological workload, particularly in developing countries.

Energy Metabolism; Workload; Workers; Solid Waste Collection

Introduction

Garbage collection is an essential public service with a large workforce. It is estimated that 90,000 workers are employed in domestic garbage collection in Brazil. In the city of Rio de Janeiro, a total of approximately 5,000 tons of household garbage is collected daily. In general, the job varies according to local technological development, geographic characteristics, and the population's culture and education ¹. For the workers, the job involves walking and running up and downhill and lifting variable-weight loads all day long ², during which time the worker is under constant stress because of traffic ³ and in many cases a lack of tolerance by pedestrians.

Assessment of energy expenditure during work and its physical demand is important for the fields of work physiology and workers' health, because it provides useful information for determining the job's physiological workload ⁴ and estimating the workers' energy requirements ⁵. The expenditure values for various jobs according to the Brazilian legislation fail to account for individual characteristics, technological development, and work organization and were derived from currently outdated studies conducted elsewhere in the world ⁶. It is thus necessary to specifically assess the physiological response to work in the Brazilian workforce in an effort to document the appropriate relationship between maximum acceptable work time and physiologi-

¹ Departamento de Nutrição Social, Universidade Federal Fluminense, Niterói, Brasil.

² Escola Nacional de Saúde Pública Sergio Arouca, Fundação Oswaldo Cruz, Rio de Janeiro, Brasil.

³ Faculdade de Engenharia, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brasil.

⁴ Instituto de Nutrição, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brasil.

Correspondence

L. A. Anjos
Centro de Estudos da Saúde do Trabalhador e Ecologia Humana, Escola Nacional de Saúde Pública Sergio Arouca, Fundação Oswaldo Cruz, Rua Leopoldo Bulhões 1480, Rio de Janeiro, RJ 21041-210, Brasil.
anjos@ensp.fiocruz.br

cal workload^{7,8,9}. The present study reports the physiological assessment of domestic garbage collection conducted in the field, in a probabilistic sample of workers from the Municipal Solid Waste Management Utility Company in the city of Rio de Janeiro, Brazil.

Materials and methods

Standard operational garbage collection crews in Rio de Janeiro consist of 4 male workers who gather and throw the garbage deposited along curbside into the garbage truck. Each team has its own routes, which are repeated every other day (one route on Mondays, Wednesdays, and Fridays and the other on Tuesdays, Thursdays, and Saturdays). Workers are only free to go home after completing their daily route, no matter how long it takes. Daily routes are planned not to exceed eight hours, and in most cases they are completed in no more than seven hours.

Subjects

The sample size for the study (approximately 80) was established based on heart rate (HR) values obtained in a pilot study. From a list of all male workers involved in daytime garbage collection provided by the Municipal Solid Waste Management Utility Company ($n = 503$), 166 workers were randomly selected and invited to participate in the study. This number was used because it was anticipated that a large number of individuals might not be interested in participating or would be unavailable. Since the morning shift had the largest contingent of subjects in the company, it was decided to invite only daytime workers. Therefore, the primary sampling unit was the selected worker in a simple randomized design.

Procedures

Data collection took place from June to November 1996 and occurred in three stages, comprising field and laboratory components. The 166 selected workers were invited to appear at the laboratory on a specific day and time. Only 126 workers accepted the invitation and participated in the first stage of the study, consisting of obtaining anthropometric measurements (body mass – BM, stature, and body mass index – BMI = $BM \cdot stature^{-2}$) and socioeconomic, dietary, health, and physical activity characteristics. Subjects signed an informed consent form at this appointment. All procedures were approved by the Research Ethics Committee of the Oswaldo Cruz Foundation (FIOCRUZ), Rio de Janeiro.

The second stage consisted of HR monitoring during work shifts on 4 consecutive days (Monday through Thursday) for all workers participating in the first stage. Due to equipment malfunctioning, absence, refusal, worker unit, and shift transfer and other changes in labor organization it was possible to monitor 83 workers on a total of 314 worker-days. HR was monitored by telemetry using POLAR Vantage NV monitors (Polar Electro Oy, Finland), which were placed on subjects early in the morning before the truck left the worker's unit and removed upon their return at the end of the daily work routine. The units were coded so that it was possible to monitor more than one worker in a team. Information on time of truck departures and arrivals and breaks for truck unloading were obtained from the daily log filled out by the truck driver. It was thus possible to calculate total daily working hours (TWH), that is, the time elapsed between departure from and return to the unit and the daily time of garbage collection (TGC), calculated as TWH minus haul time. Calculation of these two times is important because theoretically workers' activity can vary while trucks are unloading: some rest, while others prepare the garbage for collection while waiting for the truck to return.

The third stage consisted of measuring resting energy expenditure and performing a sub-maximal walking treadmill test. Only 70 of the 83 workers whose HR had been monitored came to the laboratory for these measurements. Resting energy expenditure (EE) was measured by indirect calorimetry (Aerosport TEEM 100, INBRASPORT, Porto Alegre, Brazil) in which ventilation, O_2 consumption (V_{O_2}), and CO_2 production (V_{CO_2}) minute values were obtained¹⁰. Workers were instructed to fast for 12 hours and to appear at the laboratory around 7:00 AM. Upon arrival, they rested for 30 minutes in a dark quiet room with ambient temperature kept at around 25°C. After this rest period, HR and gas exchange were measured for 25 minutes with the worker lying down, then 5 minutes sitting and 5 minutes standing. Minute resting EE was calculated using Weir's equation¹¹ and expressed in kcal using the last 20 minutes the subject was supine.

A sub-maximal walking treadmill test was conducted to obtain an individual calibration curve based on the relationship between HR and EE. It included 3-minute stages with initial speed of 2.5mph and 0% slope followed by an increase in speed to 3.5mph and maintenance of this speed with elevation of 2.5% for each subsequent stage (up to 10%). The test ended after 18 minutes (3.5mph and 10%); upon request of the subject or if HR reached 60% of reserve HR ($\% HR_{res} = \{HR - HR_{resting} / [(220 - age) - HR_{resting}] \} \times$

100). $HR_{resting}$ was established as the mean heart rate value during resting EE measurement (last 20 minutes).

Measurements and statistical analysis

Working HR (stage two) was expressed both in absolute values and relative to individual maximum (220-age) and HR_{res} daily ($n = 314$ days) in all 83 workers. Energy expenditure was estimated using the Flex heart rate method¹² in 266 days of all 70 workers for whom the heart rate-energy expenditure relationship was obtained during the walking treadmill test (calibration curve). The method consists of determining the critical HR (Flex) which is equal to the mean of the highest resting and the lowest walking HR values, to which 10bpm is added (FlexHR + 10). For all working heart rates below this value, EE is assumed to be the mean value for lying (resting EE), sitting, and standing. When HR is higher than the FlexHR + 10 value, EE is estimated from the regression equation individually calculated during the walking calibration curve. This method has been validated against other more sophisticated methods of energy expenditure measurement such as doubly labeled water and direct calorimetry and is recognized as a feasible method to be used in epidemiological studies¹³.

EE during TWR and TGC was calculated by adding energy expenditure for all minutes of the respective periods and expressing the result in absolute values (kcal) and relative to resting EE, a ratio that is called integrated energy index (IEI)^{5,14} and is used along with HR_{res} to determine the workload intensity.

Some data were not obtained for all workers, so the number of subjects and monitored days are thus presented in the tables. Statistical analysis included comparison of working hours and physiological variables on workdays using ANOVA one-way and Tukey¹⁵ for the differences between means for the significant variables ($p < 0.05$) using SAS version for microcomputer (SAS Inst., Cary, U.S.A.). Pearson correlation coefficients were calculated between TGC and workload (IEI).

Results

Mean age of workers was 36.8 ± 8.0 years (mean \pm SD) and varied from 19.7 to 63.0 years. Mean body mass was 67.7 ± 11.0 kg and mean stature 171.8 ± 6.3 cm, representing a mean BMI of 22.9 ± 3.2 kg.m⁻² (Table 1).

Heart rate information was obtained for a total of 153,584 minutes (approximately 2,560

hours) in the 83 workers on 314 days, with an average daily TWH of 489.1 ± 171.6 minutes.day⁻¹ (approximately eight working hours/day, Table 2). Daily TGC totaled 90,284 minutes and varied from 76 to 578 minutes (\cong 1 to 9.6 hours) with an average of 293.1 ± 103.9 minutes, approximately 5 hours per day of actual garbage collection working time (Table 3). Neither absolute HR nor $\%HR_{max}$ differed between subjects who completed all the procedures ($n = 70$) and those in whom the metabolic measurements were not taken ($n = 13$).

There was no significant difference in TWH or TGC comparing Mondays and Tuesdays or Wednesdays and Thursdays, but both were significantly shorter in the latter two days. Minute HR and EE did not differ significantly among days. Since working time was longer on Mondays and Tuesdays, total daily EE was significantly higher on these days in both TWH and TGC.

There was no significant difference among the days of the week in terms of work intensity, which on average was greater than 50% of maximum heart rate ($\%HR_{max}$) and 30% of reserve heart rate ($\%HR_{res}$). Expressed as a multiple of resting metabolic rate (IEI = EE/RMR), the value was greater than 5 for TGC (Table 3) and slightly lower for TWH (Table 2). There was no relationship between time worked and workload (Figure 1).

Discussion

The work process in household garbage collection exposes garbage workers to various risks¹⁶, thus aggravating its exhaustive intensity¹. Brazilian legislation classifies garbage collection as one of the unhealthiest jobs because of exposure to biological agents¹⁷. The physiological workload data from the current study also document the extreme intensity of physical exertion in garbage collection. The average total workday and garbage collection time were 8 and 5 hours, respectively. This apparently large difference (3 hours) was due to the fact that the data collection coincided with: (1) a process of outsourcing trucks, which had just recently begun, causing long delays in the trucks' arrival in the morning and (2) unusually heavy rain in Rio de Janeiro, causing traffic delays and requiring more time to cover the collection routes.

A job's physical effort can be assessed by the cardiovascular response and EE level, and both can be expressed in absolute terms and relative to either the resting or maximum values. Garbage collection is definitely strenuous, as documented by the high mean $\%HR_{res}$ and IEI. Absolute HR values appear to be relatively low, considering the job's obviously high intensity, but it is impor-

Table 1

Physical and physiological characteristics of a sample of 83 garbage collectors from Rio de Janeiro, Brazil.

Variable	Mean	SD	Minimum	Maximum
Age (years)	36.8	8.0	19.7	63.0
Body mass (kg)	67.7	11.0	49.0	119.0
Stature (cm)	171.8	6.3	160.0	188.0
Body mass index (kg.m ⁻²)	22.9	3.2	16.7	34.0
Resting metabolic rate (kcal.min ⁻¹)*	0.93	0.14	0.67	1.43
Resting heart rate (bpm) *	54.9	5.7	42.0	66.0

* n = 70.

Table 2

Total working hours (TWH), total working time (TWT), absolute (HR), percent maximal (%HR_{max}), and percent reserve heart rate (%HR_{res}), energy expenditure (EE), and integrated energy index (EE/RMR – resting metabolic rate) during daily garbage collection routes for 83 garbage collectors from Rio de Janeiro, Brazil.

Variable	Days of the week				Total Mean ± SD
	Mondays Mean ± SD	Tuesdays Mean ± SD	Wednesdays Mean ± SD	Thursdays Mean ± SD	
	n = 74	n = 80	n = 80	n = 80	n = 314
TWH (min) *	562.4 ± 160.1	590.4 ± 137.1	397.7 ± 123.2	411.4 ± 170.2	489.1 ± 171.6
Heart rate (HR – bpm)	99.4 ± 9.6	96.4 ± 10.4	97.4 ± 11.3	97.4 ± 11.0	97.6 ± 10.6
% HR _{max}	54.4 ± 5.8	52.7 ± 6.1	53.3 ± 6.6	53.4 ± 6.5	53.4 ± 6.2
	n = 63	n = 69	n = 67	n = 67	n = 266
TWT of energy expenditure (min) *	581.5 ± 155.5	600.0 ± 133.4	402.4 ± 127.4	420.6 ± 178.4	500.7 ± 174.3
% HR _{res}	34.4 ± 7.0	31.6 ± 6.6	32.8 ± 8.7	32.5 ± 7.5	32.8 ± 7.5
Energy expenditure (EE – kcal.min ⁻¹)	4.8 ± 1.3	4.4 ± 1.3	4.5 ± 1.6	4.5 ± 1.5	4.5 ± 1.4
Total energy expenditure (kcal) *	2814.7 ± 1167.7 a	2581.9 ± 827.9 b	1769.8 ± 702.1 a,b	1818.8 ± 839.7 a,b	2240.3 ± 1001.5
Integrated energy index (EE/resting metabolic rate)	4.98 ± 1.52	4.50 ± 1.22	4.71 ± 1.69	4.67 ± 1.64	4.71 ± 1.53

* Values with the same letter are significantly different (p < 0.05).

% HR_{max} = [HR/(220-age)] × 100.% HR_{res} = {HR – HR_{resting}/[(220-age) – HR_{resting}]} × 100.

tant to note that garbage collection workers in Rio de Janeiro were in good physical condition, as shown by their relatively low resting HR. Duarte¹⁸ found similar mean daily HR (105.3bpm) in 26 garbage workers from all three shifts (morning, afternoon, and night) in the city of Florianópolis, Santa Catarina State, Brazil. Mean HR for the TWH in the present study (97.6bpm) was lower than in Dutch workers (99.5bpm)¹⁹.

Although the empirical data are limited, work physiologists generally assume that in order to avoid fatigue, the task cannot exceed 30 to 35% of the maximum individual load for a total daily working time of 8 hours⁴. In the present study, mean HR_{res} values were all greater than 30% for

both TWH and TGC on all the assessed days, which can be considered overload (or heavy load) according to the classification by Kemper et al.¹⁹, who suggest that garbage collection work should not be performed at greater than 30% of maximum individual load. In an experimental study on cycling in the laboratory with 12 young adults in Taiwan, Wu and Wang⁸ suggested a value of 24.5% of HR_{res} for an 8-hour workday and 39% for a 4-hour day. Garbage collectors in Rio de Janeiro work far above these levels.

Workers' mean EE was high: approximately 2,800kcal during 9.7 hours on Mondays, which is approximately 5 times the resting metabolic rate (IEI). This level of EE is only found in elite

Table 3

Total time of effective garbage collection (TGC), absolute (HR), percent maximal (%HR_{max}), and percent reserve heart rate (%HR_{res}), energy expenditure (EE), and integrated energy index (EE/RMR – resting metabolic rate) on daily garbage collection routes for 83 garbage collectors from Rio de Janeiro, Brazil.

Variable	Days of the week				Total
	Monday Mean ± SD	Tuesday Mean ± SD	Wednesday Mean ± SD	Thursday Mean ± SD	
	n = 73	n = 79	n = 78	n = 78	n = 308
TGC (min) *	353.0 ± 106.6	343.2 ± 97.5	250.6 ± 82.9	228.9 ± 62.8	293.1 ± 103.9
Heart rate (HR – bpm)	105.1 ± 11.3	102.7 ± 10.6	103.8 ± 13.2	104.6 ± 11.8	104.0 ± 11.7
% HR _{max}	57.6 ± 6.7	56.1 ± 6.2	56.9 ± 7.5	57.3 ± 6.7	56.9 ± 6.8
	n = 62	n = 68	n = 65	n = 65	n = 260
TGC of energy expenditure (min)*	366.8 ± 102.8	349.3 ± 99.5	255.2 ± 82.4	231.0 ± 64.2	300.4 ± 105.6
% HR _{res}	38.6 ± 7.8	36.4 ± 6.9	37.6 ± 9.9	37.9 ± 7.8	37.6 ± 8.2
Energy expenditure (EE – kcal.min-1)	5.5 ± 1.4	5.2 ± 1.4	5.3 ± 1.8	5.4 ± 1.6	5.4 ± 1.6
Total energy expenditure (kcal) *	2035.3 ± 817.4 a	1825.7 ± 710.9 b	1339.4 ± 590.6 a,b	1242.5 ± 506.0 a,b	1608.3 ± 738.5
Integrated energy index (EE/RMR)	5.71 ± 1.62	5.41 ± 1.37	5.56 ± 1.95	5.64 ± 1.87	5.67 ± 1.71

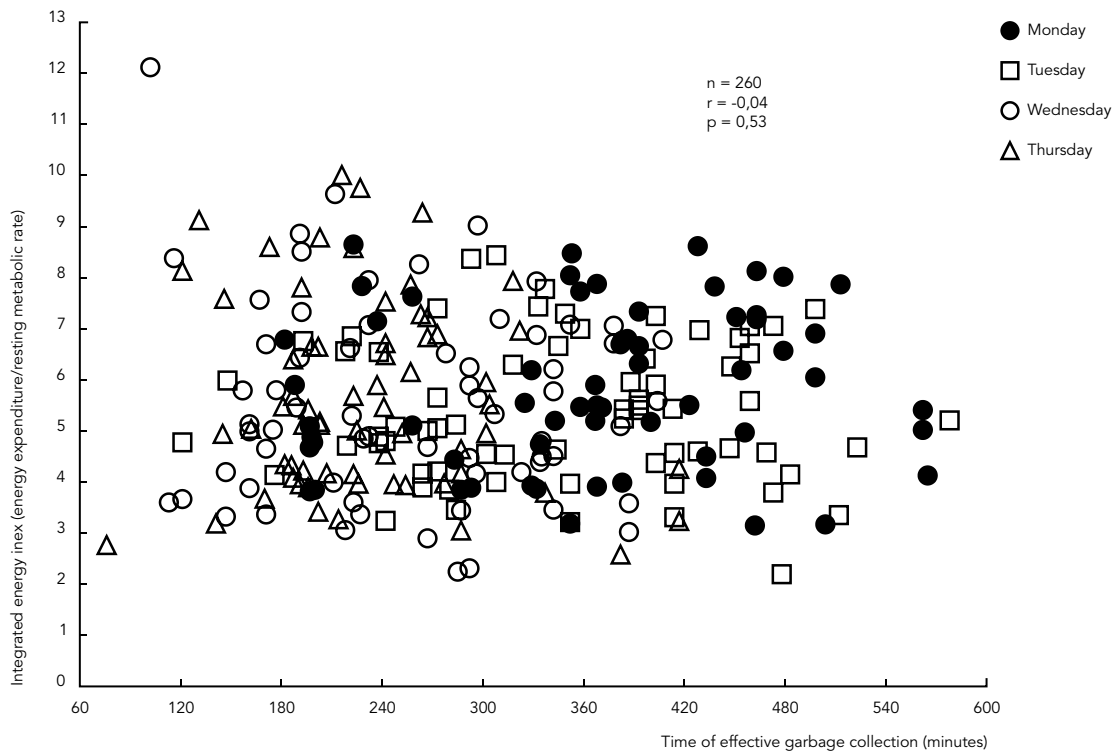
* Values with the same letter are significantly different (p < 0.05).

% HR_{max} = [HR / (220-age) x 100.

% HR_{res} = (HR – HR_{resting} / [(220-age) – HR_{resting}]) x 100.

Figure 1

Relationship between integrated energy index and duration of effective garbage collection for 70 garbage collectors from Rio de Janeiro according to day of the week.



athletes during intensive training. In general, the work's intensity is indirectly related to the duration of the activity, which can be used to determine the maximum acceptable work time for a specific task⁸. In the specific case of garbage collection, this relation is not present due primarily to the fact that the activity is set by the speed of the truck, which determines the work pace and is approximately constant. Although the route was the same, total EE was higher on Mondays and Tuesdays than on Wednesdays and Thursdays, probably because of longer working hours resulting from greater amounts of household garbage produced on weekends.

The data obtained in garbage collectors emphasize the need for the development of appropriate classification of workload and maximum acceptable work time to be used in health-related research in Brazil⁶ and in the assessment of energy needs and nutritional status of the working population, particularly in developing countries²⁰.

There are relatively low-cost alternatives to reduce the workload intensity for garbage collection in Brazil and many other developing countries. Larger wheeled trash containers could be easily transported to the truck and could be hoisted and emptied mechanically, as in many developed countries. This change in the work process would reduce not only EE, but also the movements involved in handling loads: crouching, lifting weight, and torso rotation. Such operational improvements would cost relatively little in relation to the enormous benefit for workers' health and well-being, by reducing the physical demands of garbage collection. Garbage collection conditions have not changed significantly in Rio de Janeiro since 1996. Trucks are almost the same type, with some improvement in noise reduction. In the last two or three years, the use of mechanically hoisted containers has increased mainly in downtown areas and wealthier neighborhoods.

Resumo

A carga de trabalho fisiológica é utilizada para estimar a demanda física de uma tarefa na população de trabalhadores adultos; no entanto, nos países em desenvolvimento há poucos dados disponíveis sobre as diversas atividades ocupacionais. Oitenta e três trabalhadores masculinos participaram neste estudo, com o objetivo de avaliar a carga fisiológica do trabalho de coleta de lixo domiciliar no Município do Rio de Janeiro, Brasil. A frequência cardíaca foi medida em quatro dias de trabalho consecutivos. O gasto energético foi extrapolado a partir da frequência cardíaca, com base em dados individuais obtidos em laboratório para a curva de frequência cardíaca/consumo de oxigênio em 70 trabalhadores. A frequência cardíaca média durante a coleta de lixo era $104,0 \pm 11,7$ bpm, o que representa $56,9 \pm 7,5\%$ da frequência cardíaca máxima. O gasto energético era de $1.608,3 \pm 738,5$ kcal para uma média de $293,1 \pm 103,9$ minutos de trabalho por dia. Com base em todas as medidas, o trabalho de coleta de lixo domiciliar pode ser classificado como excessivamente pesado. Os dados destacam a necessidade de se desenvolver uma classificação apropriada do trabalho, a ser utilizada em pesquisas sobre saúde do trabalhador e para definir cargas máximas de horas de trabalho em relação à carga de trabalho fisiológica, particularmente nos países em desenvolvimento.

Metabolismo Energético; Carga de Trabalho; Trabalhadores; Coleta de Resíduos Sólidos

Contributors

L. A. Anjos and J. A. Ferreira planned the study and supervised the data collection. L. A. Anjos and J. J. Damião performed the data analysis. All the authors participated in writing the text.

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