Evaluation of Workloads of Package Deliverers Focusing on Their Pickup and Delivery Tasks in Republic of Korea

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Abstract: Package deliverers are facing increasing workloads due to a rapid increase in online shopping caused by the recent outbreak of COVID-19 in the Republic of Korea. The purpose of this study was to evaluate the physical workload of package deliverers during pickup and delivery tasks. Heart rate reserve (HRR), metabolic equivalent of task (MET), standardized Nordic questionnaire (SNQ), and visual analogue scale (VAS), measured on site using a wristband, were used as indicators of their workload. Twenty deliverers participated in this study. Work analysis was performed to categorize their tasks into sorting inside a truck, delivering, picking up, driving, and resting. Statistical analysis showed that participants spend 4.3 h per day picking up and delivering 331.9 packages per day. Their work requires about 29.7% of HRR and 4.7 of MET, which are thus considered as of “moderate level” difficulty. SNQ and VAS revealed that their lower back and wrist/hand were the most painful body parts due to repetitive trunk bending and small package handling. The use of a cart would be recommended as it has the advantage of handling many packages at once with less physical effort in deliverers.

Keywords: courier service; heart rate reserve; metabolic equivalent of task; standardized Nordic questionnaire; visual analogue scale

1. Introduction

With the rapid growth of online shopping accelerated by the recent COVID-19 pandemic, courier services have greatly developed worldwide and become a representative logistics industry. Courier services in the Republic of Korea achieved a revenue of approximately USD 7.17 billion in 2021, which is a 14.6% increase over the previous year. The number of packages couriered was about 3.63 billion, corresponding to about 70 packages per person in the same year [1].

The courier service involves delivering packages from one place to another. The typical process of a domestic courier service in the Republic of Korea takes two days, one day for pickup from the shipper to a terminal and the next day for delivery from the terminal to the destination. Shin and Lee [2] surveyed 500 deliverers to identify task durations, working hours, and the number of packages. A pickup task takes 1.6 h. A sorting task at a terminal takes 3.9 h. A delivery task takes 6.9 h. Other tasks, including invoice, scanning, and so on, take 1.1 h on average a day. A deliverer generally starts work at 6:54 a.m. and ends at 8:17 p.m. One deliverer picks up an average of 65.7 packages and delivers an average of 186.9 packages a day. Thus, a deliverer in the Republic of Korea works for about 13.5 h a day, spending 51% of their workhours mainly on delivery. A package only takes 2.2 min to be delivered.

As the courier service develops, the unit price per package continues to decline due to stiff competition between courier companies. Thus, the treatment of deliverers is substantially deteriorating to reduce cost [3]. Most research on the courier service has been limited to truck driver safety [4,5] or drone development for better delivery services [6–8]. For instance, Anderson et al. [4] surveyed courier drivers for safety perceptions of driving...
trucks, and found that loading, drowsy driving, and work tension could cause work-related accidents. Christie and Ward [5] conducted an online survey of courier drivers on car accident experiences caused by fatigue, speeding, and cell phone use while driving a truck.

To the best of our knowledge, only a few studies have been conducted on the workload of deliverers themselves. Jang et al. [9] have measured the labor intensity and physical load of mailmen. They found that mailmen in the Republic of Korea worked eleven hours a day—significantly longer than appropriate working hours. They reported that this overworking could increase the risk of cerebrocardiovascular disease. This heavy workload may lead to a fatal accident. It was associated with the deaths of 15 package delivers from cerebral hemorrhage and myocardial infarction in 2020 [10].

Therefore, more research is required on package deliverers to identify exclusive working conditions in the Republic of Korea and the cardiovascular burden associated with physical workload. The purpose of this study was to assess the physical workloads of deliverers by measuring the heart rate reserve (HRR) and metabolic equivalent of task (MET) on site using a wristband. The ergonomic risk factors of musculoskeletal disorders were also examined by administering the standardized Nordic questionnaire (SNQ) and visual analogue scale (VAS).

2. Materials and Methods

2.1. Participants

The overall experimental procedure that represents the research method of this study is shown in Figure 1. The experimenters personally contacted package deliverers and asked them to voluntarily participate in this study. A total of 20 deliverers (19 male and 1 female) were recruited for this study. Each of them participated only for one day with a payment of USD 200. Their average age, height, and weight with standard deviations were 43.5 ± 6.2 years, 174.4 ± 6.2 cm, and 70.3 ± 11.9 kg, respectively.

Figure 1. Overall study procedure and research method.
2.2. Apparatus

A Fitbit Inspire HR (FB413, Fitbit Inc., San Francisco, CA, USA) wristband was used to measure heart rate (bpm) and energy consumption (kcal/min) in real time with a sampling rate of 1 min while participants performed their tasks for objective evaluation of their workloads.

The standardized Nordic questionnaire (SNQ) and visual analogue scale (VAS) were utilized for the subjective evaluation of workload. Kuorinka et al. [11] developed the SNQ for screening musculoskeletal disorder symptoms. The SNQ contains a general questionnaire constructed with a picture of nine anatomical human body regions of neck, shoulder, elbow, wrist/hand, upper back, lower back, hip/thigh, knee, and ankle/foot by asking the following three questions with binary and multiple choices: (1) “Have you at any time during the last 12 months had trouble (ache, pain, discomfort) in: (a truncated expression of “in the last 12 months” is used from now on in the study)”, (2) “Have you at any time during the last 12 months been prevented from doing your normal work (at home or away from home) because of the trouble? (a truncated expression of “in the last 12 months interfering with work” is used from now on in the study)”, and (3) “Did you have any trouble at any time during the last 7 days? (a truncated expression of “in the last 7 days” is used from now on in the study)”. The SNQ is widely recognized to have good utility in analyzing the physical load of workers with a high repeatability and validity [12].

The VAS is a pain rating scale. Unlike the Likert scale, taking a discrete categorization of none, mild, and severe, the VAS has a unidimensional continuum of pain intensity, representing with a 10 cm line and verbal anchors of “no pain” for 0 and “extreme pain” for 10 [13]. The VAS is internationally used in epidemiologic and clinical research to measure the intensity of various symptoms [14].

2.3. Procedure

The purpose of the experiment was described to participants. They were surveyed for their demographic and job characteristics. The demographic characteristics included gender, age, height, and weight. Job characteristics included career period, working hours per week, the number of packages handled per day, and the number of delivery and pickup places per day.

Participants wore a Fitbit Inspire HR on their wrist. Their age, height, and weight information were added to their smartphone application. After confirming them that the wristband continuously tracks heart rate and energy consumption in real time, their resting heart rates were measured for 5 min in a seated position [15]. Participants then kept wearing the wristband until the end of the experiment.

The experimenter accompanied the participant on his or her duties in order to time their tasks of sorting inside a truck, delivering, picking up, driving, and resting, as well as the usage of carts, stairs, and ramps, as shown in Figure 2, by recording the start time and end time of every task and usage. The sorting task stretched from entering the truck to select the packages to be delivered to stacking them in a cart outside the truck. The delivering task lasted from handling the cart to dropping all packages in designated locations. The pickup task lasted from picking up a package at a designated location to dropping it in a truck. The driving task involved operating a truck to the next location. Resting was taking a break during duties.

The typical working conditions of deliverers involve the use of carts, stairs, and ramps during pickup and delivery tasks. All the carts the participants used had four wheels to transport many packages at once. Stairs and ramps were often observed at the entrances of apartments and shopping areas.

The SNQ and VAS were administered to every participant before participants returned the wristband at the end of his or her duties.
2.4. Data Processing

2.4.1. Data Synchronization

Heart rate and energy consumption measured by the wristband were extracted for every minute using the heart rate and activity intraday time series functions of the Web API provided by Fitbit in the Jason format. After data in the Jason format were converted to Excel data, they were synchronized with the start time and end time of every task recorded on site by the experimenter accompanying the participant.

2.4.2. Heart Rate Reserve (HRR)

Heart rate increased when an activity involved heavy physical tasks. Therefore, it was used as an objective indicator to reflect the degree of workload. Different people have different physical conditions. Their heart rates might be different even if they perform the same physical activity. Thus, heart rate reserve (HRR) was utilized to evaluate the workload reflecting different physical conditions of the participants. HRR was calculated using the following equation [16–18]:

\[
HRR(\%) = \frac{HR_{work} - HR_{rest}}{HR_{max} - HR_{rest}} \times 100
\]  

(1)

where \( HR_{work} \) was the average heart rate, determined by dividing the sum of heart rates collected with the wristband every minute by the working time for each task performed by the participant. \( HR_{rest} \) was the heart rate measured from the participant resting in a seated position for 5 min [15]. \( HR_{max} \) was the maximum heart rate estimated using the age-prediction equation of \((220–age)\) [19].

2.4.3. Metabolic Equivalent of Task (MET)

Energy consumption was also used as an objective indicator to assess work intensity by measuring the energy required for a physical activity, because an arduous task requires more energy [20]. For reasons similar to heart rate, the metabolic equivalent of task (MET) was calculated using the below equation, reflecting the weight of the participant with different physical conditions:

\[
ET = \frac{energy\ consumption}{3.5 \times weight \times 5/1000}
\]  

(2)

where energy consumption is the average energy consumption (kcal/min), determined by dividing the sum of energy consumptions collected with the wristband every minute by
the working time required for each task to be performed by the participant. Weight was the body mass (kg) of the participant. One MET was defined as the energy consumption required for sitting quietly, which was approximately 3.5 mL/kg/min for an average adult and 5 kcal energy were released when 1000 mL of oxygen were metabolized [21].

2.5. Statistical Analyses

Descriptive statistics were analyzed to obtain means and standard deviations for the information of career period, working hours per week, the number of packages handled per day, and the number of delivery and pickup places per day, as well as time taken for every task and the use of carts, stairs, and ramps.

One-way analysis of variance (ANOVA) and Tukey HSD (honest significant difference) tests were performed with HRR and MET as dependent variables. The independent variable was the five-level task of sorting inside a truck, delivering, picking up, driving, and resting. A Student’s t-test was also performed using two-level cart use, two-level stair use, and two-level ramp use, separately, as independent variables. The following statistical model for the ANOVA of HRR and MET was analyzed to determine the statistically significant main effect of the task:

\[ x_{ij} = \mu + t_i + e_{ij} \]  

where \( x_{ij} \) is the dependent measure of either HRR or MET, \( \mu \) is the mean value of the dependent variable, \( t_i \) is the main effect of the five-level tasks, and \( e_{ij} \) is the residual.

The frequency and percentage of the prevalence of musculoskeletal symptoms were obtained for the last 12 months, the last 12 months interfering with work, and the last 7 days for nine body parts of neck, shoulder, elbow, wrist/hand, upper back, lower back, hip/thigh, knee, and ankle/foot by the standardized Nordic questionnaire (SNQ). One-way ANOVA and Tukey’s HSD tests were performed for the frequency as a dependent variable, with body part as an independent variable. The following statistical model for the ANOVA of SNQ was utilized to determine the statistically significant main effect of the body part.

\[ y_{ij} = \mu + b_i + e_{ij} \]  

where \( y_{ij} \) is the dependent measure of the three questions of SNQ, \( \mu \) is the mean value of the dependent variable, \( b_i \) is the main effect of the nine-level body part evaluation, and \( e_{ij} \) is the residual.

One-way ANOVA and Tukey HSD tests were also carried out with visual analogue scale (VAS) as the dependent variable. The independent variable was nine-level body part. Statistical significance was considered at \( p < 0.05 \). Similarly to SNQ, the following statistical model for the ANOVA of VAS was used to determine the statistically significant main effect of the body part:

\[ z_{ij} = \mu + b_i + e_{ij} \]  

where \( z_{ij} \) is the dependent measure of VAS, \( \mu \) is the mean value of the dependent variable, \( b_i \) is the main effect of the nine-level body part, and \( e_{ij} \) is the residual.

3. Results

3.1. Job Characteristics

Participants had an average career period of 8.8 ± 7.0 years. Their average working hours per week were 72.4 ± 7.2 h. The average number of packages handled per day was 331.9 ± 89.4. The average number of delivery and pickup places per day was 193.4 ± 81.8. Participants spent an average of 4.3 ± 1.1 h (equal to 258 ± 66 min) per day on delivery and pickup. When the period was divided into the five tasks of sorting inside a truck, delivering, picking up, driving, and resting, delivering accounted for the most time, at 162.3 ± 39.7 min. The times required were 48.7 ± 31.0 min for sorting inside a truck, 28.7 ± 17.4 min for driving, 11.1 ± 9.7 min for picking up, and 7.2 ± 6.1 min for resting.
Participants used carts, stairs, and ramps primarily during delivering. The average times of using cart, stairs, and ramps were 24.8 ± 9.2 min, 15.7 ± 11.3 min, and 2.5 ± 4.0 min, respectively.

3.2. Heart Rate Reserve (HRR)

ANOVA showed that the tasks had a significant effect on HRR (F(4, 1117) = 7.58, p = 0.001). Tukey’s HSD test revealed that sorting inside a truck, delivering, picking up, and driving tasks had the same HRR. However, resting had a significantly lower HRR than others, as seen in Figure 3 and Table 1. Student’s t-tests revealed no significant difference in HRR resulting from the usage of a cart (t(598) = −1.748, p = 0.081), stairs (t(581) = 0.869, p = 0.386), or ramps (t(518) = −1.267, p = 0.206).

![Figure 3. Heart rate reserve (HRR) results for performing different tasks and using cart, stairs, and ramps. The asterisk represents a significance level of 0.05.](image_url)

| Task       | Sorting Inside a Truck | Delivering | Picking up | Driving | Resting |
|------------|------------------------|------------|------------|---------|---------|
| Sorting inside a truck | 29.5  | 29.1  | 28.7  | 23.3  | 30.4  | 32.0  | 31.6  | 30.7  | 29.8  | 32.1  |
| Delivering | 31.6  | 23.3  | 30.4  | 32.0  | 31.6  | 30.7  | 29.8  | 32.1  |
| Picking up | 29.1  | 28.7  | 23.3  | 30.4  | 32.0  | 31.6  | 30.7  | 29.8  | 32.1  |
| Driving    | 28.7  | 23.3  | 30.4  | 32.0  | 31.6  | 30.7  | 29.8  | 32.1  |
| Resting    | 23.3  | 30.4  | 32.0  | 31.6  | 30.7  | 29.8  | 32.1  |

* The mean difference is significant at p < 0.05.

3.3. Metabolic Equivalent of Task (MET)

Similar to the results for HRR, the tasks also had a significant effect on MET (F(4, 1117) = 8.00, p = 0.001), as assessed by ANOVA. Tukey’s HSD test showed that the METs of the sorting inside a truck, delivering, picking up, and driving tasks were similar to each other. However, resting was associated with a significantly lower MET than other tasks, as seen in Figure 4 and Table 2.

Student’s t-tests showed significant differences in MET resulting from cart use (t(598) = −3.260, p = 0.001). Cart use had a lower MET than non-use. However, the MET was not significantly changed by stair use (t(581) = −0.258, p = 0.796) or ramp use (t(518) = −0.146, p = 0.884).
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![Figure 4. Metabolic equivalent of the task (MET) of performing different tasks and using carts, stairs, and ramps. The asterisks represent a significance level of 0.05.](image)

### Table 2. Mean differences in the metabolic equivalent of task (MET) when performing different tasks, assessed by Tukey’s HSD test.

| Task                  | Sorting Inside a Truck | Delivering | Picking Up | Driving | Resting |
|-----------------------|------------------------|------------|------------|---------|---------|
| Sorting inside a truck|                        |            |            |         |         |
| Delivering            | −0.3                   | 0.1        | 0.2        | 1.3 *   |
| Picking up            |                        |            | 0.5        | 1.6 *   |
| Driving               |                        |            |            | 0.1     |
| Resting               |                        |            |            | 1.2 *   |

*The mean difference is significant at p < 0.05.*

3.4. Standardized Nordic Questionnaire (SNQ)

The results of the standardized Nordic questionnaire (SNQ) reveal that the average prevalence rate of having any trouble (ache, pain, discomfort) was 43% for the last 12 months, 3% for the last 12 months that interfered with work, and 20% for the last 7 days, as illustrated in Table 3. The results of the ANOVA show that the lower back and wrist/hand were the most affected body parts by the prevalence of musculoskeletal symptoms in the last 12 months (F(8, 171) = 3.12, p = 0.003) and in the last 7 days (F(8, 171) = 3.03, p = 0.003). The lower back had the greatest prevalence rate, of 90% in the last 12 months and 50% in the last 7 days. The prevalence of wrist/hand symptoms was 50% in the last 12 months and 25% in the last 7 days.

### Table 3. Prevalence of musculoskeletal symptoms in body parts among participants (N = 20).

| Body Parts     | In the Last 12 Months | In the Last 12 Months Interfering with Work | In the Last 7 Days |
|----------------|-----------------------|--------------------------------------------|-------------------|
| Neck           | 6 (30%)               | 0 (0%)                                     | 3 (15%)           |
| Shoulder       | 8 (40%)               | 1 (5%)                                     | 4 (20%)           |
| Elbow          | 6 (30%)               | 0 (0%)                                     | 0 (0%)            |
| Wrist/hand     | 10 (50%)              | 0 (0%)                                     | 5 (25%)           |
| Upper back     | 7 (35%)               | 0 (0%)                                     | 2 (10%)           |
| Lower back     | 18 (90%)              | 3 (15%)                                    | 10 (50%)          |
| Hip/thigh      | 7 (35%)               | 0 (0%)                                     | 3 (15%)           |
Table 3. Cont.

| Body Parts       | In the Last 12 Months | In the Last 12 Months Interfering with Work | In the Last 7 Days |
|------------------|-----------------------|--------------------------------------------|-------------------|
| Knee             | 8 (40%)               | 0 (0%)                                     | 4 (20%)           |
| Ankle/foot       | 7 (35%)               | 1 (5%)                                     | 5 (25%)           |
| **Mean**         | **8.6 (43%)**         | **0.6 (3%)**                               | **4.0 (20%)**     |

3.5. Visual Analogue Scale (VAS)

The ANOVA revealed that body parts had a significant effect on the pain of VAS (F(8, 171) = 4.41, p < 0.001). Tukey’s HSD test revealed that lower back and wrist/hand were included in the most painful group, as illustrated in Figure 5 and Table 4. Lower back and wrist/hand had pain scores of 4.15 and 3.35, respectively. Ankle/foot, shoulder, and knee were in a different group. Hip/thigh, elbow, upper back, and neck were in another group.

Figure 5. Pain levels of body parts based on the visual analogue scale (VAS). The asterisk represents a significance level of 0.05.

Table 4. Mean differences in the visual analogue scale (VAS) for Tukey’s HSD test of body parts.

| Task               | Lower Back | Wrist/Hand | Ankle/ Foot | Shoulder | Knee | Hip/Thigh | Elbow | Upper Back | Neck |
|--------------------|------------|------------|-------------|----------|------|-----------|-------|------------|------|
| Lower back         | 0.8        |            |             |          |      |           |       |            |      |
| Wrist/Hand         |            | 0.7 *      |             |          |      |           |       |            |      |
| Ankle/ Foot        | 1.5 *      |            | 0.6         |          |      |           |       |            |      |
| Shoulder           | 2.1 *      | 1.3 *      | 0.7         | 0.1      |      |           |       |            |      |
| Knee               | 2.2 *      | 1.4 *      | 1.1 *       | 0.5 *    | 0.4 *|           |       |            |      |
| Hip/Thigh          | 2.6 *      | 1.8 *      | 1.0 *       | 0.9 *    | 0.5 |           |       |            |      |
| Elbow              | 3.1 *      | 2.3 *      | 1.5 *       | 0.9 *    | 0.5 |           |       |            |      |
| Upper back         | 3.4 *      | 2.6 *      | 1.3 *       | 1.2 *    | 0.8 | 0.3       |       |            |      |
| Neck               | 3.4 *      | 2.6 *      | 1.9 *       | 1.3 *    | 1.2 *| 0.8       | 0.3   | 0.1        |

* The mean difference is significant at p < 0.05.
4. Discussion

The purpose of this study was to evaluate the physical workload of package deliverers, focusing on pickup and delivery tasks in the Republic of Korea via heart rate reserve (HRR), metabolic equivalent of task (MET), standardized Nordic questionnaire (SNQ), and visual analogue scale (VAS) using a wristband on site. Deliverers who participated in this study worked for 72.4 h per week, spent 4.3 h per day on pickup and delivery tasks, and handled 331.9 packages per day. Shin and Lee [2] found similar working hours per week, of 74.0 h. However, their participants spent 8.5 h on pickup and delivery tasks, and handled more than 252.6 packages. Jang et al. [9] found that mailmen in the Republic of Korea have shorter working durations per week, at 57.5 h, than those in the present study and in Shin and Lee’s study [2]. Such differences among studies are mainly due to the period of experiment, and the pickup and delivery areas covered by the participants. The experiment in the present study was performed in a week prior to Korean Thanksgiving Day, when the volumes of deliverers usually increased. In addition, the participants were in charge of apartments and shopping areas where many packages were handled at one time, with a relatively short carrying distance.

It was found that deliverers spent the longest time (162.3 min) on delivering among the five tasks examined in the study. They used stairs and ramps only for short durations (15.7 min and 2.5 min, respectively) while delivering and picking up. The occasional use of stairs and ramps due to the required delivery method would not be related to the physical fatigue of deliverers. The participants use a loaded cart to get from the truck to the entrance of an apartment, and dragged the cart up a short ramp installed in the entrance for the disabled. They then took an elevator with the cart, moved up to the top floor, and stopped at each floor to deliver packages to the designated door while the elevator door was opened. They generally only used stairs for low stories.

This study has revealed that package deliverers required about 29.7% of HRR for pickup and delivery tasks. This amount of HRR was similar to that of about 27% of mailmen in the Republic of Korea [9], and 29.2% of short distance gas cylinder deliverers in Canada assessed by Sekkay et al. [22]. They concluded that a gas cylinder delivering task would be moderate work, and that 3.5 h would be appropriate for the task in a given working day.

Although this study did not find any statistically significant difference in HRR or MET among task types, the tasks of delivering as well as sorting inside a truck appeared to be difficult, because delivering required handling many packages at once and walking a long distance. Sorting inside a truck required loading packages into a cart placed outside by repetitively moving up and down the truck. Picking up showed a relatively low workload because a few packages were returned from an apartment complex to a truck.

The use of cart, stairs, and ramps had no significantly different effects on the physical fatigue of deliverers in terms of HRR or MET, because they mainly used elevators—instead of carts or stairs and short ramps—for the short duration they spent at the entrance of an apartment. Participants used carts to move slowly when handling many packages, while they carried them by hand in the case of only having a few packages. Both cases resulted in a lower burden on heart rate and energy consumption. In addition, they used stairs at low stories after getting off an elevator, which required less physical exertion than ascending stairs [23].

Both the standardized Nordic questionnaire (SNQ) and visual analogue scale (VAS) showed that the lower back and wrist/hand were the most painful body parts, resulting in a greater prevalence of musculoskeletal symptoms due to repetitive trunk bending and small package handling while performing pickup and delivery tasks.

5. Conclusions

This study performed empirical research by systematically categorizing factors affecting package deliverers into demographic characteristics, job characteristics, task type, and working conditions in order to evaluate the degree of their physical workload. The
two objective indicators of heart rate (converted to heart rate reserve (HRR)) and energy consumption (converted to metabolic equivalent of task (MET)) were measured with a wristband in real time, and the two subjective indicators of standard Nordic questionnaire (SNQ) and visual analogue scale (VAS) were surveyed.

The statistical analyses of the indicators revealed that the pickup and delivery tasks carried out by the package deliverers in the Republic of Korea could be considered as having a “moderate level” of work difficulty. Deliverers suffered from pain in the lower back and wrist/hand due to repetitive lifting and handing motions. Based on the results found of the current study, the use of a cart is recommended, as it has the advantage of enabling the handling of many packages at once, with less physical effort required of deliverers.

This study established a research method suitable for assessing the degree of physical workload of package deliverers through a series of research processes. It could fill in the gaps in the research on deliverers themselves. Although only twenty deliverers were recruited in this study, the sample sizes of the objective indicators of HRR and MET may be just about enough to reach statistically significant conclusions, because data were collected from the wristbands every minute. However, the data surveyed from deliverers would not be enough to reliably generalize the results on the subjective indicators of SNQ or VAS. More research on deliverers is necessary to derive significant generalized results. The method suggested by this study would be helpful for such research.

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