Evaluation of Ergonomic Risks among Last-Mile Delivery Workers during Parcel Delivery

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Abstract

A delivery employee in E-Commerce industry carrying bulky logistics backpack on their shoulder to deliver the item to the right destination in scheduled duration. Their body muscles are subjected to constant strain when executing last-mile delivery. The objective of this study is to investigate Erector spinae muscles subjected to high loading while walking over a flat surface. The impacts of the varying weight of the logistics backpack were studied for activation by muscle. Walking speed at 1.11 m/s with no load, 10kg, 20 kg and 30kg was maintained by twelve healthy adult male participants. Response of Erector spinae (ES) muscles, longissimus (LO), and iliocostalis (IC) have been measured for sEMG. With increasing load conditions determined by one-way ANOVA. The mean surface electromyography (sEMG) for ES muscle activation was found not statistically significant while walking over the flat surface on a higher load. When comparing the muscles of both sides of the erector spinae, LO and IC, a statistically significant change was observed while walking with a weight of 10kg ($p = 0.0001$), 20kg ($p = 0.0001$), and 30kg ($p = 0.00003$).Among last-mile delivery employees, normalized sEMG activation in the ES muscles is found statically significantly within muscle groups while carrying a backpack load condition.

Keywords

backpack, erector spinae, electromyography, e-commerce, low back pain.

1. Introduction

During the COVID-19-induced lockdown, the role of the gig economy was clearly visible, with significant growth in E-commerce. With increasing demand in the E-commerce industry, there is demand for delivery workers. As a result, the gig economy has been popular among occupational workers in India. Small pick-up trucks are used for delivery of parcels with large weight and volume, while for the inner-city centers with high population density; two-wheelers are used to deliver parcels with a logistics backpack. Various factors in occupational jobs are responsible for developing stress. Extreme target pressure, on-time delivery, and the desire for incentives, as well as working long hours, all have a negative impact on performance and have adverse effects on one's health(Cousins et al., 2004; Heiland, 2022).This will also increase with growing number of B2C e-commerce shipments. It is expected to reach 12 million per day shipments by 2024(Statista, 2022). The fatigue issues are worse experiences among delivery staff in densely populated areas. It includes workplace environment, driving habits, and crash engagement of delivery employees, all of which have an impact on job efficiency. Heavy load, experiences of exhaustion, and risk-taking actions all had direct and substantial effects on crash involvement, whereas time pressure and other work-related qualities influenced accident involvement indirectly by impacting riders' feelings of fatigue and riding behaviors. (Zheng et al. 2019)**.**Carting heavy delivery bags and work pressure increase the health disorders among last mile delivery workers (Nasreen and Purohit 2017).

1.1 Objectives

The activation of the ES muscle group comprising left iliocostalis (LI), left longissimus (LL), right iliocostalis (RI), and right longissimus (RL) has not yet been studied using an e-commerce logistics backpack with different weights. The objectives of the research work is to examine the impact of backpack weight on key modifications in the erector spinae (ES) muscles during walking. The study had hypothesized that increasing the load masses on logistics backpacks would enhance muscular activation in the erector spinae muscle. The effects of load may vary between the left and the right group of muscles of ES. It may provide a better approach to developing improved carriage methods and support systems to reduce ergonomic risk among last-mile delivery personnel.

2. Literature Review

In the E-Commerce sector, human factors should be considered. The investigation of various research studies gave evidence that human factors had largely been ignored in planning models for order picking (Grosse et al., 2017). The design of a backpack must lower the pressure on the spine. The backpack weight must, however, be limited to 10% of body mass. Heavier backpack load has a direct relation with back pain, higher thoracic flexion, lower ES muscle activation, and elevated heartbeat (Devroey et al. 2007; Rohlmann et al. 2014). A last-mile delivery worker uses a backpack carriage with a weight with a larger volume. In densely populated areas, a delivery method that combines driving and walking has been suggested as the latest solution to last-mile delivery difficulties(Bates et al. 2018; Martinez-Sykora et al. 2020). Last-mile delivery workers typically stand and walk with backpacks while delivering packages. The risk of fatigue may rise in back muscles, which can contribute to Low Back Pain. Various research studies have shown that manual lifting of a load and traveling while carrying the load at the back causes work-related musculoskeletal disorders (wMSDs) in humans (Knapik et al. 1996).

Various studies had conducted to analyze the effect of backpack loading on school-age students, soldiers, and other activities. Low back pain arises when carrying a load on the back as it affects the spine too (Ozguler et al. 2000). Different research analyses of muscle activity and joint forces are important in studies. To understand the mechanisms linked to wMSDs as higher internal loading and its rate are linked with both severe and chronic injury (Burr and Milgrom 2000). Lower back musculoskeletal systems (Bruno et al. 2015, Christophy et al. 2012)were also considered in full-body models to study load on the spine while in motion (Actis et al., 2018; Wettenschwiler et al. 2017). The disproportionality of variations in joint load between light and large backpack carriage weight indicates significant variation in the lumbar spine. Effects of backpack load on the lower limbs while walking on the level ground had also been investigated and significant muscle activation has been observed (Singh et al. 2021). During last-mile logistics delivery in urban cities in India, similar load carrying conditions with backpacks are observed.

During this investigation, a logistic backpack was considered an external source of stress on the erector spinae (ES) muscles while walking. Surface electromyography (EMG) has been proved to be a valid technique for measuring muscle activation and has already been seen in research to evaluate the functioning of muscle in the lower back (Adams and Dolan, 2005; Lawin et al. 2018).The activation of the ES muscle group comprising left iliocostalis (LI), left longissimus (LL), right iliocostalis (RI), and right longissimus (RL) has not yet been studied using an e-commerce logistics backpack with different weights.

3. Methods

A. Subjects

A convenience sample of twelve healthy male adult volunteers who gave consent willingly for the analysis was selected. The experimental procedures were approved by the university ethics committee. They were informed of the experimental protocol and a written consent letter for this study was submitted. These participants were advised to wear body shorts. All of the respondents reported no medical issues in the last 12 months. Exclusion criteria included pre-existing cardiovascular, musculoskeletal disorders, or major surgery within the previous year. Demographic data of subjects were measured and recorded. The participants' age (years), height (cm.), weight (kg.), and body mass index (kg/m2) were measured and recorded on the day of the experiment (Table 1).

B. Experimental Protocol

All studies were carried out in a laboratory with standard settings at temperatures ranging from 25 to 28°C. Before conducting the study, all participants were requested to relax for a half-hour rest period. The logistic bag chosen in our trial was of a similar model which is used by most of the E-Commerce enterprises as their logistics delivery bag, as shown in Figure 1. Each participant has been requested for walking for 5 minutes with a pace of 1.11 m/s on a flat ground level (Liu et al., 2020; Paul et al., 2016; Saibene and Minetti, 2003). The individuals walked on the level surface with a backpack weighing no load, 10kg, 20kg, and 30kg. To simulate the real experimental conditions, the participants were asked to carry a backpack with defined load conditions. Then they have to begin walking for at least 5 minutes before the experiment. Participants were instructed for resting for a minimum of 5 minutes between two consecutive testings. This procedure was carried out following each load condition of the backpack and was followed by all participants (Figure 1 and Table 1).

Table 1. Demographic details of subjects

No. of Subjects	**Age (yr. ±SD)**	**Weight (kg. ± SD)**	**Height (cm. ±SD)**	**BMI (kg/m2 ±SD)**
12	23.63 ± 6.35	75.88 ± 7.86	178.34 ± 7.44	23.79 ± 1.20

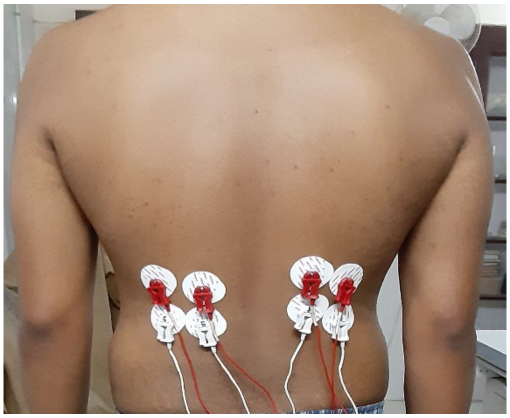

Figure 1. Electrode Placement on ES muscles

4. Data Collection

EMG Signal Measurement

Surface electromyography (sEMG) signals were recorded from the bilaterally muscles activation of Longissimus and Iliocostalis using Biopac MP150 system, Biopac Inc., USA(G. K. Singh et al., 2018; G. K. Singh and Srivastava, 2020). Surface Electromyography (sEMG) procedures were carried out according to the International Society of Electrophysiology and Kinesiology's guidelines(Drost et al., 2006; Me, 2018).Latex-free disposable Ag/AgClsEMG electrodes (Romsons Scientific and Surgical Pvt. Ltd, Agra, U.P., India) with a circular shape with 45 x 42 x 1 mm size were placed as shown in Figure 2. Both pairs of sEMG electrodes were placed under SENIAM guidelines for electrode placement (Cousins et al., 2004; Stegeman and Hermens, 2007). The amplitude and other spectral variables of the EMG data may be greatly changed by moving the electrode across the muscular belly. As a result, it was essential to precisely place the electrode on the muscular belly, which resulted in the best EMG output. A faulty electrode placement can lead to data inaccuracies and misleading findings. Both electrode pairs had been aligned with the muscle fibers' direction. Before trials, the area was shaved and excess hair was removed, where the skin surface at the sensor location was covered with hair and cleaned the skin with medicinal spirit and allowed it to vaporize so that the skin surface gets dry before the sensor is positioned.

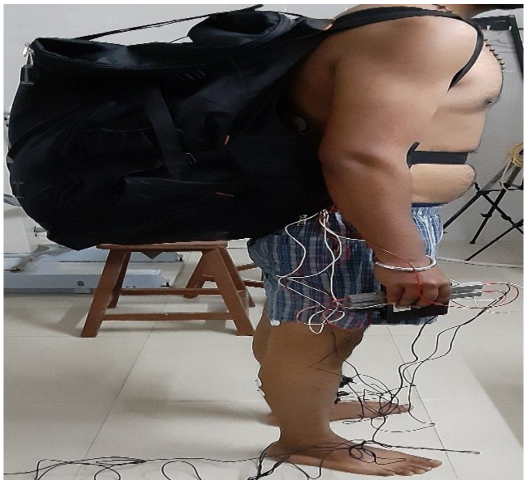

Figure 2. Subject with a logistics backpack load

Participants contracted each muscle during the trials, the data and condition of the EMG signals were checked carefully (Figure 2). The electrode position was carefully examined. EMG data of muscles filtered with a cut-off frequency of 20-400Hz and rectification was done with Biopac Systems, Inc'sAcqKnowledge 4.1 software (Ekström et al., 2020; G. K. Singh et al., 2018).This study also calculated the root mean square for each muscle. The window length kept constantly at 100ms (Konrad P, 2005). The final 30 seconds of every participant was taken into consideration for obtaining EMG data for during testing. The filtered EMG signals have been used to calculate the mean EMG to estimate individual muscular activity while experimenting, as shown in Figure 3. Normalisation of EMG data was done to the mean amplitude from MVC trial taken before data collection for different loading at different weights of 10kg, 20kg, and 30kg.

EMG differences at various loads were being used to determine the statistical significance of the findings by one-way repeated measures analysis of variance (ANOVA) for individual muscles. Statistical data analyses were performed with the Statistical Package for the Social Sciences (SPSS 16.0, Chicago). The least significant difference (LSD) test was applied for post hoc analysis. If significant ($p < 0.05$) major were detected, it supported comparing average sEMG of an individual muscle(Kim and Lee, 2017; G. K. Singh et al., 2018).

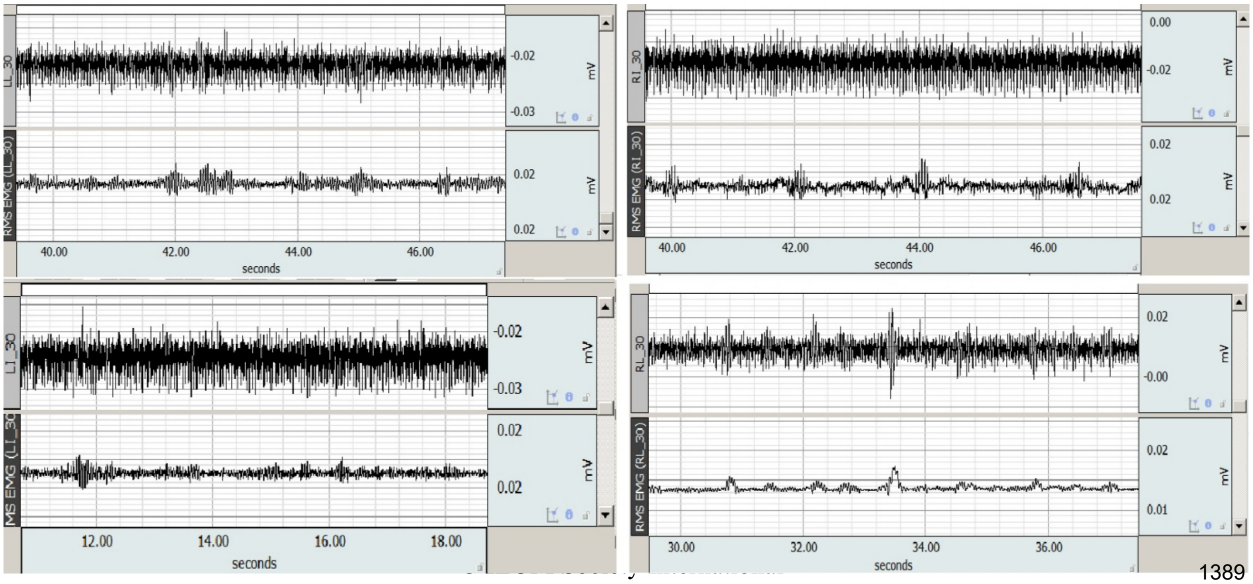

Figure 3 Rectified and RMS EMG signal of LL, LI, RL, and RI at 30 kg load

It has been implemented to use to define which muscle activation with given backpack conditions is distinct from one another (Figure 3).

5. Results and Discussion

There were twelve participants and no statistically significant difference was observed in between 0L, 10L, 20L, and 30L load conditions ($p > 0.05$). The mean EMG signals of muscle fibers were collected during walking, carrying backpack load in a trial. Normalization was done to the mean activation with the peak mean EMG signal of muscular activity within that group of provided loading. However, a statistically significant difference was observed among LI, LL, RI and RL while walking with 10kg ($p = 0.0001$), 20kg ($p= 0.0001$) and 30kg ($p = 0.00003$). At the 95 percent confidence level, the significance level has been calculated to be less than p ($p=0.05$). So, it was inferred as statistically significant. Except for RI and LI, all of the group -muscles showed statistically significant muscle activation in post hoc analysis. When applying and increasing backpack load, there was a statistically significant difference among the ES muscle group ($p < 0.05$) (Table 2).

Our investigation's purpose was to investigate the effect of backpack load over muscle activation on ES muscles while walking and carrying a logistics bag during last-mile delivery. The study found a minor variation in muscle activation as the load of the backpack increased. These results are not significant statistically while they were observed as significant during walking uphill with a backpack in previously published findings (Paul et al., 2016).The present study's findings supported our hypothesis regarding the significant variation observed in the left and right groups of ES muscles during all loading conditions while walking with a backpack. The variation among the mean EMG activation of LI, LL, RI, and RL was depicted, and it can be predicted about unsymmetrical muscle activation on the left and right portion of the body among all subjects as shown in Figure 4.

When walking with a heavier backpack above 10% of body weight, the increase in the ratio of normalized mean EMG was observed in LL and RL. The rise of 44% to 69% of EMG muscle activation was depicted by the ratio of LL and RL. The ratio of both LO muscles, when compared to the 0L condition, showed an increase of up to 8% in higher backpack load conditions. Whereas, a decrement of 8% to 15% was found in the ratio of LI and RI. An increment of up to 3% was found in their ratio when compared to 0L (Table 3). These differences in muscle activation on the left and right sides of the body could be due to asymmetrical muscle activation caused by the subjects' dominant side. Furthermore, these findings point to future research into subjects' dominant sides as well as symmetrical and asymmetrical logistics backpack loading (Table 2 and Table 3).

Table 2. Mean ±SD peak muscle activation across muscles

Muscle	No Load	10kg	20kg	30kg
LL	0.987 ± 0.006	0.979± 0.021	0.948± 0.056	0.956± 0.06
RL	0.610 ± 0.241	0.957± 0.229	0.656± 0.094	0.569± 0.218
LI	0.833 ± 0.051	0.823± 0.061	0.799± 0.078	0.843± 0.087
RI	0.937 ±0.122	0.892± 0.151	0.937± 0.116	0.921± 0.159

Table 3. Mean ±SD peak muscle activation

Muscle	No Load	10kg	20kg	30kg
LO	1.62	1.69	1.45	1.68

IC	0.89	0.92	0.85	0.92

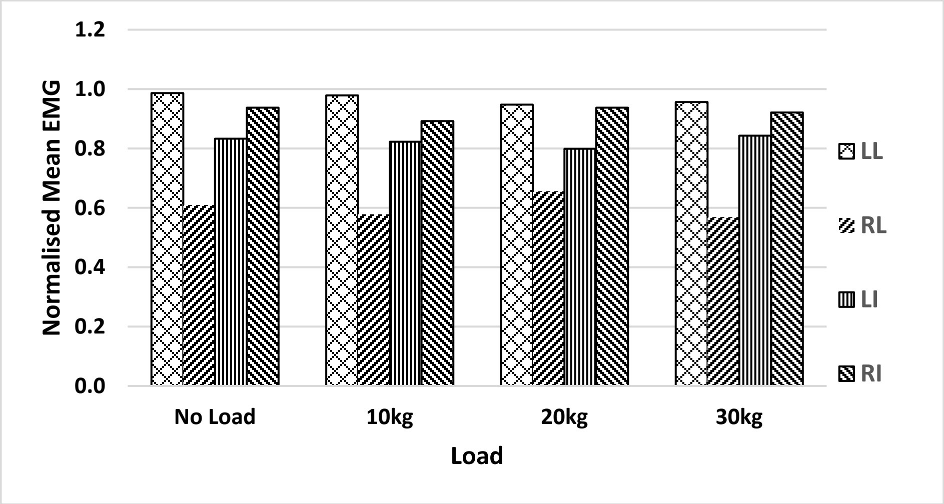

Figure 4. Normalised Mean EMG of LL, RL, LI, and RI at different load conditions

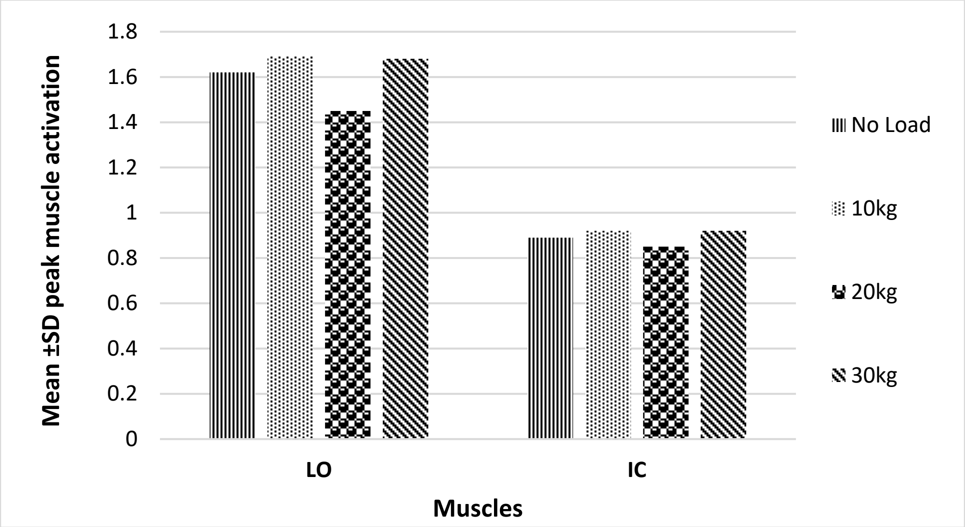

Figure 5. Mean ±SD peak muscle activation on both muscles group.

In our study, the comparison of different load conditions of logistics backpacks was limited to sEMG from the ES muscle group. These muscles play an important role in load-carrying(Sturdy et al., 2021). However, as per indications of results, no significant difference was observed for the higher load on ES muscles (Figure 4).The Mean ±SD peak muscle activation on both muscles groups shown in (Figure 5). Hence, our primary hypothesis is that ES muscle activation may be higher in increasing a load of the backpack when walking and maintaining proper posture. The comparison of the left and right sides of LO and IC approached significance and can be investigated further. Determination of the kinematic data was one of the limitation of the present analysis. Furthermore, one more restriction of our evaluation can be more muscles can be investigated and other conditions might have been investigated to explore more substantial improvements and reduce fatigue.

6. Conclusion

In this study investigation was done over EMG activation of muscle group of ES under the influence of varying load conditions of logistics backpack while walking over flat surface. It was found that the no significance of load over LO and IC with the increased load but it was noteworthy that variation in muscles activity was observed during walking with weights mostly among the left longissimus as compared with the right side. Future research can explore the effects of strain rate on various other muscle groups like the upper back, shoulder, and lower limb muscles. It will benefit in providing support in the modification and better designing logistic backpacks. It will help in developing better lumbar extensor strengthening exercises to increase the endurance of last-mile delivery workers.

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