EFFECT OF LOGISTICS BACKPACK LOAD ON LOWER LIMB MUSCLES ACTIVATION IN E-COMMERCE WORKERS

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ABSTRACT

Background: In the E-Commerce sector, a delivery person carries a heavy logistics bag on the back to deliver the parcel to customers on time. While performing last-mile delivery tasks, their body muscles are prone to heavy loading.

Purpose: The existing study intends to examine the effects of higher load during floor walking on various lower limb muscles.

Methods: The muscle activation was examined with the effects of the different weights of the logistics delivery backpack. Eight healthy adult male participants walked at a speed of 1.11 m/s with zero load (0L), 10 kg (10L), 20 kg(20L), and 30kg(30L). The Surface Electromyography (sEMG) responses of leg muscles Gastrocnemius (GA) and Vastus Medialis (VM) were recorded.

Results: On comparing with no load condition, statistically significant rise was noticed for GA and VM while walking with 30kg load (GA, p = 0.04049 and VM, p = 0.02788). The mean sEMG of muscle activation increases significantly with increasing load conditions on the human body indicated by One-way ANOVA.

Conclusion: sEMG activity of lower limb muscles is higher at higher load conditions than their activation at lower and no load on last mile delivery staff.

Keywords: Electromyography, Last mile delivery, Logistics backpack, Lower limb, Muscle activation.

I. INTRODUCTION

A rapid growth in the E-Commerce sector across the world in last decade has developed a substantial rise in parcel delivery jobs in market. Last mile delivery is one of the most significant elements of the order fulfilment process and one of the critical aspects of the supply chain [1-2]. With the growing number of online orders, businesses are under pressure to provide customers with quick, on-time product delivery [3,5-7]. Crowd shipping is one of the supply chain strategies used since employees are only recruited for one or several deliveries in a short period of time, and there are no expenditures for long-term wages, medical insurance, fuel, or automobiles [8]. Different last mile delivery models are proposed by various researchers like delivery through van, two wheelers, walking which involves at least one human to complete this delivery process. In recent studies
driverless vehicles and delivery through drones are also proposed as model of delivery process. Research studies has also suggested that in urban densely populated city centers are suggested with delivery through walking can be preferred in improving genuine delivery process. A combination of driving and walking delivery system is also considered as alternative of last-mile delivery issues in populated places [9,12]. But mostly in crowdsourced shipping, a human with a logistic backpack is hired in order to deliver the parcel. Last-mile delivery workforce working in such a physically strenuous working environment. Similar cases such as parcel delivery, where severe working conditions and low pay are routinely reported in the media [4]. In order to improve his performance, numbers of trips are increased and repetitive task of loading and unloading of bag is involved too. The repetitive and strenuous task, walking with the logistics backpack exposes human body to muscular pain and injuries [10].

Several research studies were also done over increased risk of muscle injuries while performing task with backpack loading while walking and physiological and biomechanical aspects of various subjects have been explored too. Walking while carrying load requires high energy and joint moments. Many researches have been carried to investigate the energetics and kinematics with different backpack loads during level walking [12-15]. Musculoskeletal stiffness was examined on basis of different waling speed and was observed that it varies as speed and load changes. Researchers have made investigations on muscle activation patterns during level walking with load carriage [16-18]. The muscle activation changes with increased weights to manage the balance and reduced the loads exerted over the lower limbs [18]. When walking with a backpack, the metabolic expenditure rises significantly due to the higher energy requirement related with developing muscle effort to sustain the increased load. [19]. The effect of balanced rather than unbalanced load carriages on older adults’ muscle revealed that unstable load carriages increases rectus femoris and soleus activity, while balanced load carriage increases RF activation [20]. Greater lower limb muscle activation found in the vastus lateralis (VA), vastus medialis (VM), rectus femoris (RF), and gastrocnemius (GA) comparing unloaded walking with walking [21-23]. The studies reported that backpack load can be an element to rise the dynamic forces on the human body. Young adults had higher spatio-temporal gait variability, 61 double support time, and shorter step length when walking while loaded. [24-26]. As suggested in study for combining walking with driving in last mile delivery model, the constraint is further emphasized by walking for more duration, which can be investigated using restrictions like mass and size, as in logistic parcel bags. The muscle activation in lower limb was not yet examined with these kinds backpack with varying weight.

The aim of this research is to see how different loads affect a pair of lower-limb muscle activities while walking carrying a logistic parcel bag. It may provide a better insight to develop better backpack design or support system to reduce effect of weight on delivery boy working in last mile delivery. We hypothesized that lower limb muscles like Gastrocnemius (GA) and vastus medialis (VA) muscle activation will increase on increasing load on backpack as compared with zero load(0L). It is expected to get increased muscle activity during increased load of backpack. Muscle activation would be higher in Gastrocnemius (GA) than vastus medialis (VA) muscle.

II. METHODS

Subjects

Eight young healthy male adult participants agreed voluntarily to participate in this study. All the subjects were instructed to wear shorts on the body and obtained a written consent for the experimental protocol. All the participants reported no health injuries since last one year. Exclusion criteria included pre exiting cardiovascular, orthopaedic diseases and major surgeries during the last one year. Demographic details of participants were measured and collected. On the day of the test, the subjects’ height in centimetres, weight in kilograms, and body fat percentage were calculated (Table 1).

Experimental Protocol
All the experiments performed in laboratory with standard setting within a temperature range 25-28°C. All the participants were asked to sit for half hour to take rest before staring of the experiment. The logistic bag chosen for experiment was same model which majority of E-Commerce companies are using as logistics delivery bag. Each subject was required to walk at a speed of 1.11m/s for 5 minutes on a flat ground floor. The speed was selected refereeing to the standard data as per American College of Sports Medicine [32]. The subjects walked on the level ground floor at with backpack having weight zero load(0L), 10kg(10L), 20kg(20L), and 30kg(30L). Before the actual experiment, the subject was required to carry the backpack of given load condition and walk for 5 min to get the real experimental conditions. Subjects were asked to take rest for at least for 5 min between different load tests. This procedure was done after every load conditions of backpack and followed by all the subjects.

<table>
<thead>
<tr>
<th>No. of Subjects</th>
<th>Age (yrs. ±SD)</th>
<th>Weight (kgs.±SD)</th>
<th>Height (cms.±SD)</th>
<th>BMI (kg/m²±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>23.5 ± 6.0</td>
<td>77.13 ± 7.7</td>
<td>179.07 ± 7.43</td>
<td>24.03 ± 1.66</td>
</tr>
</tbody>
</table>

Table 1: Demographic data of participants
Electromyography Signal Measurement and Data Analysis

EMG activities were recorded using Biopac MP150 system, Biopac Inc., USA [38,39]. The muscles selected included GA and VM in which the muscles activation is found during the human lower extremity during the human lower extremity movements [29]. EMG procedures that were followed as guidelines suggested by International Society of Electrophysiology and Kinesiology [28].

After the preparation of the skin surface, the sEMG electrodes (Ag-AgCl) (Romsoms Scientific & Surgical Pvt. Ltd, Agra, Uttar Pradesh, India) were positioned on the muscle bellies. Before placement of electrode hair were removed from skin and was cleaned with spirit and towel. The skin surface was made dry to ensure proper attachment. To restrict displacement between the sensors and the muscles while walking, double-sided tapes were used to hold the sEMG signal sensors. The electrodes were placed parallel to the direction of the muscle fibres on the GA and VM [fig.1 & fig.2]. When subjects contracted each muscle, the quality of the EMG signals was inspected visually, and electrode positioning was checked thoroughly. The ground electrode was positioned 6 to 8 cm from the inferior pole of the patella along the shaft of the anterior tibialis, as per standard norms [30,31]. The EMG signals of muscles were filtered by applying a cut off frequency of 20 - 400Hz and rectified on AcqKnowledge 4.1 software, Biopac Systems, Inc [39]. For each muscles root mean square calculation was also done by this software. The window length was kept 100ms [27]. The EMG data was recorded for the duration of the final 30 s of each subject trial. The filtered EMG signals were taken into use to determine the mean of EMG to find individual muscle activation during the activity as in fig.3 & fig 4(a)&(b). All EMG data of different load conditions with the weight of 10kg, 20kg and 30kg was normalized to mean amplitude of maximum data activation of muscle in that group.

Figure 3. Raw EMG Signal for GA and VM muscles
Statistical Analysis

sEMG differences among the muscles were taken to test the statistical significance by using one-way repeated measures analysis of variance (ANOVA) for individual muscle. The least significant difference (LSD) test was performed for post hoc analysis to compare the average sEMG of particular muscle conditions if significant (P < 0.05) main effects were discovered [39]. It was used to specify which backpack conditions distinct from one another (Table 3).

III. RESULTS

The mean muscle activities of lower limbs increased with increasing load of bag (Figure 5). The mean EMG signals of muscles while walking with a load mass in one stride, normalized to the mean activity with maximum mean EMG of the activation of muscles within that group of given backpack load (Table 3). As compared to walking with 0L, statistically significant increase was observed for GA and VM during walking with 30L (GA, p = 0.04049 and VM, p = 0.02788). p (p=0.04049) was determined to be less than standard p(p=0.05) at the 95 percent confidence level. So, it was inferred as statistically significant. Increasing backpack load had shown a significant change on both the muscles(p<0.05). On comparing with the walking with 0L, the mean EMG of GA increased by 2% to 5% with backpack of 30L and the VM increased by -4 % to 16% (Table 2).

Table 2: The ratio of EMG between walking with backpack load and without load

<table>
<thead>
<tr>
<th>Muscle</th>
<th>0L</th>
<th>10L</th>
<th>20L</th>
<th>30L</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA</td>
<td>1.00</td>
<td>1.01</td>
<td>1.02</td>
<td>1.05</td>
</tr>
<tr>
<td>VM</td>
<td>1.00</td>
<td>1.00</td>
<td>1.08</td>
<td>1.16</td>
</tr>
</tbody>
</table>

Table 3: Normalized Mean (Mean SD) EMG activation while walking with different backpack loads.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>0L</th>
<th>10L</th>
<th>20L</th>
<th>30L</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA</td>
<td>0.92±0.04</td>
<td>0.94±0.69</td>
<td>0.94±0.75</td>
<td>0.97±0.80</td>
</tr>
<tr>
<td>VM</td>
<td>0.69±0.06</td>
<td>0.69±0.07</td>
<td>0.75±0.07</td>
<td>0.8±0.11</td>
</tr>
</tbody>
</table>
The motive of our investigation was to find the effect of an increase in load on the muscular activity in the lower limbs of the human body carrying a logistics backpack while walking during last mile delivery. The study results with increased mean EMG of leg muscles correspond to previously published findings [33]. The findings of present study endorsed our hypothesis which was lower limb muscles like Gastrocnemius (GA) and vastus medialis (VM) muscle activation will increase on increasing load on backpack as compared with zero load(0L). When walking with a heavier backpack(30L), the increase in the amplitude of GA and VM sEMG signals became statistically significant (30L). The mean amplitude of GA and VM rise with loads in our investigation, which was consistent with earlier findings [33,34].

The purpose of VM is to facilitate leg extension. This increase in muscle activation in the current study possibly suggests that knee extension and flexion is managed to compensate the greater load and maintain lower limb stability while level walking with backpack. Increase in the knee extensor muscle produce more force for body support during the initial phases of stride [22,35,36]. By increasing the plantar flexing, increased activation of the GA resulted in greater effort for walking, which had been thought to counteract inertia caused by heavier backpacks [37]. When walking with larger backpack loads, the knee extensor muscles might be a significant muscle, as in findings [22]. Our study involved flat walking conditions with a backpack load, whereas other research involved slope walking. The EMG of GA and VM were evaluated in this study to explore at muscle activation when walking with a backpack load during delivery operations in supply chains of e-commerce sector.

One limitation of the present analysis was that we have not determined kinematic data in our investigation, which could have added support to our findings. Moreover, another limitation of our analysis is that the muscles examined were limited in number, and other leg extensor muscles could have been studied to determine more significant changes. The higher muscle activation is observed in lower limb muscles findings while walking over slopes with backpack loads and without backpack load in soldiers.

V. CONCLUSION

The effects of a logistics backpack load on the lower limb muscles activation while level walking was investigated in this study in findings. It was found that the knee extensor muscles activity were increased while walking with loads mostly among the GA muscles as compared with VM muscles of lower limbs. Future study aims to look into the effect of increasing load on various other muscles, of increasing load on different other muscles of lower limbs as well as upper back muscles, more participants can be included. It will support in more modification of designing logistic backpacks, making last mile delivery more efficient.

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CONFLICT OF INTEREST

No conflicts of interest to report.

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