Ergonomic Benefits of the Patented LogOX 3-in-1 Forestry MultiTool

By: Jonathan Canniff, Gabriella Borea, Gabriella D'Angelo, Gunnar Brewen

Advisor: Dr. Sriharsha Srinivas Sundarram, Department of Mechanical Engineering

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Fairfield University, Fairfield, CT 06824

ABSTRACT

Treecare industry workers experience a higher than average percentage of back related injuries due to the nature of the work involved. Hence, a market has evolved for tools that help mitigate these injuries. The US manufactured LogOX 3-in-1 Forestry MultiTool is one of such tools. The goal of this study is to empirically test the potential ergonomic benefits of using the LogOX Hauler and develop an Excel calculation tool to estimate the potential total cost-savings to an organization supplying the LogOX Hauler to its workforce. The results of the biomechanical experiments using the LogOX Hauler showed significant empirical data that corroborates the claimed benefits of the hauler. The results showed that while lifting the test log using the LogOX Hauler when compared to utilizing the two-handed lifting technique correctly, the lower back strain was reduced by up to 54% or by as much as 93% when compared with using improper lifting techniques. It was also shown that the bicep strain was reduced by 47% by the LogOX Hauler, when compared to using proper lifting techniques and by 76% as compared to using improper lifting. The overall findings conclude that the LogOX Hauler effectively distributes the weight of the load across the user's body, by placing it closer to the body's center of gravity, and at the same time effectively distributes a portion of the lifting effort from the back to the user's quadriceps.

INTRODUCTION

Back injuries in the workplace represent a major challenge to many organizations, as they not only place an enormous drain on financial resources, in the form of direct and indirect cost, but cause significant pain and suffering to employees. According to the Bureau of Labor Statistics, more than a million workers in the United States suffer back injuries, which account for 20% of total workplace injuries [1]. This results in back injuries accounting for 24% of days away from work due to injuries, and require on average 12 days of recuperation, before returning to work [2–4]. Data shows that in the US alone, the cost of back pain treatment approaches $50 billion per year, while the direct annual cost of back pain due to the above-discussed statistics exceeds $100 billion per year [5]. These costs include lost wages, productivity, legal and insurance overhead and an incalculable negative impact on families.

Occupations within the tree care industry (arborists, loggers, sawyers, vegetation management specialists) encounter a higher than average percentage of back-related worker injuries, due to the nature of the work involved. These workers perform strenuous lifting, twisting, and pulling movements throughout the day, which places enormous strain on their backs. Daily work in these professions entail extensive manual material-handling tasks. Studies show that 80% of back injuries are due to manual material handling tasks, with 75% of those injuries occurring when employees are lifting objects [1,6]. The proper

lifting technique is to bend your knees, lower your body, and squat before lifting [7]. Thereby employing the body's major muscle groups to better handle the weight while preforming the lift. However, a large majority of employees typically lift by bending at the waist, as it is perceived to be easier and faster. This places enormous pressure on the lower back, with studies showing that lifting a 10 lb. object from the waist, places a pressure of 100 lb. (10X) on the lower back [8]. The net result is a high risk of lower-back injuries in the tree care industry, which translates to a higher cost for organizations through lost time, productivity, and training new workers. Insurance data provided by the Tree Care Industry Association's endorsed program with ArborMax Insurance, shows that the average claim paid per worker is approximately $12,000, with time lost averaging 20 days [9]. It has to be noted that some injuries required recuperation time of more than 6 months. This leads to the supposition that the best way to prevent these injuries is by employing suitable mitigation techniques, such as utilizing proper tools, training workers in correct lifting techniques, and conducting preventative stretching/exercises. Amongst these, one of the most easily implemented strategies is utilizing proper tools, which have been shown to help reduce unnecessary physical strain associated with instances of back injuries. This has led to a growing market for tools designed to assist workers while lifting and moving logs in a way that reduces this physical strain for them. Improved worker performance efficiency also correlates with increased productivity. The US manufactured LogOX 3-in-1 Forestry MultiTool is a recently patented tool, which in its literature states that it, "helps users perform their tasks faster, safer, and easier." Consisting of three main parts, this tool combines three forestry tools into one modular unit; a LogOX Hauler, cant hook, and timberjack. The LogOX company further claims that by adding the appropriate attachment to the LogOX Hauler, while processing a fallen tree, the user will benefit from the tool configuration's specific mechanical advantages, which reduces the overall strain involved in performing the tasks required.

The intent of the experiments described in this article, were to empirically test the potential ergonomic benefits of using the LogOX Hauler only. Testing was conducted by measuring the quantifiable changes in muscle strain in the lower back, legs, and biceps of the test subjects lifting and moving a test log, as compared to conducting the same movements with the LogOX Hauler. Testing compared and categorized the strain recorded while conducting lifts using both correct and incorrect techniques. In addition, an Excel calculation tool was developed to estimate the potential total cost-savings to an organization supplying the LogOX Hauler to its workforce.

EXPERIMENTATION

Tool Used

A standard production LogOX 3-in-1 Forestry MultiTool was provided for testing by LogOX LLC [10]. The tool was used in the LogOX Hauler configuration, which can be operated using either hand, for all experiments in this study. An image of the fully assembled LogOX 3-in-1 Forestry MultiTool and the Hauler configuration is shown below in Fig. 1a and 1b respectively.

Quantifying Ergonomics

In order to quantify the benefits to the human body when using the LogOX Hauler tool, electromyography (EMG) data from each targeted muscle group was obtained, using

a module manufactured by BIOPAC [11]. The data was gathered by placing active electrodes on the back, leg, and arm muscles of the user. The data collected focused on three different scenarios: (a) manual lifting a log with correct posture, (b) manual lifting a log with improper posture, and (c) lifting a log with the LogOX Hauler. The exact same 11" diameter by 16" long, 20 pound log was used for the tests, and data was collected from two users. The data was then conditioned, using AcqKnowledge® [12] software, for further analysis.

(a) (b)

Fig. 1. (a) LogOX 3-in-Forestry MultiTool and (b) Tool in Log Hauler Configuration

Cost Savings Analysis

In order to determine the potential cost savings realized by organizations who utilize the LogOX tool in their operations, a Microsoft Excel calculation tool was developed. This calculation takes into account the estimated average distance walked by a treecare industry worker per day, the number of employees, and average worker compensation claims. This tool can be easily modified to adjust for company specific data and additional parameters, as deemed relevant by the user.

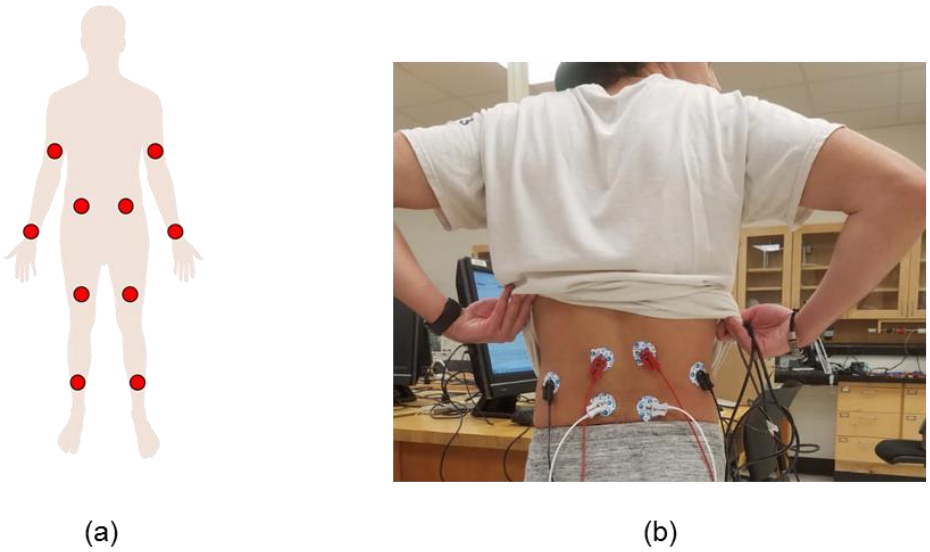
RESULTS AND DISCUSSION

Quantifying Ergonomics

The goal of this experiment was to obtain empirical data to examine the manufacturer's claim that by using their LogOX Hauler, the user places less strain on their back and arms, improves productivity, and reduces energy expenditure by the user. The data gathered was crucial to verifying that the tool benefits specific muscles in the body and decreases the amount of strain put on those muscles by the load, when using the tool. It was determined, from a visual examination of a user lifting a log manually without the tool, that muscle groups in the lower back, arms, and legs are engaged in the majority of the activity. Subsequently, it was decided to gather EMG data from these muscle groups. The benefit arising from gathering the EMG data is that we can clearly visualize

and present the muscle groups being activated during the lifting process, while determining the precise instant when the maximum strain is being placed on the muscles. The EMG essentially records the electrical potential generated by the muscle cells in units of millivolt (mv), which corresponds to the activation of the muscles. The measuring electrodes for obtaining EMG data were placed at ten different locations on the user's body, as highlighted by the red dots in Fig. 2a. In order to obtain data from a specific muscle group, three electrodes were affixed to the user as shown in Fig. 2b. Since placing all of the ten electrode sets at the same time results in too many wires that would hinder the motion of the user, only two muscle groups were studied at a given time.

The raw data gathered from the electrodes was conditioned using the AcqKnowledge® software package. The Integrated EMG (iEMG) tool was used, which calculates the mathematical integral of the absolute value of the raw EMG signal. This provides a way to better visualize the data and eliminates the noise from the data.



(a) (b)

Fig. 2. (a) Location of placement of active electrodes to obtain EMG data and (b) Electrodes affixed to gather data from left and right lower back.

Lower Back

The EMG data obtained from the left and right lower back, without using the LogOX Hauler, is shown in Fig. 3. The data collection began from the instant the user bent their knees and moved into a squat position over the log to begin the process of lifting the log, which is the correct technique to lift as discussed in the Introduction section. As can be seen, from the raw data portion of the graph in Fig. 3, the muscle activity corresponds to the user lifting the log from the squat position and then going back to the squat position. Both the left and right muscles in the lower back are activated during this process. This

demonstrates that during manual lifting, both the left and right muscle groups in the lower back are affected. The integrated data presents a saw tooth pattern, which provides a better determination of the maximum electrical potential generated. The maximum electrical potential recorded during this experiment, as observed from the integrated data, was 0.0261mV, which is similar across the left and right muscle groups.

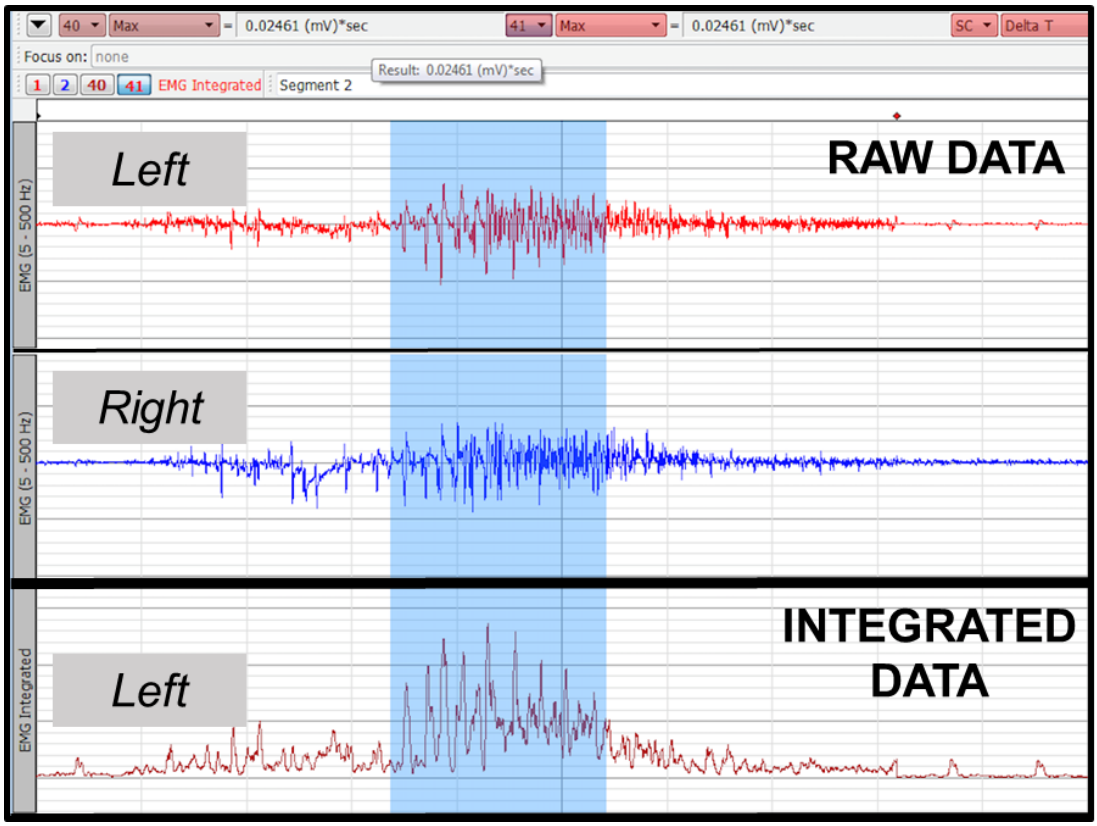


Fig. 3. Raw and Integrated EMG data obtained from left and right lower back when lifting the log using the correct technique and without the LogOX Hauler.

In the next experiment conducted, the electrodes were again placed on the lower back region, and the Log Hauler was used to lift the log. The EMG data obtained from the left and right lower back, when using the log Hauler, is shown in Fig. 4. It is observed from the raw data that there is significantly less activity occurring in the muscle group, implying that when the tool is being used, the strain on the muscles is lower. It has to be noted however, that the raw data shows that there is much more activity taking place in the right muscle groups, as opposed to the left muscle groups. This is attributed to the fact that the user handling the log Hauler was right-handed, which led to the right-side muscles in the lower back being activated more, as would be the reverse case for a user holding the tool in their opposite hand. The maximum electrical potential recorded during this experiment, as observed from the integrated data, was 0.0112 mV. The results of this experiment demonstrate that using the correct manual lifting procedure places 138% more strain on the lower back, than when the Hauler is employed. Stated differently, there

is a 54% reduction in lower back muscle strain when using the Hauler as compared to utilizing a proper two-handed lifting technique.

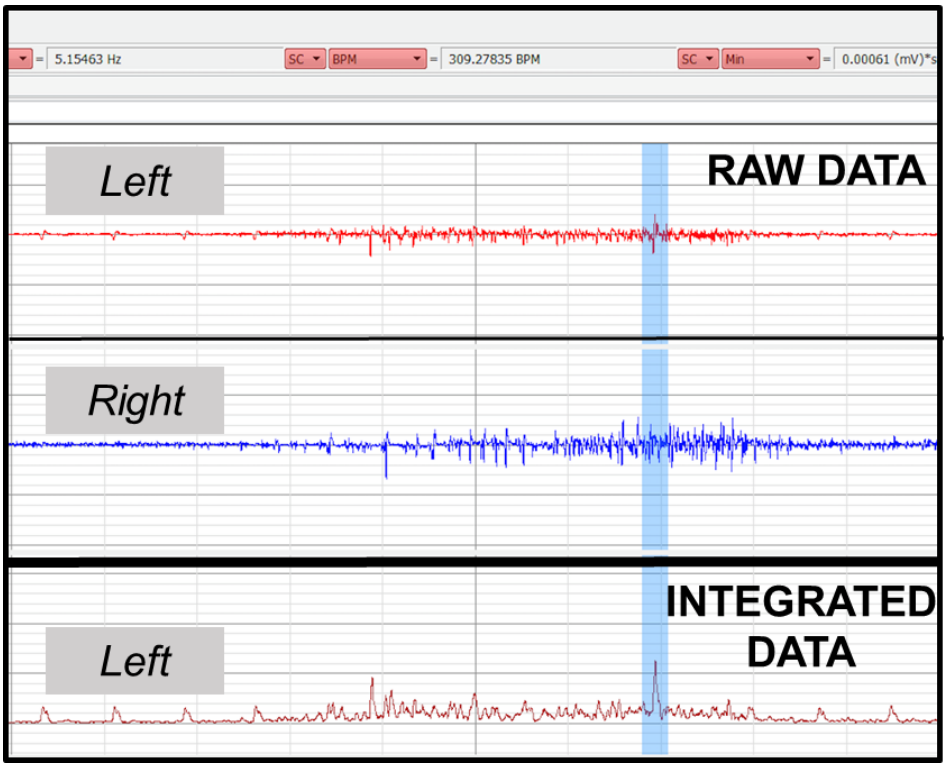


Fig. 4. Raw and Integrated EMG data obtained from left and right lower back, when lifting log with log Hauler

Lower Back and Quadriceps

In order to understand the benefits derived from using the Hauler compared to lifting with improper technique, experiments were conducted with the electrodes placed on the right lower back and right quadriceps (upper thigh). This is an important test, because in the real world, tree workers who have not been properly trained, do not want to slow down to execute proper lifting form towards the end of the day, or once overly fatigued often revert to an improper lifting method. As previously noted, the “improper technique” is characterized by the user bending straight down from the waist to lift the logs, without first bending their knees and performing a squat movement. The EMG data obtained from the quadriceps and the lower back when lifting, using the improper technique, is shown below in Fig. 5.

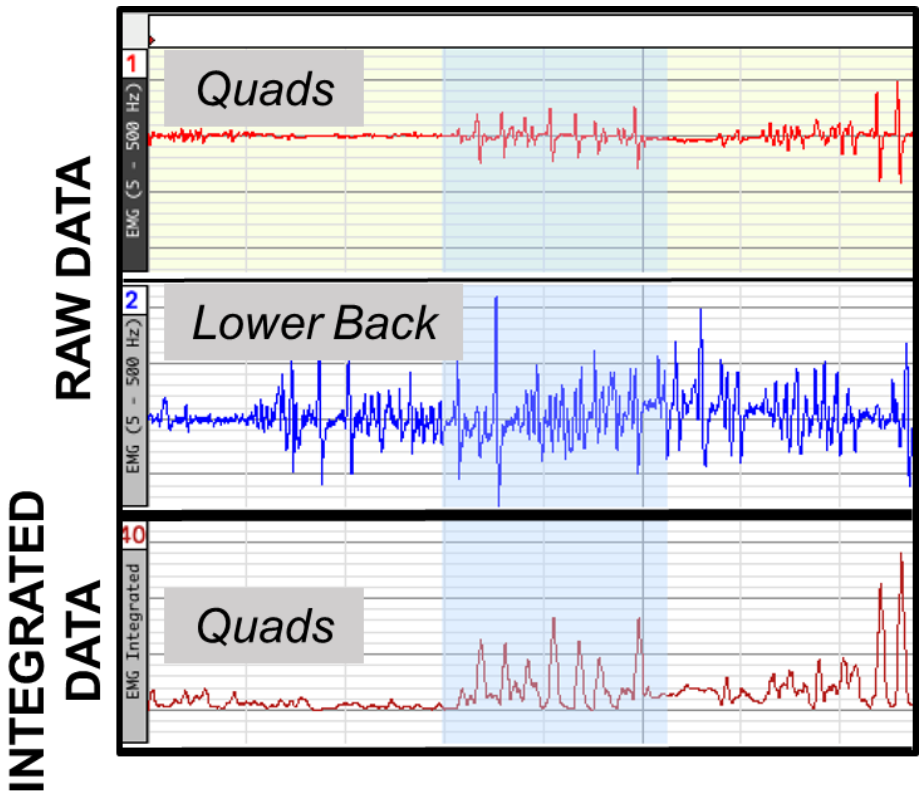


Fig. 5. Raw and Integrated EMG data obtained from right quadriceps and lower back, when lifting log with improper technique

The data captured corresponds to the user lifting the log to waist height, and then taking a few steps forward, while holding the log in place. The portion of the curve highlighted in blue corresponds to the period of time when the user lifted the log off the ground. It can be clearly seen that during improper lifting, there is significantly higher strain on the back, compared to upper quadriceps. The data points adjacent to the highlighted portion correspond to the user walking with the log held in their hands, in front of them, or at their side, when using the Hauler. It is also observed that even while walking, there is a significant amount of strain put on the back, as opposed to the quadriceps. The maximum potential generated, as calculated from the integrated data, are 0.576 mV and 0.0824 mV, in the lower back and quadriceps, respectively. This corresponds to an almost 600% higher strain on the back, compared to the quadriceps, when doing improper lifting.

The EMG data obtained from the quadriceps and the lower back, when lifting using the log Hauler, is shown below in Fig. 6. The portion of curve highlighted in blue corresponds to the user lifting the log with the Hauler. It can be seen that the muscle activity in the lower back is significantly lower than what was observed in the data curve for improper lifting in Fig. 5. The maximum potential recorded in the lower back was 0.576 mv when proper technique was used and only 0.0412 mv, when the Hauler was employed. Improper lifting technique places 1,298% (13X) more strain on the lower back

than when using the Hauler. It is worth noting that this experimental result is in the same order of magnitude as referenced in the introduction (10X) for improper lifting. Again, stated differently, there is a 93% reduction in lower back strain when using the Hauler as compared to utilizing an improper lifting technique and as noted earlier, a 54% reduction as compared to using proper lifting. Noticeable activity was observed in the upper quadriceps during this part of the experiment, because in order to use the Hauler properly, the user has to bend their knees slightly. Distributing some of the body's muscle strain from the lower back to the quadriceps while lifting, will help mitigate the potential for lower back injuries. The maximum electrical potential recorded in the quadriceps was 0.0824 mv, when lifting improperly, and 0.1442 mv, when using the Hauler. This suggests that 75% of the strain is being transferred to the quads, which is placing more of the strain on the correct muscle group.

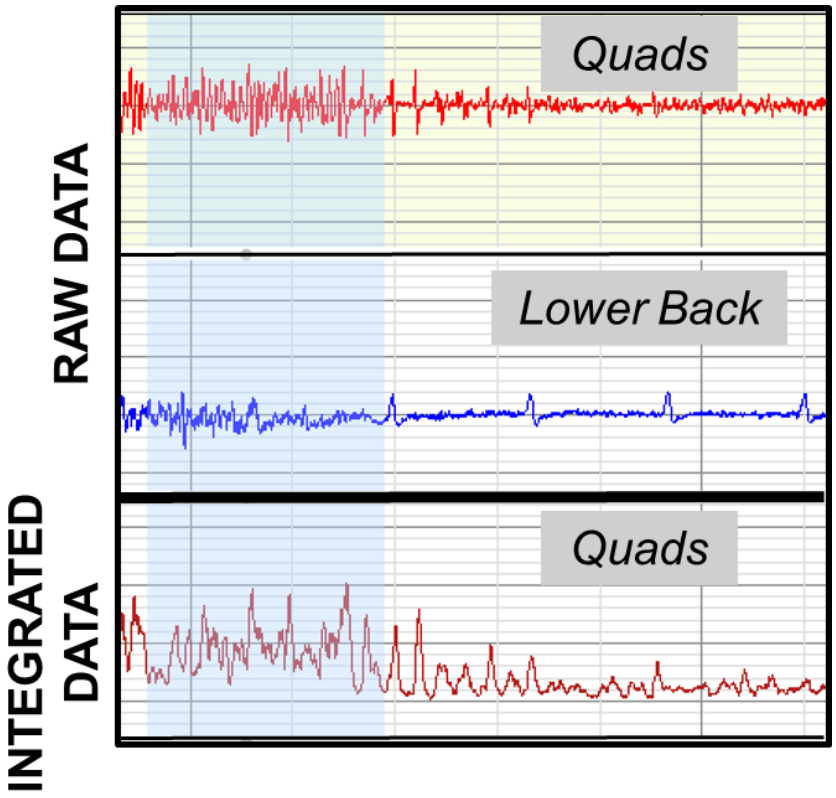


Fig. 6. Raw and Integrated EMG data obtained from right quadriceps and lower back, when lifting log with log Hauler

The data points adjacent to the highlighted portion in Figure 6, correspond to the user walking, while holding the Hauler, which is carrying the test log at their side. In this region, there is virtually no activity going on in the lower back, which clearly demonstrates the benefits of using the log Hauler. The maximum electrical potential recorded while walking with the log held in front of the body was 0.2678 mv and when walking with the test log carried by the Hauler at the user's side was 0.0309 mv. The 667% greater strain on the lower back, when carrying the log in front of the user, is attributed to the effort of

the back muscles required to counter the forward torque generated by the log being held in front of the user.

A similar effect was observed in the quadriceps. The maximum electrical potential recorded while walking with the log held in front of the user was 0.1854 mv, and 0.0206 when walking with the Hauler and the log held at the user's side. The 800% difference points to how the quadriceps are influenced by the position of the load in relationship to the center of gravity of the user.

Biceps

The last set of experiments focused on recording muscle activity in the biceps. Three different data sets were collected, which correspond to: (a) improper lifting, (b) proper lifting, and (c) lifting using the LogOX Hauler. The EMG data obtained, while using proper lifting technique, is provided below in Fig. 7. It can be observed that there is activity being recorded in both the right and left arms, when lifting the log, using the proper technique, as the user is required to use both their hands.

The electrical potential recorded in the right and left arm from the integrated data were evenly balanced at 0.00307 mV and 0.00312 mV respectively.

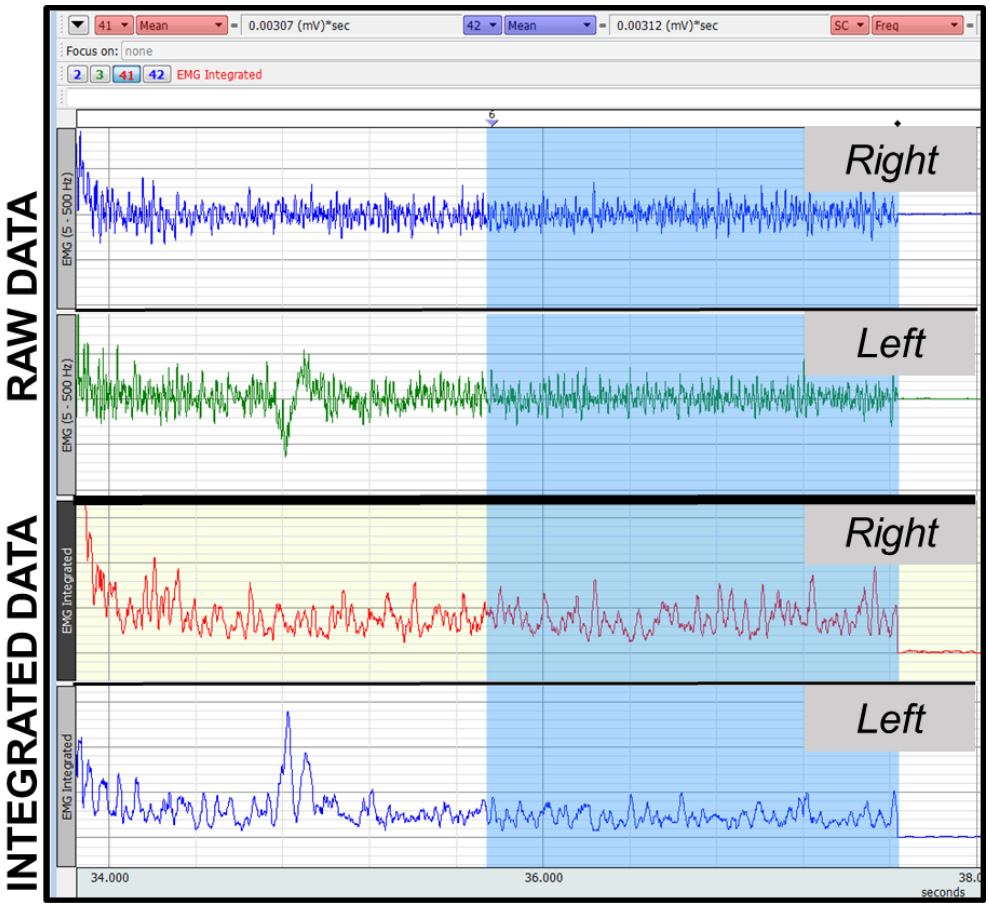


Fig. 7. Raw and Integrated EMG data obtained from right and left biceps when lifting log with proper technique.

The EMG data obtained from right and left biceps, while using improper lifting technique, is provided below in Fig. 8. It can be observed that there is activity being recorded in both the right and left arms, when lifting the log using the improper technique, as again, the user is required to use both their hands. The mean electrical potential recorded in the right and left arm from the integrated data were 0.00628 mV and 0.0072 mV, respectively. This is 116% more strain than when using proper lifting technique. It has to be noted that when using the improper technique, apart from the biceps, there is also a significant strain being placed on the lower back, as observed previously in Fig. 5.

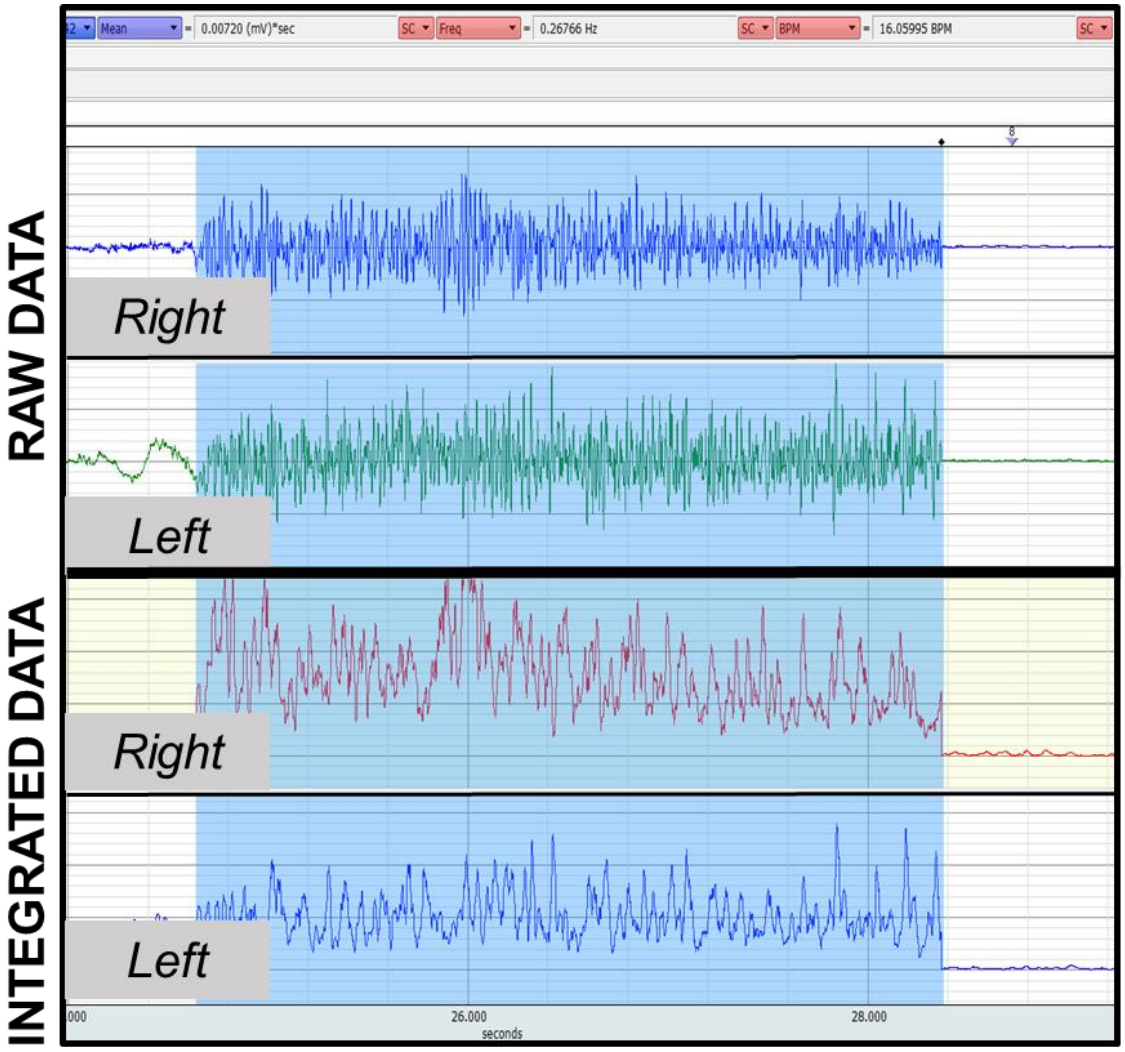


Fig. 8. Raw and Integrated EMG data obtained from right and left biceps when lifting log with improper technique.

The EMG data obtained from right and left biceps, while using the LogOX Hauler, is provided below in Fig. 9. It can be observed that there is activity being recorded only in the right arm, as the user was holding the Hauler with their right hand. The mean electrical potential recorded in the right arm from integrated data was 0.00163 mV.

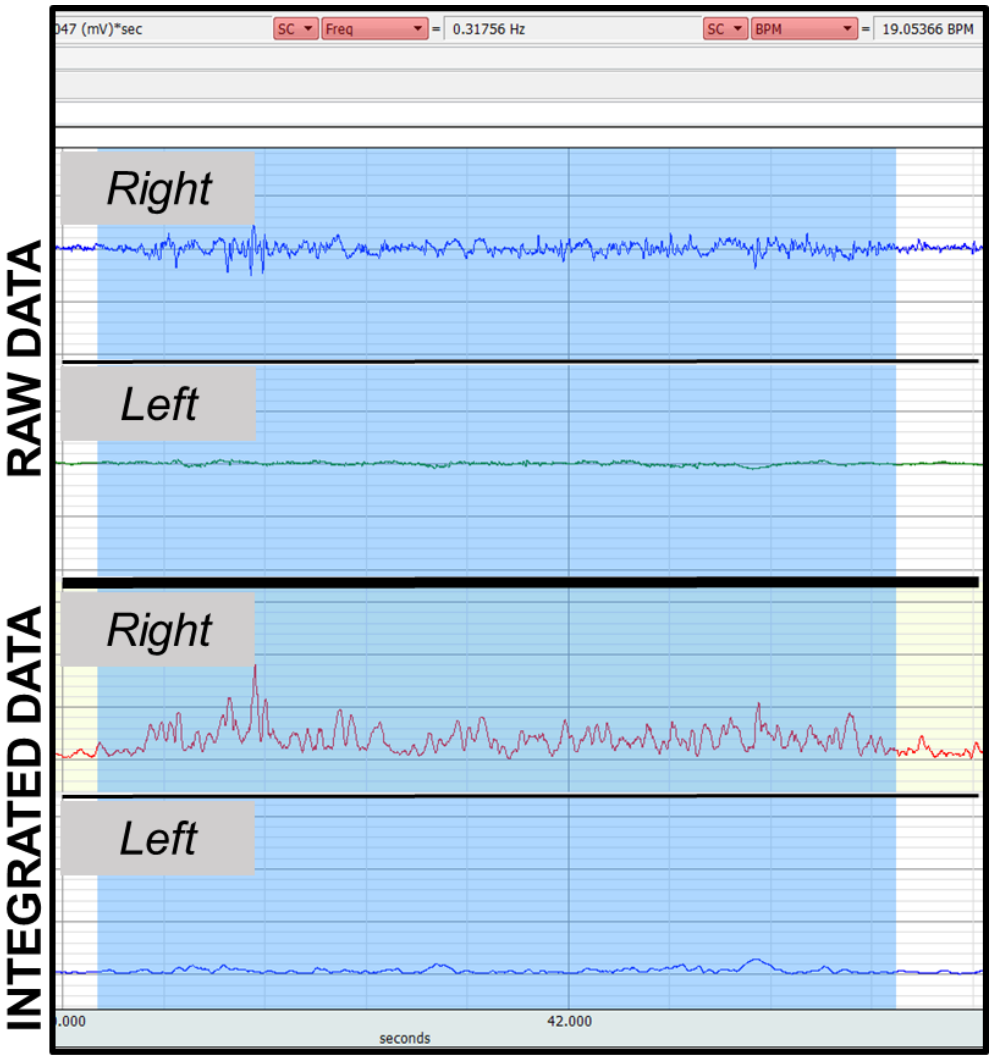


Fig. 9. Raw and Integrated EMG data obtained from right and left biceps, when lifting log with log Hauler

This translates to the fact that lifting a log with proper technique places a strain on the two arm's biceps that is 90% higher, compared to the one arm using the log Hauler. Stated differently, by using the Hauler there is a 47% reduction in bicep strain as compared to properly lifting the test log. This difference in strain is attributed to holding the log in front of the user, at chest level height, as compared to using the Hauler, which positions the user's arm straight down at their side. When using the Hauler, the weight of the log is distributed between the biceps, shoulder and chest muscles.

In the case of correct lifting, the weight of the log is maintained closer to the body than when lifting improperly. Maintaining the load close to the body's center of gravity, and retaining proper posture, minimizes muscle strain. Lifting the log with improper technique places a strain on the biceps that is 311% higher, compared to using the log Hauler. A summary of all the EMG measurements is provided in Table 1.

Table 1. Summary of EMG data collected from all tests

Activity and Impacted Muscles	(mv) Reading Without Hauler	(mv) Reading With Hauler	Percent (%) Reduction in strain when using the LogOX Hauler
Lifting log correctly – Lower Back (Test 1)	0.02461	0.01122	54
Lifting log incorrectly – Lower Back (Test 2)	0.5760	0.0412	93
Walking with log – Lower back (Test 2)	0.2678	0.0309	88
Walking with log – Quadriceps (Test 2)	0.1854	0.0206	89
Lifting correctly – Biceps (Test 3)	0.0031	0.00163	47
Lifting incorrectly – Bicep (Test 3)	0.0067	0.00163	76

Maintaining the load close to the user's center of gravity reduces the applied torque of the load, while retaining proper posture and minimizing muscle strain. These results, when combined with experiments in this study on the lower back, biceps and the quadriceps, demonstrate significant ergonomic benefits for a user working with the Log Hauler, specifically on their back and biceps, while transferring some of the strain to their quadriceps. The reduction in muscle strain also results in reduced worker fatigue and therefore lessens the probability of injuries, while allowing the user to perform more tasks during the work period.

Cost Savings Analysis

The other claim tested in this experiment was that utilizing the LogOX 3-in-1 Forestry MultiTool, apart from the ergonomic benefits, could result in significant cost savings from increased productivity. The cost savings model was developed based on the analysis of two main components: (a) the potential reduction in time taken by employees to perform the tasks and (b) a potential reduction in worker compensation claims due to injury, which is a substantial expense to organizations, as discussed in the Introduction Section. In order to estimate the possible cost savings to organizations employing the LogOX Hauler, a cost-estimating tool was built, utilizing Microsoft Excel. Initially, the time taken to lift a log and walk 20 feet, with and without the tool, was determined as a constant. The average time was calculated using two different users and their overall time. The recorded time to walk 20 feet, with and without the Hauler, are 5.05 and 6.21 seconds respectively. Manually lifting the log was found to be 23% slower than using the Hauler. On average, a tree service worker who works for 8 hours a day takes around 20,000 steps. This information, combined with the time measurements, allowed us to estimate the average time taken by a worker to accomplish the tasks with and without the LogOX Hauler tool. The calculations were further extended to time saved per year, per employee and extrapolated to the overall time saved, taking into account the number of employees. A screenshot of the tool is provided in Fig. 10. As an example, for a company with twenty-two arborists, an average number of workers based on insurance data provided by the Tree Care Industry Association (TCIA) for this study, and an average

hourly salary of $40, the total cost savings per year could approach $90,000. This is purely the cost savings attributed to the use of the Hauler, as compared to the current more labor-intensive manual process.

When taking into account the cost savings realized by reduced number of worker compensation claims, the potential total savings could be substantially more. Insurance data provided by the TCIA states that the average worker compensation claim per employee paid by companies in the tree care industry specific to back injuries is $12,000. This versatile calculation tool is at the disposal of organizations to estimate possible cost savings realized with LogOX tool, and can be easily modified to fit their needs based on their own wage structure, lost time and claims history.

Cost Savings Analysis Using the LogOx Tool (Assuming 20,000 steps per day)

Time Saved Using LogOx	
Time taken to walk per day (seconds)	5047.00
Time taken to walk per day (hour)	1.40
Time per Week (hours)	7.01
Time per Month (hours)	28.04
Time per Year (hours)	336.47

Time without the LogOx	
Time taken to walk per day (seconds)	6207.00
Time taken to walk per day (hour)	1.72
Time per Week (hours)	8.62
Time per Month (hours)	34.48
Time per Year (hours)	413.80

Total Time Saved in Hours per Year	77.33
Hourly Pay of Worker ($ per hour)	$40.00
Money Saved per Worker Using LogOx ($)	$3,093.33
Number of Employees in Company	22
Cost Savings for all Employees ($)	$68,053.33
Overhead Cost (Assume 30%)	$20,416.00
Cost Savings with Overhead ($)	**$88,469.33**

Average Worker Compensation Claim ($)	$12,000.00
Total Claim for all Employees ($)	
Cost due to time lost ($)	
Assumed Claims with LogOX ($)	
Annual Total Cost Savings (time + worker compensation claims)	

Fig. 10. Snapshot of Cost Savings Tool

SUMMARY

In summary, the results of the biomechanical experiments using the LogOX Hauler showed significant empirical data that corroborates with the sentiments expressed in customer testimonials the LogOX 3-in-1 Forestry MultiTool has received. Testing confirmed that using the LogOX Hauler reduced strain on the body, as well as the working time required to lift and move the test log, while potentially making the overall workflow much safer. In addition, it has been documented that improper lifting generates thirteen times more strain to the lower back, as compared to using the LogOX Hauler. Using the correct lifting technique was verified to cause less strain on the lower back than improper lifting. However, even when compared to utilizing the two-handed lifting technique correctly, it was demonstrated that while lifting the test log using the LogOX Hauler, the lower back strain was reduced by up to 54% or by as much as 93% when compared with using improper lifting techniques. It was also shown that the bicep strain was reduced by 47% by the LogOX Hauler, when compared to using proper lifting techniques and by 76% as compared to using improper lifting. The overall findings conclude that the LogOX Hauler effectively distributes the weight of the load across the user's body, by placing it closer to the body's center of gravity, and at the same time effectively distributes a portion of the lifting effort from the back to the user's quadriceps.

Reduced back and bicep strain decreases the total energy required to execute the manual tasks commonly performed in the tree care industry. Minimizing fatigue is a key factor in reducing the probability of mistakes, accidents, and injuries. Lowering the strain to the back, arms, and body as a whole, will predictably reduce the total number of back and other related injuries, while decreasing direct and indirect costs to the organization.

In addition to the LogOX Hauler component of the LogOX 3-in-1 Forestry MultiTool, there are two additional forestry tools incorporated into the overall design, which includes a 38" cant hook and a "timberjack" log lifter. The biomechanical analysis of these tools was beyond the scope of this study; however, given their intrinsic utility, which provides the user with greater leverage force in their intended applications, they can be reasonably expected to produce additional ergonomic benefits in a working environment. In addition, it should be noted that the LogOX Hauler is effectively a 21" lever in the form of a short cant hook that can be used to turn logs, which facilitates sawing the reverse side of the initial cut, in order to avoid ground strikes with the chainsaw. This mechanical advantage could also prove to be beneficial in reducing the overall muscle strain associated with turning logs. Additionally, the benefits of using the LogOX Hauler to effectively drag tree brush and/or larger logs than a user can carry, was also beyond the scope of this study. This capability is a close second in importance to being able to carry a log. It is a method, which again, provides a biomechanical advantage to the user compared to an unassisted manual approach.

Protecting employees and promoting a healthier work force by minimizing hazards and maximizing safety is the primary objective of every occupational safety program. From this engineering study, it is concluded that the LogOX Hauler is a tool that could be a pivotal addition to any comprehensive safety program in achieving these objectives for those organizations engaged in the manual activities covered in this paper.

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