Medycyna Pracy 2022;73(3):201–207
http://medpr.imp.lodz.pl/en
https://doi.org/10.13075/mp.5893.01175
ORIGINAL PAPER

MUSCLE FATIGUE RELATED TO HUMAN POSTURE USING A BRUSH CUTTER FOR LANDSCAPE GARDENING: A PRELIMINARY STUDY

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Abstract

Background: Brush cutters are widely used in Chinese landscape gardening and agricultural laboring which leads the operators being exposed to many risks. Low back pain (LBP) is particularly common and can lead to substantial personal, community and financial burdens. The aim of the presented study was to measure the activity and function of each torso muscle of the operator when using the bush cutter, so as to evaluate the muscle injury of the operator during using several common brush cutters for different landscape tasks. **Material and Methods:** The human postures of 6 workers using 2 types of brush cutters in the 3 working conditions were recorded and measured by using a surface electromyography (sEMG) system and a camera. The test results were compared by t-test and sign test. The effect of human posture on the sEMG signal of trunk muscles in different working condition were analyzed by ANOVA. **Results:** In the 3 working conditions, except for the left trapezius muscle, the muscle load of operating the backpack brush cutter is higher than that of operating side-mounted brush cutter. When operating the side-mounted backpack brush cutter, the force on both sides of the trapezius muscle is uneven, the load of the left trapezius muscle is >25%, and the maximum value is >30%. **Conclusions:** The results highlighted significant differences in the effects of different working postures on the muscle activities of workers' trunk. Safe operation standards should therefore be taken to protect the exposed workers and to improve the industrial design of irrigation cutters to prevent the occurrence of occupational diseases. Med Pr. 2022;73(3):201–7

Key words: working posture, muscle activity, occupational diseases, ergonomics of work, agriculture and forestry, brush cutter

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Received: July 11, 2021, accepted: March 27, 2022

INTRODUCTION

Brush cutters are widely used in Chinese landscape gardening and agricultural laboring because of their affordability and easiness of use. Gardeners frequently use brush cutter to remove weeds and trim shrubs. Meanwhile, famers frequently use brush cutter to harvest grasses and crops. However, when the operators prolonged exposure to the natural environment, their workload will increase due to the bearing weight, vibration and noise generated mainly from the rotating engine, which can provoke working fatigue, occupational diseases and even working accidents [1–5]. As a result, gardeners are at increased risk of a number of health problems which can affect their working lives.

Low back pain (LBP) is particularly common and can lead to substantial personal, community and financial burdens [6–8]. Low back pain is a common and costly public health problem causing individual and societal burden worldwide. By definition, LBP is a symptom that can be caused by several pathologies, but often the specific nociceptive cause remains undetermined. One of the most common symptoms is LBP with related leg pain, which is described using several terms such as sciatica, lumbar radicular pain, or nerve root pain, and is related to a less favourable prognosis than LBP without leg pain [9,10]. According to previous surveys conducted among gardeners in China, the prevalence of LBP was found to be 60%. There is a growing body of evidence to suggest that the inappropriate work posture

Funding: this work was supported by the Fundamental Research Funds for The Central Universities of China (project No. 2572016CB05, entitled "Multi-index Evaluation Method and Experimental Research on Working Fatigue of Brush Cutter," project manager: Bo Li) and by the Fundamental Research Funds for The Central Universities of China (project No. 2572019BF07, entitled "Evaluation and Experimental Research on the Comfort of Office Chair Based on Ergonomics," project manager: Wanying Yang) and by Industry-University Cooperation Collaborative Education Project by MOE of China (project No. 202102055012, entitled "Human Fatigue Assessment Method for Gardening Operations Based on Dynamic Bayesian Network," project manager: Bo Li).

can lead to musculoskeletal strain, discomfort, and chronic pain, which is the main cause of LBP [11,12].

The aim of the presented study was to measure the activity and function of each torso muscle of the operators when using the bush cutter, so as to evaluate the muscle injury of the operators during using several common brush cutters for different landscape tasks.

MATERIAL AND METHODS

A group of 6 operators were examined. In a garden company, 6 professional gardeners were randomly selected, all were male, aged: 42.1±8.7 years, body weight: 68.5±9.4 kg, body height: 171.3±5.4 cm, BMI: 23.3±3.5, working years: 11±4.5, no LBP in the last 3 months, no history of lumbar surgery or fracture. The percentage of respondents who reported taking part in regular stretching exercises was 33.3%; 66.6% of the participants had a drinking habit and 50% of them smoked cigarettes.

The brush cutters used for the experiment include 2 types: backpack brush cutter (BG140, HuaSheng, China, weight 9.5 kg, working rod length 1330 mm, Figure 1a) and side-mounted brush cutter (CG140, HuaSheng, China, weight 8.5 kg, working rod length 1330 mm, Figure 1b), the side-mounted bush cutter is usually mounted on the right side.

The tests were conducted with a 16 channel surface electromyography (sEMG) system (ANT Neuro, Netherlands).

As a non-invasive and dynamic technique of muscular function measurement, sEMG has been used for objectively evaluating trunk muscular activity [13–15]. In this study, sEMG system was used to measure the posture of operators using 2 types of brush cutter in 3 kinds of working conditions [16,17].

The surface EMG signals of middle part of left and right trapezius (LTU, RTU, LTC, RTC, LTL, RTL), rectus abdomin (LRA, RRA), lumbar segment of left and right erector spinae (LESL, RESL), thoracic segment of left and right erector spinae (LEST, REST), left and right abdominal external oblique muscle (LOEA, ROEA) were collected. The illustrations of each muscle are shown in Figure 2.

The electrode position is placed according to the test standard recommended by surface electromyography for non-invasive assessment of muscles (SENIAM). Surface electrodes (Ag/AgCI) were placed adequately and exactly on a given muscle so that the signal properly reached the middle part of the muscle belly, at the distance of ca. 1–2 cm, as far as possible from the muscle

Figure 1. a) Backpack brush cutter, b) side-mounted brush cutter

motor points and muscle tendons, lengthwise relative to the muscle fibre sEMG signals have individual differences, if authors want to compare and analyze different participants and different muscles, it is necessary to standardize the sEMG signals. The method is as shown in formula (1), in which the actual measured EMG amplitude (RMS_{ACT}) is expressed as a percentage of the sEMG amplitude (RMS_{MVC}) during maximum spontaneous contraction, namely MVE% [18,19].

$$MVE\% = \frac{RMS_{ACT}}{RMS_{MTC}} \times 100\% \quad (1)$$

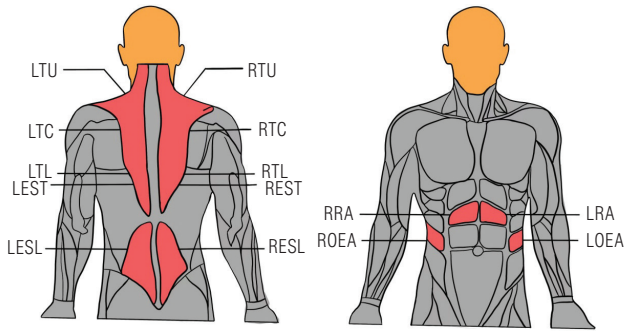
where:

MVE% – the muscle load in this action or posture is equal to the percentage of maximum voluntary contraction,

RMS_{ACT} – actual measured myoelectric amplitude,

RMS_{MVC} – myoelectric amplitude during maximum voluntary contraction.

The meaning of MVE% is that the muscle load in this action or posture is equal to the percentage of maximum voluntary contraction (MVC) [20]. For the same muscles



LESL – left erector spinae lumbar, LEST – left erector spinae thoracic, LOEA – left abdominal external oblique, LRA – left rectus abdomen, LTC – left trapezius central, LTL – left trapezius lower, LTU – left trapezius upper, RESL – right erector spinae lumbar, REST – right erector spinae thoracic, ROEA – right abdominal external oblique, RRA – right rectus abdomen, RTC – right trapezius central, RTL – right trapezius lower, RTU – right trapezius upper.

Figure 2. Sketch map of each muscle

of the same participants, the changes over time can reflect the changes of muscle load. For different muscles of the same operator, the difference of load degree in the same action can be compared. The same comparison and statistical analysis can be made among different subjects.

According to the characteristics of the gardener's cutting object and human posture when using the brush cutter, the working condition can be divided into 3 types: P1 – mowing grass, P2 – cutting shrubs, and P3 – cutting high branches. The test was conducted in 2 days. Before starting the test each day, the MVC of the trunk muscle of the participants was tested for 3 times, and the average value of the continuous and stable muscle signal of 2 s in the middle of each contraction was taken.

On the first day, the operator uses backpack brush cutter to perform P1, P2 and P3 tasks in a real work environment, each lasting 30 min with simultaneous recording of the sEMG signal. After the operators got enough rest at night, the next day, the subjects used side-mounted brush cutter to perform P1, P2 and P3 tasks in the actual working environment, each lasting 30 min with simultaneous recording of the sEMG signal. The 2-day test was all filmed by the camera. Posture and sEMG signal for each participant was subjected to detailed analysis on the basis of the results obtained from sEMG records and cameras.

T-test and sign test were used to compare the effects of knapsack brush cutter and side-mounted brush cutter on human trunk muscle MVE% in 3 working conditions. Sign test is to test the sign of the difference between each pair of data of 2 related samples, so as to compare the significance of the 2 samples. Statistical significance was set at $p < 0.05$, and very significant at $p < 0.01$. The effect of human posture on the sEMG signal of trunk muscles in different working condition were analyzed by one way non-parametric analysis of variance (ANOVA).

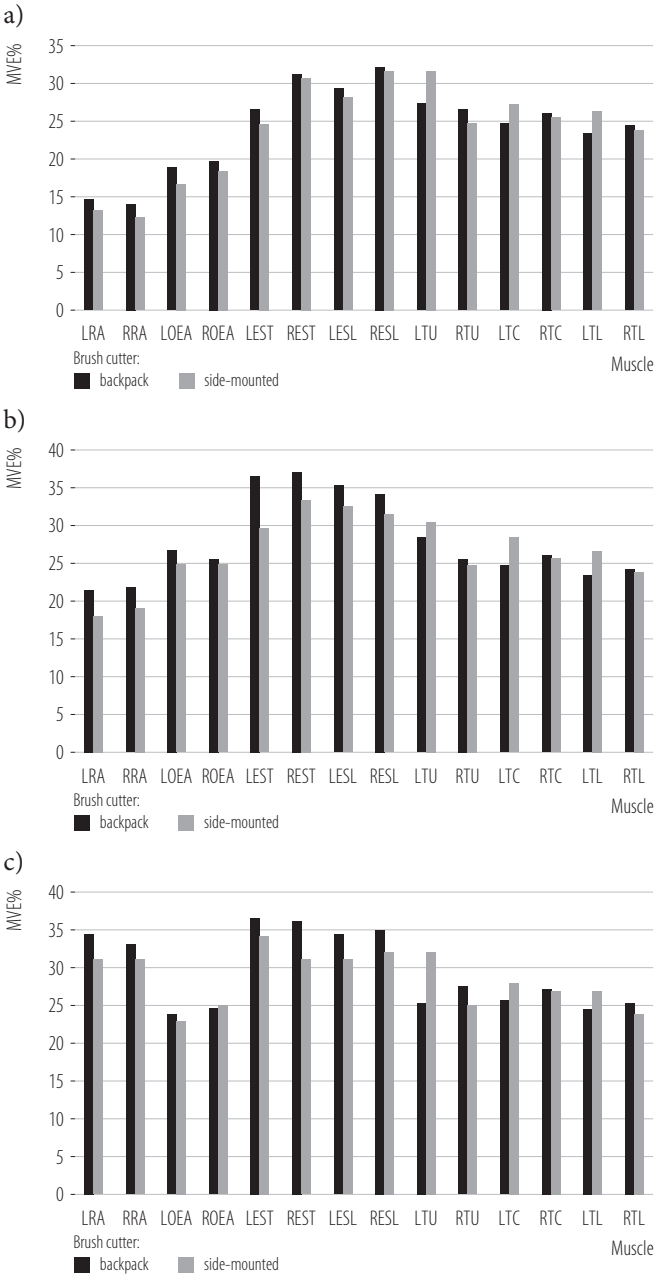
RESULTS

As can be seen from the MVC values of the major muscles of the operators, the MVC values of their major muscles are basically similar. The values of the same muscles on the left and right sides of the trunk are basically similar, although there is a slight difference, but there is no statistical significance. Among them, LRA and RRA has the highest value, because the rectus abdomen is muscle has a large physiological cross section, is the main flexor muscle of the trunk, and has considerable muscle strength. The results of MVC test showed that the muscle strength of dorsal extensor and abdominal flexor of the trunk of the participants was balanced, and the muscle development of the left and right sides of the trunk was balanced.

As shown in Figure 3a, there were differences in the MVE% of different muscles when the operators operated the 2 types of brush cutters for P1 operation. The value of the lower back is the largest, and the MVE% of the erector spinae muscle (LEST, REST, LESL, RESL) is about 30%. The second is the value of the upper back, and the MVE% of the trapezius muscle is about 20%. The MVE% of rectus abdomen and the MVE% of abdominal external oblique muscle are <20%. The average MVE% value of each trunk muscle of the human body is 24.2.

Figure 3b shows the MVE% values of torso-related muscles of operators with 2 types of brush cutters when cutting shrubs. It can be seen that in P2 condition, there is no difference between the same muscles, but there are differences between different muscles. The MVE% of rectus abdominis was the lowest, followed by obliquus externus abdominis, and the MVE% of left and right erector spinae was >30%. Except for the trapezius muscle, the MVE% values of the left and right sides of the same muscle were basically similar, and the difference was not statistically significant. The average MVE% value of each trunk muscle of the human body is 27.24, which is higher than the value in the P1 condition.

Figure 3c shows the MVE% values of trunk-related muscles of the operators operating 2 types of brush cutters in P3 condition. When the operators cut the high branches, the MVE% values of the erector spinae and rectus abdomen were higher, followed by the trapezius, and the MVE% values of erector spinae and rectus abdomen were all >30%. Except for the trapezius muscle, the MVE% values of the left and right sides of the other



MVE% – the muscle load in the action or posture is equal to the percentage of maximum voluntary contraction.
P1 – mowing grass, P2 – cutting shrubs, P3 – cutting high branches.
Other abbreviations as in Figure 2.

Figure 3. The MVE% of operators' main muscles using different brush cutters in a) P1, b) P2, and c) P3 working condition, May–June 2021, Harbin, China

same muscles were basically similar, and the difference was not statistically significant. The average MVE% value of each trunk muscle of the human body is 29.28, which is the highest in the 3 working condition.

As shown in Table 1, ANOVA results demonstrated significant differences in the MVE% of different working conditions (F = 112 872, Sig. = 0.000).

DISCUSSION

The sEMG has been widely used in the field of fatigue detection in various industries. Zhichuan et al. [21], Na et al. [22], Balasubramanian and Jagannath [23], and Li et al. [24] used sEMG to evaluate the load of smartphone texting, manual material handling, motorcycle riding and other operations, including the judgment of muscle tension and fatigue status in different operating postures, positions and movements. In order to evaluate the effect of muscle workload and fatigue, the changes of muscle activity of workers operating brush cutters were analyzed by (sEMG) in this study.

The results show that in P1 condition, the load on the back and waist of the torso is greater than that on the abdomen. When using backpack brush cutters to mow the grass, the torso leans forward slightly, and the body's center of gravity is located on the back of the spine. At this time, the erector spinae muscle bears the greatest load, because according to the principle of torque balance, the erector spinae muscle contracts to maintain spinal balance, maintain upright posture, and overcome the backward torque caused by weight. The rectus abdomen is mainly the flexor muscle, which plays a role in preventing the extension of the spine. As an antagonistic muscle of the erector spinae, it makes the spine in a neutral position and maintains the balance of the spine. At this time, because of the weight of brush cutter, the spine is subjected to a large backward torque, so in order to achieve dynamic balance of the spine, the rectus abdomen needs a certain amount of force to make the spine in a state of dynamic balance, so it bears part of the workload. The difference between the contractile value of the left and right abdominal external oblique muscle is small, and the force is the same, which mainly plays the role of rotating the body angle and expanding the mowing area, and the workload is the smallest.

According to the data in Figure 3a, when operating the side-mounted brush cutters, the load of the left trapezius muscle is larger, because the operators generally chooses to hang the shoulder strap on the left shoulder, the weight of the brush cutter is loaded on the left shoulder through the shoulder strap, and the upper part of the left trapezius muscle plays a main supporting role. When operating 2 types of brush cutters, the muscle load was the highest in the erector spinae muscle of the lower back, the MVE value was about 30%, the MVE% value of the trapezius muscle of the upper back was about 20%, and the MVE% value of rectus

Table 1. The results of ANOVA for the MVE% in P1–P3 condition, study carried out in May–June 2021, in Harbin, China

MVE%	Sum of squares	df	Mean square	F	Sig.
Between groups	157.109	2	78.554	112.872	0.000
Within groups	22.967	33	0.696		
Total	180.076	35			

MVE% – the muscle load in this action or posture is equal to the percentage of maximum voluntary contraction.
P1 – mowing grass, P2 – cutting shrubs, P3 – cutting high branches.

abdomen and abdominal external oblique muscle was <20%. The above results show that when mowing, the load of the erect spine muscle of the lower back of the trunk and the trapezius muscle of the upper back is greater than that of the abdomen, and the fatigue intensity is greater. When operating the side-mounted brush cutter, the force of the trapezius muscle on both sides is uneven, the load of the left trapezius muscle is >25%, the maximum value is >30%, and the fatigue strength is larger.

In P2 condition, the MVE% value of erector spinae and ventral external oblique muscle increased greatly, because the torso of the operators was twisted left and right, the angle of shoulder and hip increased, and the contractile intensity of erector spinal muscle and abdominal external oblique muscle was strong, which made the spine rotate to the left and right sides. The MVE% value of other trunk muscles was not significantly different from that of mowing. When operating the 2 types of brush cutters, the muscle load is still the highest in the lower back erector spinae muscle, the MVE value is >30%, the highest value is close to 40%. The MVE% value of the upper back trapezius muscle is >25%, the MVE% value of the rectus abdomin muscle is <20%, and the MVE% value of the abdominal external oblique muscle is about 25%. The above results show that in the shrub cutting operation, the load of the erect spine muscle of the lower back of the trunk and the trapezius muscle of the upper back is greater than that of the abdomen, and the fatigue strength of the external oblique muscle of the abdomen is larger than that of the abdomen. When operating the side-mounted brush cutter, the fatigue strength of the left trapezius muscle is higher.

In P3 condition, when cutting high branches with the backpack brush cutters, the MVE% values of all trunk muscles except left trapezius muscle were higher than those of MVE% when the side-mounted brush cutters was operated. The reason is that in the P3 working condition, the human torso is in the backward posture, the back elevation angle is 4–20°, the center of gravity of the human body is located at the back of the spine, the erector spinae muscle should strengthen the contractile force to maintain the spinal balance, avoid tipping, and overcome the backward torque caused by the machine weight, therefore, the erector spinae muscle bears the greatest load. Rectus abdomen is muscle should also increase the contractile force to maintain dynamic balance in order to antagonize the moment of brush cutter and spinal retroversion. The upper part of the trapezius muscle should help the head to lean back, and the lower part contraction helps the spine to stand upright, and the load is higher than that of P1 and P2. When operating the 2 types of brush cutters, the muscle load is still the highest in the erector spinae muscle of the lower back, the MVE% value is >30%, the highest value is close to 40%; the MVE% value of rectus abdomin and trapezius muscle is >30%, both are in a state of high fatigue.

Based on the analysis of the effects of operating 2 types of brush cutters on the bioelectric signals of the main muscles of the trunk in different working conditions, it can be found that in the 3 working conditions, except for the left trapezius muscle, the muscle load of operating the backpack brush cutters is higher than that of operating the side-mounted brush cutters, which shows that workers are easy to get tired when operating backpack brush cutter. This may be related to the fact that the weight of the backpack brush cutters is larger than that of the side-mounted brush cutters. It has been proved that the cause of the injury of the lower back of the human body is related to carrying overweight objects or bearing for a long time [25].

When operating the side-mounted backpack brush cutters, the force of the trapezius muscle on both sides is uneven, the load of the left trapezius muscle is >25%, and the maximum value is >30%. This result is similar to the effect of Bobet and Norman [26] on the back myoelectric activity when the weight is concentrated in the high and low position of the back. This means that the weight load distribution of side-mounted brush cutter is uneven, which can easily lead to fatigue of operators.

CONCLUSIONS

There are significant differences in the effects of different working postures on the muscle activities of operators' trunk. Although in the operation, garden workers will subconsciously adjust their body movements to obtain the best working posture, but due to the differences in workers' operating habits and the level of postural awareness, it may lead to problems such as uneven strength of trunk muscles and overwork of erector spinae muscles, resulting in low back injury of workers. Therefore, researchers and garden management departments should optimize the industrial design of brush cutter, strengthen the study of working posture, and apply the results to operational guidance, so as to prevent the occurrence of occupational diseases.

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Publisher: Nofer Institute of Occupational Medicine, Łódź, Poland