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The contribution of lower leg muscles during vertical jump: An electromyographic study

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Abstract
Introduction: Electromyography is the technique for evaluating and recording the electrical activity produced by skeletal muscles. Surface Electromyography (sEMG) is the evaluation of muscle function by analysing the electrical signals originated from muscular contraction. Vertical jumping is a critical movement in many sports, requiring complex coordination and significant muscular power. Understanding the activation patterns of muscles during a vertical jump is essential for enhancing athletic performance and preventing injuries.
Objective: To analyse the contribution of the lower leg muscles during vertical jump.
Materials and Methods: Delsys Avanti Trigno EMG Sensors and the ADM Labchart 8.0 software was used to capture the activation data of the lower leg muscles i.e. Medial and Lateral Gastrocnemius muscles, Soleus and Tibialis Anterior while performing vertical jump. Normalisation of activation was performed for each muscle using Maximal Voluntary Isometric Contraction (MVIC). The EMG signals were converted to Root Mean Square (RMS), the data was expressed as the percentage of MVIC. The data was presented through descriptive, ANOVA and Correlation statistics.
Findings and Conclusions: The m. Soleus showed the highest activation, and TA showed the least activation compared to Gastrocnemius. The left extremity muscles showed more activation, most probably due to the left extremity being more powerful but was not statistically significant. When muscles were paired on the right and left sides, TA showed significant difference. The study is not conclusive regarding the difference in activation between muscles. Further studies could be done regarding the role of muscles during the concentric and eccentric phase of the vertical jump.

Keywords: Electromyography (EMG), surface electromyography (sEMG), vertical jump, lower leg muscles, medial gastrocnemius, lateral gastrocnemius

Introduction
Electromyography is the technique for evaluating and recording the electrical activity produced by skeletal muscles. Surface Electromyography (sEMG) is the evaluation of muscle function by analysing the electrical signals originated from muscular contraction [1].
It is used for medical diagnostics, rehabilitation, ergonomics, movement analysis and chronic pain management Application of EMG is not only for research purpose, it also for sports performance and sports medicine and also important tool for biofeedback during training and rehabilitation [2]. sEMG measures muscle activity by detecting the electrical potentials generated by muscle cells when they are activated [3].
Vertical jump is ability to jump vertically. It is one of the determining variables of jumpers' performance. Successful vertical jumps require muscle strength of lower extremity [4]. Vertical jumping is a critical movement in many sports, requiring complex coordination and significant muscular power. Understanding the activation patterns of muscles during a vertical jump is essential for enhancing athletic performance and preventing injuries.
Human lower extremity consists of two joint muscles, whose function during human movement is the transportation of mechanical energy from proximal to distal joints. It is believed that this transportation causes an effective transformation of rotational motion of body segments into translation of the body centre of gravity [5]. Gastrocnemius muscle is a two-joint muscle that is passing the knee and the ankle joints and acts as a knee flexor and ankle extensor.

In jumping, the activation of the biarticular gastrocnemius muscle prior to the end of the push-off enables the transportation of the power generated by the knee extensors from the knee to the ankle joint [6]. There are not enough studies done on the role of single-joint muscle like soleus which is also a plantar flexor and the antagonists in plantar flexion such as m. tibialis anterior. Therefore, this study attempts to document the relative contribution of these muscles during vertical jump.

Objective of the study: The objective of the Study was to explore the activation of selected lower extremity muscles during vertical jump.

Materials and Methods

Participants

- Forty sportspersons undergoing their Teacher Education Programme in Physical Education and who were in active sports participation in various games were considered for the study.
- It was ensured that the participants did not suffer from any injury or any other ailment which would affect the performance during the experiment and also affect the EMG reading.
- The subjects were explained the purpose of the study, they underwent trials to familiarise themselves with the procedure.
- They were also administered an Informed Consent Form for which they voluntarily agreed.
- The Study was approved by the University.

Instrumentation: The muscle activation was acquired by using the Delsys Trigno EMG system, US. It was ensured that the EMG device was calibrated and functioning correctly. The data was analysed with AD Instruments Labchart 8.0 software.

Data recording: The skin was cleaned with alcohol wipes and excess hair if any was shaved to ensure good electrodes contact. The Delsys Avanti sensors were placed on the belly of the muscle to be studied as per the SENIAM guidelines, with the help of adhesive tape. The muscles tested were the Gastrocnemius Medialis (GM), Gastrocnemius Lateralis (GL), Soleus (SL) and the Tibialis Anterior (TA) on both the legs.

Normalisation: Normalisation of muscle activation of each of the muscles was conducted by performing maximum voluntary isometric contraction (MVIC) in a pre-determined movement. Participants were instructed to perform an isometric contraction at maximum force for a time window of 5 seconds for 3 trials with a rest period of 2 minutes in between each trial. The average of 3 trials was taken as the measure of MVIC.

Medial and lateral gastrocnemius muscle: The MVIC of Gastrocnemius (lateral and medial) was conducted with the subject sitting with the back against the wall, with legs outstretched in the front. Resistance was placed against the ball of the feet, and the subject was required to try to plantar flex the feet against the resistance.

Soleus muscle: The MVIC of the Soleus muscle was conducted with the subject sitting on a chair with the knees flexed to 90 degrees, to isolate the Soleus muscle. Resistance was placed against the ball of the feet, and the subject was required to try to plantar flex the feet against the resistance.

Tibialis anterior muscle: The MVIC of Tibialis Anterior (TA) was conducted with the subject sitting with the back against the wall with the legs outstretched in the front. Resistance was placed against the top of the feet (on the metatarsals), and the subject was required to try to dorsi flex the feet against the resistance.

Vertical jump

After performing the MVIC, the subject performed 3 trials of vertical jump with 2 minutes of rest between each repetition. Surface electromyography (sEMG) was used to record the electrical activity of selected lower leg muscles that is Gastrocnemius (medial and lateral), Soleus and Tibialis Anterior while performing the vertical jump.

Data analysis

The sEMG data generated during both MVCs testing and while performing exercise was acquired and (Trigno Wireless System, Delsys, Natick, MA, United States) analysed to quantify muscle activity. The data was converted into root-mean-square (RMS) technique using Labchart 8.0 software, by AD Instruments, USA.

Statistical analysis

Demographic data of the participants

Table 1: Demographic data of the participants

Gender	N	Age	Height	Weight	BMI
Male	25	23.4±1.5	1.72±0.06	68.4±7.1	23.0± 2.8
Female	15	24.1±1.5	1.59±0.06	53.710.6	21.2±3.7

Table 1 indicates the characteristics of the participants. The height and weight of the participants are normal which would ensure that they are homogeneous in their BMI and add reliability to the data.

Activation of lower extremity muscles during vertical jump

From Table 2 it is evident that SL shows the highest activation during vertical jump. The MG and LG are equally activated while the TA shows the least activation (Figure 1). MG, LG and SL being the prime movers for plantar flexion which occurs during vertical jump predictably show the highest activity, it is interesting to note that among them, MG works the most. TA which is a major activator for dorsal flexion, participates most probably during the eccentric phase of the vertical jump, and understably has the least activation in plantar flexion which majorly occurs during vertical jump.

Table 2: Descriptive statistics of muscle activation during vertical jump

Muscle types	Extremity	N	Mean±standard deviation
Medial Gastrocnemius	Right Extremity	40	104.16±32.29
	Left Extremity	40	99.57±40.78
Lateral Gastrocnemius	Right Extremity	40	100.57±45.67
	Left Extremity	40	98.07±43.06
Soleus	Right Extremity	40	160.74±52.91
	Left Extremity	40	158.77±64.72
Tibialis Anterior	Right Extremity	40	71.52±41.65
	Left Extremity	40	88.70±65.27

Note: The data is collected for 40 samples for each muscle for the R and L extremity and is expressed is expressed as percentage of MVIC.

Fig 1: Activation of the muscles of the right and left extremity during vertical Jump

Table 3: Contribution of lower leg muscles to vertical jump

Muscles	N	% total activation of right extremity	% total activation of left extremity
Medial gastrocnemius	40	23.84	22.37
Lateral gastrocnemius	40	23.01	22.03
Soleus	40	36.78	35.67
Tibialis anterior	40	16.37	19.93

Note: The data is collected for 40 samples for each muscles for the R and L extremity and is expressed percentage of the combined value of activation of all the four muscles.

Table 3 indicates the contribution of the four lower leg muscles in vertical jump performance. As already indicated in table 1, SL contributes the highest in both the right and left leg (35.67% and 36.78% respectively) followed by MG (22.37% and 23.84% for R and L respectively). The TA shows the least, mostly because it is a dorsi flexor, and therefore contributes only 19.93% and 16.37% for R and L respectively.

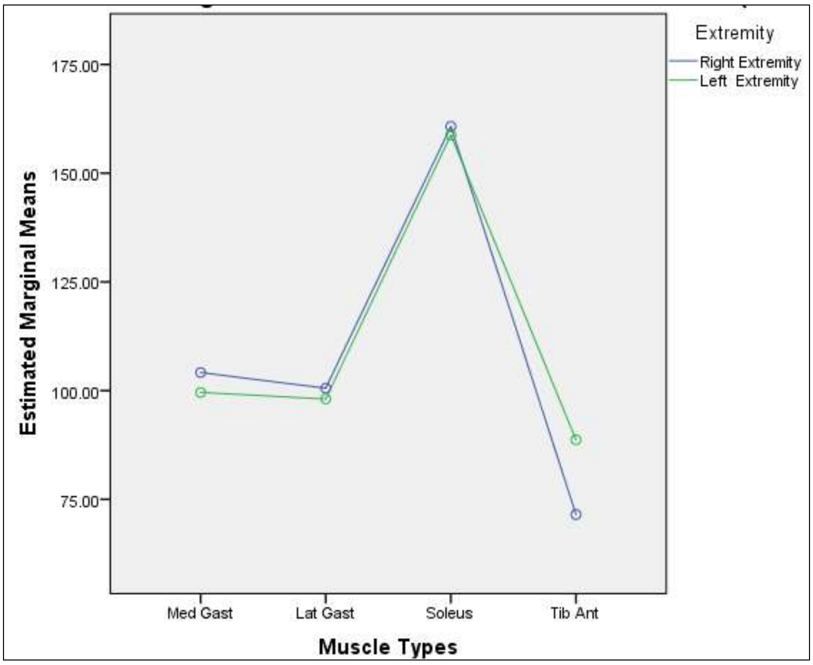

Fig 2: Estimated marginal means of muscle activation during vertical jump

Combined Activation of muscles on the right and left extremity during vertical jump

Table 4: Activation of muscles on the right and left extremity during vertical jump

Activity	Extremity	N	Mean±SD	t-test for Equality of Means		
				t	df	Sig. (2-tailed)
Vertical Jump	Right Extremity	160	109.25±54.13	-0.315	318	0.753
	Left Extremity	160	111.28±60.90			

Note: The data is collected for four muscles of 40 samples each (totally 160 samples) combined for R and L extremity and is expressed as percentage of MVIC.

From Independent sample t test, we can observe that there exists no difference in the combined activation of all the four muscles on the right and left extremity at 5% level of significance as p value is greater than 0.05. Though, the left side shows slight increase in activation it is not statistically significant.

Activation of corresponding muscles on the right and left extremity

Table 5: Descriptive statistics of the paired muscles on the right and left extremity

		Mean	N	Std. deviation	Std. error mean
Pair 1	LMG	99.5725	40	40.7876	6.44909
	RMG	104.161	40	32.292	5.10581
Pair 2	LLG	98.0768	40	43.06191	6.80869
	RLG	100.572	40	45.67133	7.22127
Pair 3	LSL	158.776	40	64.72158	10.23338
	RSL	160.741	40	52.91149	8.36604
Pair 4	LTA	88.7021	40	65.27612	10.32106
	RTA	71.5267	40	41.65438	6.58614

Note: The data is collected for 40 samples for each muscle for the R and L extremity and is expressed is expressed as percentage of MVIC

Table 6: Paired samples t test for paired muscles on the right and left extremity

		Paired differences		t	df	Sig. (2-tailed)
		Mean	Std. deviation			
Pair 1	LMG - RMG	-4.5888	36.4645	-0.796	39	0.431
Pair 2	LLG - RMG	-2.4949	47.10254	-0.335	39	0.739
Pair 3	LSL - RSL	-1.9656	71.65678	-0.173	39	0.863
Pair 4	LTA - RTA	17.1754	43.12444	2.519	39	.016*

*- Significant at 5% level of significance

Table 5 compares the activation of each pair of muscle between the right and left extremity during the vertical jump. It is evident that, since the combined effect of the muscles are not significantly different on the right and left side, individually also the muscle activation is not statistically different, except in the case of TA. Since TA show antagonistic action during vertical jump, the left TA shows significantly more activation, compared to RTA at 5% level of significance as p value = 0.016 < 0.05. (Table 6)

Discussion and Conclusion

This study was conducted with the objective of analysing the muscle activation during vertical jump. Contribution of four lower leg muscles notably, Medial and Lateral Gastrocnemius, Soleus and Tibialis Anterior on both extremities were analysed. The muscle activation was acquired using Delsys Avanti Trigno EMG sensors and AD Instruments Labchart 8.0 software. The muscle activation was measured in millivolts and expressed as the percentage of the normalised muscle activation for each muscle (MVIC).

The data indicated that there is no statistical difference in muscle activation between the right and left leg muscles paired together, except in the case of TA. Overall, the SL showed greatest activation among the four muscles while the medial and lateral gastrocnemius were similar in activation. TA was the lowest probably because it is mainly a dorsi-flexor and it may come into action during the eccentric phase. Though the study is not conclusive regarding the differences in activation between different muscles during vertical jump, it soes throw light on the important role of SL during vertical jump. As an advancement to this study, it would be educative to analyse the muscle activation during concentric and eccentric phase separately and also the sequence of muscle activation during different phases of vertical jump.

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