Eng Int Syst (2023) 5: 363–367
© 2023 CRL Publishing Ltd

Engineering
Intelligent Systems

Effect of Strength Training on Muscle Group Activation in Track and Field Athletes

Tian Huang and Jinxia Gao*

Physical Education College, Sichuan University, Chengdu, Sichuan 610065, China

Objective: The aim of this study is to understand the effect of strength training on muscle group activation.
Methods: Experiments were conducted with 20 track and field athletes. Muscle group activation data were collected by means of surface electromyography (EMG) equipment. Strength training was performed on a vibration table with the movement of half-squat and rise, and the frequency was controlled at 0 Hz, 30 Hz, 40 Hz, and 50 Hz. The EMG root-mean-square (EMGrms) (%MVC) of muscle groups at different frequencies were compared.
Results: In the thigh muscle group, the EMGrms (%MVC) increased with the increase of vibration frequency; compared with 0 Hz, the EMGrms (%MVC) of the thigh muscle group increased significantly at the frequency of 50 Hz ($p < 0.05$). In the calf muscle group, the EMGrms (%MVC) increased with the increase of the vibration frequency; the EMGrms (%MVC) of the thigh muscle group under a frequency of 50 Hz was significantly different from that under 0 Hz.
Conclusion: Vibration strength training has a significant effect on the activation level of muscle groups and can be applied in practice.

Keywords: strength training, sprinting, muscle group activation, lower extremity muscle groups, track and field athletes

1. INTRODUCTION

Track and field events are physical fitness-oriented and are widely popular (Pierpoint et al., 2016). In these events, strength is very important, and athletes need to have good body control, i.e., good body stability and balance, which are closely related to muscle strength. Strength training is basic training in track and field. Good strength training can effectively strengthen the neuromuscular system (Harridge et al., 2015), build muscle, reduce fat (Skrypnik et al., 2015), and improve body function (Sundstrup et al., 2016) and body flexibility (Bilodeau et al., 2015). To understand the training effect better, sensors (Liang et al., 2020), video technology (Xi et al., 2021), and surface electromyography (EMG) have been applied in sports training. The state of the muscles during exercise can indicate many conditions, and has also been studied extensively (Marri and Swaminathan, 2016). Borms et al. (2017) used electromyography (EMG) to analyze the progressive (medium to high) load training process of the biceps, providing some guidance for athletes' exercises for non-surgical or post-operative rehabilitation. Marotta et al. (2020) studied the activation of the quadriceps in soccer players and found that the medial vastus muscle of female athletes had delayed activation. Samadi et al. (2017) studied athletes with functional ankle instability (FAI) and found, by comparing the sequence of pre-activity in the leg muscles, that FAI athletes had a slower onset of pre-activity in the gastrocnemius, tibialis anterior, and flounder muscles than other athletes. Youdas et al. (2019) studied the role of suspension training equipment by means of surface EMG analysis; through experiments involving 32 participants, they found that more trunk muscles were raised after suspension training than standard push-ups, suggesting that suspension

*Corresponding address: Unit 1, Building 3, Shihaoruili, Tianfu Second Street, High-tech District, Chengdu, Sichuan 610065, China. Email: xiaju265565@163.com

Table 1 General data of research subjects.

Age/years	21.67 ± 2.16
Height/m	1.76 ± 2.48
Body weight/kg	73.21 ± 5.83
Training time/year	7.82 ± 3.45

training has a positive effect on the training of trunk muscles. This paper focuses on the effect of vibration strength training. Taking track and field athletes as an example, in this study, we analyzed the effect of training on the activation of athletes' lower limb muscle groups in order to understand the reliability of vibration strength training and provide some theoretical bases for its better application in actual sports training.

2. RESEARCH SUBJECTS AND METHODS

2.1 Research Subjects

Twenty track and field athletes from the Physical Education College of Sichuan University were selected as the study subjects. All the athletes reached the level 2 standard of national track and field athletes and were specialized in sprinting. The right leg was their dominant leg. They were in good health, had no bad habits, did not engage in strenuous exercise before the experiment, and had no limb injury and history of surgery in the last six months. They all understood the purpose and procedure of the experiment and signed the informed consent formS. The general data of the athletes are shown in Table 1.

2.2 Experimental Protocol

The equipment used for the experiment was the surface EMG equipment of the Noraxon 16-lead telemetry DTS system (Noraxon Inc, Scottsdale, USA). The EMG data were processed using the MyoReserach XP Master Software Version 1.07.17 analysis system. The data were collected by the following methods. The athletes wore loose shorts. The place where the electrode pads would be attached were depilated and cleaned, then keratin was removed with sandpaper, grease was removed, and the area was disinfected with 75% medical alcohol cotton. The experimenter stuck two disposable electrode slices (Shanghai Qiankang Medical Treatment Equipment Co., Ltd., China) on each muscle, 2 cm apart and parallel to the muscle fibers. After all the electrode slices had been attached, the EMG amplifier and signal cable were connected and fixed with medical tape. The main muscle groups studied were the thigh muscle group, including the rectus femoris muscle, the vastus lateralis muscle, the vastus medialis muscle, the biceps femoris muscle and the semitendinosus muscle, and the calf muscle group, including the anterior tibialis muscle, the lateral head of the gastrocnemius and the medial head of the gastrocnemius.

After understanding the experimental procedure, the athletes warmed up for 15 mins, had the electrode slices attached, and performed the maximal voluntary isometric contraction (MVC) test of lower limb muscles. During the test, the athletes exerted force slowly, reached the maximum force after 2 s, maintained it for 5 s, gradually relaxed for 3 s and returned to the inactive state. The activation of muscle groups was reflected by the muscle activation rate (%MVC). They rested for 5 mins after the MVC test and then did four sets of strength training (half-squat and rise) on a vibration table. There was a rest time of 3 mins between every set. The vibration stimulation frequency was 0 Hz, 30 Hz, 40 Hz and 50 Hz. The data were collected during the training.

2.3 Training Movements

The warm-up movements are as follows.

(1) Stretch the anterior thigh muscles: the athlete lunged on a mat, with the knee of the rear leg on the ground, grabbed the ankle of the rear leg to pull it towards the leg until feeling the anterior thigh muscles stretched, and switched legs after maintaining this position for 15 s. The movement was repeated three times.

(2) Stretch the posterior thigh muscles: the athlete straightened both legs, drew the toes backward, touched the toes with fingertips until feeling the posterior thigh muscles being stretched, and maintained the posture for 15 s. The movement was repeated three times.

(3) Stretch posterior calf muscles: the athlete kept a push-up posture, moved the center of gravity, touched the ground with heels until feeling the posterior calf muscles being stretched, and maintained the posture for 15 s. The movement was repeated six times.

(4) Stretch hip muscles: the athlete lay on a mat, dropped the right ankle above the left knee, held the left knee with both hands to pull it towards the body until feeling the hip muscles being stretched, and switched the leg after maintaining the position for 15 s. The movement was repeated three times.

(5) Stretch all the muscles of the body: the athlete kept his legs together, bent knees to squat, touched the ground with both hands, slowly moved forward until both hands could no longer move forward, and moved both legs slowly forward to position the feet as close as possible to the hands until reaching the maximum limit of the body. The movement was repeated six times.

Strength training movements: the athlete stood on a vibration table, grabbed the safety handrail, squatted down,

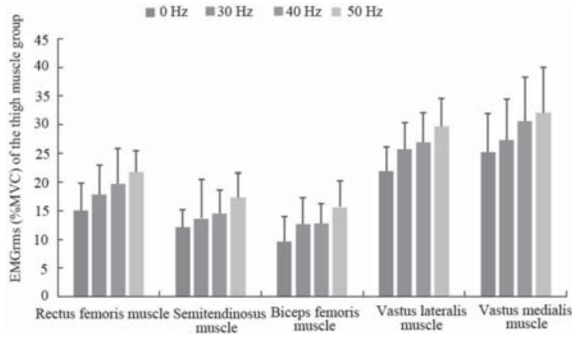

Figure 1 EMGrms (%MVC) of the thigh muscle group under half-squat and rise.

Table 2 Comparison of EMGrms P values for the thigh muscle group with and without vibration stimulation.

	30 Hz	40 Hz	50 Hz
Rectus femoris muscle	0.066	0.053	0.042
Semitendinosus muscle	0.078	0.055	0.037
Biceps femoris muscle	0.074	0.061	0.045
Vastus lateralis muscle	0.063	0.052	0.028
Vastus medialis muscle	0.071	0.053	0.029

rose after the knee joint formed an angle of 120°, and lifted the heels after extending the hip and knee joints. The movement was repeated ten times.

3. STATISTICAL ANALYSIS

SPSS20.0 software was used. The data were expressed as $\bar{x} \pm s$. The T-test was used for comparative analysis. $P < 0.05$ indicated a significant difference.

4. RESULTS

The activation of the thigh muscle group of the athletes under different vibration strength training is shown in Figure 1.

For comparison, Table 2 shows statistical analysis results of the EMGrms for the thigh muscle group with and without vibration stimulation.

It can be seen from Figure 1 and Table 2 that the activation of the rectus femoris muscle was 15.12 ± 4.68 (%MVC) in the absence of vibration stimulation; with the increase of the vibration frequency, the activation level of the rectus femoris muscle gradually increased; the activation level increased to 17.84 ± 5.12 (%MVC) when the frequency was 30 Hz, to 19.67 ± 6.11 (%MVC) when the frequency was 40 Hz, and to 21.67 ± 3.69 (%MVC) when the frequency was 50 Hz; $p < 0.05$ in the comparison of the activation level of the rectus femoris muscle between 0 Hz and 50 Hz, i.e., the difference was significant. The other muscles of the thigh muscle group showed similar characteristics to the rectus femoris muscle. The activation level of the semitendinosus muscle was 12.16 ± 3.08 (%MVC) under 0 Hz and 17.31 ± 4.26 (%MVC) under 50 Hz. The biceps femoris muscle showed an activation level of 9.67 ± 4.32 (%MVC) under 0 Hz and an activation level of 15.67 ± 4.51 (%MVC) under 50 Hz. The activation level of the vastus lateralis muscle was 21.89 ± 4.23 (%MVC) under 0 Hz and 29.64 ± 4.95 (%MVC) under 50 Hz. The activation level of the vastus medialis muscle was 25.12 ± 6.85 (%MVC) under 0 Hz and 32.09 ± 7.86 (%MVC) under 50 Hz. In general, the activation level of the thigh muscles increased gradually with the increase of the vibration frequency. It showed a significant difference in the activation level of the thigh muscle group under 50 Hz vibration stimulation and without vibration stimulation, demonstrating the effect of vibration strength training on the activation of the thigh muscles.

The activation of the calf muscle group in the athletes is shown in Figure 2.

As shown in Figure 2 and Table 3, the activation level of the calf muscle group increased with the increase of vibration frequency, and the activation level of the anterior tibial muscle was 11.69 ± 4.12 EMGrms (%MVC) under no vibration stimulation; the activation level of the calf muscle group increased to 14.68 ± 5.16 (%MVC) when the frequency was 30 Hz, to 16.78 ± 5.64 (% MVC) when the frequency was 40 Hz, and to 18.64 ± 8.77 (%MVC) when the frequency was 50 Hz. $p < 0.05$ in the comparison of the activation level of the anterior tibial muscle between 0 Hz and 50 Hz, i.e., the difference was significant. The activation level of the lateral head of the gastrocnemius was 16.36 ± 6.15 (%MVC) under 0 Hz and 25.12 ± 7.67 (%MVC) under 50 Hz. The action level of the medial head of the gastrocnemius was 21.27 ± 6.56 (%MVC) under 0 Hz and 33.54 ± 9.12 (%MVC) under 50 Hz ($p < 0.05$). The results indicated that vibration strength training could improve EMGrms (%MVC) in the calf muscle group.

5. DISCUSSION

The ability of muscles and joints to overcome external resistance during movement determines the level of strength of the human body. Not only is the level of strength a source

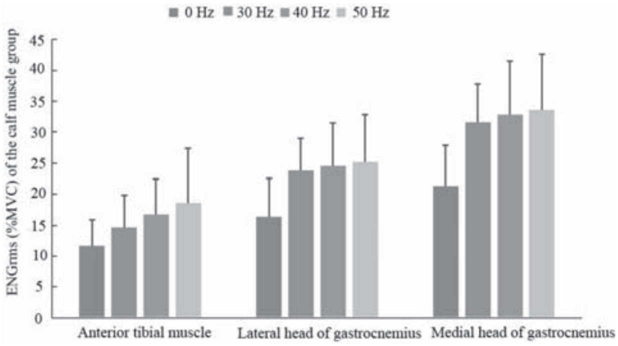

Figure 2 EMGrms (%MVC) of the calf muscle group under half-squat and rise.

Table 3

	30 Hz	40 Hz	50 Hz
Anterior tibial muscle	0.071	0.056	0.036
The lateral head of gastrocnemius	0.072	0.064	0.027
The medial head of gastrocnemius	0.069	0.062	0.042

of human power: it can also impact the development of other skills, which is the basis of track and field sports and other sports. The increase in strength can effectively improve sports performance (Styles et al., 2015). In strength training, in order to achieve better training effects, it is necessary to constantly break the original load of athletes, gradually improve the load by scheduling to stimulate the body, alternate exercises for different muscle groups, and avoid sports fatigue and injury. In the past, strength training was usually based on muscle load training, which was monotonous and boring. With the development of modern technology, more and more strength training methods are being applied, such as suspension training (Masteller et al., 2016), Swiss ball training (Thevan et al., 2020) and core training (Ozmen and Aydogmus, 2016). The focus of this current study was on the study of vibration strength training. Vibration stimulation was first used in the field of medical rehabilitation (Oberste et al., 2018) to induce muscle contraction in patients (Lai et al., 2021), thus reducing pain and spasm (Souron et al., 2016) and improving human health (Mohamed, 2016). Subsequently, this method was introduced into sports training (Rosenberger et al., 2017).

Sprinting requires athletes to have the maximum intensity of muscle activity, and both thigh and calf muscle groups are involved in the work; therefore, the activation of thigh and calf muscle groups is necessary. The experimental results this study demonstrated that vibration strength training could effectively improve the activation level of thigh and calf muscle groups and increase the level of muscle activity. For the thigh muscle group, the EMGrms (%MVC) increased gradually with the increase of the vibration frequency, and $p < 0.05$ in the comparison of the EMGrms (%MVC) of the muscle group under 0 Hz and 50 Hz. Similarly, the EMGrms (%MVC) of the calf muscle group also increased with the increase of the vibration frequency, and there was a significant difference in the EMGrms (%MVC) under 0 Hz and 50 Hz. Under the vibration stimulation, the length of the extra-saccadic muscle changes, and the excitability of the muscle shuttle is enhanced. The motor unit is maximally recruited, and type I and type II muscle fibers are activated simultaneously, improving the synchronization degree of the motor unit; thus, the contraction capacity of the muscles becomes stronger, improving the synchronization and coordination of the active muscle. Moreover, the flexibility of the nervous system is also enhanced, and fast and slow muscle neurons reach their excitation threshold, improving the body's response and resilience and the muscle's ability to contract. In addition, the experimental results demonstrated that high frequencies were more effective for muscle activation. The higher the vibration, the stronger was the stimulation of the nerves, the better was the coordination of the system, the higher was the threshold of the motor units recruited, and the higher was the activation level of the muscles.

This paper has several shortcomings that need to be investigated in future work. For instance, the sample size could be expanded, experiments could be conducted with higher-level athletes to study the effects of a greater range of strength training techniques on muscle group activation.

6. CONCLUSION

This paper analyzed the activation of muscle groups of athletes under vibration strength training. Through experimental analysis, it was found that the lower limb muscle groups of the athletes were effectively activated after vibration strength training; with the increase of the vibration frequency, the EMGrms (%MVC) of the muscle groups also gradually increased; the activation level of the muscle groups under a frequency of 50 Hz was significantly different from that under 0 Hz ($p < 0.05$). The experimental results verified the effectiveness of vibration strength training in improving the activation level of muscle groups. Vibration strength training can be further applied in actual sports training to enhance the training effect and improve athletes' skills.

REFERENCES

1. Bilodeau, M., Keen, D.A., Sweeney, P.J., Shields, R.W. & Enoka, R. (2015). Strength training can improve steadiness

in persons with essential tremor. *Muscle & Nerve*, *23*(5), 771–778.
2. Borms, D., Ackerman, I., Smets, P., Van den Berge, G. & Cools, A.M. (2017). Biceps disorder rehabilitation for the athlete: a continuum of moderate- to high-load exercises. *The American Journal of Sports Medicine*, *45*(3), 642–650.
3. Harridge, S., Kryger, A. & Stensgaard, A. (2015). Knee extensor strength, activation, and size in very elderly people following strength training. *Muscle & Nerve*, *22*(7), 831–839.
4. Lai, Z., Lee, S., Chen, Y. & Wang, L. (2021). Comparison of whole-body vibration training and quadriceps strength training on physical function and neuromuscular function of individuals with knee osteoarthritis: A randomized clinical trial. *Journal of Exercise Science & Fitness*, *19*(3), 150–157.
5. Liang, Y., Lan, J. & Lu, C. (2020). Multi-Sensor Data Fusion Technology for the Single Bamboo Drifting. *Engineering Intelligent Systems*, *28*(2), 73–81.
6. Marotta, N., Demeco, A., de Scorpio, G., Angelo, I., Iona, T. & Ammendolia, A. (2020). Late Activation of the Vastus Medialis in Determining the Risk of Anterior Cruciate Ligament Injury in Soccer Players. *Journal of Sport Rehabilitation*, *29*(7), 952–955.
7. Marri, K. & Swaminathan, R. (2016). Analysis of concentric and eccentric contractions in biceps brachii muscles using surface electromyography signals and multifractal analysis. *Proceedings of the Institution of Mechanical Engineers Part H Journal of Engineering in Medicine*, 0954411916654198.
8. Masteller, B., Laurent, C.S., Laurent, T.S., Bigelow, C. & Sirard, J.R. (2016). Effect Of A Suspension-Training Movement Program on Muscular Fitness In Youth: 509 Board #346 June 1, 9: 30 AM - 11: 00 AM. *Medicine and Science in Sports and Exercise*, *48*, 147–148.
9. Mohamed, M.E. (2016). Impact of Whole-Body Vibration versus Resistive Exercise Training on Lipid Profile in Elderly. *World Journal of Medical Sciences*, *13*(1), 01–08.
10. Oberste, M., Großheinrich, N., Wunram, H.L., Graf, J.L., Ziemendorff, A., Meinhardt, A., Fricke, O., Mahabir, E. & Bender, S. (2018). Effects of a 6-week, whole-body vibration strength-training on depression symptoms, endocrinological and neurobiological parameters in adolescent in-patients experiencing a major depressive episode (the "Balancing Vibrations Study"): Study protocol for a randomized placebo-controlled trial. *Trials*, *19*(1), 347.
11. Ozmen, T. & Aydogmus, M. (2016). Effect of core strength training on dynamic balance and agility in adolescent badminton players - ScienceDirect. *Journal of Bodywork and Movement Therapies*, *20*(3), 565–570.
12. Pierpoint, L.A., Williams, C.M., Fields, S.K. & Dawn, R. (2016). Epidemiology of Injuries in United States High School Track and Field: 2008–2009 Through 2013–2014. *American Journal of Sports Medicine*, 1463.
13. Rosenberger, A., Beijer, Å., Johannes, B., Schoenau, E., Mester, J., Rittweger, J. & Zange, J. (2017). Changes in muscle cross-sectional area, muscle force, and jump performance during 6 weeks of progressive whole-body vibration combined with progressive, high-intensity resistance training. *Journal of Musculoskeletal & Neuronal Interactions*, *17*(2), 38–49.
14. Samadi, H. & Rajabi, R. (2017). Comparing the Onset of Pre-Activity of Leg Muscles between Athletes with Functional Ankle Instability and Healthy Athletes During Landing from a Jump. *Journal of Babol University of Medical Sciences*, *19*(11), 7–13.
15. Skrypnik, D., Bogdański, P., Mądry, E., Karolkiewicz, J., Ratajczak, M., Kry ś ciak, J., Pupek-Musialik, D. & Walkowiak, J. (2015). Effects of Endurance and Endurance Strength Training on Body Composition and Physical Capacity in Women with Abdominal Obesity. *Obesity Facts*, *8*(3), 175–187.
16. Souron, R., Farabet, A., Féasson, L., Belli, A., Millet, G.Y. & Lapole, T. (2016). Effects of an 8-week local vibration training on corticospinal properties of the tibialis anterior muscle. *Annals of Physical and Rehabilitation Medicine*, *59*, e52.
17. Styles, W.J., Matthews, M.J. & Comfort, P. (2015). Effects of Strength Training on Squat and Sprint Performance in Soccer Players. *Journal of Strength & Conditioning Research*, *30*(6), 1534–1539
18. Sundstrup, E., Jakobsen, M.D., Andersen, L.L., Andersen, T.R., Randers, M.B., Helge, J.W., Suetta, C., Schmidt, J.F., Bangsbo, J., Krustrup, P. & Aagaard, P. (2016). Positive effects of 1-year football and strength training on mechanical muscle function and functional capacity in elderly men. *European Journal of Applied Physiology*, *116*(6), 1127–1138.
19. Thevan, A.A., Kalaiselvi, M., Manoranjith, R., Prasanna, A. & Pounraj, C.P. (2020). High Technology Letters Consequence of bulgarian bag training and swiss ball training on selected explosive power and muscular strength of college men volleyball players. *High Technology Letters*, *26*(5), 539–547.
20. Xi, Y., Yang, S., Wang, P. & Feng, Y. (2021). Human Motion System Model Based on Real-Time Image Acquisition and Data Simulation. *Engineering Intelligent Systems*, *29*(3), 175–181.
21. Youdas, J.W., Baartman, H.E., Gahlon, B.J., Kohnen, T.J., Sparling, R.J. & Hollman, J.H. (2019). Recruitment of Shoulder Prime Movers and Torso Stabilizers during Push-Up Exercises Using a Suspension Training System. *Journal of Sport Rehabilitation*, *29*(7), 1–8.