Muscle Activity Characteristics Between Correct and Incorrect Bodyweight-Squats

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Summary

Physical exercise is essential for managing various injuries and conditions, yet at-home exercise routines often lack professional supervision, increasing the risk of improper execution. Machine learning models offer a promising solution by providing automated feedback to bridge this gap. However, validating these models requires a biomechanically informed approach. This study compares surface electromyography (sEMG) data from major leg muscles to evaluate differences between a correctly performed bodyweight squat and two common faulty executions, providing insights into movement quality assessment.

Introduction

Physical exercises are vital for rehabilitation and enhancing performance, yet limited access to professional supervision often leads individuals to rely on self-directed exercise routines via apps or social media. Without proper guidance, incorrect execution can hinder progress and increase the risk of musculoskeletal injury. To reduce these risks, automated feedback could be employed. When integrated with biomechanical models, machine learning offers a promising approach to identifying and predicting movement patterns. To apply this approach to squat assessment, we aim to quantitatively distinguish and compare the biomechanical characteristics of correct and incorrect squatting movements. For this purpose, we utilize motion capture, surface electromyography (sEMG), ground reaction forces (GRF), and dual-camera smartphone recordings. In this work, we specifically focus on analyzing sEMG data to assess muscle activity differences between proper and faulty squat executions.

Methods

All twelve participants were tested in each of the three conditions, completing three sets of ten repetitions per condition, with a two-minute rest between sets. In the correct condition, the participants were instructed to perform a squat with an upright posture and as deep as possible while maintaining a straight back and heel contact with the floor. In the forward leaning condition, squats were executed with excessive forward leaning. In the right-side leaning condition, participants shifted their weight onto the right leg while squatting. Muscle activity was recorded from eight muscles per leg (Fig. 1) using wireless sEMG (Trigno Avanti, Delsys). After standard EMG preprocessing [1], the mean absolute value (MAV) was computed for each repetition and subsequently averaged across all repetitions and subjects.

Results and Discussion

The EMG MAVs revealed distinct differences in muscle activation patterns across the three squatting conditions

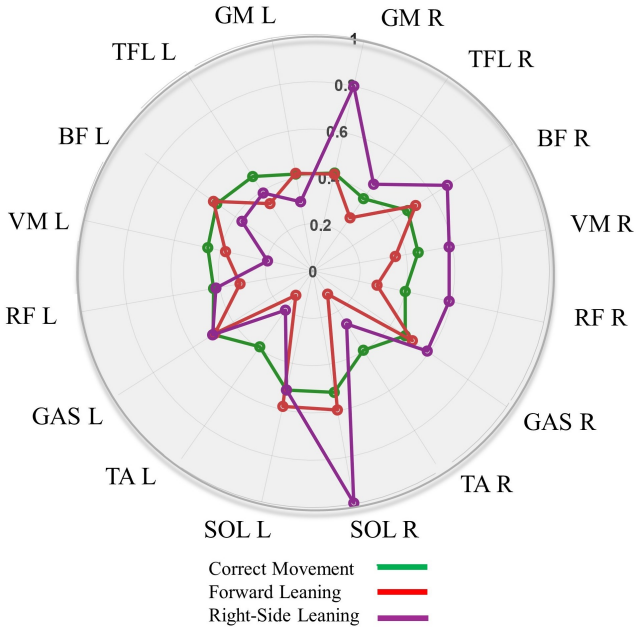

Figure 1: MAV from the left (L) and right (R) soleus (SOL), gastrocnemius (GAS), rectus femoris (RF) and vastus medialis (VM), biceps femoris (HAM), gluteus maximus (GM), tibialis anterior (TA), and tensor fasciae latae (TFL).

(Figure 1): In the correct condition, muscle activation was symmetrical between the legs. Quadriceps activations (VM and RF) were reduced by 17.65 % to 30.6 % across both legs during the forward-leaning squat variation, suggesting a redistribution of muscular effort towards the posterior chain. The right-side leaning condition showed increased activations in nearly all muscles of the right leg and decreased activations of the left leg muscles, resulting in a noticeable asymmetry. The most pronounced increases in the right leg were observed in GM(+95.0 %), SOL(+90.3 %), and RF(+51.2 %), whereas VM and BF also showed notable increases (+28.8 % and +42.5 %, respectively). Conversely, the left side exhibited substantial decreases, particularly in VM(-57.7 %), BF(-26.0 %), and TA(-48.7 %).

Conclusions

In summary, the results reveal significant differences in muscle activation patterns between the correct and incorrect squatting conditions. Leaning forward shifts the activation distribution between anterior and posterior muscles, while leaning sideways creates asymmetries between the legs. These changes in movement execution can affect lower limb muscle balance, limiting the effectiveness of training for daily tasks and potentially increasing the risk of injury.

References

[1] Grimmer M et al. (2022). *Front. Neurorobot.*, **16**