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SURFACE ELECTROMYOGRAPHIC ASSESSMENT OF LATERAL DELTOID AND RECTUS ABDOMINIS ACTIVATION DURING PLANK IN FEMALE COLLEGIATE ATHLETES

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ABSTRACT

The plank is a widely used isometric exercise for core stabilization, but most studies report mixed results, and very few have focused on female athletes. This **within-subject, single-session observational study** investigated muscle activation of the rectus abdominis and lateral deltoid during the plank in female collegiate athletes using surface electromyography (sEMG). Thirty healthy female students (aged 18–22 years, mean 18.63 ± 1.59) performed a standardized 30-second plank while sEMG signals were recorded from both muscles for a maximum duration of 20 seconds. Muscle activation was quantified using Root Mean Square (RMS) and Average Rectified Value (ARV). Paired-sample *t*-tests assessed differences in activation between muscles, and Pearson correlation analysis evaluated their co-activation. The rectus abdominis exhibited significantly higher activation than the lateral deltoid while correlation analysis indicated no significant relationship between the two muscles, at 5% level of significance, suggesting largely independent recruitment patterns. These findings highlight the rectus abdominis as the primary stabilizer during the plank, with the lateral deltoid contributing independently, providing practical insights for optimizing core and shoulder training in female athletes.

KEYWORDS: Muscle Activation, Surface Electromyography, Plank, Female athletes, Rectus Abdominis, Lateral Deltoid, core stability.

INTRODUCTION

The rigorous demands of competitive sports necessitate optimal physical conditioning and continuous monitoring of an athlete's physiological state. Central to this vigilance is the assessment of muscle activation, a critical factor that influences performance and increases the risk of injury (Cederbaum et al., 2023; Gomes et al., 2025; Harato et al., 2021; Moon et al., 2021). In collegiate athletics, understanding and mitigating muscle activation is essential not only for peak performance but also for ensuring the holistic well-being of athletes (Borja et al., 2022; Harato et al., 2021; Kacem et al., 2021). Unmanaged activation can compromise power output, impair neuromuscular control, and heighten susceptibility to injury (Harato et al., 2021; Sun et al., 2022).

Despite the universal relevance of muscle activation assessment, research focusing on female collegiate athletes remains limited. Female athletes often exhibit distinct physiological responses to training and activation, which may not be fully captured by studies primarily conducted on male populations (Akagi et al., 2019; Bouffard et al., 2018; Heyward et al., 2020; Santos et al., 2022; Welde et al., 2024). This underscores the need for targeted investigations designed to inform effective training protocols and injury prevention strategies for this demographic.

Surface electromyography (sEMG) offers a reliable, non-invasive means to quantify muscle activation and track the progression of activation (Helmi et al., 2017; Li et al., 2024; Miaoulis et al., 2025; Sun et al., 2022). Parameters such as root mean square (RMS) and average rectified value (ARV) provide precise measures of the intensity and consistency of muscle recruitment. The plank, widely adopted in both athletic and rehabilitation settings, serves as an ideal model for evaluating the endurance and activation of core and shoulder stabilizers, particularly the rectus abdominis and deltoid muscles (Byrne et al., 2014; Can et al., 2023; Kim et al., 2016; Lee et al., 2016).

While previous studies have examined core or shoulder muscles in isolation or compared variations of the plank, there is a lack of comprehensive research exploring the simultaneous activation patterns of both deltoid and rectus abdominis muscles in female collegiate athletes. Understanding these patterns is critical for optimizing training programs, preventing overuse injuries, and elucidating neuromuscular coordination strategies during static postures.

The present study aims to investigate muscle activation in the deltoid and rectus abdominis during the standard plank in healthy female collegiate athletes. Using sEMG to quantify RMS and ARV, the study examines both the relative activation levels of these muscles and the relationship between deltoid and rectus abdominis activation. Findings from this research are expected to provide actionable insights for enhancing performance, refining exercise prescription, and reducing injury risk in female athletes.

2. MATERIALS AND METHODOLOGY

2.1 Participants: A total of thirty healthy female collegiate students, aged between 18 to 22 years with a mean and SD (18.63 ± 1.59), were selected from Lakshmibai National Institute of Physical Education, Gwalior, India. These participants were randomly selected. Consent from participants and approval from the Institute were secured before the study.

2.2 Variables of the Study: In this study, the plank served as the independent variable, with its duration or performance being the key manipulation. The dependent variables under investigation were lateral deltoid muscle activation and rectus abdominis muscle activation, both quantified using BTS FREEEMG 300.

2.3 Administration of Tests: Participants performed a 30-second plank following the placement of surface EMG electrodes on the target muscles. Surface EMG signals were recorded for a maximum duration of 20 seconds to ensure consistent muscle activation and minimize signal noise. Proper placement of surface EMG electrodes on the target muscles as described below:

a) ***Rectus Abdominis:*** An imaginary line was drawn on the right side of the muscle, parallel to the linea alba, extending from the xiphoid process to the level of the anterior superior iliac spine (ASIS).

Location: The abdominal wall was palpated near the umbilicus. Since a thick layer of adipose tissue may cause surface EMG (sEMG) signal contamination, electrodes were carefully positioned 3 cm apart and parallel to the muscle fibres of the rectus abdominis. The electrodes were placed approximately 2 cm lateral to the umbilicus.

b) ***Lateral Deltoid:*** An imaginary line was drawn from the acromion process to the lateral border of the scapular spine, following the orientation of the lateral deltoid fibres.

Location: The electrodes were placed approximately halfway along this line, on the most prominent portion of the muscle belly, identified by palpating during resisted shoulder horizontal abduction or extension. The electrodes were positioned parallel to the muscle fibers, with an inter-electrode distance of 2 cm. Care was taken to avoid crosstalk from the infraspinatus and middle deltoid muscles to ensure selective recording of lateral deltoid activity.

2.4 Testing Procedure: All testing was conducted in the Sports Biomechanics Laboratory at Lakshmibai National Institute of Physical Education (LNIPE), Gwalior. Before the assessments, demographic information—including name, age, gender, height, and weight—was recorded.

Physiological measurements for the Rectus Abdominis and Lateral Deltoid muscles were obtained using a BTS FREEEMG 300 system, a reliable device for surface EMG analysis. Muscle activation parameters were assessed in terms of Root Mean Square (RMS) and Average Rectified Value (ARV). Data collection for each participant was conducted in a single session.

2.5 Study Design: This study used a **within-subject, single-session observational design**. A single group of 30 healthy students completed a standardized plank during one visit. Surface EMG of the right rectus abdominis and Lateral deltoid was recorded to compare activation levels and assess co-activation patterns.

2.6 Statistical analysis: Statistical analyses were performed using SPSS version 24. Descriptive statistics are presented as mean ± standard deviation and 95% confidence intervals. The normality of the data was assessed using the ***Shapiro–Wilk test***. Since muscle activation data for the rectus abdominis and lateral deltoid were obtained from the same participants under identical conditions, ***a paired-sample t-test*** was conducted to compare RMS and ARV values between the two muscles. This test was appropriate because the data were dependent within subjects. ***Paired correlation analysis*** was also performed to examine the relationship between the activation of both muscles, providing insights into their co-activation patterns during the plank. Statistical significance was set at $p < 0.05$.

Results: The Shapiro-Wilk test was conducted to assess the normality of data distribution across the group ***(Table 1)***. The normality assumption was considered satisfied as the test results exceeded 0.05, indicating non-significant outcomes for all cells *($p \geq 0.05$)*.

The mean sEMG activity of the *Lateral Deltoid* and *Rectus Abdominis* muscles during the plank was quantified using both RMS and ARV values. ***Descriptive analysis*** shown in ***Table***

2 revealed that the *Lateral Deltoid* had a mean RMS of 53.24 ± 8.91 µV and a mean ARV of 55.92 ± 9.13 µV, whereas the *Rectus Abdominis* had a mean RMS of 86.54 ± 12.60 µV and a mean ARV of 95.24 ± 20.70 µV. *Figure 1* represents the graphical representation of the Descriptive Statistics of the RMS and ARV Values of the Lateral Deltoid and Rectus Abdominis Muscles.

A paired-samples t-test shown in ***Table 3*** revealed that the *Rectus Abdominis* exhibited significantly higher activation than the *Lateral Deltoid*. Specifically, RMS values were significantly greater in the *Rectus Abdominis* (Mean difference = -33.30 ± 15.06 µV, 95% CI [-38.93, -27.67], t (29) = -12.10, *p = 0.000*), and ARV values were also significantly higher in the *Rectus Abdominis* (Mean difference = -39.31 ± 23.22 µV, 95% CI [-47.98, -30.64], t (29) = -9.27, *p = 0.001*).

Pearson correlation analysis (*Table 4*) indicated no significant relationship between *Lateral Deltoid* and *Rectus Abdominis* activation across participants. The correlation between *Lateral Deltoid* and *Rectus Abdominis* RMS was *r = 0.050*, *p = 0.79*, and between *Lateral Deltoid* ARV and *Rectus Abdominis* ARV was *r = -0.072*, *p = 0.704*. Since both *p*-values exceeded 0.05, the correlations were not statistically significant. These findings indicate that, although both muscles are active during the plank, the level of activation in one muscle does not predict the level in the other, suggesting largely independent recruitment patterns.

Table 1: Tests of Normality.

	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
L. Deltoid RMS	.935	30	.066
L. Deltoid ARV	.950	30	.173
R. Abdominis RMS	.965	30	.421
R. Abdominis ARV	.937	30	.076

*** Significant at 5% degrees of freedom**

Table 2: Descriptive Statistics of RMS and ARV Values of Lateral Deltoid and Rectus Abdominis Muscles.

	N	**Mean**	**Std. Deviation**
L. Deltoid RMS	30	53.24	8.91
L. Deltoid ARV	30	55.92	9.13
R. Abdominis RMS	30	86.54	12.6
R. Abdominis ARV	30	95.24	20.7

Significant at 5% degrees of freedom

Table 3: Paired t-test Comparisons of Root Mean Square (RMS) and Average Rectified Value (ARV) Between Lateral Deltoid and Rectus Abdominis Muscles.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	**L. Deltoid RMS and R. Abdominis RMS**	-33.30	15.06	2.75	-38.93	-27.67	-12.1	29	**.000***
Pair 2	**L. Deltoid ARVand R. Abdominis ARV**	-39.31	23.22	4.24	-47.98	-30.64	-9.27	29	**.001***

*** Significant at 0.05 degrees of freedom**

Table 4: Paired Samples Correlations.

		N	Correlation	Sig.
Pair 1	**L. Deltoid RMS and R. Abdominis RMS**	30	.050	.791
Pair 2	**L. Deltoid ARV and R. Abdominis ARV**	30	-.072	.704

Significant at 0.05 degrees of freedom

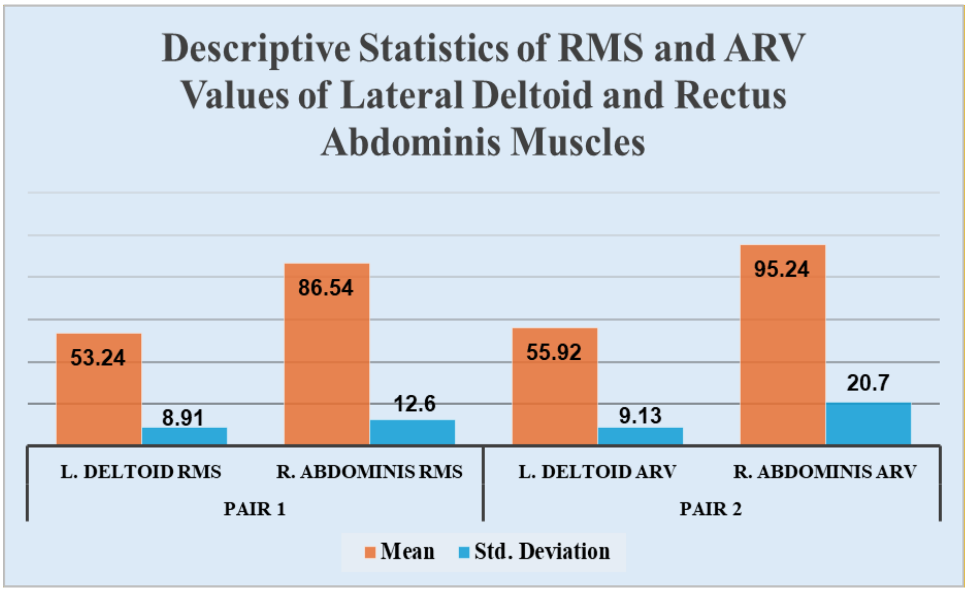

Figure 1: Graphical representation of the Descriptive Statistics of the RMS and ARV Values of the Lateral Deltoid and Rectus Abdominis Muscles.

4. DISCUSSION OF RESULTS

The present study demonstrated that during the plank, the rectus abdominis exhibited significantly higher activation than the lateral deltoid, as reflected by both RMS and ARV values. This finding aligns with the biomechanical demands of the plank, which primarily challenges trunk stability and engages the core musculature to maintain a neutral spine against gravitational forces (Kim et al., 2016; Lee et al., 2016; Pi et al., 2019; Do & Yoo, 2015; Ko & Song, 2018; Moreno-Navarro et al., 2024; Park & Park, 2019; Roth et al., 2015; Bautista et al., 2020; Kang et al., 2016; Lee et al., 2017; Fidale et al., 2019). The deltoids, while contributing to shoulder stabilization and upper body support, showed lower activation, consistent with their supportive rather than primary stabilization role during the plank (Can et al., 2023; Lee et al., 2016).

Higher RMS and ARV values in the rectus abdominis not only indicate greater instantaneous activation but also suggest a higher cumulative neuromuscular effort over time. Given that sustained muscle activation is associated with prolonged force production, the elevated rectus abdominis activation implies that this muscle experiences greater endurance demands and may fatigue faster during prolonged plank holds (Bautista et al., 2020; Kang et al., 2016). In contrast, the lower activation of the deltoids suggests a comparatively lower workload and slower onset of activation, consistent with their supportive role.

In addition to mean differences, Pearson correlation analysis revealed no significant relationship between the activation of the rectus abdominis and lateral deltoid. This indicates that these muscle groups operate largely independently during the plank. The lack of correlation suggests that activation in one muscle does not predict activation in the other, likely reflecting their distinct biomechanical roles and separate neuromuscular control strategies (Bautista et al., 2020; Can et al., 2023; Kang et al., 2016; Lee et al., 2017). Individual variations in plank execution, such as differences in body alignment or weight distribution, may further influence which muscles bear greater load, potentially accelerating activation in one muscle group while sparing the other (Lee et al., 2016; Can et al., 2023).

Overall, these results indicate that muscle activation patterns during the plank provide valuable insights into the recruitment, endurance demands, and independent functioning of stabilizing muscles, highlighting the distinct roles of core versus shoulder stabilizers in maintaining plank posture.

CONCLUSION

This study examined the muscle activation characteristics of the rectus abdominis and lateral deltoid during the plank in female collegiate athletes. Analysis of RMS and ARV values demonstrated that the rectus abdominis exhibits significantly higher activation than the lateral deltoid, highlighting its primary role in trunk stabilization during this isometric exercise. Elevated ARV values further indicate greater cumulative muscle effort and endurance demands in the rectus abdominis, suggesting higher susceptibility to fatigue compared to the lateral deltoid.

In contrast, the lateral deltoid, while contributing to shoulder support, showed lower activation and endurance demands, reflecting an imbalance in recruitment between core and shoulder stabilizers. The lack of significant correlation between the two muscles indicates largely independent neuromuscular control during the plank.

Overall, these findings reinforce the plank as a compound isometric exercise that predominantly engages the core, with the rectus abdominis serving as the central stabilizer and the deltoids supporting independently. This knowledge provides practical guidance for trainers and coaches, enabling targeted interventions to optimize core stability, shoulder support, and muscle endurance, thereby enhancing performance and reducing injury risk in female collegiate athletes.

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