Journal of Physical Education and Sport ® (JPES), Vol. 24 (issue 6), Art 174, pp. 1542- 1550, June 2024
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Electromyographic analysis of core muscle activity during pole dance movements using the knee lock

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Accepted for publication : June 15, 2024
DOI:10.7752/jpes.2024.06174

Abstract:
Problem Statement: Current literature lacks comprehensive research on the manner in which variations in pole dance movements affect core stabilizing muscle activity.
Purpose: This study aimed to analyze the electromyographic activity of the rectus abdominis, obliquus externus abdominis, and erector spinae (lumbar) muscles during different pole dance movements using the knee-lock technique to stabilize the body on a vertical bar in horizontal, vertical, and inverted positions.
Approach: An experimental study was conducted with a convenience sample of ten female pole dance practitioners, each with over one year of experience in the physical activity. The electromyographic activity of the rectus abdominis, obliquus externus abdominis, and erector spinae lumbar muscles was recorded during the execution of three pole dance movements – Indian, Genius, and Monkey – in a randomized and counterbalanced order. The electromyographic signal obtained during all exercises was quantified in the time domain using the root mean square and normalized by the maximal voluntary isometric contraction. Data were collected using simple differential surface electrodes and analyzed using repeated measures analysis of variance.
Results: The rectus abdominis, obliquus externus abdominis, and erector spinae lumbar muscles demonstrated greater electromyographic activity during the Genius movement (from moderate to very high activation) compared to the Indian and Monkey moves (low activation).
Conclusions: These results can facilitate the selection of movements for possible progression in pole dance training and performance. Additionally, they can be used to increase the muscular resistance and neuromuscular control of the trunk, reduce the risk of injury, and improve overall physical health.

Keywords: rectus abdominis, obliquus externus abdominis, erector spinae, electromyography, pole dance

Introduction

Pole Dance is a physical exercise that uses friction and opposition between the body and a vertical bar to create plastic, static, or dynamic moves, that can compose a choreographic sequence or acrobatic maneuvers (Cinti et al., 2022). It is an exercise that demands a lot of physical and motor skills.

However, scientific literature involving the practice of pole dance still scarce. According to Teixeira et al. (2024), only 33 studies have been published on the topic, and the majority of studies address sociological and/or anthropological aspects. Therefore, it is important to develop biomechanical research to direct and guide professionals and scholars in the area in the search for updating and building new training guidelines.

In general, to execute the moves, the practitioner undergoes a transition from more basic movements until reaching the desired move and remains static in it with the aim of stabilizing the body in a specific posture and demonstrating correct form, body execution, and strength applied to the exercise. In this sense, it is necessary to stabilize the body in a given move, which requires a large isometric contraction of the core muscles (Nawrocka et al., 2017).

Plastic moves are composed of different locks and manual grips to keep the practitioner in a vertical position (head up), horizontal position (parallel to the ground), or inverted position (upside down). The constant contact between the skin and the vertical bar allows for better fixation by the practitioner. Therefore, any part of the body other than the hands, such as the elbow, armpit, neck, waist, thigh, knee, and feet, is used to guarantee greater adherence of the body to the vertical bar and is called a lock (see Figure I). Manual grips differ by the hand position in the bar (see Figure II).

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FIG. I – Body locks: Knee, thigh, elbow, and armpit locks

FIG. II – Manual Grips: Basic, full-bracket, twisted, and cup

Pole dance is a complex exercise that requires training for the correct trunk stabilization. The core is a segment of the body related to the trunk, or more specifically, to the lumbopelvic region (Oliver et al., 2010). Core stability is essential to provide a basis for movements of the upper and lower limbs in daily activities or sports, withstand loads, prevent disorders such as low back pain, develop strength, and protect the spinal cord and neural roots (Ellsworth, 2012; Tan et al., 2013). The core muscles play a fundamental role in the performance of this sport, in particular the rectus abdominis (RA), obliquus externus abdominis (OE), and erector spinae (ES) muscles. These are the global core muscles that act in multisegmental stabilization and are agonist muscles in trunk movements (Sundstrup et al., 2012).

In this study, we selected three moves from the initial phase of the pole dance training that use the knee lock to fix the body on the vertical bar and keep the trunk in different stable positions. These were the Indian (IN), the genius (GE), and the monkey (MO) moves (see Figure III), which correspond to the vertical, horizontal, and inverted positions, respectively.

FIG. III - Pole Dance moves: A) the Indian (IN), B) the genius (GE) and C) the monkey (MO)

Teixeira et al. (2024) analyzed the electromyographic (EMG) activity of the core muscles during the execution of different isometric pole dance exercises using the thigh lock to fix the body on the bar in vertical, horizontal, and inverted positions. The results showed a significant difference only for the ES muscle, which was higher in the inverted position when compared to the vertical and horizontal ones.

In this context, surface electromyography (EMG) can be an initial assessment tool to establish acute differences in muscle activity between these exercises. It provides important information for guidance and progression in the training program, indicating which exercises should be prescribed to strengthen the trunk musculature or to prevent injuries. According to Martuscello et al. (2013), exercises that maximize EMG activity can provide greater challenges for the neuromuscular system and, consequently, be more effective in improving muscle strength.

Current literature lacks research on how variations in pole dance moves affect core stabilizing muscle activity. Given the scarcity of studies on this subject and to contribute to the development of the sport, this study aims to analyze and compare the EMG activity of the RA, OE, and ES muscles during the execution of different pole dance moves using the knee lock to fix the body on the vertical bar in different positions (horizontal, vertical, and inverted). As for the hypothesis, due to the trunk postural alterations, it is expected to find greater EMG activity in the core muscles for the movements performed in the horizontal position, followed by the movements in the vertical position, and finally, in the inverted position. Moves using some other support on the vertical bar (hands or feet) may require less EMG activity of the abdominal musculature since it will be less required for move stabilization.

Material & methods

Characterization of the study:

An experimental, quantitative, laboratory, and cross-sectional study is proposed to compare the EMG activity of the RA, OE, and ES muscles during the execution of three pole dance moves using the knee lock to fix the body on the vertical bar.

Subjects:

A non-probabilistic convenience sample was selected. In total, 10 healthy adult females with more than one year of experience in pole dance participated in the study. Their mean age was 34.77 ± 8.9 years, weight was 58.39 ± 9.53 kg, height was 159.9 ± 4.68 cm, and body mass index (BMI) was 22.62 ± 3.3. Volunteers who used anti-inflammatories, analgesics, or myorelaxants, which may influence muscle activity, or had excessive body fat, or who had any contraindications for carrying out the proposed moves – such as heart disease, neurological disorders, alcoholism, smoking, diabetes, myopathies, neuromyopathies, low back pain, osteomioarticular diseases, pain in the abdominal region, or any other type of clinical problem that could interfere with the execution of the exercises – were excluded.

The research was approved by the Human Research Ethics Committee of the Federal University of Uberlândia (number 5.425.278).

Procedures:

Data collection was carried out on three different days, with an interval of 48 to 72 hours and a pre-scheduled time. On the first day, the volunteers were informed about the research purposes and methodology at the Laboratory of Kinesiological Electromyography (LABEC) of the Institute of Biomedical Sciences at the Federal University of Uberlândia (UFU). All volunteers agreed and signed the informed consent form, according to the Norms for Conducting Research on Human Beings (resolution no. 466/12 of the Brazilian National Council of Health). Then, a short version of the International Physical Activity Questionnaire (IPAQ) was administered to assess the level of physical activity of the participants. We selected for the study those assessed as physically active (five volunteers) or very active (five volunteers) (Silva et al., 2007). The lumbar disability index (Functional Assessment Questionnaire – Oswestry Disability Index) was also evaluated, and all volunteers had a score of zero (0–20: minimal disability) (Yates & Hurst, 2017). Anthropometric characteristics (body mass, height, and body fat percentage) were determined using a bioimpedance scale (InBody 230) with a 4-pole electrode system, according to the manufacturer's recommendations. Based on the percentage of body fat obtained by bioimpedance (1997), which uses a range of values according to age and gender, only volunteers with a fat percentage between 25 and 38% were included in the study and had the recommended level of body fat, varying between low and middle levels (25 and 32%).

On the second and third days, we collected the EMG signals of participants during the maximum voluntary isometric contraction (MVIC) tests and pole dance moves using an EMG 830C electromyograph (EMG System do Brasil Ltda, 1232WF Signal Acquisition System) with 12 channels conditioned with analog filters (Butterworth – 4th order), with a cutoff frequency band of 20 (high pass) and 500 Hz (low pass), an amplifier gain of 1,000, and a common mode rejection ratio > 120 dB. Data were obtained using a 16-bit analog-to-digital converter (EMG System do Brasil Ltda) at a sampling frequency of 2000 Hz. The surface electrodes, composed of two Ag/AgCl discs with a diameter of 10 mm (EMG System do Brasil Ltda.), were attached to disposable self-adhesive electrodes (Solidor brand), separated by an inter-electrode distance of 2 cm. The system was composed of active bipolar electrodes displaying a preamplification gain of x20.

On the second day, the volunteers were familiarized with the MVIC tests. The EMG signals were collected for the maximum strength and quantified in the MVIC test (see Table I) of trunk flexion, trunk lateral flexion, and trunk extension (see Figure IV) (Maeo et al., 2013). The volunteers performed two five-second MVICs for each test, with three-minute rest intervals to avoid the effect of muscle fatigue (Brown, 2008; Maeo et al., 2013). The MVIC tests were performed in a randomized and counterbalanced order.

TABLE I: Maximum Voluntary Isometric Contraction (MVIC) test procedure

MVIC	PROCEDURE
Trunk flexion	The volunteer was placed in the dorsal decubitus position on the device with the trunk partially flexed, the hips and knees flexed, and the feet resting on the seat held by a belt. A vest with a set of chains was attached to the device. The volunteer maintained this position and was instructed to perform maximum isometric trunk flexion in the sagittal plane for five seconds (Maeo et al., 2013; Gregorio et al., 2020).
Trunk lateral flexion	The volunteer was placed in the lateral decubitus, position with the left side of the trunk resting on the device and the lower limbs extended. The hips and feet were secured with a belt, and the trunk was partially free to flex laterally. A vest with a set of chains was attached to the device. The volunteer maintained this position and was instructed to perform maximum isometric trunk lateral flexion in the frontal plane for five seconds (Maeo et al., 2013; Gregorio et al., 2020).
Trunk extension	The volunteer was placed in the ventral decubitus, position with the abdomen resting on the device and the lower limbs extended. The hips and ankles were secured with a belt, and the trunk was partially free to extend. A vest with a set of chains was attached to the device. The volunteer maintained this position and was instructed to perform maximum isometric trunk extension in the sagittal plane for five seconds (Maeo et al., 2013; Gregorio et al., 2020).

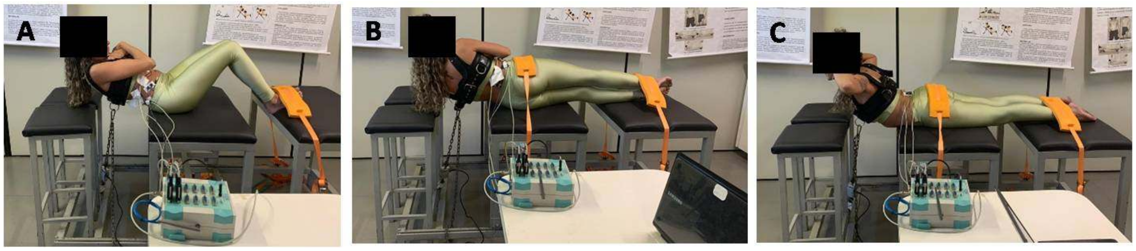

FIG. IV – Maximum voluntary isometric contraction tests (MVIC): (A) trunk flexion; (B) trunk lateral flexion; (C) trunk extension.

The electrodes were placed based on the literature (see Table II). After confirming the correct position (see Figure V), maps were prepared (Silva et al., 2020) using acetate paper (transparent) for each volunteer. Electrode position and other references (scars, skin spots, tattoos, etc.) were marked to ensure the repositioning of the electrodes on the next collection day. Before placing the electrodes, a trichotomy was performed, and the skin was cleaned with 70% alcohol to remove dead cells and oiliness. After that, the skin showed a slightly red color, indicating a good skin impedance condition (Konrad, 2005). The electrode to skin contacts need some time to reach a stable electrical (impedance) condition, therefore; 5 minutes were waited to start collecting the EMG signal (Konrad, 2005). The analyses of EMG signals were conducted individually for investigation of recording and signal routine, and only the signs that showed no interference of any kind were considered in the study. All collections of the EMG signal of the experimental procedure were preceded by real-time analysis of the frequency spectrum, which allows us to observe any interference that may be present in the collections (Gregorio et al., 2020). The reference electrode (Bio-logic Systems, SP Médica, Científica e Comercial Ltda, São Paulo, SP, Brazil) was attached to the skin over the anterior superior iliac spine (ASIS) of the right hip bone (Kang et al., 2012).

TABLE II - Electromyography sensor locations

MUSCLE	ELECTRODE POSITION
Rectus abdominis	Attached to the center of the muscle belly, at the midpoint between the xiphoid process of the sternum and the umbilicus, at a distance of 3 cm lateral to the right of the midline of the body (Escamilla et al., 2010).
Obliquus externus abdominis	Attached superiorly to the anterior superior iliac spine (ASIS) of the hip bone, positioned obliquely at a distance of approximately 15 cm lateral to the umbilicus (Garcia-Vaquero et al., 2012).
Erector spinae	Attached laterally to the spinous process of the third lumbar vertebra, on the right side of the body, at a distance of approximately 2 to 3 cm from the midline of the body (Garcia-Vaquero et al., 2012).

FIG. V - Electromyography sensor locations: (A) rectus abdominis; (B) obliquus externus abdominis; (3) erector spinae.

On the third day, in a pole dance studio located in Uberlândia, state of Minas Gerais, Brazil, the EMG signals were collected from the RA, OE, and ES muscles during the execution of the pole dance moves – IN, GE, and MO (see Figure 3). An Ali Fitness bar made of 304 stainless steel with an external diameter of 44.45 mm and a height between 3.20 and 3.40 m was used for static or rotating moves. The EMG signals of each muscle were collected during two repetitions of each exercise for five seconds with three-minute rest intervals (Brown, 2008; Maeo et al., 2013) and performed in a randomized and counterbalanced order. To control for order effects, the three exercise conditions were counterbalanced using the Latin Square Procedure, creating three different sequences; the sequences were then randomized among the ten subjects.

For the tests, the volunteers were instructed to avoid alcohol and caffeine consumption in the 24 hours before the test (Pesta et al., 2013).

Data analysis:

The EMG signals obtained during the MVIC tests and the pole dance moves were analyzed and quantified in the time domain by the root mean square (RMS) parameter using the Myosystem Br1 software (version 3.5.6). The signal treatment involved full-wave rectification and linear cover by a fourth-order Butterworth filter with a 5-Hz cut-off frequency (Amorim et al. 2012). A moving window of one second was used for three central seconds, corresponding to the average stretching of the EMG activity, to calculate the RMS peak in MVIC tests and pole dance moves. The maximum values (peak) of RMS in the exercises were normalized in terms of the percentage of the MVIC peak (%MVIC) (Garcia-Vaquero et al., 2012).

Statistical analysis:

Statistical analysis was performed using GraphPad Prism (version 5.0, GraphPad Software, Inc). Data were presented as mean and standard deviation, with a significance level of 5%. The intraclass correlation coefficient (ICC) values were calculated to assess the reproducibility between the repetitions in the MVIC tests and in the pole dance moves based on the following criteria (Fleiss, 1999): > 0.75, excellent; 0.40-0.75, moderate; and < 0.40, low.

The Shapiro-Wilk test was employed to assess data normality. Subsequently, a one-way repeated-measures analysis of variance (ANOVA) was conducted to compare the normalized RMS of the same muscle in different moves. The Tukey multiple comparison test was utilized to identify any differences in all analyses. The effect size was calculated using Cohen's formula for recreationally trained subjects based on the following criteria (Rhea 2004): < 0.35 trivial; 0.35-0.80 small; 0.80-1.50 moderate; and > 1.5 large effects.

Results

Intraclass Correlation Coefficient (ICC):

The ICC values obtained between the two repetitions in each MVIC test (trunk flexion, trunk lateral flexion, and trunk extension) for the RA (0.96), OE (0.98), and ES (0.81) muscles demonstrated excellent replicability (Fleiss, 1999), reflecting strong reliability between the two repetitions. The ICC values obtained between the two repetitions in the pole dance moves for the RA (0.82), OE (0.82), and ES (0.83) muscles also demonstrated excellent replicability (Fleiss, 1999).

Rectus abdominis (RA):

For the EMG activity of the RA muscle (see Figure VI and Table III), there were significant differences between moves (F = 18.00; p = 0.0001). After post-hoc analyses, the EMG activity of the RA muscle was significantly higher in the GE move compared to the IN (p = 0.0002, d = 1.86) and MO (p = 0.0001, d = 1.97) moves.

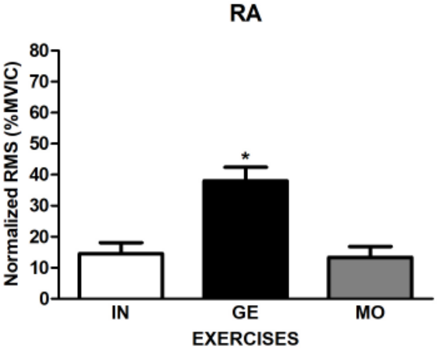

FIG. VI - Rectus abdominis - Comparison of the normalized RMS (%MVIC) of the rectus abdominis (RA) muscle in pole dance exercises. Indian (IN); Genius (GE); Monkey (MO).* Significantly higher compared to IN and MO.

Obliquus externus abdominis (OE):

For the EMG activity of the OE muscle (see Figure VII and Table III), there were significant differences between the moves (F = 31.44; p = 0.0001). After post-hoc analyses, the EMG activity of the OE muscle was significantly higher in the GE move compared to the IN (p = 0.0006, d = 2.43) and MO (p = 0.0003, d = 2.80) moves.

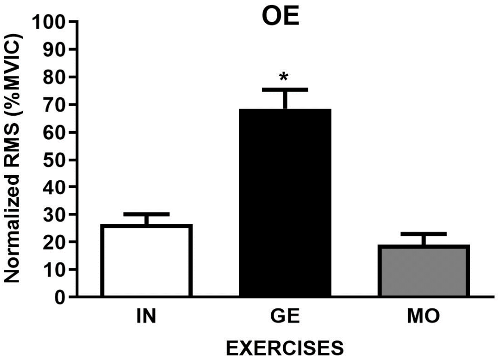

FIG. VII - Obliquus externus abdominais - Comparison of the normalized RMS (%MVIC) of the obliquus externus abdominis (OE) muscle in pole dance exercises. Indian (IN); Genius (GE); Monkey (MO).* Significantly higher compared to IN and MO.

Erector Spinae– lumbar part (ES)

For the EMG activity of the ES muscle (see Figure VIII and Table III), there were significant differences between moves (F = 12.97; p = 0.0003). After post-hoc analyses, the EMG activity of the ES muscle was significantly higher in the GE move compared to the IN (p = 0.0006, d = 2.29) and MO (p = 0.0018, d = 1.68) moves.

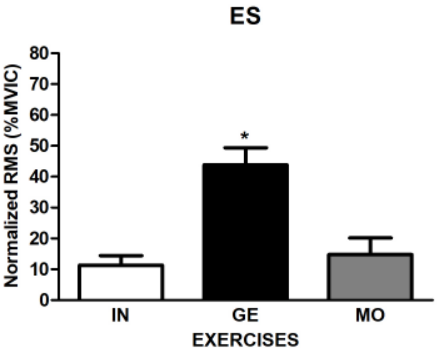

FIG. VIII - Erector spinae - Comparison of the normalized RMS (%MVIC) of the erector spinae (ES) muscle in pole dance exercises. Indian (IN); Genius (GE); Monkey (MO).* Significantly higher compared to IN and MO.

TABLE III: Mean (SE) and confidence interval (90% CI) of the normalized RMS (% MVIC) during the execution of three pole dance moves: Indian (IN), genius (GE), and monkey (MO). Rectus abdominis (RA); Obliquus externus abdominis (OE); Erector spinae (ES).

MUSCLES			
EXERCISES	**RA**	**OE**	**ES**
IN	14.56 ± 3.52 (8.11 / 21.02)	26.58 ± 3.58 (20.01 / 33.14)	11.28 ± 3.15 (5.50 / 17.06)
GE	38.06 ± 4.40 (29.99 / 46.13)	68.54 ± 6.82 (56.02 / 81.05)	43.86 ± 5.51 (33.74 / 53.97)
MO	13.39 ± 3.44 (7.08 / 19.70)	19.03 ± 3.93 (11.82 / 26.24)	14.77 ± 5.41 (4.83 / 24.69)

Discussion

This study compared the EMG activity of the RA, OE, and ES muscles during the execution of pole dance moves in the horizontal, vertical, and inverted positions using the knee lock to fix the body on the vertical bar. The results showed that the GE move demanded greater EMG activity when compared to the other moves. Although the pole dance moves analyzed used the knee lock to fix the body on the bar, they kept the body in completely different positions. The body positions in IN, GE, and MO were vertical, horizontal, and inverted, respectively.

These results are similar to Gregorio et al.'s study (2016), which compared the EMG activity of different core muscles during seven different types of trunk stabilization exercises. The authors highlighted a great EMG activity of the RA, OE, and ES muscles in the side plank (the participant remains in lateral decubitus position with the right arm abducted at 90 degrees, the right forearm flexed at 90 degrees, and the elbow and right forearm resting on the ground), a position similar to the GE move. This position was the one that generated the greatest EMG activity in the OE muscle.

For the RA muscle, Gregorio et al. (2016) also demonstrated that the side plank did not show greater EMG activity only for the rocking exercise (the participant remains kneeling with the torso erected and the knees aligned with the hips and arms along the body sides and the trunk inclined backward) and the ventral plank (the participant remains in ventral decubitus position with the arms and forearms flexed at 90 degrees and the elbows and forearms resting on the ground). For the ES muscle, the lateral plank presented lower EMG activity only for the dorsal plank (with lower limbs extended, torso slightly inclined backward, and with both hands and heels on the ground, the participant must raise the body, forming a straight line between these body segments) and the plank with two supports (the participant must raise one arm and extend the leg on the opposite side in a four-support position).

Gregorio et al. (2016) highlight that the side plank can improve trunk stabilization since it presents a high EMG activity of both the agonist and antagonist muscles compared to the other exercises. Thus, for the body in the lateral position during the GE move, the high EMG activity of the RA, OE, and ES muscles may be justified by the great need for trunk stabilization, as it happens during the side plank.

The EMG activity pattern in the GE move may also be attributed to the torque produced by the RA, OE, and ES muscles to counterbalance the torque generated by the gravitational force. However, a kinematic analysis is necessary to substantiate this hypothesis. The torque, or moment of force, is the rotating effect created by an external force acting on a body, and it is algebraically calculated by the product of the force and the perpendicular distance between the force line and the axis of rotation (Hall, 2016). Thus, with the same force acting on the body (gravitational force), the torque will depend only on the distance between the force application line and the axis of rotation. The greater this distance, the greater the demand of the RA, OE, and ES muscles to stabilize the trunk in an isometric contraction. In the GE move, the torque could cause passive trunk lateral flexion. However, this does not occur because the RA muscle (responsible for trunk flexion), OE muscle (responsible for trunk lateral flexion), and ES muscle (responsible for trunk extension when acting bilaterally and unilaterally on the trunk) (Van De Graaf, 2003) are activated to compensate for the torque generated by the gravitational force, which promotes trunk stabilization. The hand on the vertical bar also exerts an auxiliary force, acting as a vertical component of force, generating an opposite torque to the one generated by gravity. This same effect can be performed without the aid of this hand, which could increase the EMG activity of the RA, OE, and ES muscles.

Therefore, even using the same lock (knee lock), the body position during a pole dance move stabilization requires isometric muscle contractions with different levels of muscle activity. In other words, depending on the trunk position, the relative contributions of each muscle vary to maintain posture and trunk stability, which becomes important for movement prescription.

Escamilla et al. (2010) classify the levels of muscle activity as low (0% to 20% of the MVIC), moderate (21 to 40% of the MVIC), high (41 to 60% of the MVIC), and very high (above 60% of the MVIC). Considering our results, the GE move produced an EMG activity greater than 38% for RA, 68% for OE, and

43% for ES muscles. These values demonstrate that the level of muscle activity in this move is moderate to very high, while in the other moves, it is considered low.

In this way, the study can help indicate a training progression, as well as demonstrate that the proposed exercises can be prescribed to improve muscular endurance and neuromuscular control of the trunk. Improved trunk control can also contribute to the spine supporting greater loads and reducing micromovements (instability) in the spinal joints, resulting in a reduction in pain and the risk of injury, both for pole dance performance and for health promotion.

This study is a pioneer in terms of EMG activity and muscle function in pole dance moves, contributing to the development of this sport. We determined the level of EMG activity in three global core muscles in different positions that characterize the sport.

Therefore, pole dance is a complex exercise that requires training aimed at the correct use of trunk stabilization. By studying the EMG activation of the core abdominal muscles, the best exercise options within the modality can be analyzed. This analysis aims for a greater gain in strength in favor of postural stabilization, an increase in physiological and physical demands by recruiting a greater amount of muscle mass, and, finally, a reduction in the chances of falls during the exercises.

A limiting factor of this study was the small sample due to the reduced number of pole dance practitioners with more than one year of experience in the city of Uberlândia, which certainly impairs the data analysis. Other limiting factors include skin adherence to the vertical bar and insecurity when executing the moves, which may influence the level of EMG activity of the muscles, as well as the absence of kinematic data records, which may have changed the spine posture during the exercises. Another limitation of this work was the lack of measurement of abdominal, supraspinal, and supraliac cutaneous folds.

Conclusions

The RA, OE, and ES muscles demonstrated greater electromyographic activity during the Genius movement (from moderate to very high activation) compared to the Indian and Monkey moves (low activation). These results can facilitate the selection of movements for possible progression in pole dance training and performance. Additionally, they can be used to increase the muscular resistance and neuromuscular control of the trunk, reduce the risk of injury, and improve overall physical health.

The results were limited to comparing the EMG activity of the RA, OE, and ES muscles during trunk stabilization in just three pole dance moves in healthy women who practice the activity recreationally. Future studies should analyze the effect of pole dance training on the electromyographic activity of the core muscles in order to contribute to the development of the sport.

Conflicts of interest

The authors declare no conflict of interest.

Acknowledgments

We would like to thank the Federal University of Uberlândia, especially the technicians at the kinesiological electromyography laboratory and the pole dance studio, where the data were collected, for their technical support on this research. We are grateful for the grant support from FAPEMIG and CAPES.

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