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How the multiplanar trunk resistance affects the dynamic postural control during single-leg vertical jumps in college athletes with poor movement quality

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HIGHLIGHTS

- Multiplanar predictable trunk resistance during single-leg jumps increases mediolateral displacement of the center of pressure.
- Multiplanar trunk resistance affects postural control of female athletes with poor movement quality even at low intensity.
- It is recommended to assess movement quality before incorporating training involving multiplanar trunk resistance in jumps with female athletes.

ABBREVIATIONS

COP	Center of pressure
COPap	COP maximum displacement in the anteroposterior direction
COPml	COP maximum displacement in the mediolateral direction
HipSIT	Hip Stability Isometric Test
RMSap	Root Mean Square in the anteroposterior direction
RMSml	Root Mean Square in the mediolateral Direction
ROM	Range of motion
SLS	Single Leg Squat Test
Vap	COP mean velocity in the anteroposterior direction
Vml	COP mean velocity in the mediolateral direction

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BACKGROUND: Poor movement quality of the trunk and the lower limbs as well as dynamic postural control have a strong relation with non-contact injuries in sport. Aiming to reduce the risk of injuries, training approaches using loaded jumps with trunk resistance have been proposed.
AIM: To describe how a multiplanar trunk load affects the dynamic postural control and the peak vertical ground reaction force of college athletes with poor movement quality of the trunk and the lower limbs.
METHOD: Center of Pressure (COP) variables and peak vertical ground reaction force of 24 female college athletes during single-leg jumps with and without a trunk resistance were compared.
RESULTS: There was a significant decrease of the COP displacement (p=0.006), RMS (p=0.009) and velocity (p=0.007) in the anteroposterior direction, and an increase of the COP displacement (p=0.016), RMS (p=0.043) and velocity (p=0.043) in the mediolateral direction, with a moderate effect size. No significant difference was found in the peak vertical ground reaction force.
CONCLUSION: Exercises involving multiplanar trunk resistance may negatively impact dynamic postural control in women with poor movement quality.

KEYWORDS: Center of pressure| Misalignments | Jump

INTRODUCTION

Single-leg landings and change of direction are common sports tasks that are related to severe lower limb injuries, such as non-contact ACL injuries [1]. Studies have shown a strong relation between poor movement quality of the trunk and the lower limbs (such as misalignment, excessive movement and imbalances [2,3]) and joint overload [4,5]. Additionally, another essential factor in situations where non-contact injuries mainly occur is the dynamic postural control [6]. Considering that the incidence of non-contact injuries in sport is high, there is a need for appropriate approaches for training and reducing injury risks.

While the exact knee injury mechanism involving the trunk and the lower limbs during jumps has not been identified, some studies point that certain dynamic postures are strongly associated with acute or overuse injuries. These include pronounced lateral trunk flexions, shallow trunk flexions, and significant trunk rotations during landing [5,7,8].

Considering that 45% of the total body mass is concentrated in the trunk segment, strength deficits or a lack of adequate neuromuscular control can lead to greater misalignment and excessive range of motion [9], which can influence the position of the ground reaction force and, consequently, the load in the knee [10]. Therefore, strategies aiming the improvement of segment alignment and dynamic postural control should incorporate trunk resistance training during sports gestures. Additionally, Dischiavi et al. [4] indicate that the trunk resistance should represent a multiplanar load, that is, applied simultaneously in the three movement planes to enhance force transmission between the trunk segment and the lower limbs improving movement quality and approximating the exercise complexity to the athletic demands.

However, it is widely recognized that simply developing neuromuscular capacities of strength and endurance does not guarantee improvements in dynamic postural control or movement quality [10,11]. Therefore, it is essential that exercises include strategies that encourage and stimulate these abilities. Although Dischiavi et al. [4] suggest a multiplanar resistance of the trunk to achieve these goals, to the best of our knowledge, there is no study describing how a multiplanar trunk load affects dynamic postural control, which would be an essential knowledge to understand the potential training applications of this kind of loading during jumps.

Therefore, the objective of this study was to describe the effects of multiplanar trunk resistance on dynamic postural control during single-leg jumps in female college athletes with low-quality movement. We hypothesized that applying an external predictable multiplanar load to the trunk during jumps would improve the dynamic postural control, possibly due to the increased muscular activation.

METHOD

Participants

A sample size of 28 subjects was calculated, based on an alpha error of 0.05, a power of 0.80, and an effect size of 0.25. However, due to sample loss of four participants during the course of the study, the final sample consisted of 24 female college athletes (defined as a student who is enrolled at an institution and is listed as a member of an intercollegiate athletics team at the institution) [12]. They had the following characteristics: mean age of 20.54 ± 2.04 years; mean height of 1.62 ± 0.05m; mean body mass of 63.44 ± 8.47Kg; and was enrolled in team sports modalities (volleyball, handball, soccer, and basketball). All the participants signed the informed consent form. The study was approved by the Human Research Ethics Committee (CAAE: 56427822.7.0000.5404).

The inclusion criteria was: sport practice at least twice a week for at least one year; participation in sports competitions; no history of surgery, pain or injury in the lower limbs and the lumbar spine in the last 6 months, low quality movement during a Single Leg Squat Test (SLS) (at least 2 points out of 4 in the validated and reliable score ($\kappa = 0.82$) for qualitative assessment of movement quality proposed by Ressman et al. [2]).

To evaluate the quality of the movement, the participants performed three consecutive single-leg squats while an experienced physical therapist observed and scored movement deviations from the vertical alignment of the body segments — foot, knee, pelvis, and trunk. No deviation was scored as 0 points, and 1 point was attributed to the deviation of each segment. A deviation of one segment could only be scored once (one point), even if it occurred in all three squats. Thus, the total score for the multi-segmental SLS test could range from 0 to a maximum of 4 points.

Data Collection

Participants were assessed in two stages. The initial stage aimed to collect information about three physical capacities previously linked to low-quality movement patterns [13–15], in order to characterize the sample: hip posterolateral strength (Hip Stability Isometric Test - HipSIT) using a hand held dynamometer (SPTech MedEOR Medtech®) [16]; close kinetic dorsiflexion range of motion (ROM) using the iOS app Clinometer® (version 4.9.4) [17]; and side plank endurance time using a chronometer [18].The normalized values of HIPsit (Kgf) and absolute values of Dorsiflexion range of motion (degrees) was registered and classified as: 1 – below the reference values; 2 – within the reference values; 3 – above the reference values. This classification followed the reference values stipulated for a similar population [16,17]. Finally, the side plank endurance time identified those who have sufficient (≥60sec) or insufficient (<60sec) trunk muscular resistance [18].

The experimental protocol was conducted in a second meeting, at least 7 days apart. Initially, a 5-minute warm-up was performed (running at preferred speed and ballistic stretching). The experimental protocol consisted of 2 series of 5 consecutive single-leg jumps with the athlete's preferred leg on a force platform (Kistler model 9286B) at a sampling rate of 1000Hz, being the first serie without trunk resistance (No-Resistance) and the second one with trunk resistance (With-Resistance). The jump height was not controlled, the participants were instructed to perform consecutive vertical jumps as high as possible [19], replicating possible training series. The interval between sets was at least 30 seconds. To create multiplanar resistance of the trunk, a band was attached to the ipsilateral shoulder of the volunteer's supporting leg, crossing the trunk posteriorly (Fig 1), and attached to a moderately tensioned elastic tube (Elastos, color black) fixed to the floor.

Figure 1. Placement of the shoulder band used to generate the multiplanar trunk resistance.

Previously to the With-Resistance jump set, the elastic band was calibrated to impose an initial load equal to 6% of the athlete's body mass. The magnitude of this load was chosen based on studies that showed improvement in muscle performance through post activation potentiation [19]. Calibration was performed using a traction scale (Electronic Portable Scale, model 50Kg) tied to the elastic band.

The analysis focused on the three intermediate jumps, excluding the first and last ones from the series. This approach aimed to reduce the impact of transient factors associated with the beginning and the end of the series, such as initial adaptation and deceleration in the last jump. Additionally, the sequence of jumps was standardized as No-Resistance followed by With-Resistance, as the previously described phenomenon of post-activation potentiation could influence the execution of jumps without resistance performed after loaded jumps and, consequently, could influence our results.

Force plate data were used to obtain the center of pressure position (COP) and the peak vertical force during the landing phase (determined from a threshold of 20N). Data was smoothed (4th order Butterworth filter at a cut-off rate of 20 Hz), and six COP variables were extracted: COP maximum displacement in the anteroposterior (COPap) and mediolateral directions (COPml); the dispersion of the COP relative to its mean position, represented by the COP Root Mean Square in the anteroposterior (RMSap) and mediolateral directions (RMSml); and COP mean velocity in the anteroposterior (Vap) and mediolateral (Vml) directions. Subsequently, the average peak vertical force and COP variables across the three jumps were calculated for both No-Resistance and With-Resistance series.

Statistical Analyses

Since not all COP variables showed normal distribution (Shapiro-Wilk test) or variance homogeneity (Levene’s test), the Wilcoxon test was used to compare No-Resistance and With-Resistance results. The results are presented as median and interquartile range. To evaluate the trunk resistance effect on the peak vertical ground reaction force, the paired t-test was used. The effect size was also calculated (d-Cohen) and a p value <0.05 was considered significant for all the analyses.

RESULTS

Considering the characterization of the participants, they presented the following quality movement’s scores: seventeen participants (70.85%) scored 2 points, six participants (25%) scored 3 points, and one (4.15%) scored 4 points. Regarding the HipSIT measurements, they showed an average of 0.42 Kgf/Kg (±0.09). The reference value for a similar population is 0.27 Kgf/Kg (±0.07). Proportionally, participants exhibited the following distribution: eighteen (75%) participants above the reference value and six (25%) within the reference value. As for the Range of Motion (ROM) measurements, participants had an average of 47° (±6.64). The reference range for this measurement is 36°- 45°. Participants showed the following distribution: fourteen (58.33%) above the range, eight (33.33%) within the range, and two (8.33%) below the range. Regarding trunk endurance, fifteen (62.5%) participants achieved 60 seconds.

All the COP variables showed a significant difference and a medium effect size (Table 1). There was a significant decrease of the COPap (Z=-2.771, p=0.006), RMSap (Z=-2.600, p=0.009) and Vap (Z=-2.714, p=0.007), and an increase of the COPml (Z=-2.400, p=0.016), RMSml (Z=-2.029, p=0.043) and Vml (Z=-2.029, p=0.043) during the jumps with trunk resistance.

Table 1. Median and interquartile range (IQR) of the center of pressure (COP) variables considering jumps without (No-Resistance) and with multiplanar trunk resistance (With-Resistance).

COP Variables	No-Resistance	With-Resistance	d
COPap (m)	0.063 (0.051-0.090)	0.055 (0.041-0.068)*	0.7
COPml (m)	0.022 (0.015-0.029)	0.029 (0.019-0.048)*	-0.5
RMSap (m)	0.019 (0.015-0.024)	0.016 (0.012-0.019)*	0.7
RMSml (m)	0.006 (0.004-0.008)	0.007 (0.005-0.013)*	-0.5
Vap (m/s)	0.774 (0.377-1.272)	0.708 (0.140-1.169)*	0.6
Vml (m/s)	0.222 (0.172-0.332)	0.305 (0.196-0.536)*	-0.5

COPap: anteroposterior displacement of the center of pressure. **COPml:** mediolateral displacement of the center of pressure. **RMSap:** anteroposterior root mean square. **RMSml:** mediolateral root mean square. **Vap:** anteroposterior mean velocity. **Vml:** mediolateral mean velocity. * Significantly different from No-Resistance at $p < 0.05$. d: effect size.

The mean peak vertical force during No-Resistance jumps was 1437N (±210), while With-Resistance jumps were 1470N (±227). No significant difference was found ($p = 0.457$; $d = -0.1555$).

DISCUSSION

This study aimed to describe the influence of multiplanar trunk resistance on dynamic postural control during single-leg jumps in female college athletes with poor movement quality. We observed a decrease in COP variables in the anteroposterior direction and an increase in the mediolateral direction.

Our hypothesis suggesting that dynamic postural control would improve with the use of trunk resistance was partially confirmed. A reduction in COP values in the anteroposterior direction was observed, while an increase occurred in the mediolateral measures. Generally, the reduction in COP displacements, dispersion and velocities indicates an improvement in postural control. Therefore, it could be said that dynamic postural control improved in the sagittal plane. However, when contextualizing these measures with jumping tasks and considering that the main damping movements occur in the sagittal plane through trunk and lower limb joint flexion, the reduction in these values may indicate smaller movements in this plane, such as shallow trunk flexion.

Landing with shallower trunk flexion angles tend to exhibit more rigid patterns and consequently higher vertical force values [8]. However, there was no significant difference in the peak vertical force among our participants, which suggests that the decrease in the anterior-posterior COP displacement and velocity is not related to a more rigid landing.

Regarding COP measures in the frontal plane, an increase during the use of the trunk resistance was observed. This result indicates a worse dynamic postural control. Furthermore, an increase in mediolateral measures may indicate an increase in lateral trunk flexion and, possibly, an increased load in the knee due to the medial-lateral displacement of the ground reaction force [8,20]. Hewett T et al. [21] observed that greater lateral inclinations of the trunk and abductor moment of the knee were associated with episodes of ACL injuries in women. It has also been reported that athletes with a deficit in reaction time to sudden external forces on the trunk had a greater number of ACL injuries, compared to those with more efficient trunk control responses [21,22].

From a training perspective, to develop neuromuscular capacities, it is essential to employ challenging exercises. Nevertheless, our results suggest that college athletes with poor movement quality should use the trunk multiplanar resistance with caution. Considering the increase in the mediolateral displacement of the position of the ground reaction force (COP), the indiscriminate use of this resistance could lead to overloads beyond the physiological limit of adaptation, predisposing to acute or overuse injuries. Since our study did not measure knee forces, this hypothesis of risk of knee overload due to the increased body sway in the mediolateral direction should be investigated in future studies. Nevertheless, taking into account the potential risks, while this issue is not clarified, less complex exercises involving low speed movements should be used initially, such as single-leg squats. Besides, the influence of the magnitude of the initial load imposed by the elastic tube should also be investigated.

The study has some limitations. We did not include a control group composed by college athletes with good movement quality. Nonetheless, our objective was to describe the acute responses from the multiplanar trunk resistance in the population where this kind of approach was indicated by the literature to better understand its potential training applications, instead of the adaptations induced by training. Additionally, we did not test other load magnitudes, which must be investigated in future studies to better guide the prescription of the multiplanar trunk resistance. The lack of randomization of the jump sequences may also be considered as a possible limitation. However, based on the study of Halteman [19], which described the post-activation potentiation effect in low-intensity external loaded jumps, we decided not to randomize, keeping the jumps without resistance first, since the pre-loaded jump could alter the execution of subsequent vertical jumps without load. Lastly, due to a sample loss, we did not achieve the calculated sample size by 4 subjects.

CONCLUSION

Performing single-leg jumps with multiplanar trunk resistance may negatively impact dynamic postural control in female college athletes with poor movement quality. Therefore, strategies for gradually increasing the complexity of training exercises using multiplanar trunk resistance should be carefully considered in the prescription of workouts to improve postural control ability of athletes with poor movement quality.

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