**THE INFLUENCE OF DYNAMIC AND PLYOMETRIC EXERCISES ON KNEE JOINT MOTION FOR COUNTERMOVEMENT JUMP PERFORMANCE.**

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The purpose of this study was to analyze the effects of dynamic and plyometric exercises on knee joint motion for countermovement jump performance (CMJ). Forty-five college male non-athletes were distributed in a dynamic group (DG) using dynamic exercises, a plyometric group (PG) using jumping exercises, a control group (EG) using traditional exercises for physical education, and performed CMJ test. Motion analysis data from the knee angle joints were obtained during countermovement moments in the sagittal plane using video recording. To our findings, plyometric and dynamic exercises can improve jumping performance in college non-athletes and enhance the strength, force, and power of lower limb muscles and joints. Motion analysis could help in the identification of a range of motion in knee joints, plyometric and dynamic exercises would contribute in jumping performance.

**KEYWORDS:** countermovement, plyometric, knee joint angle, jumping kinetics, strength

**INTRODUCTION:** The countermovement jump (CMJ) is one test widely used to monitor athletic performance, the differences in CMJ performance are related with the effective use of the stretch-shortening cycle, this basic muscle function starts with an eccentric action and then followed by a concentric action (Nicol, Avela, Komi, 2006). During PE classes in China, college students are encouraged to participate in sport-related activities (eg., football, basketball, volleyball, rugby). In these sports, jumping performance and lower limb muscles explosive actions are very important. The assessment for students who participate in sports-related PE classes includes two parts known as fitness or physical test (e.g. CMJ, 50m sprints) and technique test (e.g. shooting, dribbling). Teachers have to evaluate a large number of students and collect data in a short time. The implementation of force platforms, contact mats, infrared systems, and video recording systems to evaluate students in PE class are costs expensive and difficult to transport to the field. However, mobile apps are other alternatives of technology more accessible by college teachers and coaches, which integrates slow-motion for the identification of different variables of jump performance (Stanton, Kean, Scanlan, 2015) and motion analysis. These apps can provide quick feedback and the information required during sport-related PE classes or training sessions.

Concerning CMJ performance and lower limb motion analysis, some studies reported about the knee and hip joint contributions with a large or small range of motion, and lower limb muscle strength effects in vertical jump performance. The literature evidence that knee starting angles, jumping with knees more flexed, the velocity and depth of the countermovement would induce better CMJ performance (Gheller et al., 2015) (Pérez-Castilla et al., 2019). Besides, plyometric jumping protocols are characterized by the transition of rapid eccentric muscle contraction to a rapid concentric contraction, producing specific neural adaptations, increase the activation of motor units, and the maximum muscle force production in short period to improve power and speed (Slimani et al., 2016). Similarly, dynamic exercises involve a full range of motion and high neuromuscular activation, thus enhance power and agility performance. As evidence, researchers found that dynamic and plyometric exercises have effective results to improve jumping performance (Stojanović, Ristić, McMaster, & Milanović, 2017). The purpose of this study was to analyze the effects of dynamic and plyometric exercises and to compare groups with two different exercise protocols in college PE students and their respective efficacy in jumping kinetics. The knee joint angle (KA) during countermovement moment was obtained to determine possible changes in CMJ kinematics. We hypothesized that knee joint angles would negatively affect or influence CMJ performance in college non-athletes.

**METHODS:** This study followed forty-five college male non-athletes (mean age 19.04 ± 0.88 years; 168.51 ± 5.62 cm; 58.94 ± 9.45 kg). The subjects were written informed of the experimental procedures and the study was approved by the Institutional Review Board.

**Procedures:** For data collection, subjects were distributed in three groups: a control group (CG), dynamic exercises group (DG) and a plyometric exercises group (PG). The groups performed one CMJ on three different days. Motion analysis and CMJ data were collected using a GoPro HERO5 Black version 2.70, myDartfish Express App, and iPad Pro 10,5 inches with iOS 11.3, and a two 0.75m aluminum tripods with calibration at 90 degrees. The angle of the GoPro and iPad camera was adjusted to a horizontal and vertical position respectively at 90 degrees in front of subjects. The location of the GoPro camera was 2m facing the subjects in a lateral plane. The location of the iPad camera was 3.70m facing the subjects in a frontal plane and zooming in on the feet (Gallardo-Fuentes et al, 2016). This location allowed teachers to record the complete movement of CMJ. Subjects were asked to jump at maximum effort from the initial position.

**Protocols:** The plyometric group (PG) was instructed to perform a 15 minutes warm-up, which consists of dynamic activity for 5 minutes and plyometric jumps for 10 minutes in the following order: squat jump, CMJ with and without arms, and jumping lunges. The PG subjects completed 3 sets of 10 reps of each with 15 seconds rest after a set, and 45 seconds rest after a new exercise. The DG was instructed to warm up for 10 minutes using dynamic exercises in the following order: jogging and arms oscillation forward and back, lateral shuffle, carioca back and forth, high knee pulls, high knees, butt kicks, lunges with trunk torsion, and two sprints. The DG subjects completed two sets of each exercise at 20m. The control group (CG) was instructed to perform a 10 minutes warm-up that included traditional exercises used in college PE class such as 400m track jogging, static and dynamic stretching (upper and lower limbs flexion, extension, rotation, for 8 reps; triceps, shoulders, quadriceps hamstring and groin stretch for 8 seconds). PG, DG and CG groups had one class/week. The subjects were assessed in three different times in the CMJ test and performed with maximum effort.

**Kinematic Analysis:** Knee joint angle data were obtained using myDartfish Express App measure tools. The videos were analyzed using still shots at 1/8 frames per second. Data were obtained for all subjects in the three tests. The convention for measuring the knee joint angles was to measure in the direction of the lateral malleolus along the fibula and finishing at the lateral condyle, and from the lateral condyle to the greater trochanter finishing at the hip joint. KA was collected from the countermovement moment of CMJ in the sagittal plane. KA was included for data analysis in one complete phase of CMJ. KA and CMJ performance was compared between the groups.

**Statistical Analysis:** The CMJ was measured in a frontal plane, using My Jump 2 App and the KA was measured in the sagittal plane, using myDartfish Express camera two-dimensional video recording of the participants. this study analyzed the following variables: KA, jump height, push-off, flight time, velocity, force, power of the CMJ. Age, gender, height, and weight were also included for data analysis. Effect-size statistics were assessed using Cohen’s d and as small (<0.2), medium (<0.5), or large (<0.8). The obtained data were analyzed using descriptive statistics (mean ± standard deviation [SD]) and Multi-factor ANOVA SPSS Statistics® software version 26, with a statistical significance p≤0.05.

**RESULTS:** Healthy, college male non-athletes and written consent were included in this study. Forty-five subjects met the inclusion criteria. Subjects with injuries or who did not complete the protocols during the evaluation were excluded. DG, PG, and CG were used in this investigation and multiple comparisons between subjects were realized showing statistical significance as follows: DG, PG and CG groups produced statistical significance (p<0.001) in push-of, force, and power. The comparison between the group, flight time (p=0.685), velocity (p=0.679) did not produce statistical significance.

**T****able 1. Knee joint angles, jump length and groups mean and standard deviation.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Group | Mean | Std. Deviation | N |
| Jump Height | CG | 42.97 | 5.67 | 14 |
| PG | 43.59 | 7.21 | 17 |
| DG | 45.12 | 6.80 | 14 |
| Total | 43.87 | 6.55 | 45 |
| Knee Joint Angle | CG | 70.75 | 12.42 | 14 |
| PG | 71.04 | 9.36 | 17 |
| DG | 70.49 | 11.46 | 14 |
| Total | 70.78 | 10.78 | 45 |

The comparison between CG, DG, and PG did not produce a statistically significant in jump height (p=0.680) and knee joint angles (p=0.990). Cohen’s effects size between the groups in jump height, knee joint angles, flight time, velocity, force, and power were small. Besides, the effect size between the groups and push-off was medium.

**DISCUSSION:** The literature showed that a countermovement phase smaller than 90 degrees or jumping with a squat depth position produced the best jump performance. Besides, CMJ performance would be affected by different KA (Gheller et al., 2015). About this aspect, we measured the KA of PG, DG, and CG during the countermovement phase of the CMJ. Our study showed that KA did not produce statistical significance between the groups. While the knee joint kinetics is associated with control of the direction and the improvement of jump performance. Plyometric jumping exercises utilize the stretch-shortening cycle producing a different range of knee joint motion. Jumping exercises can enhance the mechanical output of the lower limbs improving muscle and tendon function. Moreover, a greater muscle stretch tolerance would interpret as increasing the range of joint motion. Furthermore, dynamic exercises improve eccentric quadriceps strength and hamstrings flexibility (Kariyama, 2019). Dynamic movements are designed to elevate core body temperature, enhance motor unit excitability, and maximize ranges of motion. Hence, both types of exercises implemented with college students in PE class that can improve strength for knee joints are essential for jumping performance.

Plyometric and dynamic exercises induce explosive force and power by increasing the neuromuscular function. Push-off, force and power produce statistical significance between the groups. The authors mentioned that countermovement allowed the subjects to attain greater knee joint moments at the start of push-off. Knee angle during the push-off had to reach 90 degrees or lower range of motion before starting jump, the descending movement of the push-off had to be performed with a rapid descend. Our study showed that the PG, DG, and CG knee joint angles mean was 70.78 degrees during countermovement, which agree with the suggested to be an adequate range of knee motion in CMJ. The contribution of the countermovement allows the muscles to increase a high level of active state and force before the start of the shortening. This muscle active state at the beginning of the jump affects more the force capabilities of the neuromuscular system, the greater force of the lower limbs extensor muscles would influence a higher CMJ height (Bobbert MF, Gerritsen KG). Plyometric and dynamic exercises are used to improve this muscle force and power production, and plyometric jumps are associated with maximum isometric force. Therefore, plyometric and dynamic exercises should be not difficult to perform by college students and to put into practice during PE classes.

Jumping drills for the plyometric exercises, and low to moderate dynamic exercises can increase power output capabilities, and would also explain the enhancement of jump height average. Findings revealed that PG 43.59±7.21 and DG 45.12±6.80 jump height was higher than CG 42.97±5.67, showing a difference of PG 0.62 cm, and DG 2.15 cm respectively in comparison to the CG. Our findings revealed that DG jump height was higher than PG. Dynamic exercises seem to be enough to potentiate CMJ height and reaction force. Besides, potentiation of subsequent performance can be found with low and moderate-intensity dynamic exercises. Although plyometric exercises are considered as highly effective for enhancing strength and power, nevertheless PG preceding to CMJ performance showed a lower height than DG, conceivably for plyometric-induced fatigue. Concerning our findings, plyometric jumping exercises and dynamic exercises improve CMJ height in college male non-athletes and are effective for enhancing strength, force, and power. Future studies should extend into different age groups, other sport-related PE classes and more frequency of training sessions or classes per week.

**CONCLUSION:** Our study identified that through mobile app technologies, college PE teachers and coaches analyzed CMJ performance and distinguish jumping kinetics. This method of analysis can be used in sport-related PE classes or training sessions and it can also enhance the understanding of the range of motion of knee angles, and the influence of strength, force, and power in jumping performance. Plyometric and dynamic exercises as jumping drills, low to moderate-high intensity exercises can increase jump height and reaction force. The range of motion of the knee joint can influence the countermovement phase in CMJ performance. For this reason, observing and evaluating knee angles joints during the countermovement phase and the implementation of plyometric and dynamic exercises can help to improve the range of knee joints motion, enhance jumping kinetics and enhance CMJ performance.

**REFERENCES**

Bobbert, M.F., Gerritsen, K.G., Litjens, M.C., Van Soest, A.J. (1996). Why is countermovement jump height greater than squat jump height? *Medicine & Science in Sports Exercise.*28, 1402-12.

Gallardo-Fuentes, F., Gallardo-Fuentes, J., Ramírez-Campillo, R., Balsalobre-Fernández C, Martínez, C., Caniuqueo, A., Cañas, R., Banzer, W., Loturco, I., Nakamura, F.Y., Izquierdo, M. (2016). Intersession and Intrasession Reliability and Validity of the My Jump App for Measuring Different Jump Actions in Trained Male and Female Athletes. *Journal of Strength and Conditioning Research.*30, 2049-56

Gheller, R.G., Dal Pupo, J., Ache-Dias, J., Detanico, D., Padulo, J., dos Santos, S.G. (2015). Effect of different knee starting angles on intersegmental coordination and performance in vertical jumps. *Human Movement Science.* 42, 71-80.

Kariyama, Y. (2019). Effect of Jump Direction on Joint Kinetics of Take-Off Legs in Double-Leg Rebound Jumps. *Sports.* 7, 183.

Nicol, C., Avela, J. & Komi, P.V. (2006). The stretch-shortening cycle: a model to study naturally occurring neuromuscular fatigue. *Sports Medicine.* 36: 977-99.

Pérez-Castilla, A., Rojas, F.J., Gómez-Martínez, F., García-Ramos, A. (2019). Vertical jump performance is affected by the velocity and depth of the countermovement. *Sports Biomechanics.* 30, 1-16.

Slimani, M., Chamari, K., Miarka, B., Del Vecchio, F.B., Chéour, F. (2016). Effects of Plyometric Training on Physical Fitness in Team Sport Athletes: A Systematic Review. *Journal of Human Kinetics.* 53, 231-247.

Stojanović E, Ristić V, McMaster DT, Milanović Z. (2017). Effect of Plyometric Training on Vertical Jump Performance in Female Athletes: A Systematic Review and Meta-Analysis. *Sports Medicine.*  47, 975-986.

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