COMPARING THE RESPECTIVE EFFECTS OF THREE TYPES OF WARM-UP ON THE COUNTERMOVEMENT JUMP: AN ANALYSIS OF NON-ATHLETE COLLEGE STUDENTS

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The purpose of this study was to examine and compare the respective effects of traditional, dynamic, and plyometric warm-ups on non-athlete college students' performance of the countermovement jump (CMJ). Forty-seven male non-athlete college students were respectively allocated to three separate groups: the traditional warm-up group (TG), dynamic warm-up group (DG), and the plyometric warm-up group (PG). The DG and PG showed statistically significant improvements in push-off, force, and power ($p<0.001$) when compared to the TG. No statistically significant differences were observed in jump height, flight time and velocity, and the effect sizes were small. The findings of this study showed that dynamic and plyometric warm-up protocols could influence CMJ performance among non-athlete college students.

KEYWORDS: jumping performance, plyometric exercises, power, strength

In Chinese colleges, the physical fitness of non-athlete students is often evaluated through tests conducted during physical education (PE) lessons. These PE lessons are based on sport-related activities such as football (i.e., soccer), basketball, volleyball, and rugby, which require movements such as jumping and explosive action in the lower limb muscles. It is commonly known that the implementation of different types of warm-ups before physical tests is crucial, and can affect performance (Johnson, Baudin, Ley & Collins, 2019). However, when preparing students for sport-related PE lessons or tests, Chinese PE teachers usually apply traditional warm-up protocols that involve a static stretching component. Authors and professionals in fitness sectors have varying opinions regarding the effects of this type of warm-up; in particular, the benefit of applying a static stretching protocol alone has been questioned.

Previous studies have shown that static stretching can affect muscle strength and power production by reducing the contractile force of the muscles, impairing isometric and isokinetic force, decreasing muscle activation, and decreasing reaction/movement time; these factors combine to decrease consequent vertical jump performance. The literature widely documents that low- to moderate-intensity aerobic activities are an essential component of a dynamic warm-up, and that such a warm-up increases muscle temperature, the range of movement in the joints, and the rate of nerve impulses. Regarding other types of warm-ups, plyometric exercise protocols that include jumping exercises (e.g., drop jumps, CMJs) have been found to enhance the force-generating capacity of the muscles (Oxfeldt, Overgaard, Hvid & Dalgas, 2019). These warm-up protocols show contrasting results across college athletes and professional athletes, and studies have demonstrated the detrimental effects of static stretching when included in traditional warm-ups. Consequently, there is a need to evaluate the respective effects of these warm-up interventions for non-athlete college students during sport-related PE lessons, while also identifying means of facilitating the incorporation of relatively portable equipment in the field.

The purpose of this study was to examine and compare the respective acute effects of traditional, dynamic, and plyometric warm-ups on the CMJ performance of non-athlete college students. We hypothesized that the traditional warm-up protocol, which incorporates static stretching exercises, decreases CMJ height, while warm-ups involving dynamic and plyometric exercises, respectively, improve CMJ performance.

METHODS: Seventy-four male non-athlete college students volunteered to participate in this study. Twenty-seven subjects did not complete all the study procedures. The final sample was 47 male non-athlete college students. Subjects were assigned randomly to the different groups (TG = 14, DG = 16, and PG = 17 participants). The means ± standard deviations (SDs) for the subjects' age, weight, and height were 19.1 ± 0.9 years, 58.8 ± 9.3 kg, and 168.8 ± 5.7 cm, respectively. Exclusion criteria comprised having an injury and failure to complete the testing procedures. The Academic Committee of the Institutional Board Review of the Physical Education and Sports Department of the Dongguan University of Technology approved this study.
Procedures: The traditional warm-up protocol comprised 10 minutes of jogging at low to moderate intensity and static stretching of the lower and upper limbs; this involved performing 10 static stretching exercises. Each static stretching pose (e.g., quadriceps stretch) was held for eight seconds, with five seconds rest, while each static exercise (e.g., head rotation) was performed for eight repetitions (reps). The dynamic warm-up protocol comprised 10 dynamic exercises (jogging with arm swings, straight leg raises, high knee pulls, walking quad stretch, side lunges, twist lunges, carioca, high knees, butt kicks, and 2 accelerations), performed at moderate to high intensity over a 10-minute period. For each drill, participants began at one sideline on the football field and performed the drill while traveling a 20-m distance. The plyometric warm-up protocol was 15 minutes in duration. Over the first five minutes, participants performed 10 dynamic exercises and, over the following 10 minutes, they performed four jumping exercises (squat jump, CMJ without arm swing, CMJ with arm swing, jumping lunges), from moderate to high intensity.
Countermovement Test: The CMJ was measured on a frontal plane, using the My Jump 2 App (Haynes, Bishop, Antrobus & Brazier. 2019). The app calculated the time (in milliseconds) between the take-off and landing frames, which were selected by the teacher, and then calculated the CMJ push-off, height, power, force, velocity, and flight time. Motion analysis and CMJ data were collected using an iPad Pro (10.5 inches) running iOS 11.3, which featured a high-speed camera with a quality of 720p, and was mounted on a 0.75-m aluminum tripod that was calibrated at 90 degrees. The iPad was positioned vertically, with the camera pointed at the subjects at a 90-degree angle. The camera was 3.70 m from the subjects on the frontal plane, and was zoomed-in on their feet. This setting allowed the teachers to record a complete CMJ. When performing the jump, the subjects placed their hands on their hips to avoid any arm-swing motion. Each subject from the TG, DG, and PG performed one CMJ during the tests. The subjects performed a pre-test (PT) on the first week and a post-test (PST) on the fourth week. The groups performed these evaluations on different days during the week; the TG and PG groups performed the PT and PST on Mondays between 8 and 10 AM, and 10 AM and 12 PM, respectively. The DG performed these on Fridays between 10 AM and 12 PM. Teachers encouraged the subjects to jump as high as possible, using maximum effort, from the starting position.
Statistical Analysis: Data for the push-off, jump height, force, power, velocity, and flight time for the CMJ were collected. Researchers calculated descriptive statistics (means ± SDs) for age, weight, and height, and a repeated-measures multivariate analysis of variance (MANOVA) with post-hoc comparisons (LSD) was used to analyze the differences between the three warm-up protocols from the baseline to post-test. The effect-size statistics were calculated using Cohen's d, categorized into small (< 0.2), medium (< 0.5), and large (< 0.8), respectively. Statistical significance was set at $p \leq 0.05$. The within-subject variation and reliability for CMJ performance variables were determined by the following means: the intra class correlation coefficients (ICC) 2-way random single measures (absolute agreement) and the standard error of measurement. Data analysis was performed using the Statistical Package for Social Sciences version 26.0 (SPSS, Inc., Armonk, NY).

RESULTS: The MANOVA revealed that there was no statistically significant inter-group or inter-test differences in flight time ($p = 0.976$), velocity ($p = 0.979$), or jump height ($p = 0.980$) for the CMJ. However, for push-off, force, and power, the DG and PG groups showed statistically significant improvement ($p < 0.001$) when compared to the TG. Post-hoc comparison for CMJ push-off revealed a statistical difference ($p < 0.001$) between all groups. Further, the DG participants' results for CMJ force and power showed a significant improvement ($p < 0.001$) when compared to those for both the TG and PG. The ICC values for CMJ variables push-off (ICC= 1), force (p=0.984) and power (ICC= 0.958) demonstrated high reliability. The ICC values of jump height (ICC= 0.872), flight time (ICC= 0.867), and velocity (ICC= 0.868) demonstrated a moderate reliability. The SEMs values for CMJ variables were push-off (Hp0 in m) (SEM= 0.0087), jump height (cm) (SEM= 0.693), flight time (ms) (SEM= 4.699), force (N) (SEM= 37.983), velocity (m/s) (SEM= 0.868), and power (W) (SEM= 0.958). All Cohen's effects sizes for the inter-group differences regarding jump height, flight time, velocity, force, and power were small; meanwhile, the effect size between the groups for push-off was medium.

TABLE 1. CMJ performance following the warm-up protocol, presented in terms of each protocol type

	TG	DG	PG
Push-off (Hp0 in m)	0.37 ± 0.09	0.21 ± 0.04*	0.29 ± 0.04*
Jump height (cm)	42.69 ± 5.80	44.88 ± 6.47	42.96 ± 7.59
Flight time (ms)	588.69 ± 40.72	603.49 ± 43.28	589.75 ± 51.02
Force (N)	1352.41 ± 415.16	1780.68 ± 299.29*	1394.80 ± 226.44*
Velocity (m/s)	1.44 ± 0.10	1.48 ± 0.11	1.45 ± 0.12
Power (W)	1940.48 ± 555.49	2648.12 ± 572.74*	2023.13 ± 417.78*

* $p < 0.05$ when compared with TG.
TG: traditional warm-up group; DG: dynamic warm-up group; PG: plyometric warm-up group. Data collected and presented as mean ± SD.

DISCUSSION: The purpose of this study was to compare the effects of three different warm-ups (traditional, dynamic, and plyometric warm-ups, respectively) on CMJ performance. Our results showed that warm-up protocols can influence CMJ performance among non-athlete college students.

In this study, the DG and PG showed statistically significant improvements in push-off, force, and power when compared to the TG. Studies have reported that, during the push-off (or the concentric moment) of the CMJ propulsion phase, athletes should impulse their center of mass in a vertical direction, powerfully extending the hips, knees, and ankles (McMahon, Suchomel, Lake & Comfort, 2018); this indicates that lower limb strength has a direct relationship with the push-off in jump performance. The use of dynamic and plyometric exercises in a warm-up can improve muscular strength and produce a high level of activation in the lower limb muscles and a high range of joint motion, which can facilitate the CMJ push-off (Cox, Fairclough, Kosteli & Noonan, 2020). The implementation of dynamic (e.g., high knees, side lunges, and twist lunges) or plyometric exercises (e.g., CMJ, squat jump, jumping lunges) in a warm-up can contribute to muscle-strength development, achieving a higher joint moment at the beginning of the push-off, and increasing CMJ height (Berton, Lixandrão, Pinto e Silva, & Tricoli, 2018).

We observed that the use of moderate- to high-intensity dynamic exercises and specific warm-ups with jump drills help develop the highest explosive force. Further, drop jumps can be incorporated into warm-up routines to maximize force-generating capacity before jumping. The use of these types of warm-up protocols implicate optimal neuromuscular activation and muscle force; greater force from and activation of the lower limb extensor have been found to influence the upward movement in CMJ (Johnson, Baudin, Ley & Collins, 2019).

In this study, we observed that the dynamic and plyometric warm-up exercises improved jumping power. The mean power (Table 1) for the DG and PG was higher than that for the TG. The squat jump and CMJ are commonly used to measure the strength and power of the lower limb extensor muscles. Therefore, the CMJ, squat jump, and jumping lunges performed in the plyometric protocol may have allowed the PG subjects to increase the mechanical impulse at push-off, enhancing their lower limb strength and power output capability.

The results showed no statistically significant inter-group or inter-test differences for velocity, flight time, or jump height. However, the DG and PG showed slightly higher means for both velocity and flight time when compared with the TG (Table 1). These results support the theory that CMJ performance is influenced by the velocity of the countermovement (Pérez-Castilla, Rojas, Gómez-Martínez & García-Ramos, 2019), and that the changes in power, force, and velocity produced by dynamic and plyometric warm-ups can contribute to maximizing power output in CMJ performance.

Previous studies have focused on the validity and reliability of the My Jump 2 app, and compared the results with those of contact platforms and force plates. The findings in this regard have shown perfect agreements between the app and the high-level technology regarding observation of CMJ height (Haynes, Bishop, Antrobus & Brazier. 2019). In this study, the PE teachers used the My Jump 2 app to measure CMJ jump height and to evaluate the lower limb power of non-athlete college students; this was because we felt that the app was a practical means of collecting and analyzing data for CMJ performance in the field.

The limitations of this study include the fact that the results were obtained only through the My Jump 2 app; we did not use other equipment, such as force platforms or jump mats, to compare the measured variables. Another aspect to consider is that the dynamic and plyometric warm-ups were performed one day/week over four weeks, with one jump per testing session. Some subjects reported that they had participated in other sports or recreational activities (2–3 days/week) after the sport-related PE lessons, whereas other participants reported that they did not perform any other physical activity.

CONCLUSION: In conclusion, the differences observed in our research reveal that, for the CMJ, dynamic and plyometric warm-up protocols prior to testing induce improvements in push-off, power, and force when compared to traditional warm-ups. More specifically, our findings suggest that dynamic and plyometric exercises enhance CMJ performance and contribute to developing strength, force, and power in the CMJ of non-athlete college students. The ability to implement practical tools for evaluating jumping performance in the field is essential for teachers; the results of this study showed that the My Jump 2 app is a useful tool for measuring slow stretch-shortening cycle actions, such as CMJ, during sport-related PE lessons. This finding could clarify for teachers and coaches a means of quickly and effectively monitoring CMJ test performance.

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