

THE INFLUENCE OF WARM-UP EXERCISES ON KNEE AND ELBOW JOINT MOTION FOR STANDING LONG JUMP PERFORMANCE

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The purpose of this study was to analyse the influences of the motion angles of the knee and elbow joints on the standing long jump performance of high school students. Twenty-nine participants were assigned to either a control group to perform static and dynamic joint exercises or an experimental group to perform basic sprinting drill warm-up exercises. Both groups performed pre-, control, and post-standing long jump tests. Motion analysis of the knee and elbow joints was conducted in the sagittal plane by using video recording. Our findings support that basic sprint drill warm-up exercises can enhance the jump length in the youth. The implementation of warm-up exercises with basic sprint drills and motion analysis could be useful for determining the ranges of motion of the elbow and knee joints and improving standing long jump performance.

KEYWORDS: jumping kinetics, fitness test, arm swing, takeoff.

INTRODUCTION: Standing long jump (SLJ) is considered one of the best functional tests for evaluating explosive muscular strength/power of the lower limbs (Konz, 2017). It is one of the Chinese national fitness tests for high school students and a reliable field fitness test for the youth (Ramirez-Velez et al., 2017). Long jump tests that measure horizontal force production could provide parameters for predicting jump and sprint performance. For this reason, the authors investigated the role of arm and knee joint motions in SLJ (Mackala, Stodolka, Siemienski, & Coh, 2013). Other studies have analysed arm swing techniques, the contribution of the upper limbs to the centre of mass during takeoff, and the influences of simultaneous and early arm joint motions, and knee angles (KA) on jumping performance (Gutierrez-Davila, Amaro, Garrido, & Rojas, 2014).

Furthermore, the effectiveness of warm-up exercises for improving fitness test performance is a current but controversial topic amongst physical education (PE) teachers and coaches. Moreover, warm-up is considered a necessary factor for the enhancement of test performance and injury prevention (Koch et al., 2003). Previous SLJ studies compared dynamic and static stretching exercises (Blazevich et al., 2018), which have been used as warm-up exercises before jumping performance in PE classes and training sessions. However, the high-cost methods of motion analysis using sophisticated technology have led to the limited application of motion analysis in PE classes and high school sports. Owing to advances in technology, the motion analysis software is now portable and transportable to the sports field for use by PE teachers and high school coaches, and in the assessment of student sports performance (Moresi, Bradshaw, Greene, & Naughton, 2011).

The purpose of this study was to analyse the influences of the motion angles of the knee and elbow joints on the SLJ performance of high school students and compare two different warm-up protocols performed in PE classes and their efficacies for improving jumping kinematics. In this research, KAs and elbow angles (EAs) were obtained to determine possible changes in jumping kinematics variables. Our hypothesis was that the motion angles of the knee and elbow joints would negatively affect or influence SLJ performance in high school students.

METHODS: Twenty-nine high school students (17 boys and 12 girls; height, 171.7 ± 7.58 cm; body mass, 59.0 ± 9.3 kg; age, 15.5 ± 0.6 years) who were attending PE and sports classes were selected. All the participants were informed of the experimental procedures, and their consents were requested in accordance with the guidelines of the academic committee of the high school.

Procedure: The participants were divided into a control group (CTG) and an experimental group (EXG). The participants in both groups performed the SLJ pre-test (PRT) in the first week, control test (CTT) in the fourth week, and post-test (PST) in the eighth week. Data were collected using 10.5-in iPad Pro with iOS 11.3, myDartfish 360S App camera, and a 1.5-m aluminium tripod calibrated at 90°. The angle of the camera was adjusted to a horizontal position at 90° in a position ahead of the long jump pit. The location of the camera was 4.60 m from the lengthwise side of the landing pit and at a distance of 1.25 m from the width side of the landing pit. This location allowed PE teachers to record SLJ phases, focusing on takeoffs (the EA at arm swing moment and the KA at leg extension moment) for the upper and lower limbs. Jump length was recorded using a measuring tape. The teacher prompted “ready” to start and “finish” to stop the recording in the completion phase of the SLJ (starting position, takeoff, and flight and landing phases). The participants were asked to perform a SLJ from the erect position, with the feet positioned shoulder-width apart, parallel to the starting line. The participants dynamically lowered the centre of body mass by flexing the knee by applying free arm motion, double arm swing during the entire jump, and knee extension. They executed the jump as far as possible using their previous learned jumping ability.

Protocols: The participants in the CTG were instructed to perform 10 minutes of warm-up, including 5 minutes of jogging, and static and dynamic joint exercises (flexion, extension, rotation, side bending, and arm swinging for 8 repetitions; triceps, shoulder, quadriceps, and groin stretching and holding for 8 seconds) The participants in the EXG were instructed to warm up for 5 minutes using dynamic stretching and 10 minutes using basic sprinting drills in the following order: ankle drill, butt kickers, high knees, and single leg bounding. The participants completed 2 sets of 3 repetitions on a 30-m track. After warm-up, the participants continued with their regular PE class (two classes per week). They completed three SLJ tests. The PRT was completed in week 1; the CTT, in week 4; and the PST, in the eighth week. Written informed consent and verbal assent were obtained from all the participants and their parents, respectively, in accordance with the guidelines of the academic committee of the high school.

Kinematic Analysis: KA and EA data were collected using the myDartfish 360S software measurement tools (Eltoukhy, Asfour, Thompson, & Latta, 2012). The motion analysis was performed using still shots at 8 Hz. The convention for measuring the elbow joint angle was to measure in the direction of the trochlea along the humerus and finishing at the shoulder joint, and from the trochlea along the ulna and finishing at the wrist joint. The convention for measuring the knee joint angle was to measure in the direction of the patella along the femur and finishing at the hip joint, and from the patella along the tibia and finishing at the ankle joint. All the KAs and EAs were measured during the takeoff moment in the sagittal plane. EAs and KAs were included for data analysis in the takeoff phase of the SLJ, PRT, CTT, and PST. The angles and SLJ performance distances were compared between the groups.

Statistical Analysis: The KAs and EAs were measured in the sagittal plane, using myDartfish 360 camera two-dimensional video recording of the participants. This study analysed the following variables: KAs, EAs, and SLJ length (m) in the PRT, CTT and PST. The data analysis also included height, weight, age, and sex. Effect-size statistics were assessed using Cohen’s *d* and as small (<0.2), medium (<0.5), or large (<0.8). A multi-factorial analysis of variance using SPSS Statistics version 25 software was performed for the obtained data to verify statistically significant differences in KA, EA, and jump length between the groups and sexes. A descriptive statistical analysis (mean ± standard deviation [SD]) was also performed, with *p* values of ≤0.05 indicating statistical significance.

RESULTS: Two different warm-up protocols were used in the study. Participants who did not finish the PRT, CTT, or PST were excluded. Jump length was measured as the horizontal distance from the takeoff line to the closest mark made by the heels at landing. The subjects were compared as follows: The sexes showed significant differences (*p* = 0.000) in jump length and (*p* = 0.02) in EA. Jump length was significantly greater when the variables were analysed by group and sex. The male participants in the EXG had 0.27 ± 0.09 m longer jump length than those in the CTG in the PST in the eighth week. The girls in the EXG had 0.30 ± 0.15 m, 0.24

± 0.01 m, and 0.60 ± 0.09 m longer SLJ lengths than those in the CTG in the PRT, CTT, and PST, respectively.

Table 1. Knee and elbow joint angles and jump lengths in the groups

	Group	Mean	SD	n
Jump length (m)	EXG	1.87	0.32	39
	CTG	1.93	0.42	48
	Total	1.90	0.37	87
KA (°)	EXG	151.19	15.27	39
	CTG	150.23	11.38	48
	Total	150.66	13.19	87
EA (°)	EXG	103.04	33.03	39
	CTG	105.88	25.35	48
	Total	104.60	28.90	87

The comparison between the CTG and EXG did not yield a statistically significant difference ($p = 0.46$) in SLJ distance. In addition, jump length was longer in the CTG than in the EXG (Table 1). Jump length ($p = 0.65$), KA ($p = 0.16$), and EA ($p = 0.85$) also did not have significant differences.

DISCUSSION: The most important factors of SLJ performance are related to the proper execution of upper and lower limb motions, and adequate knee and ankle angles during takeoff. Angular kinematic variables of the elbow and knee joints are related to SLJ performance. Thus, in this research, we analysed the influences of knee and elbow joint motions on SLJ performance at the final takeoff phase (from ground moment, and leg and ankle extension). Sex showed significant differences ($p = 0.000$) in jump length and EA ($p = 0.02$). As already known, basic sprint drills such as high knees and single-leg bounding produce oscillation of the arms and different ranges of motion of the elbow and knee joints, and could enhance explosive muscular strength and natural arm swing. Thus, basic sprint drills would influence jumping length and elbow and knee joint angle motions. However, the boys and girls from the testing groups would have different strength development processes, and elbow and knee joint mobility. Furthermore, the knee joint angle at the final take-off phase influences the forward direction, and body mass forward movement must take occur before the extension moments of the ankle and knee joints to improve SLJ performance. KA and EA showed no statistically significant differences in jump length and jump test performance, and the differences in the effect size of KA, EA, and jump length between the groups were small. Hence, even if the improvement in SLJ performance was related to arm motion and sprint drill warm-up protocols could enhance the mobility of the elbow and knee joints, other aspects related to the previous experiences, techniques, or jumping abilities of the subjects must also be considered.

The CTG and EXG did not statistically significantly differ in jump length. Accordingly, the EXG showed lower jumping distances (Table 1), probably owing to the differences in the athletic ability of the subjects and the horizontal displacement of the centre of gravity and takeoff velocity. Sprinting time and jumping performance were related. Thus, the application of basic sprint drills can be implemented to influence in time and jump length. However, the load, exercise duration, and combination of the types of warm-up protocols should also be considered to achieve better effects on SLJ performance.

KA and EA showed no statistically significant differences between the EXG and CTG. Moreover, to improve the jumping test distance, basic sprint drills such as butt kickers, high knees, and single-leg bounding would contribute to elbow joint motion, movement control, and strengthening of knee flexor/extensor muscles (e.g., quadriceps femoris and hamstring muscles). Moreover, SLJ performance may be affected by lower limb muscular strength, maximum joint motion, and starting posture. When the results were analysed by group and

sex, the boys in the EXG had longer (0.27 ± 0.09 m) jump length than those in the CTG in the PST. The girls in the EXG had longer SLJ lengths (0.30 ± 0.15 , 0.24 ± 0.01 , and 0.60 ± 0.09 m, respectively) than those in the CTG in the PRT, CTT, and PST. The use of basic sprint drills in high school students could allow adaptations of the ranges of motion of the elbow and knee joints and in jumping kinetics. In addition, these exercises are easy to incorporate in physical education classes or training sessions by PE teachers and coaches, and young students can perform the drills without complications or overloading the hip, knee, or ankle joint. PE programs can include warm-ups, which can help improve arm oscillation and knee strengthening. Therefore, this type of warm-up could be useful for developing an adequate SLJ technique and improving performance and injury prevention in high school students.

In summary, basic sprinting drills as warm-up could influence the jump length in boys and girls. These exercises contribute to the final takeoff of the elbow and knee joint motions. However, the resultant jump length between the groups may have some variations related to the influence of adequate technique or jumping ability (as takeoff and arm swing) of the subjects.

CONCLUSION: Through a video motion analysis, coaches and PE teachers can analyse SLJ performance during PE class and distinguish jumping kinetics. This analysis method can be practical, time efficient, and economical in terms of cost and equipment conditions. In addition, it can help teachers and students observe and understand the elbow and knee ranges of motion in SLJ fitness tests. Elbow and knee ranges of motion and jumping ability would influence takeoff and, consequently, jump length. The implementation of basic sprint exercises during warm-up in PE classes can develop strength, velocity, knee and elbow joint motions, and other factors related to jumping performance. Moreover, elbow and knee ranges of motion must be observed and evaluated. The implementation of basic sprint drills during warm-up tended to improve strength and adequate range of motion and thus could help develop jumping technique kinetics, decrease injury risk, and enhance jumping performance.

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