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ACUTE EFFECTS OF ROPE JUMPING WARM-UP ON POWER AND JUMPING ABILITY IN TRACK AND FIELD ATHLETES

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Abstract
Introduction. The purpose of this study was to compare the acute effects of traditional jumps and rope jumps during warm-up on power and jumping ability in trained men. ***Material and methods.*** A group of 12 national-level track and field athletes participated in the study. Peak power and jumping ability were assessed by having participants perform five alternate leg bounds, a countermovement jump (CMJ) and a drop jump (DJ). Three different warm-up protocols were used in random order, with 3-day intervals between them. The first involved traditional jumps, the second rope jumps and the control consisted of general warm-up only (jogging and stretching). ***Results.*** The rope-jump warm-up protocol significantly improved jumping distance ($p<0.05$) as compared to the traditional protocol. There were no significant differences in peak power or jump height among experimental groups in the CMJ and DJ. The study also revealed that traditional and ropejump protocols significantly ($p<0.001$) increased peak power and jump height for the CMJ and DJ, and jump distance for the five alternate leg bounds compared to the control condition. ***Conclusion.*** The results of this study suggest that a warm-up including rope jumps may be more effective for horizontal jumping tasks than a protocol with traditional jumps, and that traditional and rope-jump warm-up protocols provide similar levels of enhancement for vertical jumping tasks.

Key words: plyometric, countermovement jump, drop jump, skipping rope jumping

Introduction

Plyometric training is widely used to improve force production, power and jumping ability through specific muscle action called the stretch shortening cycle (SSC). The SSC involves a powerful concentric contraction preceded by rapid eccentric contraction. The efficacy of the SSC is mainly related to the storage of elastic energy during eccentric contraction and its quick release during concentric contraction [1]. Examples of lower body plyometrics include such exercises as countermovement jumps (CMJs), drop jumps (DJs), bounds and hops.

Plyometrics is an intense form of physical exercise, generating high ground reaction force which may exceed 6 times an individual's body mass [2]. Therefore, it has been suggested that plyometric exercises should be preceded by adequate warm-up to improve performance and reduce the incidence of injury. A warm-up program includes the following components: a general warm-up and a specific warm-up. A general warm-up usually consists of 5 to 10 minutes of slow jogging and 5 to 10 minutes of stretching exercises. Research in recent years has shown that static stretching prior to intensive activity may be detrimental to plyometric performance due to decreases in force production [3], peak power [4] and jumping ability [5]. Thus, researchers have suggested static warm-up should be replaced with more active, dynamic stretching aimed at optimizing performance. A specific warm-up involves movements similar to those executed in the main activity. According to Chu [6], this part of a warm-up routine performed before plyometric training should incorporate march drills, fast skip, shuffle, crossover runs, backward runs, various bounds and jumps. Empirical evidence suggests that warm-up routines incorporating specific exercises lead to more effective plyometric performance than those involving jogging and stretching only in untrained men and women [3]. The research hardly ever provides information in detail about specific warm-up before plyometric performance, with a few exceptions, for example, Faigenbaum et al. study [7]. The information is often too general to be used in new research, for example: "…including 10 minute warm-up (e.g., jogging, stretching and ballistic exercises)" [8], or "…warm-up consisting of low-intensity running, striding and self-administered submaximal jumps performed as practice and specific additional warm-up" [9]. Some plyometric studies do not report any information regarding warm-up [10, 11].

Pitreli and O'Shea [12] state: "For plyometric training: 3-4 minutes of rope jumping serves as an excellent warm-up…". Other authors [13] have also suggested that including rope jumping in a warm-up routine is good preparation for plyometric training. However, these training recommendations have not been empirically verified. Improving performance through specific warm-up exercises seems essential, especially in track and field, where even minimal changes in performance may decide who wins or loses. Thus, the purpose of this study was to compare the acute effects of warm-up protocols, traditional jumps and rope jumps on power and jumping ability in national-level track and field athletes.

In addition, additional measurements to identify differences in kinetic and kinematic parameters between traditional and rope jumps were taken. On this basis, the assumption was that performing rope jumps during a warm-up may result in shorter contact time as well as timing and rhythm improvement due to lower values obtained for individual coefficients of variation (CV) in plyometric performance compared to traditional jumps.

Material and methods

In this study, a randomized, counterbalanced, within-subjects experimental design was used to compare the acute effects of three warm-up protocols, traditional jumps, rope jumps and control, on power and jumping ability in national-level track and field athletes. Participants attended a total of 3 collection sessions. Each athlete completed each warm-up protocol in random order. Prior to testing, participants performed a general warm-up that was identical for all protocols and consisted of a 5-minute jog and 5 minutes of dynamic stretching. After this part of the warm-up, they performed the following specific warm-up protocols: a traditional warm-up with selected free jumping exercises and a rope-jump protocol with rope jumping exercises. The jumping exercises had similar movement patterns in both the specific protocols. The control protocol involved only a general warm-up. The participants were tested during a countermovement jump (CMJ), a drop jump (DJ) and five alternate leg bounds, which were performed two minutes after completing the warm-up. The dependent variables, peak power and jump height and jump distance were measured. The interval between warm-up protocols was 3 days.

Materials

Twelve national-level, elite male athletes representing first national league clubs volunteered to participate in this study. An elite athlete was defined as an individual who had attained the highest national sports qualifications in track and field during the last three years. The group involved five sprinters, four long jumpers, two triple jumpers, and one high jumper (mean age 22.4 years, SD=3.1; body height 1.82 m, SD=0.8; body mass 77 kg, SD=6). All of them were experienced in plyometric exercises (including rope jumping) and injury free. This study was approved by the University's Ethics Committee. Each subject read and signed a written informed consent and completed a medical history questionnaire.

Warm-up procedures

Before data was collected, each athlete participated in five training sessions to become familiar with proper warm-up exercise techniques. Each session lasted 35-40 minutes. To allow biomechanical characteristics of traditional jumps to be compared with those of rope jumps, additional measurements were made. Participants warmed up in groups of three under the supervision of a certified track and field coach in the primary study. Using a within-participant design, subjects performed each of the three warm-up protocol: traditional jumps, rope jumps, and control in a randomized order that was counterbalanced across participants to avoid effects that might arise from changes in order. The general warm-up incorporated a 5-minute jog and 5-minute dynamic stretching routine and was the same in all three protocols. The speed of the jog was maintained to keep presumed, individual intensity. The intensity of the jog was monitored by measuring the jogger's heart rate (HR) using a Polar Sport-Tester (PE 4000). The dynamic stretching involved swings, rotations and bends with a 10-second rest between exercises.

The protocol of the specific warm-up consisted of the following jumps: pogo jumps, hip-twist ankle hop, side-to-side ankle hop, ankle flip, jump with high knee, jump with heel kick, fast skipping forward, and fast skipping backward. These exercises are described in textbooks [6, 14]. The jump exercises were performed for 15 seconds followed by 30 seconds of recovery. The rope-jump warm-up consisted of exercises similar to those performed during traditional warm-up; however, each exercise was performed with a rope jump.

A good-quality leather jump rope was used in this study. The rope consisted of wooden handles and a strip of leather for the rope. The fast turning capability facilitated a rapid jump rate. The length of the rope was adjusted for each individual.

The control protocol only involved general warm-up and is described above.

Testing procedures

Following the completion of each warm-up protocol, the subject had a passive recovery period of two minutes. The subject was examined using the following types of plyometric exercises: CMJ, DJ (from a height of 0.3 m), and five alternate leg bounds. The instruction given to each subject was as follows: “jump as high as you can” in the CMJ, “drop off the box, and jump as high as you can” in the DJ, and “jump as far as you can” in the five alternate leg bounds. The range of knee flexion was not specified in the CMJ and DJ. The subject attempted each testing exercise three times with a two-minute rest between each jump. The highest in the CMJ and DJ and farthest attempt in five alternate leg bounds were analyzed. Peak power and jump height in the CMJ and DJ, and jump distance in five alternate leg bounds were measured to assess the performance changes. The CMJ and DJ as well as traditional and rope jumps were performed on a piezoelectric force platform (Kistler 9281CA, Winterthur, Switzerland) with a sampling frequency of 500 Hz. Signals from the platform were amplified and recorded on a PC using a 16-bit A/D board and BioWare 3.24 software. Peak power in the concentric phase was calculated as the largest vertical ground reaction force F_z and vertical velocity v_z product. The vertical velocity was obtained by numerical integration of the vertical acceleration extracted from the vertical ground reaction force. The jump height was then calculated at the instant of take-off [15]. The contact time (CT) was determined as time from the onset of GRF to zero GRF. The five alternate leg bounds test was performed on a runway and long-jump sand pit. Each participant began his jump from a start line located 13 m from the pit, and then performed five consecutive bounds: a two-foot push off, four consecutive single alternate leg jumps and a two-foot landing in the sandpit. The jump length was measured with a tape measure from the start line to the nearest mark made in the sand by the subject [15].

A 2-week test-retest study conducted before the study confirmed the reliability of the selected tests. The intraclass correlation coefficients were high, that is, ICCs=0.93–0.95 for peak power and ICCs=0.94–0.96 for jumping ability.

Data analysis

All data were tested for normality and homogeneity of variance before statistical analysis was conducted. A one-way repeated measures analysis of variance (ANOVA) was conducted to examine whether there were significant differences among the three protocols (traditional jumps, rope jumps, control). Tukey's honestly significant difference was used for *post-hoc* analysis to conduct pairwise comparison between protocols. An alpha level of $p<0.05$ was used as a significance criterion in all statistical comparisons. Cohen's effect-size statistics (ES) were calculated to determine the size of observed differences between warm-up protocols. The thresholds for small, moderate and large ES were set at 0.2, 0.5, and 0.8, respectively. A coefficient of variation (CV=*SD*/mean x 100) was calculated for peak power, GRF and CT. Statistica for Windows version 5.1 PL software was used for all statistical calculations.

Results

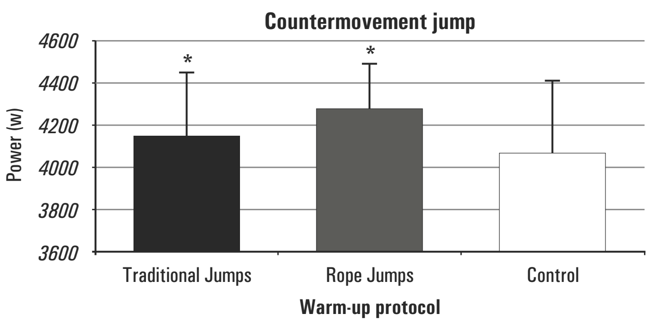
The results of the additional measurements have shown that rope jumps provided significantly ($p<0.05$) shorter contact time than traditional jumps (Tab. 1). Greater CV in all tested parameters was observed for traditional jumps compared to rope jumps.

The applied warm-up protocols resulted in significant changes in peak power (Fig. 1) and jump height (Fig. 2) for the CMJ ($F_{2,22}$=7.2, *p*<0.01; and $F_{2,22}$=19.7, *p*<0.001, respectively). There were also significant differences between warm-up protocols in peak power (Fig. 3) and jump height (Fig. 4) for the DJ ($F_{2,22}$=14.8, *p*<0.001; and $F_{2,22}$=46.2, *p*<0.001, respectively). Significant differences between warm-up protocols were also observed in jump distance (Fig. 5) for the five alternate leg bounds ($F_{2,22}$=50.2, *p*<0.001). The results of the *post-hoc* analysis revealed that the traditional-jump warm-up protocol and rope-jump warm-up protocol produced significantly greater power (ES=0.30, ES=0.48, respectively) and jump height (ES=0.33, ES=0.43, respectively) for the CMJ compared to the control protocol. Both of the experimental protocols, traditional and rope jumps, demonstrated significantly greater increases in power (ES=0.62, ES=0.97, respectively) and jump height (ES=0.66, ES=0.85, respectively) for the DJ than in the control protocol. The traditional and rope jump protocols also showed significantly larger increases in distance (ES=0.53, ES=0.81, respectively) for the five alternate leg bounds than did the control protocol. In addition, the protocol including rope jumps also demonstrated a significantly greater increase in distance (ES=0.28) compared to the traditional protocol.

Table 1. Mean ± SD of peak power (PP), ground reaction force (GRF) and contact time for traditional and rope jumps (ankle flips)

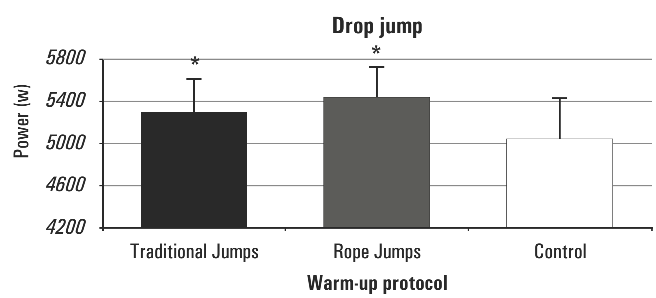
Parameter	Type of exercise	Traditional jumps	Rope jumps	Difference (%)
Peak power (W)	Single-leg	2067 ± 418	2126 ± 402	2.9
	Double-leg	3038 ± 487	3247 ± 512	6.9
GRF (N)	Single-leg	2135 ± 579	2443 ± 527	14.4
	Double-leg	3230 ± 612	3523 ± 562	9.1
Contact time (s)	Single-leg	0.23 ± 0.04	0.20 ± 0.04*	13.0
	Double-leg	0.18 ± 0.03	0.16 ± 0.03*	11.1
Range of individual CV for peak power (%)	Single-leg	3.6-4.1	2.8-3.3	-
	Double-leg	4.0-4.4	3.6-3.9	-
Range of individual CV for GRF (%)	Single-leg	4.7-5.6	3.8-4.3	-
	Double-leg	4.2-4.9	3.7-4.1	-
Range of individual CV for contact time (%)	Single-leg	3.5-4.0	2.3-2.6	-
	Double-leg	3.1-3.7	1.9-2.1	-

GRF – ground reaction force; CV – coefficient of variation; * – significantly different from traditional jumps (p<0.01)



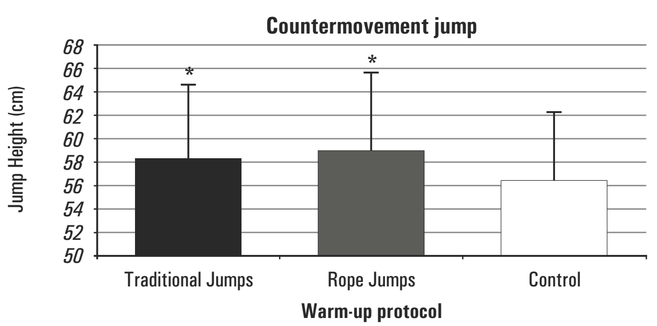
* – significantly different (p<0.001) from the control warm-up protocol; error bars represent standard deviation

Figure 1. Peak power for warm-up protocols in countermovement jump (CMJ)



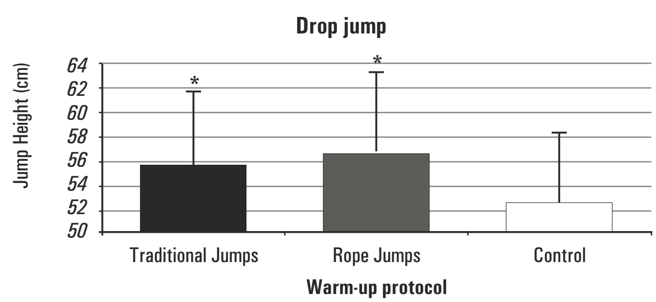
* – significantly different (p<0.001) from the control warm-up protocol; error bars represent standard deviation

Figure 3. Peak power for warm-up protocols in drop jump (DJ)



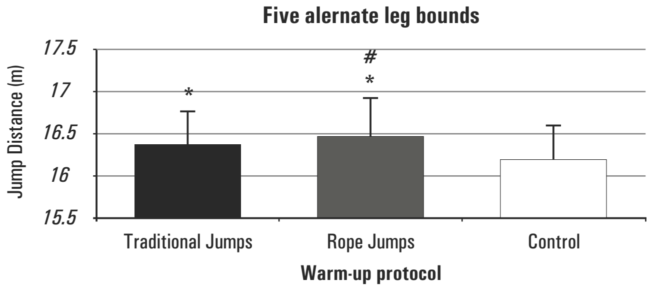
* – significantly different (p<0.001) from the control warm-up protocol; error bars represent standard deviation

Figure 2. Vertical jump height for warm-up protocols in countermovement jump (CMJ)



* – significantly different (p<0.001) from the control warm-up protocol; error bars represent standard deviation

Figure 4. Vertical jump height for warm-up protocols in drop jump (DJ)



* – significantly different (p<0.001) from the control warm-up protocol;
\# – significantly different (p<0.01) from the traditional jump warm-up protocol; error bars represent standard deviation

Figure 5. Jump distance for warm-up protocols in five alternate leg bounds

Discussion

This study was designed to examine the acute effects of warm-up protocols with different specific components, traditional and rope jumps on power and jumping ability in male athletes. Our findings provide evidence that warm-up protocols that incorporate rope jumping exercises may be more beneficial than traditional jump warm-up protocol for horizontal plyometric tasks. In our investigation, jump distance in the five alternate leg bounds was the greatest when rope jumping exercises were used during warm-up. However, there were no differences in power and jumping ability levels for warm-up protocols involving specific exercises in the main plyometric tasks, the CMJ and DJ. We also confirmed that the general and specific warm-up protocols combined led to greater increases in power and jumping ability than the general warm-up protocol alone.

Limited research is available to compare the effect of specific warm-up protocols on power and jumping ability in athletes. The results of our study are novel because they indicate that different specific warm-up protocols may influence power and jumping ability. Our findings support the results of Thompsen et al. [16], who demonstrated that long-jump distance increased following the specific warm-up protocol with a weighted vest in comparison to the same specific warm-up protocol without a weighted vest. It is interesting that both Thompsen et al. [16] and the present study showed improvement in jump distance in horizontal jumping and no differences in power and jumping ability in vertical plyometric exercises. Of course, the stimulus in both studies was completely different (a weighted vest in the study of Thompsen et al. vs. a jumping rope in the current research). The larger gains in horizontal jumping performance might be caused by shorter contact time (see Tab. 1) and more rhythmic performance during rope jumps compared to traditional jumps. We hypothesized that the beneficial rope-jumping pattern of movement translated into plyometric tasks. The short contact time during rope jump warm-up protocol probably occurred because of the high velocity of rope rotation. Studies have shown that contact time has a close relationship with horizontal jumping tasks, when a high horizontal velocity is needed [17]. In a physiological context, Walshe et al. found that shorter contact time increases the efficacy of the stretch-shortening cycle by maximizing the contribution of elastic components in the muscle-tendon unit [18]. In addition, we observed a trend (not statistically significant; see Tab. 1) toward greater power and ground reaction force in rope jumps than in traditional jumps, which may potentially enhance jumping performance [19]. It is also logical to expect a rope jump warm-up protocol to improve running speed because of the short contact time. Because running speed is important for athletic sprints and jumps, this potential effect should be examined in future studies.

Rope jumping is a skill that requires the rope swing to be properly timed and coordinated with each jump. Our additional measurements showed that rope jumps are more rhythmic (lower CV) than in traditional jumps. Probably due to a visible target (rope), which provides visual and kinaesthetic feedback to the athlete regarding the moment to begin jumping. The relatively constant velocity of rope rotation allows a stable jumping rhythm to be maintained by synchronized movements of arms and legs in time. The same feedback is not available during traditional jump exercises, therefore maintaining a stable rhythm is more difficult. Few studies showed that rhythm and timing or muscle coordination are important factors in jumping performance [20, 21].

Our findings support previous investigations indicating that a warm-up protocol that included general and specific procedures is more effective than a warm-up protocol incorporating general warm-up only [3]. However, in contrast to previous studies that used static stretching, which is a controversial warm-up method due to its negative impact on plyometric performance [16], we found that dynamic stretching without specific warm-up was also less beneficial for increasing jump height and distance compared to combined general and specific warm-up. There are also studies that do not indicate benefits for specific warm-up. For example, Burkett et al. [22] found no significant changes in jumping performance following no warm-up condition, static stretching and specific warm-up with submaximal jump in college-age athletic men.

We concluded that performing rope jump warm-up provides the greatest benefits to horizontal jumping performance for speed-power trained athletes. This observation is unique since it produces empirical evidence for previous training recommendation [6, 12, 13]. It also appears that the specific warm-up may be critical to improving the effectiveness of plyometric training. The results of this study are essential for developing optimal warm-up protocols for athletes who perform high-intensity sports, like track and field sprint and jumping events, team ball games or tennis.

Practical implications

Rope jumping may be an effective stimulus for warm-up procedures before plyometric training in power-trained athletes.

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