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The acute effects of various dynamic stretching exercises on jump performance and range of motion

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ABSTRACT

This study aimed to investigate the acute effects of different dynamic stretching (DS) protocols on vertical jump performance and range of motion (ROM). Thirty healthy male participants, with an average age of 23.48 years, body weight of 76.90 kg, and height of 181.87 cm, who had engaged in recreational exercise for at least two years, participated voluntarily. A "cross-controlled randomized" experimental design was utilized to assess four distinct DS protocols: a-DS at 100 bpm for 30", b-DS at 100 bpm for 75" s, c-DS at 150 bpm for 30", and d-DS at 150 bpm for 75". Acute ROM was measured using the Passive Straight Leg Raise Test (PSLR), while jump performance was assessed via countermovement jump (CMJ). Data were analyzed using repeated measures ANOVA and paired samples T-tests with significance set at $p<.05$. All four DS techniques significantly increased angles measured by PSLR following application ($p <.05$). CMJ values also showed significant improvements in both groups subjected to the shorter protocols lasting 30"at either tempo ($p <.05$). Consideration should be given to application duration and tempo when planning DS exercises, as structured warm-up routines can enhance flexibility and optimize athletic performance.

KEYWORDS

Dynamic Stretching; Jump; Range of Motion; Performance

1. INTRODUCTION

Warm-up stretching activities are believed to enhance joint range of motion, thereby preparing the body for physical activity and athletic endeavors, which may contribute to improved performance and a reduced risk of injury (Bandy et al., 1997; Safran et al., 1989; Shellock & Prentice, 1985; Smith, 1994). Consequently, athletes and coaches often incorporate stretching exercises into both their training programs and pre-competition warm-up routines (Gleim & McHugh, 1997). However, numerous recent review articles have questioned the potential benefits of stretching exercises performed during warm-ups (Gleim & McHugh, 1997; Behm & Chaouachi, 2011; Ingraham, 2003; Knudson, 1999; Shrier, 2004; Weldon & Hill, 2003).

Studies investigating the acute effects of dynamic stretching (DS) on performance have indicated that DS positively influences strength (Fletcher, 2010; Yamaguchi et al., 2007), sprinting (Manoel, 2008; Little & Williams, 2006; Holt & Lambourne, 2008) and jumping performance (Hough et al. 2009; Jaggers et al., 2008). Conversely, some studies have reported no significant effects on these performance metrics (Christensen & Nordstrom, 2008; Torres et al., 2008; Unick et al., 2005).

A review regarding the duration of dynamic stretching revealed that sessions lasting between 60-90 seconds exert more favorable impacts on performance compared to those lasting 0-30 seconds or over 90 seconds (Behm & Chaouachi, 2011).

In a study where metronomic guidance was used to determine the tempo (intensity) of dynamic stretching; dynamic stretching activities performed at a rate of 100 beats per minute resulted in significantly higher Counter Movement Jump (CMJ) and Drop Jump (DJ) performances compared to those conducted at a rate of 50 beats per minute (Fletcher, 2010).

There is limited research concerning the intensity associated with dynamic stretching; additionally; an optimal duration for its implementation during pre-exercise warm-up periods has not been fully defined. Overall; it is anticipated that DS exercises will yield positive effects on subsequent performances later on as suggested by Carvalho et al. (2012).

Dynamic stretching exercises influence the nervous system through two fundamental feedback mechanisms based on neurophysiological principles: muscle activation and rate coding. As stretch velocity increases; both frequency and intensity of stimuli sent to the spinal cord also increase which typically results in a proportional motor response known as the stretch reflex (Alter, 2004). Therefore, determining intensity and duration during DS applications is a critical consideration.

This study aims to investigate the effects on CMJ performance after five minutes and ten minutes post-intervention from different tempos and durations utilized in dynamic stretching exercises modeled as follows: a-DG at 100 bpm for 30 seconds; b-DG at 100 bpm for 75 seconds; c-DG at 150 bpm for 30 seconds; d-DG at150 bpm for 75 seconds.

2. METHODS

2.1. Participants

The participants in this study consisted of 30 healthy male individuals aged between 22-28 years with a Body Mass Index (BMI kg/m2) below 30 who had been engaging in recreational exercise for at least two years (Table 1). Prior to participation, individuals completed ACSM Health Risk Classification questionnaires; only those classified as low risk were included in this study. Approval was obtained from an Institutional Research Ethics Committee at Marmara University in Istanbul, Turkey (No: 09.2021.283), following ethical principles established by the Declaration of Helsinki; all participants provided informed consent affirming their voluntary participation.

Table 1. Descriptive characteristics of participants

n=30	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Age (yıl)	22.84	24.36	23.48	.40
Body Weight (kg)	63.00	93.00	76.90	8.02
Height (cm)	160.00	192.00	181.87	7.24
BMI (kg/m^2)	18.99	27.78	23.27	2.23

Our research employed an experimental design incorporating both dependent and independent variables aimed at measuring the acute effects of four distinct dynamic stretching protocols on ROM and CMJ performance:

1. Protocol A - Dynamic Stretching at 100 bpm for 30 seconds
2. Protocol B - Dynamic Stretching at 100 bpm for 75 seconds
3. Protocol C - Dynamic Stretching at 150 bpm for 30 seconds
4. Protocol D - Dynamic Stretching at 150 bpm for 75 seconds.

Each protocol was randomly assigned and applied with a gap period separating each trial by approximately seventy-two hours among participants using a crossover controlled randomized model design (Figure 1). Prior evaluations included flexibility assessments (ROM) as well as CMJ measurements before commencing any stretch protocols.

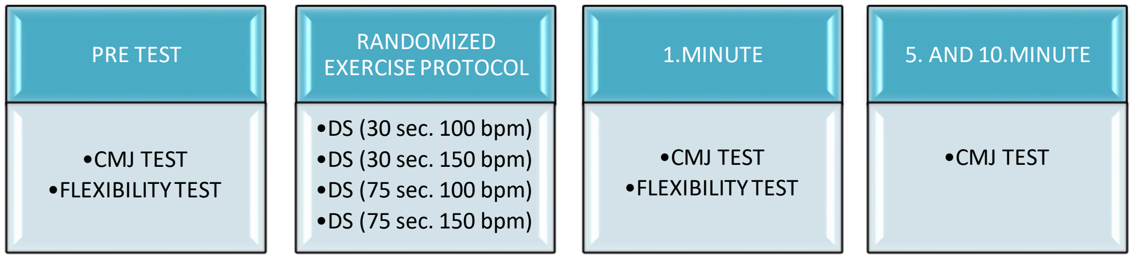

Figure 1. Study protocol and data collection

Participants performed light jogging for five minutes as general warm-up before undergoing three-minute intervals measuring CMJ performance followed by flexibility testing based upon baseline measurement parameters recorded subsequently implementing one out four specific stretch protocols followed immediately after assessing flexibility outcomes again taken within one minute post-intervention alongside subsequent assessments conducted five minutes later then again ten minutes post-protocol application.

2.2. Dynamic Stretching Exercise Procedure

Dynamic stretching exercises were specifically chosen for the hamstring muscle group. This selection is based on literature indicating that hamstring muscles are associated with lower extremity injuries (Croisier et al., 2008; Witvrouw et al., 2003) and declines in athletic performance (Garcia et al., 2015). Therefore, among the muscle groups that significantly influence jump performance, the hamstring muscle group was preferred.

Care was taken to maintain a straight torso position while performing the exercises. Each leg was treated separately, with the knee joint kept in full extension, and a swinging hip flexion movement (forward kick) (Figure 2) performed to the maximum range of motion at the hip joint for a specified duration. The desired movement was executed according to four different protocols. The tempo of dynamic stretching movements was regulated using a metronome (Musedo MT-40) as per protocol requirements.

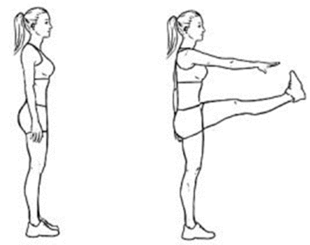

Figure 2. Dynamic Stretching Exercise

2.3. Data Collection

Passive Straight Leg Raise Test (PSLR): The Passive Straight Leg Raise test, one of the most widely used methods for assessing hamstring muscle flexibility (Ayala et al., 2012), was administered to all participants before and after the dynamic stretching protocols. To determine the hip flexion angle during the PSLR test, joint range of motion (ROM) measurement procedures were followed as outlined by Norkins C.C. (2016), using a goniometer for precise measurements.

Counter Movement Jump Test (CMJ): Maximum vertical jump height results were recorded using the Swift Performance Speed Mat 260 (Swift Performance, Brisbane, Australia). The jump heights measured with the Swift Performance mat were transferred and documented via the Speed Light iPad application (Version 493). Participants performed three consecutive jumps without rest between attempts, and only the highest jump was considered for evaluation.

2.4. Statistical Analyses

The normality of samples was confirmed using the Kolmogorov-Smirnov Test. The sample exhibited homogeneity across all test variables; consequently, parametric tests were employed for data analysis. Descriptive statistics including mean values, standard deviations (SD), minimum and maximum values were calculated.

To compare intra-group measurement data, repeated measures ANOVA was conducted followed by paired samples t-tests where appropriate. For analyzing dynamic stretch experimental conditions, analysis of variance for repeated measures was utilized along with Bonferroni's post hoc test to explore differences further.

3. RESULTS

Our study aimed at determining the effects of dynamic stretching exercises performed at different tempos and durations on CMJ performance and flexibility concluded with data from 30 volunteer participants (mean age: 23.48 ± .40 years) as shown in Table 2.

Table 2. Pretest posttest intragroup comparison of various dynamic stretching applications

	Dynamic Stretch (bpm/sec)	Before	After			
		Mean (SD)	Mean (SD)	%	t	p
PSLR (°)	100/30	75.17(5.81)	77.90(5.60)	4.34	-7.69	*
	150/30	75.17(5.81)	79.80(5.79)	7.35	-11.59	*
	100/75	75.17(5.81)	79.30(5.71)	6.56	-9.72	*
	150/75	75.17(5.81)	79.37(5.79)	6.67	-9.89	*
CMJ (cm)	100/30	32.16 (4.46)	32.76(4.76)	1.81	-3.14	*
	150/30	31.90(4.56)	35.43(4.57)	11.39	-12.49	*
	100/75	33.67(4.17)	33.59(4.25)	-.20	.39	.696
	150/75	33.77(4.36)	33.30(4.51)	-1.43	2.11	.044

*Note. *p<.05; PSLR: Passive Straight Leg Raise; CMJ: Counter Movement Jump*

It was found that PSLR angles increased after four different dynamic stretching applications (p<.05). Vertical jump values are 100 bpm / 30 sec and 150 bpm / 30 sec. It was found to increase in different protocols (p<.05). CMJ test results measured immediately after 4 different stretching protocols within 30 sec. It was found to increase in the protocols applied with a tempo of 100 bpm and 150 bpm (p <.05) (Table 2).

Table 3. Intra-group comparison with CMJ values after 5 and 10 minutes of different dynamic stretching applications

	Protocol (bpm/sec)	Before	5. Minute				10. Min			
		Mean(SD)	Mean(SD)	%	t	p	Mean(SD)	%	t	p
CMJ (cm)	100/30	32.16(4.46)	33.40(4.53)	4.02	-4.92	*	33.40(4.50)	4.06	-4.35	*
	150/30	31.90(4.56)	35.70(4.78)	12.21	11.52	*	35.97(4.65)	13.17	11.75	*
	100/75	33.67(4.17)	34.06(4.11)	1.30	-2.08	0.05	34.15(4.68)	1.40	-1.82	0.08
	150/75	33.77(4.36)	33.58(4.37)	-0.49	0.71	0.48	34.20(4.88)	1.20	-1.47	0.15

*Note. *p<.05; CMJ: Counter Movement Jump*

In the dynamic stretching protocol applied with a duration of thirty seconds and a tempo of 100 bpm, vertical jump height increased by 4.02% after 5 minutes and 4.06% after 10 minutes (p<.05). Likewise, in the dynamic stretching protocol performed with a tempo of 150 bpm for 30 seconds, vertical jump height increased by 11.52% after 5 minutes and by 11.75% after 10 minutes (p<.05).

When the change (percentage of change) between measurement pairs after different stretching protocols was compared between groups, both PSLR (F=4.204 p<.05) and CMJ measured at 3 different times (respectively F=55.59 p<0.05 / F=40) .17 p<.05 / F=31.44 p<.05) was found to have a significant difference. It was found that the percentage change in PSLR data was different between 100 bpm and 150 bpm stretching protocols performed for 30 seconds (p<.05) (Figure 3).

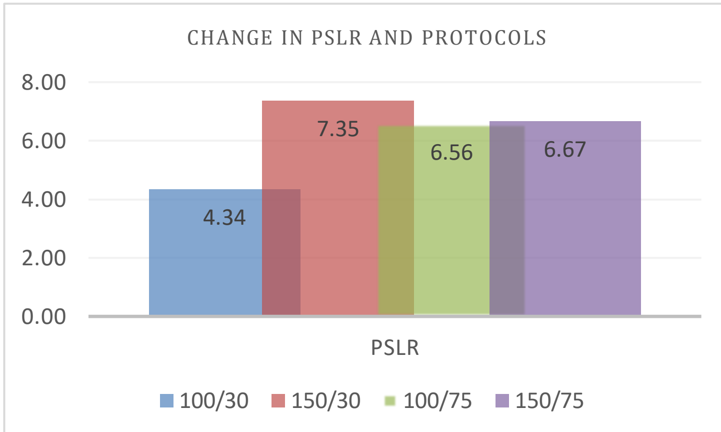

Figure 3. Percentage values of PSLR change measured after stretching protocols and comparison between groups

When the percentage values of the change between CMJ measurement pairs taken after dynamic stretching were compared between the groups; the vertical jump height measured at all times (1st min, 5th min and 10th min) was 30 sec. It was found that the dynamic stretching protocol applied with a tempo of 150 bpm showed a significant difference compared to all other protocols (p<.05) (figure 4).

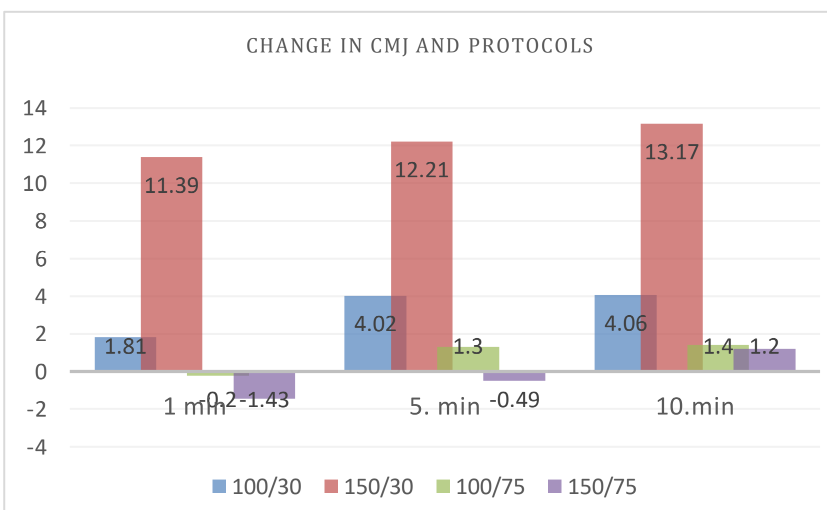

Figure 4. Percentage values of CMJ change measured after stretching protocols and comparison between groups

4. DISCUSSION

There are very few studies showing that the duration and intensity of DG application have positive effects on performance (Behm & Chaouachi, 2011; Erkut et al., 2017). Additionally, stretching intensity is not defined in most of the dynamic stretching studies. This makes it difficult to make comparisons between studies (Behm & Chaouachi, 2011; Fletcher, 2010). For this reason, we believe that application standards should be established in order to maximize the possible contribution of the DG method to performance.

Each participant applied dynamic stretching protocols in a random order. When the results obtained are examined in terms of CMJ performance, the results of both Dg/100 and dg 150/30 protocols show a significant increase (5th minute 4.02% and 12.21%, 10th minute 4.06% and 13%, respectively) was found. On the other hand, it was observed that the dg150/30 protocol provided the highest increase in terms of Hamstring flexibility compared to other protocols.

Many recent researchers have questioned the potential benefits of stretching exercises during warm-up (Erkut et al., 2017). Studies examining the acute effects of dynamic stretching on performance; He states that dynamic stretching contributes positively to power performance, sprint performance and jumping performance. However, there are also studies showing that it has no positive or negative effect on performance. In a review by Behm & Chaouachi (2011), it was shown that dynamic stretches performed between 60-90 seconds had a more positive impact on performance than dynamic stretches over 0-30, 30-60 seconds and >90 seconds, respectively. Our study also supports these findings in terms of the positive contribution of 30-second DG exercises to jumping performance. Additionally, in another study, DG exercise intensity (movement speed) was determined by metronome and dynamic stretching activities performed at a speed of 100 beats / minute resulted in significantly higher CMJ and Drop Jump (DJ) performance than dynamic stretching activities applied at a speed of 50 beats / minute. has been shown (Fletcher, 2010). In our study, DG exercises performed at 100 strokes/minute and 150 strokes/minute were compared regarding DG intensity (pace).

As a result, it was found that dynamic stretching activities applied at a speed of 150 strokes / minute significantly increased CMJ performance (Hough et al. 2009; Jaggers et al., 2008). We think that this study has an important value in terms of revealing the optimum DG exercise tempo, because while the positive aspects of DG exercises at 100 beats/min were previously discussed, in our study, we reveal the positive aspects of DG exercises performed at 150 beats/min. In this sense, it is clear that more studies are needed to determine the optimal tempo of DG exercises.

In addition, looking at the jump results at the 5th minute and 10th minute of the group applying the dk150/30 protocol, it is seen that performance gradually increases. This is supported by research

(Opplert & Babault, 2019) that is mainly attributed to mechanisms related to voluntary contractions of the muscles involved in the study, temperature and the post-activation strengthening effect. CMJ results obtained in all measurements after the DG100/75 AND DG150/75 protocols we used in our study were not found to be significant. These decreases in physical performance may be related to neural or mechanical factors or a combination of both (Weldon & Hill, 2003; Fletcher, 2010; Holt & Lamboune, 2008). One of the mechanisms associated with this condition is the decrease in the stiffness of the muscle-tendon unit (i.e., mechanical factor) (Opplert et al., 2016). Since one of the functions of tendons is to transfer the force produced by skeletal muscle to bones and joints, a decrease in tendon stiffness or a more flexible muscle-tendon unit can negatively affect force transfer, resulting in decreased performance in activities that require maximum speed. Additionally, the decrease in the stiffness of the muscle-tendon unit may cause changes in the length-tension relationship of the sarcomere (Moo et al., 2020).

In the CMJ test we used in our study, force production in the shortest possible time period is essential. When we look at the results of the DG100/75 and DG150/75 protocols, lower results were obtained in both of them at the first minute after stretching compared to the CMJ pre-test results. According to these results, we can say that long stretching time is associated with the factors mentioned above. However, the results of the second attempt of the DG100/75 group at the 5th minute were just above the pre-test, indicating that at least 5 minutes were needed for recovery due to the total workload created by the movement speed and stretching time, and for DG150/75, it was observed that recovery occurred at the 10th minute as the workload increased. According to the results of the AYD query made after each CMJ performance, the perceived fatigue level answers were: 3 (three) on average for the DG100/30 group, 4 (four) for the DG150/30 group, 6 (six) for the DG100/75 group and 7 (seven) for the DG150/75 group. is. These answers support the performance differences we associate with increased workload and delayed recovery. Participants' ratings of effort levels during DS ranged from 3 (“Moderate”) to 6 (“Strong” to “Very Strong”) on the Borg CR10 scale (7).

Increasing ROM is the main purpose of stretching exercises. There is significant evidence that DG exercises can increase acute range of motion in the relevant joints (Freitas et al., 2016). Some studies have shown that dynamic stretching provides a similar or greater acute increase in flexibility than static stretching (Smith, 1994; Carvalho et al., 2012). When looking at the effects of the DG protocols used in our study on acute flexibility, it was seen that the stretching protocol that stood out by dramatically increasing Hamstring flexibility was the 'DG 150/30' protocol, as in jumping performance. We think that this application can make a significant contribution to coaches and athletes working in the field of athletic performance in terms of providing the highest positive contribution to both jumping performance and acute Hamstring flexibility.

5. LIMITATIONS

Limitations of this study include that all participants were recreationally active but participated in different sports and trained at different intensity levels ranging from 30 minutes to 2 hours most days of the week, ranging from light-moderate to intense. Additionally, some participants reported doing stretching exercises regularly after exercise, while others reported not doing stretching exercises regularly.

6. CONCLUSIONS

Our study, together with previous similar studies, shows that pre-exercise DG may provide a performance advantage in terms of jump height. In addition, our results provide additional evidence that potential performance deficits occurring after SS may not be easily overcome with additional activity.

When designing effective warm-up routines for athletes that require explosive strength, speed or power, coaches, strength and conditioning experts should consider sport-specific DG exercises to be included in general aerobic warm-up and/or mixed warm-up routines, such as movement tempo, application time and tempo of DG stretching exercises, what effect they have on performance. It should be planned by paying attention to the total workload along with criteria such as how long it should be implemented in advance. A well-designed warm-up that includes DG can serve, separately or together, for purposes such as increasing acute flexibility or preparing the athlete for peak performance.

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All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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