Acute effects of repeated isoinertial lunges on jump and sprint parameters

Mehmet Kale[1ABCDE], Emre Çelik[1B], Ezgi Uyar[2BE], Esen Kızıldağ Kale[2BCDE]

[1] *Department of Coach Training in Sport, Faculty of Sports Sciences, Eskişehir Technical University, Turkey*
[2] *Department of Coach Training, School of Physical Education and Sports, İstanbul Nişantaşı University, Turkey*

Abstract

Background and Study Aim	Understanding the relationship between repeated isoinertial lunges and jump and sprint parameters is an important factor in achieving success in sports requiring explosive strength and speed. The aim of this study was to examine the acute effects of repeated isoinertial lunges on jump and sprint parameters.
Material and Methods	Volunteered 42 students from Sports Sciences Faculty were participated to the study. They were randomly divided into experimental group (EG) (n=22, age=22.8±1.1year, height=180.6±7.1cm, body weight=77.5±8.8kg) and control group (CG) (n=20, age=23.0±2.1year, height=173.1±5.6 cm, body weight=71.3±8.4 kg). As pre- and post-tests, each participant performed squat jump (SJ), countermovement jump (CMJ), and 30m sprint on a non-motorized treadmill. Isoinertial lunges were included in 8 reps with dominant leg (DL), 1 min rest, and 8 reps with non-dominant leg (NDL). As a statistical analysis, pre- and post-test differences were analyzed with independent t test between groups and paired t test within groups. The level of significance was taken as $p \leqslant 0.05$.
Results	There were pre-test and also post-test differences between groups in SJ ($p<0.05$) but there were no differences within groups. Both groups had significant pre- and post-test time, velocity, and power differences [for EG: $p<0.01$, $p<0.001$, $p<0.01$; for CG: $p<0.001$, $p<0.001$, $p<0.01$, respectively]. EG had significant pre- and post-test differences in stride frequency (SF) ($p<0.01$). There was a post-test SF difference between two groups ($p<0.05$). There were no statistically significant pre-test differences between the groups in 30m sprint parameters of NDL and DL. There were only significant post-test differences between the groups in SF_{DL} ($p<0.005$) and NDL horizontal force (HF_{NDL}) ($p<0.01$). EG had only significant pre- and post-test differences in SF_{DL} and P_{NDL} ($p<0.005$ and $p<0.05$).
Conclusions	Detailed studies in SF and SF_{DL} increases result by repeated isoinertial lunges should be beneficial focus on DL neuromuscular activation. Furthermore, incorporating repeated isoinertial lunges into training regimens could be a valuable strategy for enhancing specific aspects of athletic performance in sports that demand high levels of speed and explosive power.
Keywords:	stride frequency, dominant leg, isoinertial lunge, horizontal force

Introduction

Strength training produces muscle adaptations at both structural and functional levels [1]. Strength training with an isoinertial resistance has become one of the popular training methods. It is a technology that improves proprioception, neuromuscular efficiency and motor coordination based on postural control by improving neuromuscular activity. It elicits an equal amount of eccentric force against the isoinertial force (concentric force) applied by athletes [2]. The supramaximal weight generated during isoinertial eccentric strength exercises leads to a muscle-lengthening contraction, greater muscle strength gains, muscle hypertrophy. It provides greater improvements in muscle coordination compared to concentric strength training [3]. Compared to other traditional strength training methods, isoinertial resistance training method has positive effects on muscle architecture and cross-sectional area. The reason is that it achieves the same goals in less time [4]. Movements performed with isoinertial systems resulted in the same or greater strength development than the traditional weight training [5]. Isoinertial eccentric strength provides greater muscle activation on eccentric muscle contraction compared to traditional strength training [6]. Therefore, isoinertial eccentric training increases muscle strength by providing the opportunity to work on strength and speed in the muscle [7]. As a post-activity performance enhancement (PAPE), isoinertial squat and deadlift increased hamstring' eccentric strength but didn't affect the concentric strength [8]. Isoinertial system has a preventive effect against muscle tissue lesion by developing eccentric strength. It also allows gaining extensor strength [9]. It compares power/ strength and balance in eccentric/concentric phases during exercise in real-time. This supports

that isoinertial training is effective in improving vertical and horizontal strength during sprinting, squat jump (SJ) and countermovement jump (CMJ). In optimal strength training, half-squat and squat jump movements are used in preventing strength and speed reductions [10]. In addition, CMJ is a commonly used movement for the assessment of isoinertial leg strength due to its simplicity and explosiveness [11]. Relationships among isoinertial strength, speed and power help to identify the mechanism responsible for maximal power and training adaptations [12]. However, Beato et al. [13] noted very few studies have investigated the acute neuromuscular mechanisms induced by isoinertial training. These studies were associated acute musculoskeletal adaptations and acute effects on PAPE. Isoinertial systems have become widespread and started to be used in different fields and purposes because of their beneficial effects.

In an isoinertial system, a resistance is exhibited in proportion to the concentric contraction exhibited during the eccentric contraction [14]. Previous studies have used isoinertial interventions for physical fitness [15] and rehabilitation [16]. Some of them found positive effects on different populations such as the elderly [17], athletes [18], athletes undergoing rehabilitation [19]. It is known that the acute and chronic increase in various performance parameters with isoinertial training varies. They depend on the type of movement in training method, volume, intensity and protocol as well as characteristics of participants. However, there are no studies on acute effects of repetitive isoinertial lunges on sprint and jump performances. The aim of this study was to investigate the acute effects of repetitive isoinertial lunges on jump and sprint parameters.

Materials and Methods

Participants

The study included 50 male volunteers who were studying at Eskisehir Technical University, Faculty of Sport Sciences aged between 18-22 years. They had not participated in an application with the isoinertial training system before, and had no health problems. The study was completed with 42 participants due to the problems in the data. The targeted number of participants was determined by G*Power 3.1.9.7 analysis. It was based on the data entered with a power size (1-β) of 0.80, α=0.05, and an effect size (d) of 0.80. They were randomly divided into experimental group (EG) (n=22, age=22.8±1.1year, height=180.6±7.1cm, body weight=77.5±8.8kg) and control group (CG) (n=20, age=23.0±2.1year, height=173.1±5.6 cm, body weight=71.3±8.4 kg). They avoided high intensity exercise for 48 hours before the study. They were asked not to change their normal diet, smoke, drink

alcohol or consume caffeine for 24 hours before tests. Participants were informed in detail about the purpose, content, importance, application, and possible risks. They could freely discontinue the study at any time before starting the measurements and tests according to the procedures of the Declaration of Helsinki, trial measurements and tests. Each participant signed an informed consent. Istanbul Nisantası University Ethics Committee approval (2022/24) was obtained for the study. Participants were assigned to the test protocols by simple randomization.

Research Design

After the device calibration, trial measurements and tests were performed for participants to adapt to laboratory conditions, measurements, and tests. They had a 10 min warm-up consisting of light-paced jogging, stretching and exercise movements. Participants performed 2x30m sprint tests with 3 min intervals. They had a 90 sec passive rest as stated by Kacoglu and Kale [20]. Then, they were taken to the vertical jump tests consisting of 2xSJ and 2xCMJ and the pre-tests were completed. SJ and CMJ tests were performed with 30 sec of passive rest between reps and 60 sec of passive rest between tests. The best of the 2 attempts in the jump tests was included in the statistical analysis. Before the post-tests, EG performed 16reps maximum (RM) lunges (8RM with DL in front, 1min rest, 8RM with NDL in front). CG performed repetitive lunges in the same way without isoinertial force.

Isoinertial Lunge Procedure

Each participant first performed a 10-minute warm-up consisting of light jogging, flexibility and calisthenic movements individually. Afterwards, the participant was shoeless, hands on the waist and torso upright, front foot on the phalanges on the isoinertial training system (Desmotec D11 Version Sport Pro, Italy). An adjustable rope was attached to the waist with a special belt from the bottom to the flywheel. Knees were in the flexion position between approximately 110-130°. When the participant felt ready, he performed extension until the knees reached 180° and returned to the starting position. He performed 16RM isoinertial lunges with 8RM of DL in front, 1 min rest, 8RM of NDL in front.

Height and Body Weight Measurements

Height was measured with a wall-mounted stadiometer (Holtain, UK) with an accuracy of 0.1mm. The accuracy was checked by measuring the height between the ground and the head table of the stadiometer. A 60cm standard aluminum flat bar was provided for this height. Body weight was measured using an electronic laboratory scale (Seca, Vogel & Halke, Hamburg) with an accuracy of 0.1kg. The measurements were done as recommended by Lohman et al. [21].

Sprint Test

Each participant had a 10-min warm-up consisting of light jogging, flexibility and calisthenic movements. He participated in 2x30m sprint tests with a 3-min interval on a non-motorized computer-assisted treadmill (Woodway Force 3.0, Woodway Inc., Waukesha, USA). Before the test, the horizontal force strain gauge attached to the waist was adjusted to be parallel to the treadmill. The best performance in 30m sprint tests was included in the statistical analyses. The best 30m sprint speed was calculated in m/sec from the formula (V)= distance (d) / time (t). Horizontal force (HF) and vertical force (VF) data during 30m sprint were recorded on a computer at 200Hz. Means of SL and SF were determined in the best 30m sprint. The best 30m sprint HF= 30m sprint total HF (ΣHF) / 30m sprint total stride number (ΣSN) was calculated in Newton (N). The best 30m sprint VF= 30m sprint total vertical force (ΣVF) / 30m sprint total stride number (ΣSN) was calculated in N.

Jump Tests

Two different jump tests (SJ and CMJ) were applied on a jump mat that acts as an electronic on-off switch. As explained by Kale et al. [22], SJ and CMJ time was transferred to the computer. ESC 2XXX Series Data Acquisition computer software at 1000Hz [23] was used for each data transfer. Participants rested for 60sec after each jump test. Two trials were performed with 30 sec rest. Jumps were calculated with the formula h= $g.tf^2.8^{-1}.100$; h= jump height (cm), g= gravitational acceleration (9.81m.sec^{-2}.), tf= time in the air (sec) [24]. The highest jump height was taken into statistical analysis. SJ was performed on the mat with feet shoulder-width apart and hands on the waist. Eyes focused across and standing in a ~90° fixed squat position for 2-3 sec were followed by a vertical jump. CMJ was performed on the same mat with feet shoulder-width apart and hands on the waist. Eyes focused across and standing position, knees ~90° squat position as soon as possible were followed by a vertical jump.

Statistical Analysis

Data obtained from the study were analyzed using Jamovi statistical program (2.3.28.0, Stats Open Now). Skewness-Kurtosis test showed that all pre-test parameters of both groups were normally distributed. Independent sample t-test was used for between-group pre- and post-test comparisons. Paired sample t-test was used for within-group pre- and post-test comparisons. The significance level was based on $p<0.05$. Effect sizes (ES) were analyzed through means and standard deviations as stated by Wassertheil and Cohen [25]. <0.2 was considered as trivial, 0.2-0.5 as small, 0.5-0.8 as moderate and >0.8 as large inference.

Results

Each parameter in the pre-tests was normally distributed ($p > 0.05$). Participants were divided into EG and CG. All results are presented in Table 1-4.

Table 1. demonstrated that there were no significant SJ differences in pre- and post-test comparisons within two groups. A statistically significant SJ difference was found between groups in pre-test [ES: 0.72 (moderate), 95% CI: [0.07, 1.36], p<0.05]. A statistically significant SJ difference also was found between groups in post-test [ES: 0.78 (moderate), 95% CI: [0.13, 1.42], p<0.05]. There were no statistically significant CMJ differences between-group and within-group comparisons in both pre-tests and post-tests.

Table 2. showed that no statistically significant differences in 30m sprint pre- and post-test peak parameters were found between EG and CG. There was a statistically significant difference in EG between the pre- and post-test V_{peak} [ES: -0.61 (moderate), 95% CI: [-1.06, -0.15], p<0.01]. CG had also a significant difference between the pre- and post-test V_{peak} [ES: -0.63 (moderate), 95% CI: [-1.11, -0.14], p<0.01]. In addition, CG had a significant pre- and post-test P_{peak} difference [ES: -0.87 (large), 95% CI: [-1.38, -0.35], p<0.001]. There were no significant differences between pre- and post-test results of the other 30m sprint peak parameters within the group.

Table 1. Mean ± SD values and comparisons of jump parameters of pre- and post-tests for EG and CG

Parameter	Group	Pre	Post	ES [95% CI]	Inference
SJ (cm)	EG	35.0 ± 5.12	35.9 ± 5.57	0.39 [-0.82, 0.05]	Small
	CG	30.9 ± 6.00¥	31.6 ± 5.57¥	0.21 [-0.65, 0.24]	Small
	ES [95% CI]	0.72 [0.07, 1.36]	0.78 [0.13, 1.42]		
	Inference	Moderate	Moderate		
CMJ (cm)	EG	36.3 ± 4.77	37.4 ±6.49	0.30 [-0.73, 0.13]	Small
	CG	33.9 ± 6.39	34.3 ± 6.03	0.22 [-0.66, 0.23]	Small
	ES [95% CI]	0.43 [-0.19, 1.05]	0.49 [-0.14, 1.11]		
	Inference	Small	Small		

Data are Mean ± SD. EG: Experimental group; CG: Control group; ES: Effect size; 95% CI: 95% Confidence interval; SJ: Squat jump; CMJ: Counter movement jump; ¥: p<0.05, between groups; ¥.

Table 2. Mean ± SD values and comparisons of peak parameters of 30m sprint pre- and post-tests for EG and CG

Parameter	Group	Pre	Post	ES [95% CI]	Inference
V_{peak} (m.sec^{-1})	EG	4.98 ± 0.73	5.26 ± 0.57**	-0.61 [-1.06, -0.15]	Moderate
	CG	4.89 ± 0.50	5.13 ± 0.39**	-0.63 [-1.11, -0.14]	Moderate
	ES [95% CI]	0.14 [-0.47, 0.74]	0.28 [-0.34, 0.89]		
	Inference	Trivial	Small		
HF_{peak} (N)	EG	400 ± 198	381 ± 143	0.20 [-0.22, 0.62]	Small
	CG	368 ± 151	369 ± 140	-0.01 [-0.45, 0.43]	Trivial
	ES [95% CI]	0.18 [-0.43, 0.79]	0.08 [-0.53, 0.69]		
	Inference	Trivial	Trivial		
VF_{peak} (N)	EG	1626 ± 484	1687 ± 455	-0.23 [-0.66, 0.19]	Small
	CG	1611 ± 434	1594 ± 412	0.10 [-0.34, 0.54]	Trivial
	ES [95% CI]	0.03 [-0.57, 0.64]	0.21 [-0.40, 0.82]		
	Inference	Trivial	Small		
P_{peak} (W)	EG	1625 ± 873	1634 ± 636	-0.02 [-0.44, 0.40]	Trivial
	CG	1349 ± 491	1489 ± 525***	-0.87 [-1.38, -0.35]	Large
	ES [95% CI]	0.39 [-0.24, 0.10]	0.25 [-0.37, 0.86]		
	Inference	Small	Small		

Data are Mean ± SD. EG: Experimental group; CG: Control group; ES: Effect size; 95% CI: 95% Confidence interval; V_{peak}: Peak velocity; HF_{peak}: Peak horizontal force; VF_{peak}: Peak vertical force; P_{peak}: Peak power; **: $p<0.01$, within groups; ***: $p<0.001$, within groups.

As can be seen in Table 3., there was no statistically significant difference between groups in all 30m sprint pre-test parameters. A statistically significant difference was found only in SF [ES: 0.74 (moderate), 95% CI: (-0.09, 1.38), $p<0.05$]. EG had statistically significant t, V, SF and P differences ($p<0.01$, $p<0.005$, $p<0.01$ and $p<0.01$, respectively) between pre- and post-tests. The inferences were moderates (ES: 0.70, -0.79, -0.59 and -0.63, respectively). CG had significant differences in t and V [$p<0.001$, ES: 0.83 (large) and $p<0.001$, ES: -0.86 (large)], HF and P [($p<0.05$, ES: -0.51 (moderate) and $p<0.01$, ES: -0.81 (large)].

In Table 4., there were no statistically significant differences between groups in 30m sprint pre-test parameters based on DL and NDL. In the post-test comparisons between groups, no statistically significant differences were found in all other parameters except for SF_{DL} [EB: 0.91 (large), 95% CI: [0.24, 1.57], $p<0.005$] and HF_{NDL} [EB: 0. 78 (medium), 95% CI: [0.12, 1.42], $p<0.01$]. DG had a significant pre- and post-test difference in SF_{DL} [ES: -0.74 (moderate), 95% CI: [-1.21, -0.26], $p<0.005$]. DG also had a significant pre- and post-test difference in P_{NDL} [ES: -0.56 (moderate), 95% CI: [-1.00, -0.10], $p<0.05$]. There were statistically significant pre- and post-test differences in CG for HF_{BB} [ES: -0.48 small, 95% CI: [-0.94, -0.01], $p<0.05$]. It was observed that CG had a significant pre- and post-test VF_{DL} difference [Es: 0.48 (small), 95% CI: [0.01, 0.94], $p<0.05$]. CG had

also a significant pre- and post-test P_{DL} difference [ES: -0.84 (large), 95% CI: [-1.35, -0.32], $p<0.05$].

Discussion

The aim of this study was to investigate acute effects of isoinertial lunges on SJ, CMJ and 30 m sprint. In literature, there were no studies demonstrating acute effects of isoinertial lunges performed with DL and NDL on sprint and jump parameters. SJ had a statistically significant pre- and post-test difference ($p<0.05$) between groups while no differences were found within groups. Both groups had statistically significant pre- and post-test differences in t, V, P ($p<0.01$, $p<0.001$, and $p<0.01$, respectively for EG; $p<0.001$, $p<0.001$, and $p<0.01$, respectively for CG). EG had a statistically significant SF difference between pre- and post-tests ($p<0.01$). There is a statistically significant difference between groups in SF post-tests ($p<0.05$). There were no differences between groups in pre-test DL and NDL 30m sprint parameters. There were statistically significant SF_{DL} and SF_{NDL} differences between groups in post-tests ($p<0.005$ and $p<0.01$). Statistically significant differences ($p<0.005$ and $p<0.05$) was found between pre- and post-tests in SF_{DL} and P_{NDL} in EG.

Eccentric strength training activated large motor units in hamstring muscle group and increased eccentric strength-related performance such as vertical jump [26]. Timon et al. [27] compared the

Table 3. Mean ± SD values and comparisons of parameters of 30m sprint pre- and post-tests for EG and CG

Parameter	Group	Pre	Post	ES [95% CI]	Inference
t (sec)	EG	7.38 ± 1.51	6.95 ± 1.12**	0.70 [0.23, 1.17]	Moderate
	CG	7.71 ± 1.47	7.22 ± 1.08***	0.83 [0.31, 1.33]	Large
	ES [95% CI]	-0.22 [-0.83, 0.39]	-0.25 [-0.86, 0.36]		
	Inference	Small	Small		
V (m.sec⁻¹)	EG	4.23 ± 0.82	4.42 ± 0.70***	-0.79 [-1.26, -0.30]	Moderate
	CG	4.02 ± 0.70	4.24 ± 0.60***	-0.86 [-1.36, -0.33]	Large
	ES [95% CI]	0.27 [-0.34, 0.88]	0.28 [-0.33, 0.89]		
	Inference	Small	Small		
SF (Hz)	EG	5.97 ± 1.07	6.43 ± 1.21**	-0.59 [-1.04, -0.13]	Moderate
	CG	5.60 ± 0.82	5.71 ± 0.77¥	-0.24 [-0.68, 0.21]	Small
	ES [95% CI]	0.38 [-0.24, 0.10]	0.74 [-0.09, 1.38]		
	Inference	Small	Moderate		
SL (m)	EG	0.82 ± 0.11	0.81 ± 0.12	0.11 [-0.31, 0.53]	Trivial
	CG	0.83 ± 0.10	0.85 ± 0.10	-0.26 [-0.70, 0.19]	Small
	ES [95% CI]	-0.01 [-0.62, 0.59]	-0.32 [-0.93, 0.29]		
	Inference	Trivial	Small		
HF (N)	EG	152 ± 12	191 ± 161	-0.24 [-0.67, 0.18]	Small
	CG	146 ± 111	151 ± 147*	-0.51 [-0.97, -0.03]	Moderate
	ES [95% CI]	0.53 [-0.10, 1.15]	0.34 [-0.28, 0.95]		
	Inference	Moderate	Small		
VF (N)	EG	779 ± 148	767 ± 171	0.09 [-0.33, 0.51]	Trivial
	CG	776 ± 128	772 ± 132	0.31 [-0.14, 0.76]	Small
	ES [95% CI]	0.02 [-0.58, 0.63]	0.03 [-0.64, 0.58]		
	Inference	Trivial	Trivial		
P (W)	EG	691 ± 151	732 ± 161**	-0.63 [-1.08, -0.16]	Moderate
	CG	612 ± 120	681 ± 112**	-0.81 [-1.31, -0.30]	Large
	ES [95% CI]	0.57 [-0.06, 1.20]	0.37 [-0.64, 0.58]		
	Inference	Moderate	Small		

Data are Mean ± SD. EG: Experimental group; CG: Control group; ES: Effect size; 95% CI: 95% Confidence interval; t: time; V: Velocity; SF: Stride frequency; SL: Stride length; HF: Horizontal force; VF: Vertical force; P: Power; *: $p<0.05$, within groups; **: $p<0.01$, within groups; ***: $p<0.001$, within groups; ¥: $p<0.05$.

post-activation performance enhancement effect of traditional strength and isoinertial resistance different preload protocols. They found that vertical jump performance increased after the isoinertial preload protocol. Pre- and post-test results of this study between and within groups were compared. Isoinertial lunges performed 8RM of DL, 1min rest, 8RM of NDL didn't have acute effects on SJ and CMJ after 90sec. Therefore, SJ and CMJ results of current study were not considered to support Timon et al. [27]' study results. This may be due to the fact that in the study of Timon et al. [27]. Their jump tests were performed after 4min and 8min, while in the present study, jump tests were performed after 90sec.

Beato et al. [28] tested jumping and change of direction running after 4sets of 6reps isoinertial eccentric strength protocols. The results showed that soccer players had no statistical differences among 3 different leg movements (cross-cutting step, leg extension and squat). It was determined that 5m chance of direction performed 4min after 3 exercises showed statistically positive acute increases. Beato et al. [13] compared eccentric overloading with isoinertial strength and traditional strength with Olympic bar. Both of them increased vertical jump acutely in a statistically significant manner, but did not affect 5m sprint. In their another study, Beato et al. [29] determined that moderate isoinertial loads on athletes statistically significantly increased vertical jump. They also stated significant differences in chance of direction running performances at 30s, 3min and 6min after this loading.

Sabido et al. [30] studied chronic effects of

Tablo 4. Mean ± SD values and comparisons of NDL and DL parameters of 30m sprint pre- and post-tests for EG and CG

Parameter	Group	Pre	Post	ES [95% CI]	Inference
SF_{DL} (Hz)	EG	5.96 ± 1.05	6.58 ± 1.14***	-0.74 [-1.21, -0.26]	Moderate
	CG	5.57 ± 0.92	5.69 ± 0.75¥¥¥	-0.23 [-0.67, 0.22]	Small
	ES [95% CI]	0.40 [-0.22, 1.01]	0.91 [0.24, 1.57]		
	Inference	Small	Large		
SF_{NDL} (Hz)	EG	5.98 ± 1.16	6.29 ± 1.18	-0.33 [-0.75, 0.11]	Small
	CG	5.64 ± 0.82	5.73 ± 0.86	-0.14 [-0.58, 0.31]	Trivial
	ES [95% CI]	0.34 [-0.28, 0.95]	0.54 [-0.10, 1.16]		
	Inference	Small	Moderate		
SL_{DL} (N)	EG	0.80 ± 0.10	0.78 ± 0.12	0.23 [-0.20, 0.65]	Small
	CG	0.80 ± 0.09	0.83 ± 0.09	-0.32 [-0.76, 0.14]	Small
	ES [95% CI]	-0.02 [-0.63, 0.58]	-0.50 [-1.12, 1.13]		
	Inference	Trivial	Moderate		
SL_{NDL} (N)	EG	0.82 ± 0.12	0.81 ± 0.13	0.10 [-0.32, 0.52]	Trivial
	CG	0.82 ± 0.11	0.85 ± 0.12	-0.37 [-0.81, -0.09]	Small
	ES [95% CI]	0.05 [-0.56, 0.65]	-0.35 [-0.96, 0.27]		
	Inference	Trivial	Small		
HF_{DL} (N)	EG	156 ± 22	156 ± 17	0.004 [-0.41, 0.42]	Trivial
	CG	147 ± 16	153 ± 12*	-0.48 [-0.94, -0.01]	Small
	ES [95% CI]	0.48 [-0.15, 1.09]	0.18 [-0.44, 0.78]		
	Inference	Small	Trivial		
HF_{NDL} (N)	EG	147 ± 13	157 ± 16	-0.40 [-0.83, 0.04]	Small
	CG	145 ± 11	146 ± 13¥¥	0.14 [-0.30, 0.58]	Trivial
	ES [95% CI]	0.15 [-0.46, 0.76]	0.78 [0.12, 1.42]		
	Inference	Trivial	Moderate		
VF_{DL} (N)	EG	755 ± 200	805 ± 174	-0.23 [-0.65, 0.20]	Small
	CG	801 ± 119	768 ± 157*	0.48 [0.01, 0.94]	Small
	ES [95% CI]	-0.28 [-0.88, 0.34]	0.22 [-0.39, 0.83]		
	Inference	Small	Small		
VF_{NDL} (N)	EG	805 ± 180	734 ± 227	0.34 [-0.09, 0.77]	Small
	CG	753 ± 155	779 ± 142	-0.40 [-0.85, 0.06]	Small
	ES [95% CI]	0.31 [-0.31, 0.92]	-0.24 [-0.84, 0.38]		
	Inference	Small	Small		
P_{DL} (W)	EG	713 ± 187	720 ± 169	-0.06 [0.47, 0.36]	Trivial
	CG	615 ± 121	678 ± 97***	-0.84 [-1.35, -0.32]	Large
	ES [95% CI]	0.62 [-0.03, 1.24]	0.30 [-0.32, 0.91]		
	Inference	Moderate	Small		
P_{NDL} (W)	EG	678 ± 127	745 ± 173*	-0.56 [-1.00, -0.10]	Moderate
	CG	629 ± 110	679 ± 131	-0.44 [-0.89, 0.03]	Small
	ES [95% CI]	0.41 [-0.21, 1.02]	0.42 [-0.20, 1.04]		
	Inference	Small	Small		

Data are Mean ± SD. EG: Experimental group; CG: Control group; ES: Effect size; 95% CI: 95% Confidence interval; SF_{NDL}: Non-dominant leg stride frequency; SF_{DL}: Dominant leg stride frequency; SL_{NDL}: Non-dominant leg stride length; SL_{DL}: Dominant leg stride length; HF_{NDL}: Non-dominant leg horizontal force; HF_{DL}: Dominant leg horizontal force; VF_{NDL}: Non-dominant leg vertical force; VF_{DL}: Dominant leg vertical force; P_{NDL}: Non-dominant leg power; P_{DL}: Dominant leg power; *: p<0.05, within groups; ¥: p<0.05, between groups; ¥¥: p<0.01, between groups.

isoinertial bilateral squat or unilateral lunges applied to athletes. Training protocols were 7 weeks, ones a week, 4 sets of 8 reps of isoinertial bilateral squat and unilateral lunges Both protocols significantly increased in CMJ and 20m sprint. Nunez et al. [31] studied isoinertial squat and lunges for 6 weeks, 2 times a-week, 4 sets of 7 reps. They provided statistically significant improvement in lower body muscle volume, strength, CMJ, 90° change of direction. They also stated that isoinertial lunges improved 90° change of direction time and deceleration percentage of both DL and NDL. Isoinertial squats improved only the 90° change of direction time and deceleration percentage of DL. In addition, Kale et al. [32] explained that isoinertial half squats performed 4RM can support sprints by tolerating SL imbalance between DL and NDL.

Conclusions

The limited training time for coaches and athletes provides research opportunities on efficient training programs and methods. The study results showed acute effects of isoinertial lunges on SF and SF$_{DL}$ parameters. In future studies, it would be beneficial to focus on DL neuromuscular activation for optimal training in repetitive isoinertial lunges.

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Conflict of interest

The authors declare no conflicts of interest.

References

1. Aagaard P, Andersen JL, Dyhre-Poulsen P, Leffers A, Wagner A, Magnusson SP, et al. A mechanism for increased contractile strength of human pennate muscle in response to strength training: changes in muscle architecture. *The Journal of Physiology*, 2001;534(2): 613–623. https://doi.org/10.1111/j.1469-7793.2001.t01-1-00613.x

2. Aboodarda SJ, Page PA, Behm DG. Muscle activation comparisons between elastic and isoinertial resistance: A meta-analysis. *Clin Biomech,* 2016;39:52–61. https://doi.org/10.1016/j.clinbiomech.2016.09.008

3. Hollander DB, Kraemer RR, Kilpatrick MW, Ramadan ZG, Reeves GV, Francois M, et al. Maximal eccentric and concentric strength discrepancies between young men and women for dynamic resistance exercise. *J. Strength Cond. Res.* 2007;21:34–40. https://doi.org/10.1519/R-18725.1

4. Jidovtseff B, Croisier JL, Scimar N, Demoulin C, Maquet D, Crielaard JM. The Ability of Isoinertial Assessmentto Monitor Spesific Training Effects. *J Sports Med Phys Fitness,* 2008;48(1):55–64.

5. Vazquez-Guerreo J, Moras G. Changes in muscular architecture and execution velocity during squats performed using the versapulley under stable and unstable conditions in junior elite basketball players. *Cuader- nos de Psicología del Deporte,* 2015;15(3):243–252. https://doi.org/10.4321/S1578-84232015000300029

6. Norrbrand L, Pozzo M, Tesch PA. Flywheel resistance training calls for greater eccentric muscle activation than weight training. *Eur J Appl Physiol,* 2010;110(5):997–1005. https://doi.org/10.1007/s00421-010-1575-7

7. Kellett M, Patroni P, Calvetti M, Susta D. Enhanced power after a 4-week submaximal isoinertial training: a pilot study. Proceedings of the 2014 NSCA National Strength and Conditioning Association International Conference; Murcia, Spain: *CCD,* 2014;10(9):S188.

8. Beato M, De Keijzer KL, Fleming A, Coates A, La Spina O, Coratella G, et al. Post flywheel squat vs. flywheel deadlift potentiation of lower limb isokinetic peak torques in male athletes. *Sports Biomechanics*, 2023;22(11): 1514–1527. https://doi.org/10.1080/14763141.2020.1810750

9. Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sports,* 2003;13(4):244–250. https://doi.org/10.1034/j.1600-0838.2003.00312.x

10. Loturco I, Pereira, LA, Kobal R, Maldonado T, Piazzi AF, Bottino A, et al. Improving Sprint Performance in Soccer: Effectiveness of jump squat and Olympic push press exercises. *PLoS ONE,* 2016;11(4):1–12. https://doi.org/10.1371/journal.pone.0153958

11. Cormie P, McGuigan MR, Newton RU. Developing maximal neuromuscular power. Part 2. Training considerations for improving maximal power production. *Sports Med,* 2011;41:125–146. https://doi.org/10.2165/11538500-000000000-00000

12. Samozino P, Rejc E, Di Prampero PE, Belli A, Morin JB. Optimal force–velocity profile in ballistic movements—*Altius. Med Sci Sports Exerc,* 2012;*44(2):313–322.* https://doi.org/10.1249/MSS.0b013e31822d757a

13. Beato M, Bigby AE, De Keijzer KL, Nakamura FY, Coratella G, McErlain-Naylor SA. Post-activation potentiation effect of eccentric overload and traditional weightlifting exercise on jumping and sprinting performance in male athletes. *PloS One,* 2019b;14(9):e0222466. https://doi.org/10.1371/journal.pone.0222466

14. Fiorilli G, Mariano I, Iuliano E, Giombini A, Ciccarelli A, Buonsenso A, et al. Isoinertial eccentric-overload training in young soccer players: Effects on strength, sprint, change of direction, agility and soccer shooting precision. *J Sports Sci Med,* 2020;19(1):213.

15. Norrbrand L, Fluckey JD, Pozzo M, Tesch PA.

Resistance training using eccentric overload induces early adaptations in skeletal muscle size. *European Journal of Applied Physiology*, 2007;102(3): 271–281. https://doi.org/10.1007/s00421-007-0583-8

16. Romero-Rodriguez D, Gual G, Tesch PA. Efficacy of an inertial resistance training paradigm in the treatment of patellar tendinopathy in athletes: a case-series study. *Phys Ther Sport,* 2011;12(1):43–48. https://doi.org/10.1016/j.ptsp.2010.10.003

17. Sanudo B, González-Navarrete Á, Álvarez-Barbosa F, De Hoyo M, Del Pozo J, Rogers ME. Effect of flywheel resistance training on balance performance in older adults. A randomized controlled trial. *J Sports Sci Med,* 2019;18(2):344.

18. De Hoyo M, Pozzo M, Sanudo B, Carrasco L, Gonzalo-Skok O, Dominguez-Cobo S, et al.   s Effects of a 10-week in-season eccentric-overload training program on muscle-injury prevention and performance in junior elite soccer players. *Int J Sports Physiol Perform,* 2015;10(1):46–52. https://doi.org/10.1123/ijspp.2013-0547

19. Greenwood J, Morrissey MC, Rutherford OM, Narici MV. Comparison of conventional resistance training and the fly-wheel ergometer for training the quadriceps muscle group in patients with unilateral knee injury. *Eur J Appl Physiol,* 2007;101(6):697–703. https://doi.org/10.1007/s00421-007-0548-y

20. Kacoglu C, Kale M. Acute effects of lower body electromyostimulation application with two different frequencies on isokinetic strength and jumping performance. *JPES*, 2016;16(1):38–45. https://doi.org/10.7752/jpes.2016.01007

21. Lohman TG, Roche AF, Martorel R. *Anthropometric Standartization Manuel,* Champaign, IL: Human Kinetics; 1988.

22. Kale M, Asci A, Bayrak C, Acikada C. Relationships among jumping performances and sprint parameters during maximum speed phase in sprinters. *J Strength Cond Res*, 2009;23(8):2272–2279. https://doi.org/10.1519/JSC.0b013e3181b3e182

23. Tümer Elektronik Ltd. *ESC 2XXX Series Data Acquisition* [Computer software]. Turkey: Ankara; 2004.

24. Bosco C, Luhtanen P, Komi PV. A simple method for measurement of mechanical power in jumping. *Eur J Appl Physiol*, 1983;50:273–282. https://doi.org/10.1007/BF00422166

25. Wassertheil S, Cohen J. Statistical Power Analysis for the Behavioral Sciences. *Biometrics*, 1970;26(3): 588. https://doi.org/10.2307/2529115

26. Jakobsen MD, Sundstrup E, Andersen CH, Persson R, Zebis MK, Andersen LL. Effectiveness of hamstring knee rehabilitation exercise performed in training machine vs. elastic resistance: electromyography evaluation study. *Am J Phys Med Rehabil,* 2014;93(4):320–327. https://doi.org/10.1097/PHM.0000000000000043

27. Timon R, Allemano S, Camacho-Cardeñosa M, Camacho-Cardeñosa A, Martinez-Guardado I, Olcina G. Post-activation potentiation on squat jump following two different protocols: traditional vs. inertial flywheel. *J Hum Kinet,* 2019;69:271–281.

28. Beato M, Madruga-Parera M, Piqueras-Sanchiz F, Moreno-Pérez V, Romero Rodriguez D. Acute effect of eccentric overload exercises on change of direction performance and lower-limb muscle contractile function. *J Strength Cond Res,* 2019;35(12):3327–3333. https://doi.org/10.1519/JSC.0000000000003359

29. Beato M, De Keijzer KL, Leskauskas Z, Allen WJ, Iacono AD, McErlain-Naylor SA. Effect of postactivation potentiation after medium vs. high inertia eccentric overload exercise on standing long jump, countermovement jump, and change of direction performance. *J Strength Cond Res,* 2021;35(9):2616–2621. https://doi.org/10.1519/JSC.0000000000003214

30. Sabido R, Hernández-Davó JL, Botella J, Navarro A, Tous-Fajardo J. Effects of adding a weekly eccentric-overload training session on strength and athletic performance in team-handball players. *Eur J Sport Sci,* 2017;17(5):530–538. https://doi.org/10.1080/17461391.2017.1282046

31. Nunez FJ, Santalla A, Carrasquila I, Asian JA, Reina JI, Suarez-Arrones LJ. The effects of unilateral and bilateral eccentric overload training on hypertrophy, muscle power and COD performance, and its determinants in team sport players. *PLoS One,* 2018;18:e0193841. https://doi.org/10.1371/journal.pone.0193841

32. Kale M, Özmusul A, Heper E. Acute effects of isoinertial resistance application on sprint, vertical and horizontal jump performance. *Pedagogics, Psychology, Medical-Biological Problems of Physical Training and Sports.* 2019;23(2):76–82. https://doi.org/https://doi.org/10.15561/18189172.2019.0204

Information about the authors:

Mehmet Kale; (Corresponding author); https://orcid.org/0000-0002-1960-2234; mkale@eskisehir.edu.tr; Department of Coach Training in Sport, Faculty of Sport Sciences, Eskişehir Technical University; Eskişehir, Turkey.

Emre Çelik; https://orcid.org/0009-0002-6479-7234; celikemmre@outlook.com; Department of Coach Training in Sport, Faculty of Sport Sciences, Eskişehir Technical University; Eskişehir, Turkey.

Ezgi Ayaz; https://orcid.org/0000-0002-5696-201X; ezgi.ayaz@nisantasi.edu.tr; School of Physical Education and Sports, Department of Coaching Education, İstanbul Nişantaşı University; İstanbul, Turkey.

Esen Kızıldağ Kale; https://orcid.org/0000-0002-4927-8682; ekizildag@nisantasi.edu.tr; School of Physical Education and Sports, Department of Coaching Education, İstanbul Nişantaşı University; İstanbul, Turkey.