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Original research

Isokinetic resistance training combined with eccentric overload improves athletic performance and induces muscle hypertrophy in young ice hockey players

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ABSTRACT

Objectives: To determine the combined effects of slow isokinetic resistance training and eccentric overload and compare it to traditional resistance training on strength, power, body composition and muscle hypertrophy in young ice hockey players.
Design: Experimental, randomized trial.
Methods: Twenty-two resistance-trained ice hockey players (18 ± 1 year) were assigned to either isokinetic resistance training and eccentric overload (ISO/ECC; n = 11) or traditional resistance training (TRAD; n = 11). Participants underwent supervised progressive resistance training for 8 weeks (2–3 sessions/week) involving lower body multiple-joint exercises (heavy squats and explosive jump squats). The ISO/ECC group performed their training using a computerized robotic engine system (1080 Quantum synchro, Sweden), whereas the TRAD group performed the same resistance exercises with isotonic loading. Before and after the intervention, participants were evaluated in 1RM back squat, loaded jump squats, sprint- and jump performance, body composition and muscle thickness using ultrasound measurement.
Results: Similar moderate increases in 1RM back squat and power output in the jump squats were found in both the ISO/ECC and TRAD groups (11–17%, P < 0.01), whereas only the ISO/ECC group showed improvements in drop jump performance (9.8%, P = 0.01). Moreover, similar trivial changes in body composition were observed in both groups, while only the ISO/ECC training group increased muscle thickness in the vastus intermedius (P = 0.01) and rectus femoris muscles (P = 0.03).
Conclusions: Both modalities effectively increased maximal strength and power output, whereas isokinetic resistance training, combined with eccentric overload, improved drop jump performance and induced greater muscle hypertrophy than traditional training in young ice hockey players.

Practical implications

- Slow isokinetic resistance training combined with eccentric overload is an effective strategy to increase muscle mass in young ice hockey players.
- Ice hockey players could apply isokinetic resistance training and eccentric overload to their weekly regimen to improve drop jump performance.
- To improve maximal strength and power output in the jump squats, both traditional resistance training and isokinetic training combined with eccentric overload are beneficial.

1. Introduction

Resistance training (RT) is widely practiced by individuals pursuing health benefits or improved athletic performance. Traditionally, RT is performed using free-weights or in exercise machines, although other training strategies can be applied to develop muscular capacities. Among them, isokinetic RT, with the advantage of providing maximal effort throughout the range of motion,[1] is currently considered for athletic purposes due to its unique features. Earlier reports found that single-joint

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isokinetic training improved strength, muscle size and athletic performance.[2–4] Nevertheless, there is conflicting evidence whether isokinetic training elicits additional benefits compared to traditional training (e.g. isotonic resistance).[5,6] To date, two studies have investigated the effects of multiple-joint isokinetic training, reporting increases in maximal strength, strength endurance and drop jump performance.[7,8] However, as this type of training was evaluated in relation to a non-exercising group, the question whether multiple-joint isokinetic training is superior to common athletic training remains unanswered.

Lengthening muscle actions, referred to as eccentric contractions, differ from concentric contractions in terms of neurological activation and the underpinning mechanisms contributing to force production.[9] Consequently, greater forces can be generated eccentrically in dynamic exercises[10] and more robust hypertrophic responses have been identified following eccentric muscle actions compared to its concentric counterpart.[11,12] Despite this, the load used during RT is often determined by the maximum amount of weight lifted in the concentric phase (% of 1RM), thereby causing a lower relative load in the eccentric phase. This limitation has been addressed in studies applying a model of eccentric overload, showing greater hypertrophy and strength gains compared to traditional loading.[13,14] In athletes already accustomed to RT, eccentric training increased strength and induced changes in molecular markers associated with a faster muscle phenotype.[15,16] Its effectiveness has also been demonstrated during power training, where the addition of eccentric overload resulted in greater jump heights and improved power characteristics.[17]

Given the above discussion, the literature indicates that isokinetic training and eccentric overload independently induces favorable muscular adaptations, however, data regarding the combined effects of these training modalities is scarce. Therefore, in the present study, the aim was to determine the effect of multiple-joint isokinetic RT, combined with eccentric overload, and compare it to traditional RT in young ice hockey players. We hypothesized that multiple-joint isokinetic RT and eccentric overload would elicit greater increases in strength, power and muscle hypertrophy compared to traditional RT.

2. Methods

Twenty-four healthy, male ice hockey players from Swedish and Norwegian junior hockey leagues volunteered to participate in this study (two dropped out due to personal issues prior to the start). Participants were considered resistance-trained based on their performance in the back squat exercise (1RM-to-body mass ratio 1.47 ± 0.19) and their weight training experience (≥ 2 sessions/week for 2 years), although none had previous experience of isokinetic devices or eccentric overload. Before the study commenced, participants were informed about the experimental procedures and later signed an informed consent. Parental permission was obtained from participants <18 years. Procedures were in accordance with the Declaration of Helsinki and approved by the regional ethics committee (Lund, Dnr, 2013/10).

Following familiarization sessions and pre-tests, participants were matched based on their initial strength level, then randomly assigned to either the isokinetic training and eccentric overload group (ISO/ECC; age 18.4 ± 0.7 years, height 182.0 ± 5.2 cm, weight 82.4 ± 9.2 kg, n = 11) or to the traditional training group (TRAD; age 17.6 ± 0.9 years, height 182.7 ± 6.5 cm, weight 80.2 ± 7.9 kg, n = 11). The two groups had similar 1RM-to-body mass ratios when the study commenced (ISO/ECC; 1.46 ± 0.22, TRAD; 1.49 ± 0.16), ($P > 0.05$).

The 8-week intervention comprised supervised progressive RT 2-3 times/week on non-consecutive days (21 sessions total). ISO/ECC trained using a computerized robotic engine system (1080 Quantum Synchro; 1080 Motion AB, Sweden) attached to custom-made Smith machine (Panthera Gym Equipment, Sweden). In contrast to common isokinetic dynamometers, this system allows for multiple-joint training and independent load alterations during dynamic contractions. Therefore, ISO/ECC completed a program that combined heavy isokinetic strength exercises with eccentric overload training, applied only to power exercises. This was selected to improve jumping and speed performances, which most likely is achieved through a combination of heavy strength and power training.[18] The same exercises were implemented in the TRAD group, but instead performed with isotonic loading using a Smith machine. Table 1 shows an overview of the training programs, previously described elsewhere.[19]

Briefly, the programs included two exercises; heavy squats and explosive jump squats, both conducted unilaterally and bilaterally. ISO/ECC performed heavy squats using an isokinetic concentric phase, progressively decreasing the velocity over the course of the intervention, as a way of increasing load by increased force ($0.4\,\mathrm{m\,s^{-1}}$ to $0.2\,\mathrm{m\,s^{-1}}$). As repetitions were executed with maximal effort, lower isokinetic velocities meant higher forces. Meanwhile, TRAD performed isotonic heavy squats with increased loads throughout the intervention. Both groups performed the eccentric phase in a slow, controlled manner (isotonic). For jump squats, the groups executed the concentric- and eccentric phase explosively, where TRAD used equal loading in both phases and ISO/ECC used a loading ratio equivalent to 20–40% of 1RM (i.e. eccentric overload) (Table 1). The load ratios applied during the intervention (60–20% of 1RM for bilateral jumps and 20–10% of 1RM for unilateral jumps) were based on previous experience with power training using the 1080 Quantum. Three minute rest periods were applied to sets/exercises.

To log training volume in ISO/ECC, the mean concentric force (N) generated for each repetition was recorded throughout. Due to the high forces achieved during this type of training, ISO/ECC had to perform fewer total sets (Table 1). At the end of the intervention, total concentric training volume (sets × repetitions × concentric load) was similar across groups. Additionally, participants performed one session/week of team training. Based on 24-h dietary recall interviews, no changes in caloric intake or macronutrient distribution were found throughout.

Maximal strength (1RM) was determined in the back squat exercise, executed to a parallel depth (hip crease lower than top of the patellae) using a Smith machine (Eleiko Sport, Sweden). After warm-up, participants followed a standardized 1RM-protocol where the load was progressively increased until failure to complete the lift. Power output was determined during loaded jump squats (20–40–60–80 kg performed in an increasing manner), with instructions to jump as high as possible without depth requirements. For each attempt, average concentric power (W) was recorded with a linear encoder (MuscleLab, Ergotest Technology, Norway) and the average of all loads was used for further analysis.

Thirty-meter sprint performance was evaluated using single photocells and the best time of three trials was used. Jump performance was determined in counter movement jumps (CMJ) and drop jumps from 40 cm (DJ). For drop jumps, participants were instructed to takeoff as quickly as possible after landing. All jumps were performed to a self-selected depth with hands placed on the hips. Jump heights were determined using an infrared jump mat (IVARsystem, LN Sportkonsult, Sweden).

Body composition was estimated with an eight-polar bioelectrical impedance analysis (Inbody 720, Biospace, Korea) and calculated according to the manufacturer's algorithm. Participants refrained from physical activity within 24 h of the test and were scanned after an overnight fast (between 7–10 a.m.), wearing light clothing.

Table 1
Overview of the two training programs; traditional or isokinetic with eccentric overload (ISO/ECC) resistance training.

ISO/ECC resistance training		Traditional resistance training	
Sessions 1–6		Sessions 1–6	
Warm-up (increasing effort during the set)	1 × 10	Warm-up (40%, 60% and 80% of training load)	3 × 5
Squat 0.4 m s^{-1}	2 × 5	Squat	3 × 5RM
Unilateral squat 0.4 m s^{-1}	2 × 2 × 5	Unilateral squat	2 × 2 × 5RM
Jump squat (60% of 1RM + 120% ecc.)	2 × 5	Jump squat (60% of 1RM)	2 × 5
Unilateral jump squat (20% of 1RM + 120% ecc.)	2 × 2 × 5	Unilateral jump squat (20% of 1RM)	2 × 2 × 5
Sessions 7, 9, 10, 12, 13 and 15		Sessions 7, 9, 10, 12, 13 and 15	
Warm-up (increasing effort during the set)	1 × 10	Warm-up (40%, 60% and 80% of training load)	3 × 5
Jump squat (40% of 1RM + 130% ecc.)	3 × 5	Jump squat (40% of 1RM)	3 × 5
Unilateral jump squat (15% of 1RM + 130% ecc.)	2 × 2 × 5	Unilateral jump squat (15% of 1RM)	2 × 2 × 5
Squat 0.3 m s^{-1}	3 × 5	Squat	5 × 4RM
Unilateral squat 0.3 m s^{-1}	2 × 2 × 5	Unilateral squat	2 × 2 × 5
Sessions 8, 11 and 14 (power sessions)		Sessions 8, 11 and 14 (power sessions)	
Warm-up (increasing effort during the set)	1 × 10	Warm-up (40%, 60% and 80% of training load)	3 × 5
Jump squat (40% of 1RM + 130% ecc.)	3 × 5	Jump squat (40% of 1RM)	3 × 5
Unilateral jump squat (15% of 1RM + 130% ecc.)	2 × 3 × 5	Unilateral jump squat (15% of 1RM)	2 × 3 × 5RM
Sessions 16, 18 and 19		Sessions 16, 18 and 19	
Warm-up (increasing effort during the set)	1 × 10	Warm-up (40%, 60% and 80% of training load)	3 × 5
Jump squat (20% of 1RM + 140% ecc.)	4 × 5	Jump squat (20% of 1RM)	4 × 5
Unilateral jump squat (10% of 1RM + 140% ecc.)	2 × 2 × 5	Unilateral jump squat (10% of 1RM)	2 × 2 × 5
Squat 0.2 m s^{-1}	4 × 5	Squat	6 × 3RM
Unilateral squat 0.2 m s^{-1}	2 × 2 × 5	Unilateral squat	2 × 3 × 5RM
Session 17 (power session)		Session 17 (power session)	
Warm-up (increasing effort during the set)	1 × 10	Warm-up (40%, 60% and 80% of training load)	3 × 5
Jump squat (20% of 1RM + 140% ecc.)	2 × 5	Jump squat (20% of 1RM)	3 × 5
Unilateral jump squat (10% of 1RM + 140% ecc.)	2 × 3x5	Unilateral jump squat (10% of 1RM)	2 × 3 × 5
Session 20 (power session)		Session 20 (power session)	
Warm-up (increasing effort during the set)	1 × 10	Warm-up (40%, 60% and 80% of training load)	3 × 5
Jump squat (20% of 1RM + 140% ecc.)	2 × 5	Jump squat (20% of 1RM)	3 × 5
Unilateral jump squat (10% of 1RM + 140% ecc.)	2 × 3 × 5	Unilateral jump squat (10% of 1RM)	2 × 2 × 5
Session 21		Session 21	
Warm-up (increasing effort during the set)	1 × 10	Warm-up (40%, 60% and 80% of training load)	3 × 5
Jump squat (20% of 1RM + 140% ecc.)	2 × 5	Jump squat (20% of 1RM)	2 × 5
Unilateral jump squat (10% of 1RM + 140% ecc.)	2 × 1 × 5	Unilateral jump squat (10% of 1RM)	2 × 2 × 5
Squat 0.2 m s^{-1}	2 × 5	Squat	3 × 3RM
Unilateral squat 0.2 m s^{-1}	2 × 1 × 5	Unilateral squat	2 × 2 × 5

For the ISO/ECC training group, the velocity during the concentric phase of the squat is shown in meters per second. The overloaded eccentric phase for the jump squats represents a percentage of the given concentric load (50 kg concentric load + 120% eccentric load = 60 kg eccentric load). For both groups, a percentage of the 1RM back squat exercise was used to determine the load for jump squats (bilateral and unilateral). RM loads were applied in the traditional resistance training group and if sets were taken to failure, subsequent sets were performed with reduced loads so that the participant could complete the designated number of repetitions.

Muscle thickness of *vastus medialis* (VM), *vastus lateralis* (VL), *vastus intermedius* (VI) and *rectus femoris* (RF) was assessed using an ultrasound apparatus (LogicScan 128, Telemed, Lithuania) with a 60-mm probe. Four axial-plane images were taken along the horizontal line at 60% of femur length, measured from trochanter major and the lateral/medial epicondyle. The sites for each image were then transferred to transparent sheets with individual landmarks (birthmarks and scars) to ensure accurate position of post-measurements. Muscle thickness was defined as the vertical distance between the superficial fascial point to the deep fascial line or to the femur.[20] Images were saved in Echowave 2 (Telemed, Lithuania) and muscle thickness was thereafter determined by manually tracing the distance in Image J (National Institutes of Health, USA). Three measurements were taken at each site with the average used for subsequent analysis. Pre- and post- measurements were obtained 48–72 h before the study commenced and after the completion of the last training session. The same investigator performed the analyses and test-retest correlation for muscle thickness was 0.997 (intra-rater) and 0.962 (inter-rater).

Data are presented as means ± standard deviation (SD). Following test for normality, dependent variables were first analyzed in IBM SPSS (version 24.0, USA) using a two-way mixed ANOVA with factors for group (TRAD and ISO/ECC) and time (pre and post intervention). If significant main effects or interactions were found, a paired t-test was used to evaluate within-group differences. Statistical significance was set at $P < 0.05$. To further quantify the magnitude of changes, magnitude based inference[21] was used to determine the probability that a change in testing score was beneficial, harmful or trivial, and qualitative descriptors were assigned to the positive percentile scores as follows: 0.5%–5%, very unlikely; 5%–25%, unlikely; 25%–75%, possible; 75%–95% likely; 95%–99.49% very likely; >99.5% almost certainly.[22] Furthermore, Hedges'g effect sizes (ES) were calculated within groups where $ES = (M_{post} - M_{pre})/(SD_{pre})$, and interpreted according to Cohen's modified scale[23]; <0.2; trivial, 0.2–0.6; small, 0.6–1.2; moderate, >1.2; large.

3. Results

Participant characteristics, measures of performance, body composition and muscle thickness were similar across the groups at baseline, except for age ($P = 0.04$).

For performance measures, both ISO/ECC and TRAD improved 1RM and power output in the jump squats (time main effects $P < 0.01$) to a similar moderate effect (ES 0.77–0.90) following the training intervention (Table 2). Moreover, improvements in DJ were found with possible beneficial effects for ISO/ECC (9.8%, ES 0.47) over TRAD (−0.1%, ES 0.01). In contrast, no improvements were seen

Table 2
Performance and body composition measures pre and post training intervention in the TRAD and the ISO/ECC group.

	TRAD training					ISO/ECC training					
	Pre Mean ± SD	Post Mean ± SD	% Change	ES	p Values	Pre Mean ± SD	Post Mean ± SD	% Change	ES	p Values	MBI
Performance											
1RM (kg)*	119.5 ± 17.2	133.3 ± 18.5	11.6	0.80	<0.01	120.0 ± 19.7	135.1 ± 17.3	12.6	0.77	<0.01	Unclear
Jump squats (W)*	1715.1 ± 334.1	2015.1 ± 230.7	17.4	0.90	<0.01	1790.7 ± 285.5	2014.7 ± 251.5	12.5	0.78	<0.01	Very unlikely
30 m sprint (s)	4.30 ± 0.22	4.25 ± 0.17	−1.3	0.25	0.09	4.34 ± 0.18	4.31 ± 0.17	0.0	0.16	0.26	Very unlikely
CMJ (cm)	36.5 ± 3.4	38.5 ± 4.2	5.6	0.59	0.15	39.0 ± 8.0	39.2 ± 7.4	0.5	0.02	0.82	Unlikely
DJ (cm)	37.5 ± 4.8	37.4 ± 7.0	−0.1	0.01	0.98	38.3 ± 7.8	42.0 ± 9.1	9.8	0.47	<0.01	Possible
Body composition											
Body mass (kg)	80.2 ± 7.9	80.8 ± 7.4	0.7	0.08	0.36	82.4 ± 9.2	84.1 ± 8.3	2.1	0.18	0.06	Possible
LBM (kg)*	67.5 ± 8.2	68.0 ± 7.9	1.5	0.12	0.30	67.0 ± 5.4	68.0 ± 4.8	1.6	0.19	0.04	Unlikely
LBM legs (kg)*	21.1 ± 2.5	21.4 ± 2.5	1.2	0.11	0.04	21.4 ± 2.6	21.5 ± 2.7	0.8	0.07	0.37	Very unlikely
LBM legs + torso (kg)	51.0 ± 5.8	51.3 ± 6.0	0.5	0.04	0.41	51.6 ± 5.0	52.2 ± 4.9	1.2	0.12	0.09	Unlikely
Fat mass (kg)	12.3 ± 3.6	12.1 ± 3.8	−0.4	0.01	0.54	14.1 ± 5.0	14.5 ± 4.2	3.4	0.09	0.46	Possible
Muscle thickness											
V. medialis (mm)*	38.3 ± 5.3	40.7 ± 4.8	5.0	0.36	<0.01	39.5 ± 2.9	41.5 ± 3.2	5.1	0.68	<0.01	Unlikely
V. lateralis (mm)*	23.9 ± 3.1	24.7 ± 3.8	3.3	0.25	0.25	25.0 ± 5.0	26.0 ± 5.5	4.2	0.21	0.04	Unlikely
V. intermedius (mm)†	16.2 ± 3.6	16.6 ± 4.2	2.6	0.12	0.45	19.1 ± 5.0	21.3 ± 5.6	11.4	0.43	<0.01	Likely
Rectus femoris (mm)†	15.2 ± 2.8	15.1 ± 3.5	−2.6	0.03	0.87	16.1 ± 4.3	18.5 ± 6.7	14.8	0.55	0.03	Likely

TRAD: traditional resistance training, ISO/ECC: isokinetic resistance training and eccentric overload. In both groups n varied between 10–11 for some variables due to unexpected loss of data during measurements. CMJ: counter movement jump, DJ: drop jump from 40 cm height, LBM: lean body mass. Results are as follows; significant 2 × 2 ANOVA indicated as * for main effect or † for interaction at P < 0.05. P-values shown are paired t-tests pre-post intervention. ES: effect size within groups from pre- to post-intervention, MBI: magnitude based inference, intervention beneficial in favor of ISO/ECC.

in 30 m sprint and CMJ for any of the groups, however, for CMJ, the TRAD group had a small (5.6%, ES 0.59) but unlikely improvement after the intervention, which was not seen in the ISO/ECC group (0.5%, ES 0.02) (Table 2).

For body composition measures, increases were observed after training for both groups (time main effect $P < 0.05$) where ISO/ECC increased LBM (1.6%) and TRAD increased LBM legs (1.2%) however, the effect sizes were all trivial (Table 2).

ISO/ECC training resulted in a likely beneficial increase in muscle thickness in both VI and RF (group × time interactions $P < 0.05$) compared to TRAD training (Fig. 1). ISO/ECC had an increase in VI (11.4%, ES 0.43) and RF (14.8%, ES 0.55) muscle thickness, whereas the TRAD group muscle thickness remained unchanged with trivial ES for both VI and RF (Table 2). Furthermore, both groups increased muscle thickness of VM (time main effect $P = 0.01$), with a moderate training effect in the ISO/ECC group (5.1%, ES 0.68) and a small effect in the TRAD group (5.0%, ES 0.36). Lastly, muscle thickness of VL increased to a similar degree (3–4%, time main effect $P = 0.03$) with small training effects in both groups (ES 0.21–0.25).

4. Discussion

The major finding presented herein was that the combination of isokinetic RT and eccentric overload induced greater muscle hypertrophy compared to traditional RT. The results also show that this type of training improves drop jump performance, whereas gains in maximal strength and power output were similar across training modalities.

The present study found that slow velocity isokinetic RT combined with eccentric overload induced greater gains in quadriceps muscle thickness than traditional RT, which is in accordance with a recent study by Helland et al.[19] In contrast to studies using single-joint dynamometry to investigate the impact of isokinetic training on muscle hypertrophy,[5,6] we incorporated multiple-joint exercises that more directly apply to athletic abilities, such as jumping and sprinting. These data are therefore of great relevance when planning athletic training programs with the intention to improve muscle mass.

Despite implementing a training regimen primarily designed to improve maximal strength and power, ISO/ECC demonstrated a magnitude of muscle growth similar to those described after more hypertrophy-oriented protocols.[5] Because the present study involved resistance-trained participants (2 years of weight lifting experience), this finding was somewhat unexpected. However, our participants had no previous experience with isokinetic training and/or eccentric overload, thus, we cannot exclude the possibility that adaptations were driven partially by the introduction of a novel training stimulus per se. In that respect, it could be argued that the time (48–72 h) between the last training session and muscle thickness measurements may have been insufficient to avoid the confounding effect of muscle swelling, which exist during the first 3 weeks of RT.[24] However, we believe that the effect of swelling on the outcome of the present study was minimal. Firstly, a swelling bias would have affected both training modalities. Additionally, muscle damage and swelling are well documented after unaccustomed (eccentric) exercise, while in this case the measurements were conducted after an 8-week training intervention, lowering the probability of these phenomena.[25] Finally, we included a tapering/reduced exercise volume during the last sessions to avoid exhaustion during the post-tests. Altogether, these findings suggest that ISO/ECC training can be implemented in strength-trained athletes seeking to further accelerate muscle growth. Our results align with studies in already strength-trained athletes, showing greater strength gains and hypertrophy of type IIX muscle fibers

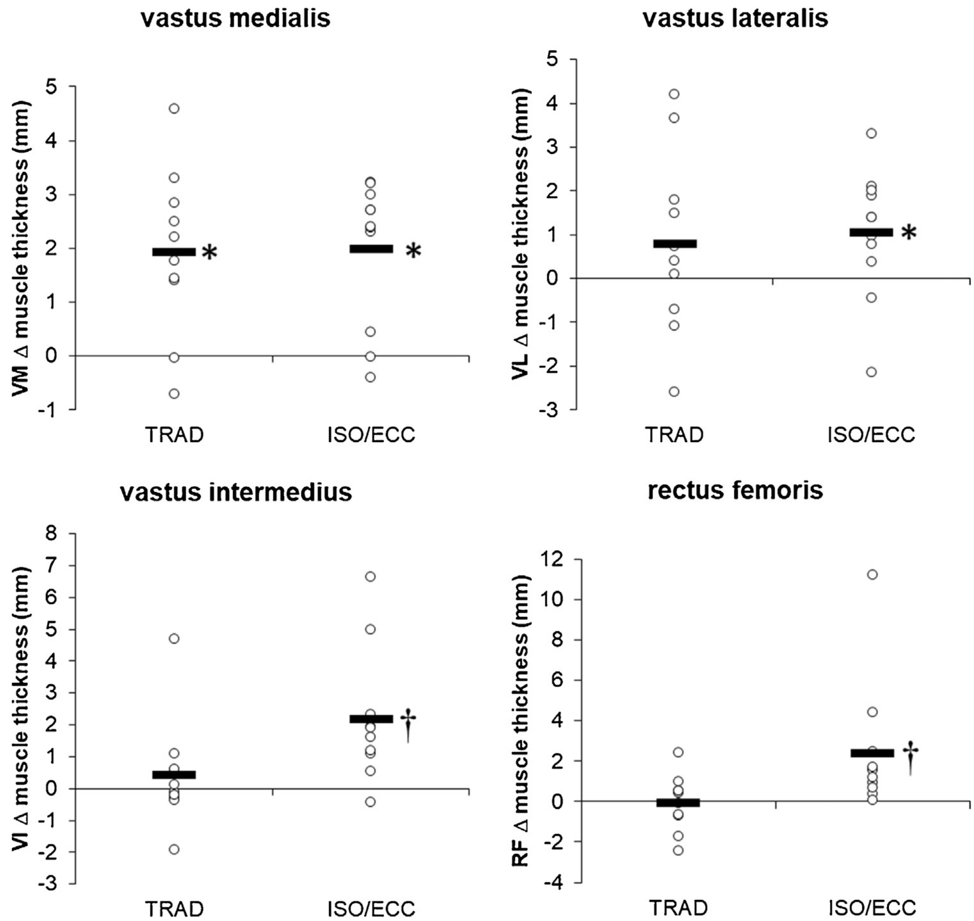

Fig. 1. Unifactorial scatterplots for differences in muscle thickness pre to post training intervention of the four individual muscles of the quadriceps in traditional (TRAD; n = 10) or isokinetic with eccentric overload (ISO/ECC; n = 11) resistance training groups. Open circles show the difference (Δ) in muscle thickness pre to post training for each participant and the black bars show the mean difference for each group. * indicates time main effect, pre to post differences at $P < 0.05$ and † indicates group × time interaction, pre to post differences at $P < 0.05$.

after applying eccentric overload training.[15,16] Nonetheless, further research is required to explore the long-term effects of such demanding protocol in order to avoid overtraining or excessive fatigue.

The greater hypertrophy observed in ISO/ECC can be attributed, at least partly, to the isokinetic repetitions performed at controlled, slow velocities (0.2–0.4 $m\,s^{-1}$). Although the evidence is inconsistent regarding muscle growth,[4,5] slow velocity resistance exercise can effectively stimulate muscle protein synthesis.[26] As these contractions require maximal effort throughout the range of motion, it is likely that the apparent hypertrophy was driven by high forces developed during the isokinetic contractions. Furthermore, the ISO/ECC program also comprised eccentric overload, a stimulus known to elicit greater hypertrophy compared to traditional loading strategies.[13,16] However, unlike previous reports, the eccentric overload was applied only to explosive jump squats, indicating a lesser impact on hypertrophic adaptations.[27] Therefore, we suggest that slow isokinetic contractions, and to some extent eccentric overload, seem to be potent strategies to induce muscle hypertrophy, although, due to the current study design, their relative contribution cannot be determined. Future studies are warranted to separately address the effects of multiple-joint isokinetic training and eccentric overload on muscular adaptations.

Greater improvement in DJ performance was found in ISO/ECC compared to TRAD. This is in line with studies showing that accentuated eccentric load acutely enhances force production in the subsequent concentric phase.[28] Although there is yet no definitive explanation for this occurrence, it is postulated that passive components within the sarcomere allow the muscle to generate additional force after active lengthening.[9] Intriguingly, the current ISO/ECC program appeared efficient for developing concentric power specifically in movements preceded by high eccentric forces, (e.g. DJ), but not for the CMJ, where the eccentric component is lower and utilization of elastic components is low or absent.[29] Such observation likely reflects the specific intensity applied in the eccentric phase, where previous reports showed that high eccentric forces enhanced DJ performance,[7] whereas improvements in CMJ were found with lower eccentric loads.[17] Thus, based on our data, jump performance can be augmented by incorporating eccentric overload training, albeit the load of the eccentric phase must be adjusted to induce load-specific adaptations.

Maximal strength (1RM back squat) increased similarly across groups following the intervention. Thus, neither the isokinetic mode nor the eccentric overload induced a benefit over traditional RT. In contrast to previous studies, applying heavy eccentric overload,[13–15] we used eccentric overload during jumping/power exercise, which probably meant too low forces for efficient transfer to a maximal isotonic test (the 1RM test). Moreover, according to the principle of training specificity, adaptations to RT are highly movement specific,[30] (muscle actions, range of motion, etc.), which favored the TRAD group in an isotonic 1RM test. Indeed, TRAD trained squats in the exact same fashion as the 1RM test was conducted. Considering that ISO/ECC gained more muscle mass in the knee-extensors, the 1RM results probably demonstrate a larger neural adaptation in the TRAD group.

Some limitations require further consideration. In this study, the concentric volume lifted in each group was controlled and equal at completion, whereas the eccentric volume remained uncontrolled. Ideally, this should have been equated to dismiss effects potentially mediated by greater training volumes. Conversely, the additional eccentric load accumulated during power exercises was rather small and an equal volume (concentric plus eccentric work) between groups would have resulted in uneven concentric work (more for TRAD). Secondly, a more comprehensive biomechanical analysis of the CMJ and DJ, including stiffness, contact time and reactive strength index, could have provided more details about the mechanisms behind the improved jump height, and probably explain the differences between changes in jump improvements. Lastly, the loads applied during the augmented eccentric squat jumps were based on concentric 1RM squats. This was a convenient approach, but the individual relative eccentric load may have varied between participants, as we did not assess eccentric 1RM. This potential non-uniform eccentric loading could have caused a bias in the training response and increased the risk of type II error. Despite this limitation, a greater efficacy for ISO/ECC was observed. We suggest that future studies consider both concentric and eccentric strength when applying augmented eccentric strength and power training.

5. Conclusion

Maximal strength and power output increased similarly across training modalities, whereas the combination of slow isokinetic RT and eccentric overload power training led to greater muscle hypertrophy and some improvements in athletic performance. Considering these findings, isokinetic training combined with eccentric overload represents a more optimal short-term strategy to induce muscular adaptations in resistance-trained athletes. However, whether this strategy is feasible during long-term training periods should be addressed in future studies.

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