MOUNTAIN TACTICAL INSTITUTE

MISSION-DIRECT RESEARCH

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MTI WHITE PAPER - TECHNICAL REPORT:

Which is Better for Building Strength, Power and Agility: Squats or Lunges?

Which is Better for Building Strength, Power and Agility: Squats or Lunges?

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1. STUDY SUMMARY

1-1. Purpose

Recently, some coaches have taken a stance against traditional bilateral movements, saying that squat-based training is less safe and less transferable to athletic performance.[1]

The purpose of this study is to test the effects of both squat-based and lunge-based training on high school athletes.

Is one type of training better at improving strength, power or agility?

1-2. Subjects

Ten voluntary members of a high school strength and conditioning program participated in the study (nine male and one female). The subjects had a mean age of 16.5 years (+/-1.1), a mean height of 67.0 inches (+/-2.5), a mean weight of 159.0 pounds (+/-42.1) and 2.7 years (+/- 1.3) of strength training experience.

1-3. Design

Subjects trained 3 times per week for five and a half weeks. Subjects were divided into two groups: Squat-based and Lunge-based. The two groups completed nearly identical training programs. The sole difference was the lower body movements. The squat group trained back squat, front squat and box squats. While the lunge group trained barbell lunges, barbell split squats and rear leg elevated split squats RLESS) with dumbbells. Due to the group sizes and the requirements of the school program, unfortunately no control group was utilized.

1-4. Results & Discussion

Both groups had statistically significant gains in strength (1RM Squat and Lunge) and agility (Pro Agility and T-Agility). One of the most peculiar findings in the study was that the lunge group actually improved more than the squat group on their 1RM squat (22.6% and 7.2%, respectively) and the squat group improved more than the lunge group on their 1RM lunge (22.1% and 13.6%, respectively). Improvements in agility were fairly even between the lunge group and squat group (8.6 and to 5.8% in the Pro Agility, respectively; and 9.9% and 5.5% in the T-Agility, respectively).

Based on our three measures of lower body power (vertical jump, left-leg vertical hop and right-leg vertical hop) neither type of training produced statistically significant improvements. The lunge group did improve slightly more than the squat groups, but none of these differences met the threshold for statistical significance.

1-5. Conclusion and Recommendations

This study found that when it comes to building strength and agility there does not appear to be a significant difference between squatting and lunging.

[1] (12) Boyle, M. *Build better legs, one at a time. Perform Better*. Updated: 2015. http://www.performbetter.com/webapp/wcs/stores/servlet/PBOnePieceView?storeId=10151&catalogId=10751&pagename=372. Accessed: 13 MAR 2016.

It should be noted that, in our study the lunge group did out improved the squat group in every measure except the 1RM lunge. Although none of these between group differences were large enough to be statistically significant they were noticeable and could possibly hint at some unmeasured benefit.

Therefore, if a coach had to pick only one form of training we would recommend unilateral training like lunges. However, our study does show that squatting does have a positive impact on both strength and agility.

2. TABLE OF CONTENTS

3. INTRODUCTION

3-1. Previous Research

Muscle Activation and Hormone Response:
Based on previous research squatting and lunging are actually relatively similar - especially when it comes to muscle activation and endocrine response.

For example, a 2014 study from the the University of Memphis found that primary muscle group activation was very similar during back squats, split squats and rear-leg elevated split squats (RLESS). The study examined seven major muscle groups (gluteus maximus, bicep femurs, semitendinous, rectus femorus, vastus lateralis, vastus medialis, tibias anterior and medial gastrocnemius) and found that muscle activation was similar across all groups. The only except was the bicep femorus, which experienced slightly greater activation during the RLESS. The study also found that vertical displacement was the same during all three exercises; as was peak vertical force.[2]

One possible except to these similarities might be in the hip abductor muscles. Studies by Gottshalk et al. and Neuman et al. have found that the hip abductors are recruited at a slightly higher rate during a single-leg stance exercise like lunging.[3],[4]

Still, another study, from Marquette University, was able to accurately predict lunge and step-up strength (both unilateral exercises) based solely on squatting strength.[5] The fact that these researches were able to accurately model strength between the bilateral and unilateral movements seems to support the idea of them using similar movement patterns, muscle groups and skills.

Lastly, in 2010, a study from the University of Connecticut found that both squatting and lunging produced similar testosterone or insulin responses during training.[6]

Training Adaptations:
Unlike the similarities found in muscle activation and endocrine response, training studies examining the adaptations to squatting and lunging have produced mixed results. Some studies, like one by Delcore et al. have suggested that unilateral plyometric exercises are more effective at improving power.[7] However, other studies like the ones conducted by McGrudy et al. and Speirs et al. have found no different between unilateral and bilateral training.

In 2005 McGrudy et al. found that unilateral and bilateral training had virtually the same effect on untrained, college-aged males and females.[8] Speirs et al.'s 2015 study of academy rugby players also found little difference between squatting and lunging. In the five week study both types of training were ineffective at improving 10m sprint times and produced nearly identical increases in 40m sprint times, Pro Agility drill times, 1RM back squats and 1RM RLESS.[9]

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[2] (11) DeForest, B; Cantrell, G and Schilling, B. Muscle activity in single- vs double-leg squats. *Int J Ex Science*; 7(4): 302-310. 2014.

[3] (7) Gottshalk, F; Kourosh, S and Leveau, B. The functional anatomy of tensor fasciae later and gluteus medium and minibus. *J Anat*; 166: 179-189, 1989.

[4] (8) Neuman, D and Cook, T. Effect of load and carrying position on the electromyographic activity of the gluteus medium muscles during walking. *Phys Ther*; 65: 305-311, 1985.

[5] (1) Ebben, W; Feldman, C; Dayne, A; Mitsche, D; Chmelewksi, L; Alexander, P and Knetgzner, K. Using squat testing to predict training loads for the deadlift, lunges, step-up, and leg extension exercises. *J Strength Cond Res*; 22(6): 1947-1949, 2008.

[6] (9) Migiano, M; Vingren, J; Volek, J; Maresh, C; Fragala, M; Ho, J; Thomas, G; Hatfield, D; Hakkinen, K; Ahtianen, J; Earp, J and Kraemer, W. Endocrine response patterns to acute unilateral and bilateral resistance exercises in men. *J Strength Cond Res*; 24(1): 128-134, 2010.

[7] (3) Declore, G; Mathieu, W; Salazar, W and Hernandez, J. Comparison between one-leg and two-leg plyometric training on vertical jump performance [abstract]. Med Sci Sports Exec; 30 (Suppl): 61, 1998.

[8] (6) McCury, K; Langford, G; Doscher, M; Wiley, L and Mallard, K. The Effects of short-term unilateral and bilateral lower-body resistance training on measures of strength and power. *J Strength Cond Res*; 195(1): 9-15, 2005.

[9] (10) Speirs, D; Bennet, M; Finn, C and Turner, A. Unilateral vs Bilateral squat training for strength, sprints and agility in academy rugby players. *J Strength Cond Res* (published ahead of print), 2015.

A 2011 study from the University of Warsaw had women train either with unilateral or bilateral plyometrics for 12 weeks. The study tested their power, agility and speed at 6 weeks, 12 weeks and again at 16 weeks (after 4 weeks of not training). The researchers found that both groups finished the study with similar levels of improvement. However, the unilateral exercises produced quicker improvements in power and jumping performance (6 weeks), but the bilateral training produced more enduring improvements (4 weeks post training).[10]

3-2. MTI's Mission Direct Approach

As can been seen above there is very little agreement as to the relative effectiveness of squatting or lunging in developing athletic performance.

Our driving purpose at the Mountain Tactical Institute is: "To improve mountain and tactical athletes' mission performance, and keep them safe."

Central to this purpose is the focused intention of being "mission direct" in everything that we do – daily training sessions, training plans, articles, research, etc.

For this particular study being "Mission Direct" means trying to identify the most efficient and effect way to build athleticism in the gym - Is it lunging or squatting?

Research is how we test and identify these actionable solutions. However, as we've worked to complete research studies, it's become clear the traditional academic research process is a poor fit to identify Mission

The goal is to quickly identify actionable solutions to improve mountain and tactical athletes' mission performance.

[10] (2) Makaruk, H; Winchester, J; Sandowski, J; Czaplicki, A and Sacewitz, T. Effects of unilateral and bilateral plyometric training on power and jumping ability in women. *J Strength Cond Res*; 25(12): 3311-3318, 2011.

4. STUDY DESIGN

4-1. Subjects

Eighteen volunteer participants of an after-school strength and conditioning program began the study. Of the original eighteen only ten attended the mandatory number of training sessions (75%) which were required to be included in the data analysis. Of the ten subjects included in the data analysis nine were male and one was female. All ten subjects had between 6 months and 4 years of weight room-based training experience (mean = 2.7 +/- 1.3 years). Subject's mean demographics are contained in TABLE 1 below:

TABLE 1: Subject Demographics

		Average	Standard Deviation
Experience	(years)	2.7	+/- 1.3
Height	(inches)	67.0	+/- 2.5
Weight	(lbs)	159.0	+/- 42.1
BMI	(kg/m/m)	24.9	+/- 6.1
Age	(years)	16.5	+/- 1.1

4-2. Data Collection

Research data consisted of seven exercises/assessments: Two lower-body strength measures, two agility tests and three measures of lower body power (one bilateral and two unilateral). All assessments were completed on non-consecutive days during the first week of the study (pre-training) and the sixth week of the study (post-training).

TABLE 2: Data Collection Assessments by Day

Day 1	Day 2
Pro Agility Test	Vertical Jump (Both feet)
T-Agility	Vertical Hop (Left foot)
1RM Back Squat	Vertical Hop (Right foot)
	1RM Lunge

4-3. Training

Subjects trained three days per week for five and a half weeks. After subtracting the four sessions which were used as assessments, the study included thirteen total training days. To be included in the data analysis subjects had to attend at least ten training sessions (75%).

Following the initial assessment subjects were randomly divided into two groups: Squat-based and Lunge-based. The group's training programs were nearly identical. The only differences were the types of exercises used. TABLE 3 show the different lower body exercises used by the groups. Basically, the squat group did all of it's lower body training from a two-footed parallel stance and the lunge group used a staggered (one foot forward, one foot back) stance.

TABLE 3: Exercises per Training Group

	BILATERAL (BI) *Squat-based*	**UNILATERAL (UNI)** *Lunge-based*
Primary Exercise:	Barbell Back Squat	Barbell Lunge (bar on back)
Secondary Exercises:	1. Barbell Front Squat	1. Barbell Split Squat
	2. Box Squat	2. Dumbbell Rear Leg Elevated Split Squat
	3. Box Jumps (Plyo)	3. Jump Lunges (Plyo)

Training loads and reps for each exercise were equal between the groups. They were both based on each group's pre-study 1RMs. Both groups also trained plyometrics twice per week as part of their strength training sessions. Plyometrics were an extremely small portion of the overall training volume (5-10%).

4-4. Training Groups

After eliminating the subjects who did not complete the required number of trials, the UNI group contained four athletes and the BI group contained six athletes. An analysis of pre-trial group demographics revealed that there was no significant difference between the two groups. The squat group did begin the study with considerably higher 1RM squat and lunge, but even these were not statistically significant ($p>.05$)*. TABLE 4 shows the pre-trail group comparisons.

TABLE 4: Pre-Study Between Group Comparison

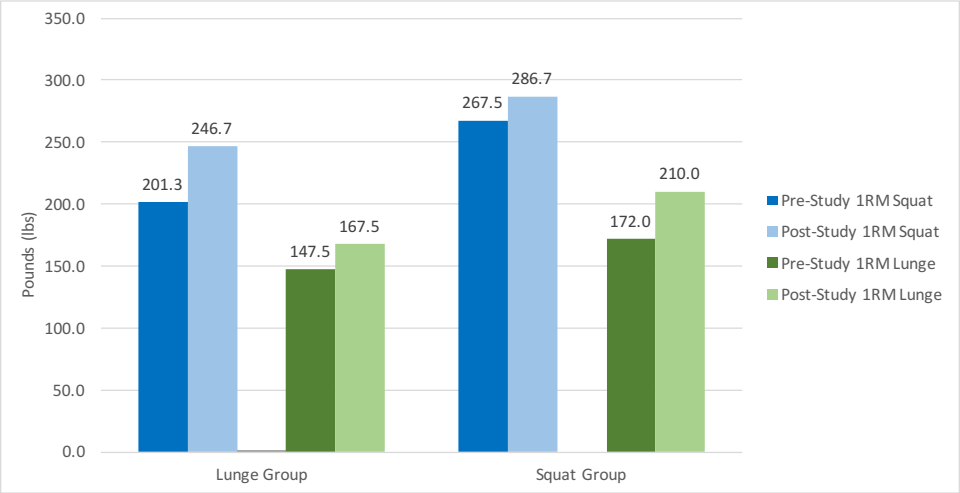
		BI *Squat-based*	**UNI** *Lunge-based*
Experience	(years)	2.9	2.5
Height	(inches)	66.4	67.1
Weight	(lbs)	145.8	167.3
BMI	(kg/m/m)	23.1	26.0
Age	(years)	16.4	16.6
*** 1RM Back Squat**	(lbs)	201.3	267.5
*** 1RM Lunge**	(lbs)	147.5	172.0
Pro Agility	(sec)	5.3	5.1
T-Test Agility	(sec)	11.5	11.2
Vertical Jump (two feet)	(inches)	24.3	25.0
Vertical Hop (Left)	(inches)	12.9	13.7
Vertical Hop (Right)	(inches)	13.0	14.4

5. RESULTS & DISCUSSION

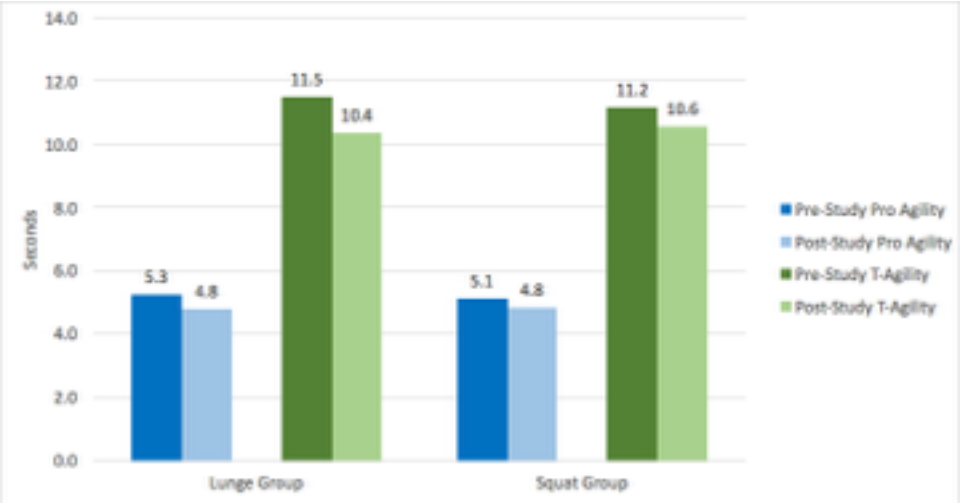
Both groups in our study experienced a slight and insignificant increase in height and slightly larger, statistically significant increases in weight (3.0-7.5%). This was not particularly surprising based on the age of the athletes (15-18 years). Overall, the lunge group did gain significantly more weight than the squat group, but we do not believe this is attributable to training program.

Looking specifically at the performance measures. Both groups had statistically significant gains in strength (1RM Squat and Lunge) and agility (Pro Agility and T-Agility). One of the most peculiar findings in the study was that the lunge group actually improved more than the squat group on their 1RM squat (22.6% and 7.2%, respectively) and the squat group improved more than the lunge group on their 1RM lunge (22.1% and 13.6%, respectively). GRAPH 1 shows the changes in strength between the groups and GRAPH 2 shows the changes in agility between the two groups.

GRAPH 1: Pre-Training and Post-Training Strength Measures



GRAPH 2: Pre-Training and Post-Training Agility
(Note: Decreased times mean better performance)

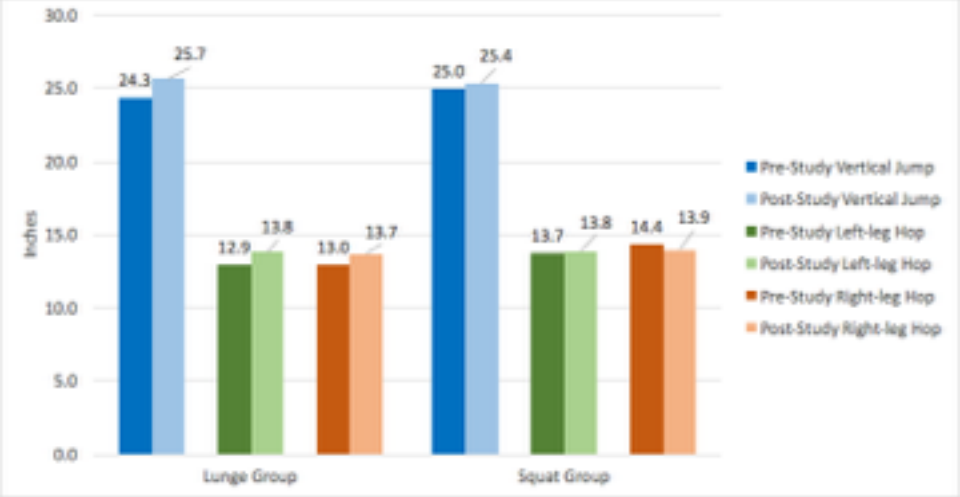


Although the lunge group did out-perform the squat group in both agility measures (8.6% to 5.8% in the Pro Agility Test, respectively and 9.9% to 5.5% in the T-Agility Test, respectively) between group comparisons did not find the group differences to be significant. Therefore, based on our finds it seems that lunge training and squat training

are both effective at improving lower body strength and agility. These findings are similar to what has been reported by McGrudy et al and Speirs et al. [11],[12]

Based on our three measures of lower body power (vertical jump, left-leg vertical hop and right-leg vertical hop) neither type of training produced statistically significant improvements. The lunge group did have slightly higher measures of improvement, but these did not meet the threshold for statistical significance. GRAPH 3 shows the changes in lower body power between the groups.

GRAPH 3: Pre-Training and Post-Training Lower Body Power



The lack of lower body power improvement between the groups is not particularly surprising. In his study of rugby players, Speirs et al. failed to find any improvements in 10m sprints using lunging and squatting.[13]

Unlike the 2011 study by Makaruk et al. which found that the unilateral exercises produced quicker improvements than bilateral exercises the current study did not find any indications of similar time differences.[14]

[11] (6) McCury, K; Langford, G; Doscher, M; Wiley, L and Mallard, K. The Effects of short-term unilateral and bilateral lower-body resistance training on measures of strength and power. *J Strength Cond Res*; 195(1): 9-15, 2005.

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[14] (2) Makaruk, H; Winchester, J; Sandowski, J; Czaplicki, A and Sacewitz, T. Effects of unilateral and bilateral plyometric training on power and jumping ability in women. *J Strength Cond Res*; 25(12): 3311-3318, 2011.

6. MTI MISSION DIRECT LIMITATIONS

Keeping in-line with our commitment to mission direct solutions this study was conducting under real-world conditions. Unfortunately this commitment created a few limitations in the study design. Some of these limitations include:

- **Short study time**
  Our study was completed in just five and a half weeks - only 4 or which were full training weeks. Most studies of this type shoot 12 full weeks (with a minimum of 6 weeks). While longer study lengths are ideal for certain physiological adaptations, MTI's experience has shown that athletes begin to lose focus during longer cycles. Furthermore, MTI training cycles are typically between 4 and 6 weeks. For this reason our study was kept to a minimum length.

- **Lack of control group**
  Obviously lacking a control group means the study lacks a true comparison for each group. This limitation is a product of the program from which the athletes were taken. However, although no control group was used, we feel fairly safe assuming that both groups would have likely improved significantly more than a "non-training" control group. The fact that training improves strength, power and agility when compared to not training seems to be fairly obvious based on practical experience and previous research.

- **Small sample size**
  Although we began the study with eight athletes, as the study progressed that number was cut to ten based on the participation requirements we enforced. Obviously smaller sample sizes mean that finding statistical significance is slightly more difficult. However, even with only ten athletes this study did find significant changes in strength and agility.

- **Additional Training**
  Some of the athletes who participated in the study also participate in sports and supplementary in-school training programs. Therefore it is possible that some of the training adaptation they experienced in our study is the result of their other training programs. There is very little we can do about this limitation. We understand that our athletes have other commitments and requirements outside of their MTI training which will effect their performance.

7. CONCLUSIONS & APPLICATIONS

Based on our study we conclude that short-term strength-based training using either squatting or lunging can effectively build lower body strength and agility. Furthermore, when it comes to building strength and agility there does not appear to be a significant difference between the two types of training.

However, when it comes to building lower body jumping power our study showed that neither training regime we used (lunging or squatting) was enough to create significant improvements. Unfortunately we are not able to determine why we failed to find significant improvements, but other studies have also shown that traditional strength training plans, like those used in this study are not the most effective ways to build the explosive power needed to improve a vertical jump.[15],[16]

Our study did hint at some possible additional benefits related to training unilateral leg exercises, but due to the small sample size we can not say for certain. It should be noted that, in our study the lunge group out improved the squat group in every measure except the 1RM lunge. Although none of these measures were large enough to be statistically significant they were noticeable and could possibly hint at some unmeasured benefit.

Therefore, if a coach had to pick only one form of training we would recommend unilateral training like lunges. However, our study does show that squatting does have a positive impact on both strength and agility.

[15] (9) Migiano, M; Vingren, J; Volek, J; Maresh, C; Fragala, M; Ho, J; Thomas, G; Hatfield, D; Hakkinen, K; Ahtianen, J; Earp, J and Kraemer, W. Endocrine response patterns to acute unilateral and bilateral resistance exercises in men. *J Strength Cond Res*; 24(1): 128-134, 2010.

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8. REFERENCES

(1) Ebben, W; Feldman, C; Dayne, A; Mitsche, D; Chmelewksi, L; Alexander, P and Knetgzner, K. Using squat testing to predict training loads for the deadlift, lunges, step-up, and leg extension exercises. *J Strength Cond Res*; 22(6): 1947-1949, 2008.

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(3) Declore, G; Mathieu, W; Salazar, W and Hernandez, J. Comparison between one-leg and two-leg plyometric training on vertical jump performance [abstract]. Med Sci Sports Exec; 30 (Suppl): 61, 1998.

(4) Ebben, W; Feldman, C, Vanderzanden, T; Faucht, M and Petushek, E. Periodized plyometric training is effective for women and performance is not influenced by the length of the post-training recovery. *J Strength Cond Res*; 24:1-7, 2010.

(5) Marques, M and Gonzalez-Badillo, J. In-season resistance training and detraining in professional team handball players. *J Strength Cond Res*; 20: 563-571, 2006.

(6) McCury, K; Langford, G; Doscher, M; Wiley, L and Mallard, K. The Effects of short-term unilateral and bilateral lower-body resistance training on measures of strength and power. *J Strength Cond Res*; 195(1): 9-15, 2005.

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(8) Neuman, D and Cook, T. Effect of load and carrying position on the electromyographic activity of the gluteus medium muscles during walking. *Phys Ther*; 65: 305-311, 1985.

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