THE EFFECTS OF LADDER TRAINING ON SPRINT AND CHANGE OF DIRECTION PERFORMANCE

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Comment [c1]: Should say "Committee Membership" centered above the list of committee members.

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ABSTRACT

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Trevor Short

Ladder training is a form of multidirectional lower limb plyometric training utilized by coaches and athletes in a variety of sports. The purpose of this study was to examine the effects of ladder training (LT) on sprint (20-m) and change of direction (COD) (L-drill) kinematics. Fourteen NCAA D-2 Basketball players were matched on baseline performance rankings and randomly assigned to a LT (n = 7) or conventional training (CT) (n = 7) group. The LT group performed all the CT exercises with the addition of 25-35 minutes of LT performed 3 times per week, for 4 weeks. Within-group analyses showed significant improvements ($p < 0.001$) in 20-m sprint performance from pretest to posttest in LT (+6.71%) and CT (+2.16%). No statistically significant difference was found in COD performance. Significant enhancements ($p < 0.005$) were found in stride frequency from pretest to posttest for 20-m sprint and COD as a result of LT (+13.58%, and +12.26%) and CT (+0.97%, and -2.33%), respectively. LT resulted in substantially better results (between-group changes) in both the 20-m sprint (ES = 1.45) and COD test (ES = 0.97). Furthermore, LT resulted in substantially greater enhancements in stride frequency (ES = 2.43, 1.65), and ground contact time (ES = 1.82, 1.25) in the 20-m sprint and COD performance respectively. LT may be more effective

than CT in improving performance and kinematics. LT should be implemented as a warm up or neural priming exercise to induce improvements in stride frequency and ground contact time.

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INTRODUCTION

Speed is valued highly in sport: an athlete that can move faster than their opponent has an advantage (15). In most sports, the ability to quickly change direction is just as, if not more important than straight line sprinting speed (7). Most team sports are characterized by rapid acceleration, deceleration, or change direction within a 10-yard window (7,14). It is rare that athletes sprint more than 30 yards before changing direction in sport (7). When athletes are sprinting, or changing direction, their performance is a function of physical capacity and technical proficiency (12). In other words, an athlete's success in speed, and change of direction is the function of an athlete's strength capacity combined with the ability to use this strength within the constraints of the activity (12).

Running speed is a product of the length and frequency of strides (5). Stride length depends on morphological characteristics, impulse at takeoff, ground contact time (GCT), and the dynamic flexibility of the hips (5). Stride length is most closely related to the impulse produced during GCT and can be increased by improving the ability to produce maximum force during high speed movements (15, 19). The training focus of improving stride length should be on generating impulse and velocity during GCT (15). Current literature suggests that the amount of vertical force applied during the stance phase may be the most critical component to improving running speed (12). Additionally, these greater forces must be applied to the ground in the shortest time possible (12). Stride frequency depends on the functioning of the nervous system, inter and intra-muscular coordination, and central and peripheral fatigue (5). Stride frequency is a

function of GCT and flight time. Overall, stride frequency is more closely related to GCT than flight time, since greater maximal stride frequencies are achieved by reducing GCT, rather than reducing the time taken to swing and reposition the limb for the next step (15, 23). Minimum swing times have been shown to be three-hundredths of a second shorter for a runner with a top speed of 11.1 vs 6.2 m/s (23). Furthermore, a more rapid repositioning of the limbs contributes little to faster speeds of elite runners (23). Faster runners simply apply greater forces during more brief contact phases, while slower sprinters apply less ground forces during an extended GCT (23). The greatest variations of stride frequency are a result of differences in GCT, and faster sprinters consistently demonstrate shorter GCT than slower sprinters (15). Therefore, efforts to improve stride frequency should focus on shortening GCT rather than cycling the legs faster (15).

COD ability is determined by the combination of the ability to decelerate, reorient the body to face the direction of intended travel, and then explosively reaccelerate (12). COD performance has been shown to improve with increased hip extension velocity, lower center of mass height, increasing breaking and propulsive impulse, increased knee flexion entering the COD, minimized trunk angular displacement entering the COD, and increased lateral trunk tilt (12). The main determinant of COD performance is a shorter GCT in the final ground contact before changing direction and reaccelerating (11). GCT in the final ground contact, explains 49.1–57.3% of the variance in COD performance (11). Shorter GCT during a COD is advantageous because athletes will spend less time braking and propelling themselves into the new direction, subsequently resulting in faster COD performance (11). Multidirectional lower limb plyometric training has received

considerable interest as an effective method to improve COD performance (11). Because COD is a multiplanar movement, multidirectional lower limb plyometric exercises can be implemented to positively improve CODS performance, given the similarity of the push-off mechanism during a COD (11).

The most effective plyometric drills to improve speed and COD performance consist of stopping, starting, and changing direction in an explosive manner (22, 17). Improvements in athletic performance due to plyometric, and speed, agility, and quickness training stem from developing footwork patterns, movement responses, arm actions, and movements in all three planes (2, 3). Ladder training (LT), a form of multidirectional lower limb plyometric training, has been shown to improve sprint and COD performance in athletes in a variety of sports (14, 3, 21, 22, 10). LT is often used to improve overall athletic performance including speed, agility, coordination, foot speed, dynamic balance, fundamental movement skills, and kinesthetic awareness (14, 3, 21, 22, 10, 7). Eight weeks of LT performance has been shown to improve the 50-yard dash (11%), pro agility shuttle (7%, and 4%), and L-drill (4%) (10, 22). Furthermore, four weeks of LT enhanced agility performance in the t-test by an average of 8.5% (14). Improvements in sprint and COD performance requires 15-50 minutes of LT, 2-3 times per week, for 4-12 weeks (14, 3, 21, 22, 10).

Despite the significant improvements in speed and agility consequent to LT shown in prior studies, it is important to note the limitations of this prior research. Previous researchers did not address and/or control for factors that may have affected the outcome variables (speed and agility), and ultimately the results of the study.

Specifically, previous research on LT may be limited due to: not controlling for participation in other training (14, 3, 21, 10); not including pre-test data (11); not specifying program design in detail (volume of ladder training, ladder drills utilized, rest time) (14, 3, 21, 10); using a 4x100 meter shuttle to test agility, which predominately measures speed endurance (3); and using testing methods including an auditory command, which includes reaction time and does not accurately measure sprint or COD performance (14, 3, 21, 10).

It is difficult to substantiate that ladder training improved sprint or COD performance due the limitations of past research. Therefore, the first purpose of this study will be to confirm or refute previous findings by examining the effects of ladder training on sprint and COD performance. Furthermore, A kinematic analysis is warranted to investigate the effects of LT on sprint and COD performance. An optimal speed and COD development model may be synthesized to enhance specific athletic attributes by understanding the effects of training methodologies on kinetics and kinematics. A proper understanding of the effects of LT will allow a strength and conditioning coach to enhance performance and kinematics at the appropriate period within the mesocycle. The effects of LT on kinematics during sprint and COD performance is yet to be explored. Thus, the second purpose of this study is to examine the effects of ladder training on kinematics (stride frequency, GCT, flight time, cycle time, and stride length) during sprint and COD tests. A sprint-specific plyometrics program has been shown to improve sprint performance by shortening GCT (20). Due to its explosive nature, and repetitive

switching of leg positions during drills, LT may improve athletic performance by increasing stride frequency and decreasing GCT.

METHODOLOGY

A matched pre-post parallel group trial was used in this study. To determine training effects the 20-m sprint (speed) and L-drill (COD) were selected. After pretesting, the athletes were matched on baseline sprint and COD rankings and randomly assigned to a LT (*n* = 7) or CT (*n* = 7) group. The LT group performed all the conventional pre-season training exercises with the addition of LT performed 25-35 minutes, 3 times per week, for 4 weeks. CT consisted of a pre-season strength and conditioning program, which included an undulating periodized resistance training program four days per week, as well as speed, agility, and quickness development and conditioning two days per week (see appendix for more detail). Testing sessions were carried out at the same time of day and under the same experimental conditions. The 4-week training program is detailed in Table 1., and Table 2.

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Subjects

Fourteen male Humboldt State University NCAA D-2 basketball players participated in this study (Table 3). The study protocol took place during the pre-season. Prior to the intervention, players were performing four weekly resistance training sessions, and two weekly sprint and COD training sessions per week. The players had never participated in LT. Based on NSCA participation criteria for plyometric training, inclusion criteria for participants were: a squat 1RM of 1.5 times body weight, squat 60% of body weight 5 times in 5 seconds and stand on 1 leg for 30 seconds without falling

(12). Participants were excluded from the study if they missed more than two training sessions. One athlete suffered an injury during practice and was excluded from the LT group. The study was approved by the Humboldt State University Institutional Review Board for the use of Human Subjects. The participants were informed of the potential risks and benefits of participation in the study and signed an informed consent form. Participants were instructed that participation was voluntary, and that they may withdraw from the study at any time with no repercussions.

Procedures

The testing procedures were performed at baseline (pretest) and at the end of the 4-week training program (posttest). All testing sessions were performed on an indoor court at the same time of day to minimize the effect of diurnal variation. The subjects were required to wear the same athletic equipment during testing. Prior to testing, participants completed a dynamic warm-up for 7-10 minutes. Participants were then introduced to the 20-meter dash and three-cone shuttle test (L-Drill). Participants were instructed on both testing procedures and performance techniques. All athletes were instructed to exert maximal effort throughout each test. Participants were given 3 minutes between testing trials, which reduced the negative effects of fatigue and allows the phosphagen system to recover, ensuring that technique does not suffer, and that enough energy is available for maximal effort (12). Sprint and COD testing procedures followed NSCA recommendations for assessment and order of testing (12) For both tests, time was recorded using the Brower Digital Timing System (Brower TC wireless timing

system, Utah). The better of the two times was recorded (12). After the testing, participants completed a cool down which included light jogging and proprioceptive neuromuscular facilitation. See Appendices for more detail.

Sprint performance was measured using the 20-meter dash from a static start, which assesses the ability to accelerate (15). The L-Drill was used to assess technique, acceleration, and COD speed (7). The L-Drill test applies to skills used in most power sports, including body position and proper technique of movement, starting, acceleration, deceleration, and changes of direction (7). For both tests, all athletes began from a standing start, with the foot placed 0.5 m from the timing gate. Timing gates were set to a height of 1 m and placed in a pair at the starting point.

Data was collected on the kinematics (stride frequency, GCT, swing time, cycle time, and stride length) of sprint and COD performance before and after the addition of ladder training to the strength and conditioning program. Force sensing insoles (sampling rate = 1000 Hz, Delsys INC, Natick, MA) were inserted into each shoe to measure stride frequency (strides/sec), GCT (sec), flight time (sec), and gait cycle time (sec) during each successive foot contact. Data was then analyzed with Visual 3D software (C-Motion INC, Germantown, MD). Average stride length was calculated by dividing average running speed by average stride frequency.

Utilizing plyometric speed, agility, and quickness training requires at least 3 workouts a week, for 4-12 weeks to significantly improve athletic performance (24). Thus, the experimental group participated in LT 3 times per week for 4 weeks, totaling 12 training sessions. Training sessions were 28-35 minutes in duration. The

recommended time between training sessions for speed and agility ranges from 48-96 hours (4). Thus, training sessions were completed on Monday, Wednesday, and Friday. During each training session participants completed a 7-10-minute dynamic warm-up which followed the RAMP protocol prior to LT (12). After the dynamic warm up, participants completed four sets of LT drills. Each set was composed of different motor movements (A-skip, High knees, Quick feet, and Hops). All LT drills are considered level 1 drills, which are basic agility drills that focus on technique and body position that include basic cuts and movement patterns (7). The LT exercises used in this study consist of several SAQ movements utilized by college and professional athletes (22). Based on NSCA recommendations, rest was 2 minutes between each set and 30 seconds between each exercise (7). The utilization of ground contacts as a measure of training volume was not used in this study. Training volumes that utilize ground contacts may not produce an adequate stimulus for improvement with this modality. For example, the icky shuffle, a widely-used ladder drill includes 27 ground contacts. Currently, the NSCA recommends 80-100 ground contacts for beginners and 100-120 ground contacts for intermediately experienced athletes (12). It does not seem appropriate that 3-4 icky shuffles can provide an adequate stimulus to improve sprint or COD performance. Therefore, total work volume (time) was used to prescribe training volume. Total work volume was 2-3 minutes, which is recommended for beginner and intermediate participants respectively (7). Participants were encouraged to exert maximal effort during each ladder exercise. During maximal effort, athletes can only maintain speed in agility or quickness drills for about 7 seconds (7). Typically, athletes perform drills for quickness, acceleration, or

quick foot movements for 3-5 seconds (7). On average, LT drills also last about 3-5 seconds in duration. The intensity of LT refers to the complexity of the ladder drill (14). To optimize the effects of ladder drills it is important to progress from less to more complex drills to complement the stages of motor learning (7). Due to the difficulty of accurately determining the intensity of LT, increasing complexity and volume was used to support progression. During the first week, the participants were introduced to LT, and participated in low complexity drills while learning and developing basic motor programs. Athletes were told to begin the drill slowly until the motor program was developed. The overload training principle was applied during the second and third week as speed, complexity, and volume increased. During the final week, the training objective was to maximize foot speed and complexity of ladder drills. The presence of a fitness specialist in speed and agility development is recommended to lead, direct, and control the specificity and overload of training to optimize athletic development (2). Each ladder training session was led by a NSCA Certified Strength and Conditioning Specialist (CSCS) to ensure that all activities were completed with proper technique and with maximum effort.

Statistical Analyses

Normality was checked using the Shapiro-Wilks test. Data are presented as mean ± *SD*. A 2 (group: LT and CT) × 2 (time: pre, post) mixed-factorial analysis of variance (ANOVA) was calculated for sprint, and COD performance, as well as kinematics (stride frequency, GCT, flight time, cycle time, stride length). Partial eta-squared ($\eta_p{}^2$) effect

sizes for time, group, and group × time were calculated. An effect of $\eta_p^2 \geq 0.01$ indicates a small, ≥ 0.059 a medium, and ≥ 0.138 a large effect respectively (6). Significance was set at an α level of 0.05. For each variable, the percentage difference in the change scores between LT and CT from pretest to posttest was calculated. The chances that the differences in performance were better/greater (i.e., greater than the smallest worth-while change [0.2 multiplied by the between subjects *SD*, based on the Cohen *d* principle]), similar, or worse/smaller were calculated (13). ES based on the Cohens *d* principle was interpreted as trivial <0.2, small 0.2-0.6, moderate 0.6-1.2 large 1.2-2.0, and very large >2 (13). Quantitative chances of beneficial/better or detrimental/poorer effects were assessed qualitatively as follows: <1%, almost certainly not; 1-5%, very unlikely; 5-25%, unlikely; 25-75%, possibly; 75-95%, likely; 95-99% very likely; and >99%, almost certainly (13). If the chances of having beneficial/better and detrimental/poorer performances were both >5%, the true difference was assessed as unclear. All statistical analyses were conducted using the statistical package SPSS for Windows 7 (version 20.0; Chicago, IL, USA).

RESULTS

Absolute values for each parameter at pretest and posttest, together with the ANOVA results are displayed in Table 4 and 5. In the within-group analysis, significant improvements in 20-m sprint performances ($F_{1,12} = 43.41$, $p < 0.001$) were found in LT (*d*=1.27) and CT (*d*=0.49). Players in both LT and CT also showed significantly faster stride frequencies ($F=_{1,12}$ $p < 0.001$; *d*= 1.45 and *d*= 0.77, for LT and CT respectively) and short swing times ($F_{1,12} = 6.45$, p = 0.026; *d*= 0.71 and *d*= 0.70, for LT and CT respectively) during sprint performance from pretest to posttest. Furthermore, players in both LT and CT also showed significantly faster stride frequencies ($F_{1,12} = 11.61$, p = 0.005; *d*= 1.38 and *d*= -0.24, for LT and CT respectively) and shorter GCT ($F_{1,12} = 4.96$, p = 0.046; *d*= 1.81 and *d*= -0.44, for LT and CT respectively) during COD performance from pretest to posttest. However, no significant improvement in COD performance was found from pretest to posttest. After 4 weeks of training, LT resulted in substantially better results in 20-m sprint (ES= 1.45 [large] [CL90% 0.55-2.34], with chances for beneficial, trivial, detrimental performance of 99/1/0), and L-Drill (ES= 0.97 [moderate] [CL90% 0.05-1.88], with chances for beneficial, trivial, detrimental performance of 95/5/2) than in CT. Kinematic analysis revealed LT resulted in substantially better results in stride frequency (ES= 2.43 [very large], 1.65 [large] [CL90% 1.53-3.32, 0.75-2.55], with chances for beneficial, trivial, detrimental performance of 100/0/0, 99/1/0) and GCT (ES= 1.25 [large], 1.82 [large] [CL90% 0.34-2.16, 0.91-2.72], with chances for beneficial, trivial, detrimental performance of 97/2/1, 100/0/0) for sprint and COD

performance respectively than in CT. Results from the between-groups analysis are illustrated in Figure 1 and 2.

DISCUSSION

This is the first study to assess the effects of ladder training on kinematics during 20-m sprint and COD tests. The main findings of this study indicate both training methods (LT and CT) seem to be effective in improving 20-m sprint performance but not COD. Although, the addition of LT showed a larger effect on both sprint and COD performance compared with CT alone after the training protocol. Furthermore, the addition of LT may be more effective than CT in improving kinematics such as stride frequency and GCT during sprint and COD performance. Despite the significant improvements in stride frequency and GCT, LT did not significantly improve COD performance.

LT is expected to improve sprint and COD performance (13, 3, 20, 22, 10). The specificity of ladder training exercises may have resulted in more functional and relevant motor programs which control the complex intramuscular coordination required during sprint and COD performance (2). The results of this study confirm that the addition of LT can significantly improve 20-m sprint performance, but not COD performance in the L-drill (14, 3, 21, 22, 10). Although, the addition of LT is substantially more effective than CT alone.

Speed is a critical component of sport performance; an athlete that can move faster than their opponent has an advantage (15). Previous studies have shown that LT can improve linear running speed (11, 21). However, no study has investigated *how*

ladder training improves sprint performance. The results of the study have shown a large and medium training effect on the 20-meter sprint for LT and CT respectively. The LT was significantly faster than the CT after 4 weeks of training, indicating that the addition of LT to CT is more effective that CT alone. The current study adds to the literature a kinematic analysis of sprint performance in response to LT (see Table 4). LT increased sprint performance (6.71%), which is likely due to a 13.58% increase in stride frequency. Furthermore, stride frequency is mostly related to GCT (15). Thus, the 27.27% reduction in GCT, likely improved stride frequency. Additionally, the reduction in GCT and swing time cumulatively reduced cycle time by 16%. It is important to note that the nature of improvement in sprint performance differed between both training modalities (LT and CT). The LT group increased stride frequency and decreased GCT, while the CT group increased stride length and increased GCT. Despite the differences in kinematic adaptations, both groups significantly improved sprint performance. These finding have important practical implications as coaches and practitioners may prescribe either LT in addition to CT or CT alone to elicit specific kinematic adaptations. A key element of speed may be the ability to produce more force in a shorter time (15). Impulse equals the force applied times the duration of force application. If GCT decreases without an increase in force, then net impulse decreases. Therefore, increased GCT allows for increased impulse so that force can be directed vertically and horizontally into the ground. Relative to the current study, GCT decreased after training. Thus, it is likely that net impulse decreased, although average running speed increased, implying that average force production must have increased (Force = Mass × Acceleration). Although, if

average force increases while GCT decreases, impulse may remain the same Therefore, the rate of force development must be fast to produce more force in less time. Rate of force development may be enhanced due to selective recruitment of type II fibers (18). If force production is required quickly, then the nervous system may either increase motor unit recruitment or bypass slower motor units (type I), and selectively recruit type II fibers (18).

The ability to quickly change direction is just as, if not more important than straight line sprinting speed (7). Previous studies have shown that LT can improve COD performance in the T-test, pro-agility shuttle, and L-drill (10, 14, 22). However, no study has investigated how LT improves COD performance. The results of this study showed that the addition of LT to CT does not significantly improve COD performance. However, the addition of LT is substantially more effective in improving COD performance than CT alone. The LT L-drill time decreased on average 0.23 seconds, while the CT time increased .05 seconds. The current study adds to the literature of LT a kinematic analysis of COD adaptations in response to 4-weeks of LT (see Table 5). The main determinant of COD performance is shorter GCT in the final ground contact (11). Despite a 30.77% reduction in average GCT, the addition of LT did not significantly improve COD performance. This indicates that the addition of LT may have decreased GCT, but also decreased the amount of force produced during the COD. A longer GCT allows for more force to be produced and directed into the ground. Thus, a longer average GCT during COD may be beneficial to decelerate, reorient the body, and reaccelerate faster. It is important to note that COD events occur in periods that prevent an athlete

from producing maximal strength (12). Therefore, the rate of force development is more important than absolute force development during COD performance. A kinetic analysis of the addition of LT is warranted to further examine the effects of LT on COD performance.

An elite level of athletic competition requires an increase in neuromuscular conditioning, because the athletes' linear, lateral, and vertical movements must be precise, explosive, and autonomous (24). With enhanced sprint and COD performance there must be increases in average force or rate of force development due to Newtons 2nd law (Force = Mass x Acceleration). To our knowledge, the duration of this study is not long enough for changes of the muscle tendon complex and muscle size or architecture to change (12). Therefore, the training adaptations that have occurred in this study are likely neural adaptations. Enhanced force production from the nervous system occurs via increased neural drive to agonist recruitment, improved neuronal firing rates, greater synchronization in timing of neural discharge (intermuscular coordination, reduction in inhibitory mechanisms) (12, 16). Potential neural adaptation sites that may lead to an increased neural drive, neuronal firing rate, or synchronization include: the motor cortex, descending corticospinal tract, golgi tendon organ, muscle spindles, and the neuromuscular junction (12). Motor cortex activity is increased when learning new motor skills, as well as when one intends to produce maximal force (9). Motor learning from LT may have increased synchronization of the agonist and antagonist, ultimately improving performance. Many LT drills simulate movements of sprint and COD performance, which may have led to enhanced sprint performance and COD kinematics. The

descending corticospinal tract adapts by increasing the speed of neural input via myelination (1). If the signal from the motor cortex is able to reach the intended muscle faster, then the rate of force development (RFD) may be increased. The neuromuscular junction adapts by increasing in perimeter length, acetylcholine receptors, and a greater total length of nerve terminal branching (8). This adaptation may increase the speed and magnitude of neural input, leading to a more forceful contraction and increased RFD. Muscle spindles sense the rate and magnitude of a stretch and may change stretch reflex excitability from plyometric training (16). Once a stretch is detected muscular activity increases, which increases the force capabilities of the muscle. The specificity of ladder training exercises may have resulted in more functional and relevant motor programs which control the complex intramuscular coordination required during sprint and COD performance (2).

The broader practical applications and interpretations of the current data must be undertaken within the limits of this unique study; there are some limitations to note. Although the sample size used in this study were similar to others that have assessed LT, our sample size was relatively small. A larger sample size could have provided more conclusive results. To circumvent this issue, different statistical methods were used, including the magnitude-based inferences. Furthermore, sprint kinetics adaptations were not included in the study due to available equipment and resources. Future ladder training research should: (a) examine the physiological adaptations that occur in response to training (motor unit recruitment, synchronization, nerve conduction velocity), (b) examine kinetics (peak power output, vertical stiffness, rate of force development), (c)

investigate a dose-response, and (d) examine potential changes in biomechanical efficiency.

PRACTICAL APPLICATION

This study offers practical applications for speed and COD development in basketball players. The effects of LT illustrate the concept of training specificity. Based on the present results, the addition of 4 weeks of LT to a pre-season strength and conditioning program seems to represent a time-efficient stimulus for a simultaneous improvement in sprint performance and kinematics (stride frequency and GCT). LT should be integrated as warm up or neural priming exercise three times per week. Kinematic adaptations (increased stride frequency and decreased GCT) can be obtained at specific periods within the macrocycle with the addition of LT.

TABLES

Table 1. Ladder Training Program

Week	Session	Complexity	# of Drills	# of Sets	Total work time	Inter-drill rest	Inter-set Rest	Duration	Effort
	1	Easy	24	4	72-120 sec	30 s	2 min	29.2-30 min	Maximal
Week 1	2	Easy	24	4	72-120 sec	30 s	2 min	29.2-30 min	Maximal
	3	Easy	24	4	72-120 sec	30 s	2 min	29.2-30 min	Maximal
	1	Moderate	28	4	84-140 sec	30 s	2 min	31.4-32.3 min	Maximal
Week 2	2	Moderate	28	4	84-140 sec	30 s	2 min	31.4-32.3 min	Maximal
	3	Moderate	28	4	84-140 sec	30 s	2 min	31.4-32.3 min	Maximal
	1	Moderate	28	4	84-140 sec	30 s	2 min	31.4-32.3 min	Maximal
Week 3	2	Moderate	28	4	84-140 sec	30 s	2 min	31.4-32.3 min	Maximal
	3	Moderate	28	4	84-140 sec	30 s	2 min	31.4-32.3 min	Maximal
	1	Hard	31	4	93-155 sec	30 s	2 min	32.3-34.1 min	Maximal
Week 4	2	Hard	31	4	93-155 sec	30 s	2 min	32.3-34.1 min	Maximal
	3	Hard	31	4	93-155 sec	30 s	2 min	32.3-34.1 min	Maximal

Table 2. Ladder Training Drills

Week	**Set 1: A-Skips**	**Set 2: High Knees**	**Set 3: Quick Feet**	**Set 4: Hops**
Week 1	2-In Each Sideways 2 in R Sideways 2 in L Icky Shuffle	2-In Each Sideways 2 in R Sideways 2 in L Icky Shuffle	2-In Each Sideways 2 in R Sideways 2 in L Icky Shuffle In-In-Out-Out 3-Out-1-In R 3-Out-1-In L 2 In-2 Out Sideways	2-In Each Side-Side Side-Side Icky Shuffle Backwards Icky Forward-back R Forward-back L In-Out
Week 2	2-In Each Sideways 2 in R Sideways 2 in L Icky Shuffle In-In-Out-Out	2-In Each Sideways 2 in R Sideways 2 in L Icky Shuffle In-In-Out-Out	2-In Each Sideways 2 in R Sideways 2 in L Icky Shuffle In-In-Out-Out 3-Out-1-In R 3-Out-1-In L Crossover Carioca 2 In-2 Out Sideways	2-In Each Side-Side Side-Side Icky Shuffle Backwards Icky Forward-back R Forward-back L In-Out
Week 3	2-In Each Sideways 2 in R Sideways 2 in L Icky Shuffle In-In-Out-Out	2-In Each Sideways 2 in R Sideways 2 in L Icky Shuffle In-In-Out-Out	2-In Each Sideways 2 in R Sideways 2 in L Icky Shuffle In-In-Out-Out 3-Out-1-In R 3-Out-1-In L Crossover Carioca 2 In-2 Out Sideways	2-In Each Side-Side Side-Side Icky Shuffle Backwards Icky Forward-back R Forward-back L In-Out
Week 4	2-In Each Sideways 2 in R Sideways 2 in L Icky Shuffle In-In-Out-Out	2-In Each Sideways 2 in R Sideways 2 in L Icky Shuffle In-In-Out-Out	2-In Each Sideways 2 in R Sideways 2 in L Icky Shuffle Backwards Icky In-In-Out-Out 3-Out-1-In R 3-Out-1-In L 3-Out-1-In Backwards R 3-Out-1-In Backwards L Crossover Carioca 2 In-2 Out Sideways	2-In Each Side-Side Side-Side Icky Shuffle Backwards Icky Forward-back R Forward-back L In-Out

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Table 3. Physical Characteristics

	N	Age (y ± SD)	Weight (kg ± SD)	Height (cm ± SD)
Ladder Training Group	7	20.85 ± 2.23	90.43 ± 11.65	193.35 ± 7.73
Conventional Training Group	7	21 ± 0.81	92.46 ± 14.38	194.67 ± 5.61

Table 4. Changes in 20-m sprint performance and kinematics after 4 weeks of LT and CT in basketball players*

	LT (n = 7)			CG (n = 7)			AVOVA *p*		
	Pre	Post	Δ (%)	Pre	Post	Δ (%)	Time	Group	Group x Time
20-meter Sprint (s)	2.83 ± 0.16	2.64 ± 0.09	-6.71	2.78 ± 0.13	2.72 ± 0.09	-2.16	**0.000 (0.783)**	0.871 (0.002)	0.013 (0.4
Stride Frequency (s/s)	4.05 ± 0.37	4.6 ± 0.44	13.58	4.12 ± 0.42	4.16 ± 0.05	0.97	**0.000 (0.924)**	**0.000 (0.880)**	**0.000 (0.9**
GCT (s)	0.22 ± 0.04	0.16 ± 0.02	-27.27	0.19 ± 0.02	0.22 ± 0.05	15.79	0.569 (0.028)	0.242 (0.112)	**0.025 (0.3**
Swing Time (s)	0.53 ± 0.12	0.47 ± 0.07	-11.32	0.52 ± 0.10	0.51 ± 0.06	-1.92	**0.026 (0.349)**	0.677 (0.015)	0.997 (0.0
Cycle Time (s)	0.75 ± 0.12	0.63 ± 0.08	-16.00	0.71 ± 0.12	0.68 ± 0.09	-4.23	0.037 (0.313)	0.995 (0.000)	0.288 (0.093)
Stride Length (m)	1.75 ± 0.12	1.65 ± 0.09	-5.71	1.76 ± 0.12	1.77 ± 0.16	0.57	**0.000 (0.882)**	**0.000 (0.847)**	**0.000 (0.821)**

*LT= Ladder Training; CT= Conventional Training; ANOVA= analysis of variance; np2 = partial eta squared; GCT= ground contact time; s/s= steps per second

Bold values are statistically significant ($p < 0.05$)

Comment [c5]: All text font (including page numbers and headings) in your thesis must be Times New Roman or Times Roman, with a 12 pt. font size (footnotes and text inside tables may be as small as 10 pt.)

Comment [c6]: All figures and tables in your document must be positioned within the listed margins.

Table 5. Changes in L-Drill performance and kinematics after 4 weeks of LT and CT in basketball players*

	LT (n = 7)			CG (n = 7)			AVOVA *p*		
	Pre	Post	Δ (%)	Pre	Post	Δ (%)	Time	Group	Group x Ti
L-Drill	7.63 ± 0.37	7.4 ± 0.27	-3.01	7.58 ± 0.12	7.63 ± 0.38	0.66	0.290 (0.093)	0.558 (0.029)	0.068 (0.25
Stride Frequency (s/s)	3.59 ± 0.20	4.03 ± 0.21	12.26	3.43 ± 0.39	3.35 ± 0.41	-2.33	**0.005 (0.492)**	0.025 (0.355)	**0.000 (0.664)**
GCT (s)	0.26 ± 0.05	0.18 ± 0.05	-30.77	0.24 ± 0.02	0.26 ± 0.05	8.33	**0.046 (0.292)**	0.241 (0.112)	**0.003 (0.531)**
Swing Time (s)	0.45 ± 0.13	0.37 ± 0.02	-17.78	0.44 ± 0.16	0.43 ± 0.08	-2.27	0.300 (0.089)	0.500 (0.039)	0.493 (0.040)
Cycle Time (s)	0.71 ± 0.18	0.55 ± 0.06	-22.54	0.68 ± 0.16	0.68 ± 0.12	0.00	0.158 (0.159)	0.322 (0.082)	0.114 (0.169)
Stride Length (m)	1 ± 0.07	0.92 ± 0.04	-8.00	1.07 ± 0.12	1.09 ± 0.12	1.87	**0.049 (0.285)**	0.043 (0.300)	**0.006 (0.485)**

*LT= Ladder Training; CT= Conventional Training; ANOVA= analysis of variance; np2 = partial eta squared; GCT= ground contact time; s/s= steps per second

Bold values are statistically significant ($p < 0.05$)

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FIGURES

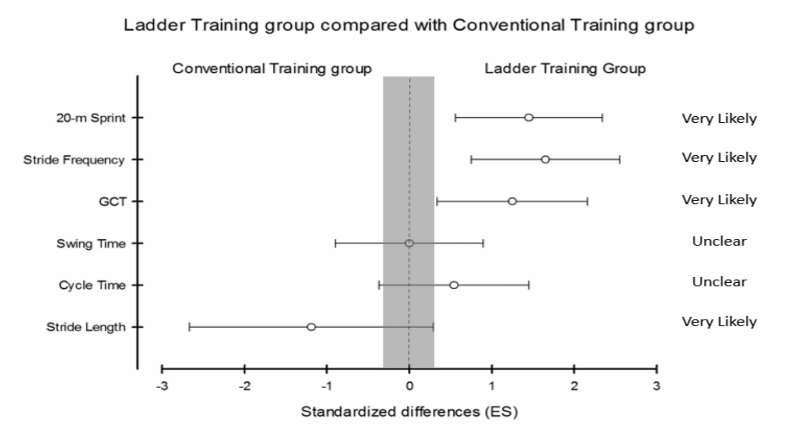

Figure 1.


Ladder Training group compared with Conventional Training Group
Conventional Training Group
Ladder Training group
L-Drill
Stride Frequency
GCT
Swing Time
Cycle Time
Stride Length
Likely
Most Likely
Most Likely
Unclear
Likely
Most Likely
-3
-2
-1
0
1
2
3
Standardized differences (ES)

Figure 2.

REFERENCES

1. Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., & Dyhre-Poulsen, P. (2002). Increased rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of applied physiology*, *93*(4), 1318-1326.
2. Bloomfield, J., Polman, R., O'donoghue, P., & McNaughton, L. (2007). Effective speed and agility conditioning methodology for random intermittent dynamic type sports. *Journal of Strength and Conditioning Research*, *21*(4), 1093.
3. Chandrakumar, N., & Ramesh, C. (2015). Effect of Ladder Drill and SAQ Training on Speed and Agility Among Sports Club Badminton Players. *IJAR*, *1*, 12, 527-529.
4. Chu, D. A. (1998). *Jumping into plyometrics*. Human Kinetics.
5. Coh, M., Babic, V., & Maćkała, K. (2010). Biomechanical, neuro-muscular and methodical aspects of running speed development. *Journal of Human Kinetics*, *26*, 73-81.
6. Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.
7. Dawes, J., & Roozen, M. (2012). *Developing agility and quickness*. Human Kinetics.

8. Deschenes, M. R., Maresh, C. M., Crivello, J. F., Armstrong, L. E., Kraemer, W. J., & Covault, J. (1993). The effects of exercise training of different intensities on neuromuscular junction morphology. *Journal of neurocytology*, *22*(8), 603-615.
9. Dettmers, C., Ridding, C., Stephan, M., Lemon, N., Rothwell, C., & Frackowiak, S. (1996). Comparison of regional cerebral blood flow with transcranial magnetic stimulation at different forces. *Journal of Applied Physiology*, *81*(2), 596-603.
10. Dhanaraj, (2014) Effects of ladder training on motor fitness variables among handball players. *International Journal of Scientific Research, 3, 4, 2277-8179*
11. Dos'Santos, T., Paul, C. T., Jones, A., & Comfort, P. (2016). Mechanical determinants of faster change of direction speed performance in male athletes. *Journal of Strength and Conditioning research*.
12. Haff, G. G., & Triplett, N. T. (Eds.). (2015). *Essentials of Strength Training and Conditioning 4th Edition*. Human kinetics.
13. Hopkins, W., Marshall, S., Batterham, A., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine+ Science in Sports+ Exercise*, *41*(1), 3.
14. Jamil, S. A., Aziz, N., & Hooi, L. B. (2015). Effects of Ladder Drills Training On Agility Performance. *International Journal of Health, Physical Education and Computer Science in Sports, 17,* 1, 17-25
15. Jeffreys, I. (Ed.). (2013). *Developing speed*. Human Kinetics.

16. Markovic, G., & Mikulic, P. (2010). Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports medicine*, *40*(10), 859-895.
17. Miller, M. G., Herniman, J. J., Ricard, M. D., Cheatham, C. C., & Michael, T. J. (2006). The effects of a 6-week plyometric training program on agility. *Journal of Sports Science and Medicine*, *5*(3), 459-465.
18. Nardone, A., Romano, C., & Schieppati, M. (1989). Selective recruitment of high- threshold human motor units during voluntary isotonic lengthening of active muscles. *The Journal of physiology*, *409*(1), 451-471.
19. Parsons, L. S., & Jones, M. T. (1998). Development of Speed, Agility, and Quickness for Tennis Athletes. *Strength & Conditioning Journal*, *20*(3), 14-19.
20. Rimmer, E., & Sleivert, G. (2000). Effects of a Plyometrics Intervention Program on Sprint Performance. *The Journal of Strength & Conditioning Research*, *14*(3), 295-301.
21. Srinivasan, M., & Saikumar, C. V. (2012). Influence of conventional training program combined with ladder training on selected physical fitness and skill performance variables of college level badminton players. *The Shield-Research Journal of Physical Education & Sports Science.*, *7*.
22. Wagner, M. C., Oden, G. L., Glave, A. P., & Hyman, W. V. (2015). Development of agility utilizing a multidimensional modality of plyometrics. *Journal of Fitness Research*, *3*, 859-895.

23. Weyand, P. G., Sternlight, D. B., Bellizzi, M. J., & Wright, S. (2000). Faster top running speeds are achieved with greater ground forces not more rapid leg movements. *Journal of applied physiology*, *89*(5), 1991-1999.

24. Yap, C. W., & Brown, L. E. (2000). Development of speed, agility, and quickness for the female soccer athlete. *Strength & Conditioning Journal*, *22*(1), 9.

APPENDICES

Appendix A

20-m Sprint Testing Manual

Purpose: To assess the ability to accelerate

Application: Forty yards is a commonly tested distance, but other distances should be selected to reflected typical sprints in the sport.

Equipment: Digital timing gates, flat running surface with start and finish lines a specified distance apart (40 yards or 37 meters) with at least 20 yards after the finish line for deceleration.

Personnel: One timer/recorder

Procedure:

1. Have the athlete warm up and dynamically stretch for several minutes
2. Allow at least two practice runs at submaximal speed
3. The athlete assumes a starting position using a three or four point stance
4. The athlete sprints the specified distance at maximal speed
5. The best split times of two trials are recorded to the nearest 0.1 second.
6. Allow at least two minutes of active recovery or rest between trials.

Appendix B

Three Cone Shuttle Test Manual

Purpose: To assess technique, acceleration, and COD speed

Application: This test applies to skills used in most power sports, including body position and proper technique of movement, starting, acceleration, deceleration, and changes of direction.

Equipment: Digital timing gates, measuring tape, 3 cones, and a flat nonslip surface

Testing Layout: Place 3 cones in an L pattern with the legs of equal length. The end cones are 1 and 3 and the one at the 90-degree corner is cone 2. Cones 1 and 2 and cones 2 and 3 are positioned 5 yards (4.6m) apart.

Procedure: The athlete starts in a sport-specific stance next to cone 1 and faces cone 2. The athlete will start when ready. The digital timing gate will begin the time on the athlete's first movement. The athlete sprints to cone 2, bends down, and touches the ground with the right hand. The athlete turns 180 degrees and sprints back to cone one, bends down, and touches the ground with the right hand again, he then sprints back to cone 2, turns around the outside, and sprints to cone 3. At cone 3, the athlete turns around it on the outside and sprints back to cone 2. At cone 2, the athlete plants the feet, turns left, and sprints back to cone 1 to finish the test. The digital timing gate will be set at cone 1 to record the time.

Appendix C

week 1					**Cleans**		**Squats**		**Bench**			
					100		**100**		**100**			
Monday												
Exercise	Set 1		Set 2		Set 3		Set 4		Set 5		Set 6	
OH Squat/Lunge/GM	45	10										
Reverse Lunge	45	5	65	5								
Clean Progressions	25	1	25	1								
CP / SC / FS / TJ	50	1	55	1	60	1	Open	1	Open	1		
Back Squat	50	5	50	5	60	5	Open	5	Open	5		
RDL BB or DB		10		10								
Push Press	45	5	65	5	95	5	Open	5	Open	5		
Blast Strap or Rows		10		10		10						
Lat Pulls 4x10	Bodyweight Circuit 1x10											
Any Abs	Partner PNF Stretch											
											Sign-off____	
Wednesday												
Exercise	Set 1		Set 2		Set 3		Set 4		Set 5		Set 6	
OH Squat/Lunge/GM	45	10										
Lunges	45	5	45	5								
Drop Snatch	45	5	45	5								
Hang Snatch	25	3	25	3	Open	3	Open	3			**Light and Fa**	
Ft. Squat	40	5	50	5	55	5	Open	5	Open	5	**Add Box Jun**	
Side Lunge		5		5								
DB Incline Press	Easy	5	Med.	5	Med.	5	Hard	5	Hard	5	**Add Ball Dro**	
Bent Row	40	8	40	8	40	8	40	8	40	8		
Roll Out Abs												
Hypers/Glute Ham/Reverse Hypers/DB RDL 1x10												
Hip Mobility Circuit	Partner PNF Stretch											
											Sign-off____	
Friday												
Exercise	Set 1		Set 2		Set 3		Set 4		Set 5		Set 6	
DB Shoulder Circuit	10	10	10	10								
Shoulder Press		5		5		5						
Bench or Incline	50	5	55	5	60	5	Open	5	Open	5		
DB Snatch	25	5	35	5	Open	5						
Lat Pull or Rows		10		10		10						
Block Push-ups/Blast Straps/Dips x2												
Barbell abs	3x20											
Curls / Push Down	3x10											
Partner PNF Stretch												
Hip Mobilty Circuit			**Weigh-in**____________								Sign-off____	

Name:												
week 2					**Cleans**		**Squats**		**Bench**			
					100		**100**		**100**			
Monday												
Exercise	Set 1		Set 2		Set 3		Set 4		Set 5		Set 6	
OH Squat/Lunge/GM	45	10										
Jump Shrugs	45	5	65	5								
Power High Pulls	25	5	25	5								
Hang Squat Clean	50	5	55	3	60	3	Open	3				
Squat	135	10	50	6	60	6	Open	6				
RDL BB or DB	50	10	50	10	50	10						
Jerk Progression	45	5										
Push Press	45	5	65	5	95	5	Open	5				
Pull-ups/Blast Strap		10		10		10						
Lat Pulls or Rows 4x10		Hip Mobility Circuit 1x10										
Regular Abs x30	Partner PNF Stretch										Sign-off____	
Wednesday												
Exercise	Set 1		Set 2		Set 3		Set 4		Set 5		Set 6	
OH Squat/Lunge/GM	45	10	45	10								
Snatch Jump Shrugs	45	5	45	5								
Drop Snatch	45	5	45	5								
Hang Snatch	25	5	25	5	Open	3	Open	3			**Light and Fa**	
Ft. Squat or Lunge	40	5	45	5	50	5	Open	5			**Add Box Jun**	
Side Lunge		5		5		5						
DB Incline Press	Easy	5	Med.	5	Hard	5	Hard	5			**Add Ball Dro**	
Bent Row	40	8	40	8	40	8	40	8				
Super Abs 1-22												
Hypers/Glute Ham/Reverse Hypers/DB RDL 1x10											Sign-off___	
Hip Mobility Circuit	Partner PNF Stretch											
Friday												
Exercise	Set 1		Set 2		Set 3		Set 4		Set 5		Set 6	
DB Shoulder Circuit	10	10	10	10								
Bench Press Warm-u	45	10	45	10								
Bench	76	5	79	4	81	3	70	6	70	6	70	**ma**
DB Snatch	25	5	35	5	Open	5						
Row or Blast Straps		10		10		10						
Block Push-ups/Australian pull-ups/Dips				3xfail								
Barbell abs	3x20										Sign-off____	
Stabilizations	3x30	**Weigh-in**____________										
Partner PNF Stretch												
Hip Mobilty Circuit												

Name:												
week 3 & 4					**Cleans**		**Squats**		**Bench**			
					100		**100**		**100**			
Day 1												
Exercise	Set 1		Set 2		Set 3		Set 4		Set 5		Set 6	
OH Squat/Lunge/GM	45	10	45	10								
Reverse Lunge	25	5	35	5								
Clean Progression	45	1	50	1								
HC, PC, HSC, PSC	50	1	55	1	60	1	Open	1	Open	1		
Squat	55	5	45	5	60	5	65	5	Open	5		
RDL BB or DB	50	10	50	10	50	10						
Hip Mobility Circuit	Barbell Abs		PNF Stretch								Sign-off / Date	
Day 2												
Exercise	Set 1		Set 2		Set 3		Set 4		Set 5		Set 6	
Jerk Progression	45	5	GM	10								
Shoulder Circuit	10	5	I-T-Y	5								
Push Press **OR**	65	5	Open	5	Open	5	Open	5				
DB Push Press		5		5		5		5				
Bench Or DB Bench	45	10	50	5	60	5	65	5	70	5	70	**max**
Pull-ups or Blast Strap		10		10		10		10				
Lat Pulls or Rows / Dips	4x10 Super Set											
Regular Abs x30	Gun workout: bi-ceps, tri-ceps, shoulders										Sign-off / Date	
Day 3												
Exercise	Set 1		Set 2		Set 3		Set 4		Set 5		Set 6	
OH Squat/Lunge/GM	45	10	45	10								
Lunge	Easy	3	Med.	3								
Drop Snatch	45	5	45	5								
Hang Snatch **Or**	65	5	Open	5	Open	3	Open	3			**Light and Fast**	
DB Snatch	25	3	35	3	Open	3	Open	3			**3 each arm**	
Ft. Squat	40	5	55	4	50	5	60	4	Open	4	**Add Box Jumps**	
Side Lunge	45	5	45	5								
Hurdle Mobility Circuit												
Hypers/Glute Ham/Reverse Hypers/DB RDL 2x10												
Super Abs 1-22	Partner PNF Stretch										Sign-off / Date	
Day 4												
Exercise	Set 1		Set 2		Set 3		Set 4		Set 5		Set 6	
DB Shoulder Circuit	10	10	10	10	**(I-T-Y)**							
Jerk Progression	45	5										
DB Bench or Incline **Or**		5		5		5		5		5		
Speed Bench	Easy	10	55	3x3	60	3x3	65	3x3	70	3x3		
Block Push-ups/Australian pull-ups/Dips				3xfail								
Lat Pulls		10		10		10		10				
Barbell abs	3x20										Sign-off / Date	
Stabilizations	3x30	**Weigh-in**____________										
Beauty Lifts												