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COMPARATIVE EFFECTS OF CIRCUIT TRAINING AND PLYOMETRIC TRAINING ON MUSCULAR STRENGTH, SPRINT SPEED, AND AGILITY IN HOCKEY PLAYERS

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ABSTRACT

Background: Hockey is a field sport of intermittent and high intensity where muscular strength, sprint speed and quick change of direction are all directly related to match outcomes. Coaches regularly employ circuit training and plyometric training to develop these qualities, but there are few comparisons between the two methods in a population of hockey players.

Objective: This study compared the effects of a four week circuit training programme and a four week plyometric training programme on maximal lower body strength, sprint speed, and agility in hockey players.

Methods: Thirty male hockey players (mean age 24.2 years) were allocated to a circuit training group (n = 15) or a plyometric training group (n = 15) and completed twelve supervised training sessions delivered across an eight week period. Strength was assessed with the one repetition maximum barbell back squat, speed was assessed with a 50 metre sprint, and agility was assessed with the T-test. Assessments were carried out before and after the intervention by testers following standardized protocols. Within group changes were examined with paired samples t-tests and between group differences were examined with independent samples t-tests, with significance set at $p < 0.05$.

Results: Both groups improved significantly on all three outcomes ($p < 0.0001$ in every case). Strength increased by 12.1 percent in the circuit training group compared with 9.1 percent in the plyometric group, and this between group difference favoured circuit training ($t(28) = 5.32$, $p < 0.0001$, $d = 1.61$). Sprint time improved by 5.6 percent in the plyometric group compared with 3.3 percent in the circuit group, favouring plyometric training ($t(28) = 7.45$, $p < 0.0001$, $d = -1.98$). Agility improved by 6.1 percent in the plyometric group compared with 4.5 percent in the circuit group, again favouring plyometric training ($t(28) = 5.04$, $p < 0.0001$, $d = -0.95$).

Conclusion: Circuit training and plyometric training both produce meaningful gains in strength, speed, and agility in hockey players, but the two methods are not interchangeable. Circuit training appears better suited to developing maximal strength, while plyometric training appears better suited to developing sprint speed and change of direction ability. Coaches designing conditioning programmes for hockey players may benefit from combining or sequencing the two approaches according to the specific quality being targeted within a training block.
Keywords: circuit training; plyometric training; hockey; muscular strength; sprint speed; agility; team sport conditioning

1. Introduction

One of the more physically taxing invasion team sports is hockey played on artificial turf. During a game, players are constantly engaged in high speed running, accelerating and decelerating quickly, turning and changing directions, aerial contests, tackling, and stick play, which are intermittent and not played at a steady pace over four quarters [1]. Hockey relies heavily on the phosphocreatine and glycolytic systems for the short, near maximal efforts and the aerobic system for recovery between efforts and for the overall match to support the aerobic capacity of the sport. Strength, speed and agility are considered as much as important for a player as stick skill and tactical understanding since each individual passage of play is determined by whether a player can win a sprint, evade an opponent or close down space a fraction of a second sooner than the player they are contesting.

In team sport players, speed is a reflection of the ability of the neuromuscular system to produce power quickly; power is force x velocity, so an athlete's strength directly influences how fast they can produce the force during each ground contact of a sprint [3]. Rugby league players have provided evidence that maximal strength is related to lower body power in a significant fashion, and that lower body power is related to first step quickness, short distance acceleration and maximal running speed, indicating that strength and speed development are related but not independent training objectives [3]. In addition, the stretch shortening cycle of the muscle tendon unit, or the sequence of quick stretches of a muscle group followed by a quick shortening that allow elastic energy to be stored and released to create a greater and faster force output than concentric muscle action alone [4], have an impact on sprint performance. The efficiency of neuromuscular activation and flexibility of the lower limb further affect the mechanical qualities of the stride and how the forces are applied during the driving and recovery portions of the running stride [4,5].

Agility is typically defined as the ability to quickly and accurately change direction in response to a stimulus that is external to the performer [6] indicating that it is a different type of a change of direction. This reactive dimension is important in hockey, where the positions of the ball and other players are constantly changing, and the ability to decelerate, reorient and reaccelerate in response to play can often determine 1-on-1 situations and defensive recoveries [7]. Agility is a composite ability that is composed of balance, speed, strength and coordination and is not a single trainable ability [6,8] and hence the transfer of any single training for on field agility cannot be assumed.

Circuit training and plyometric training are two of the most popular types of conditioning to develop these qualities in team sport athletes, but they are very different from each other in terms of their physiologic demands. Circuit training is a combination of resistance training, endurance and high intensity aerobic exercise in a single training session, usually performed on moderate loads with little rest between exercises and has been applied extensively in team sports due to the development of both muscular strength and cardiovascular endurance in the same session while being time efficient [9]. In other sprint and agility dependent sports, circuit based protocols with short, high intensity stations have been demonstrated to be effective for enhancing sprint agility performance and anaerobic endurance [10]; a comparative study between circuit training and plyometric training in strength, speed and agility in state level lawn tennis players provided an interesting methodological precedent, although with different sport [9].

In contrast, plyometric training involves quick, explosive movements, including bouncing, hopping, depth jumping and countermovement jumping, which are specifically designed to take advantage of the stretch shortening cycle [11]. A popular meta analysis revealed that structured plyometric training causes significant increases in vertical jump height, with the mean increases ranging from approximately 4.7 percent in squat jump and drop jump performance to 8.7 percent in countermovement jump performance with an arm swing [12]. Lower body explosive power is associated with vertical jump height and explosive power is a good physiological indicator of acceleration and change of direction ability, so this makes a strong sense to incorporate the plyometric component in Hockey conditioning. Six weeks of plyometric drop jump training has been shown to enhance short sprint and change of direction ability, both with and without a focus on the eccentric phase [13] which is directly applicable to the present study where both of these qualities are targeted.

The two methods are thus different in nature. Circuit training usually has submaximal to moderate loads and a relatively high total volume, while plyometric training has fewer repetitions at near maximal loads and a high focus on ground contact time and quality of movement and not on the volume. This distinction offers the conceptual framework for one to expect different patterns of adaptation to emerge with the two methods with respect to strength, speed and agility outcomes. However, the superior adaptations of each method when applied under matched conditions to the same cohort of hockey players remain relatively unanswered, as most of the comparative data have come from other sports and other groups of athletes, e.g., the adolescent or the recreational player [9,14,15].

In the present study, circuit training and plyometric training were compared over a matched training period for three outcomes that are important to hockey performance: maximal strength, sprint speed, and agility. We hypothesised that circuit training might yield greater increase in maximal strength due to the focus on moderate to heavy resistance and motor unit recruitment, and that plyometric training might yield greater increases in sprint speed and agility due to the focus on rate of force production and stretch shortening cycle efficiency.

2. Materials and Methods:

2.1 Study Design and Ethical Approval

This was a randomized parallel group comparative study where 2 training interventions were given simultaneously and evaluated before and after 8 weeks. The study was approved by the Research Ethics Committee, Prakash Institute of Physiotherapy, Rehabilitation and Allied Medical Sciences, Gautam Buddh Nagar, Greater Noida and was carried out following the Declaration of Helsinki. Written informed consent was obtained after a thorough description of the study procedures, risks and the ability to withdraw at any time without penalty.

This study was prospectively registered with the Clinical Trials Registry India (CTRI), registration number CTRI/2026/07/113369.

2.2 Setting and Participants

The test and training were conducted at the Abilities cricket academy CK PlayStation, knowledge Park-3 Greater Noida, located in Uttar Pradesh, India where the training areas were suitable to the games, sufficient space was available for sprint and agility testing and consistent environmental conditions were maintained. Male hockey players were recruited from hockey clubs and sports facilities of Greater Noida area by direct contact with the clubs and distribution of study information sheets.

Players were allowed to participate if they were between the ages of 18-35, had at least 12 sessions of organized hockey training per week, had at least 1 year of competitive playing experience, had a minimum of medical clearance for high intensity training and not enrolled in a structured strength or plyometric programme. Players were removed from the study if they had experienced an upper or lower extremity musculoskeletal injury in the six months prior to the study, had previously fractured, undergone surgery or had had a ligament injury in the six months before the study was conducted, had any condition of the nervous system that impacted movement control, had any cardiovascular or systemic disease that would contraindicate participation in high intensity exercise, were taking medication known to affect their performance or recovery, or were unable to attend all of the training and testing sessions.

Screening comprised administration of a medical history questionnaire, medical check-up of previous musculoskeletal injury and a structured interview about the current training status. The eligible players were given a baseline test and demographic details such as height, weight, competitive experience and training history.

2.3 Randomization

To minimize risk of selection bias, players were randomly assigned to either the circuit training or plyometric training group by computer-generated random number code and only revealed after baseline testing was completed. Thirty players (circuit training = 15, plyometric training = 15) finished the study.

2.4 Training Interventions

The two groups participated in eight weeks of training (3 supervised sessions/week) on non-consecutive days. The sessions were conducted in a single facility by trained research staff who supervised technique and protocol execution and attendance was recorded for each participant.

Circuit training (Group A). The five stations, squats, push ups, forward lunges, step ups onto the 40 cm high platform, and 15m shuttle runs were performed for 40 seconds at each station with a transition of 20 seconds between stations. Each participant ran 3 laps/session each with 2 minutes of rest. The squat worked quadriceps, hamstrings and gluteus maximus, the push up worked pectoralis major, triceps and front of the shoulder, the lunge and step up worked the unilateral lower body with the resistance, and the shuttle run combined the speed and agility stimulus with the resistance.

Plyometric training (Group B). Five explosive exercises, jump squats, box jump onto box (60cm), 20m bounding, box jump over obstacle (30cm), single leg hop were completed for 3 sets of 8-10 repetitions with 30s of rest between exercises and 2mins between sets. Coaching focus for all throughout was on controlled landing mechanics, correct alignment, and reducing the amount of time in contact whilst maximising the stretch shortening cycle, with exercises being progressed/regressed for each individual based on their demonstrated movement quality.

2.5 Outcome Measures

The three outcomes were measured at baseline and 3-5 days after the last training session, employing the same procedures and equipment at each measurement. All testing was preceded by a light aerobic exercise and dynamic stretching routine for 5 minutes.

Muscular strength. A 1RM barbell back squat test was used to assess maximal strength, as strength of the squat is related to acceleration, jumping and change of direction capacity in field sport athletes. The two sets of five repetitions were followed by a progressive loading of 5–10 kg in increments, taking 2–3 minutes rest between sets, until the athlete was only able to perform 1 repetition to full range of motion. The heaviest successful lift was measured in kilograms.

Sprint speed. Running speed was measured by sprinting on a track (50 metres) with cones at the start, finish, and 10, 20, 30 and 40 metres. At the word ‘go', participants sprinted as fast as possible for the finish line and time was measured to the nearest 0.01 second on an electronic stopwatch. Time was measured with a recovery period of three minutes between the two trials and the faster time was used for analysis.

Agility. Agility was evaluated using the T-test with four cones set out 10 metres directly ahead of the starting cone A, followed by cones C and D, 5 metres to the left and right of B, respectively. All participants ran as fast as possible from A to B, side shuffled to touch C, side shuffled across to touch D, side shuffled back to touch B and then run backward across the line to A (time taken recorded to the nearest 0.01 second). Two trials were conducted with a 2-minute break between the two and the faster time was accepted.

2.6 Statistical Analysis

Data were entered into Microsoft Excel, screened for entry errors and outliers, and analysed in SPSS version 26.0 (IBM Corp., Armonk, New York, United States). Continuous variables are presented as mean and standard deviation. Normality of the change scores was checked with the Shapiro-Wilk test. Baseline equivalence between groups was examined with independent samples t-tests. Within group change from pre to post intervention was examined with paired samples t-tests, and between group differences in the magnitude of change were examined with independent samples t-tests; where the normality assumption was not met, the Wilcoxon signed rank test and Mann-Whitney U test were used respectively. Effect sizes are reported as Cohen's d, and a 95 percent confidence interval accompanied each mean change. Statistical significance was set at $p < 0.05$.

3. Results

3.1 Participant Characteristics

Thirty hockey players completed the study (circuit training, n = 15; plyometric training, n = 15). Age, body mass index, and playing experience did not differ significantly between groups, indicating that randomization achieved comparable groups on these demographic variables (Table 1).

Table 1. Baseline demographic characteristics by group

Variable	Circuit (n=15) M (SD)	Plyometric (n=15) M (SD)	t-value	p-value	Sig.
Age (years)	24.33 (4.01)	24.13 (3.87)	0.139	0.891	ns
BMI (kg/m²)	25.47 (1.89)	26.23 (2.04)	-1.363	0.184	ns
Experience (years)	3.77 (1.97)	4.07 (1.76)	-0.439	0.664	ns

3.2 Baseline Performance

Independent samples t-tests on the three outcome variables at baseline showed one significant group difference: the circuit training group had higher pre training strength than the plyometric group ($t(28) = 2.307$, $p = 0.029$, $d = 0.96$). Baseline speed ($p = 0.776$) and agility ($p = 0.444$) did not differ between groups (Table 2). This baseline imbalance in strength is addressed further in the discussion, since it has a bearing on how the strength results should be interpreted.

Table 2. Baseline performance by group

Measure	Circuit M (SD)	Plyometric M (SD)	t(28)	p-value	Cohen's d
Strength (kg)	94.13 (9.24)	85.27 (8.67)	2.307	0.029*	0.96
Speed (s)	7.58 (0.42)	7.67 (0.38)	-0.288	0.776	-0.24
Agility (s)	11.48 (0.71)	11.51 (0.63)	-0.776	0.444	-0.04

3.3 Within Group Changes

Both groups improved significantly on all three measures from pre to post intervention ($p < 0.0001$ throughout), although the size of the improvement differed by training type and outcome (Table 3).

For strength, the circuit training group increased 1RM by a mean of 11.39 kg, a 12.1 percent gain (95% CI 10.14 to 12.64), $t(14) = -19.55$, $p < 0.0001$, $d = 0.997$. The plyometric group increased 1RM by a mean of 7.76 kg, a 9.1 percent gain (95% CI 6.80 to 8.72), $t(14) = -21.87$, $p < 0.0001$, $d = 0.797$.

For speed, the circuit training group reduced sprint time by a mean of 0.25 seconds, a 3.3 percent improvement (95% CI 0.22 to 0.29), $t(14) = 18.99$, $p < 0.0001$, $d = -0.632$. The plyometric group reduced sprint time by a mean of 0.43 seconds, a 5.6 percent improvement (95% CI 0.38 to 0.48), $t(14) = 20.82$, $p < 0.0001$, $d = -1.115$.

For agility, the circuit training group reduced T-test time by a mean of 0.52 seconds, a 4.5 percent improvement (95% CI 0.46 to 0.58), $t(14) = 18.10$, $p < 0.0001$, $d = -0.788$. The plyometric group reduced T-test time by a mean of 0.71 seconds, a 6.1 percent improvement (95% CI 0.63 to 0.79), t(14) = 28.19, $p < 0.0001$, d = -1.057.

Table 3. Within group pre to post changes and effect sizes

Measure	Group	Δ (SD)	% Change	t(14)	d
Strength	Circuit	11.39 (4.68)	+12.1%	-19.55***	0.997
(1RM kg)	Plyometric	7.76 (4.09)	+9.1%	-21.87***	0.797
Speed	Circuit	-0.25 (0.18)	-3.3%	18.99***	-0.632
(50m sec)	Plyometric	-0.43 (0.20)	-5.6%	20.82***	-1.115
Agility	Circuit	-0.52 (0.20)	-4.5%	18.10***	-0.788
(T-test sec)	Plyometric	-0.71 (0.20)	-6.1%	28.19***	-1.057

Note. Δ = Mean change; SD = Standard Deviation; % Change = percentage change from baseline; d = Cohen's effect size; *** $p < 0.0001$

3.4 Between Group Comparisons

Independent samples t-tests on the magnitude of change confirmed statistically significant differences between groups on every outcome (Table 4). Circuit training produced a significantly larger strength gain than plyometric training (11.39 kg versus 7.76 kg, t(28) = 5.324, $p < 0.0001$, d = 1.61). Plyometric training produced a significantly larger improvement in sprint speed than circuit training (-0.43 s versus -0.25 s, t(28) = 7.445, $p < 0.0001$, d = -1.98) and a significantly larger improvement in agility (-0.71 s versus -0.52 s, t(28) = 5.036, $p < 0.0001$, d = -0.95).

Table 4. Between group comparison of change scores

Measure	Circuit ΔM (SD)	Plyometric ΔM (SD)	t(28)	p-value	d
Strength (kg)	11.39 (4.68)	7.76 (4.09)	5.324	<0.0001***	1.61
Speed (s)	-0.25 (0.18)	-0.43 (0.20)	7.445	<0.0001***	-1.98
Agility (s)	-0.52 (0.20)	-0.71 (0.20)	5.036	<0.0001***	-0.95

Taken together, these results indicate that neither training method was superior across the board. Circuit training produced the larger gain in maximal strength, while plyometric training produced the larger gains in sprint speed and agility, and all three between group differences were associated with large effect sizes.

4. Discussion

4.1 Principal Findings

This study compared circuit training to plyometric training in hockey players and determined that both training techniques were effective for improving strength, speed and agility in hockey players over an 8 week time frame, but that the two types of training were different in the magnitude of improvement they provided. Circuit training led to higher gains in maximal strength (12.1 percent compared with 9.1 percent for plyometric training), while plyometric training resulted in higher gains in sprint speed (5.6 percent compared with 3.3 percent) and agility (6.1 percent compared with 4.5 percent). All between group differences were significant and all of the effect sizes associated with those differences were large, indicating that this pattern is not likely attributable to sampling noise.

The comparative advantages of circuit training for enhancing strength are presented.Circuit Training Favoured Strength (4.2).

The strength advantage seen with circuit training is consistent with well established principles of resistance training adaptation. The circuit protocols employed in this design have moderate to heavy external loads and mechanical tension of this type is thought to be a key factor in the initiation of strength adaptation as it requires the recruitment of a large percentage of the available motor units and it stimulates neural and hypertrophic adaptation. The format of circuit training also made it easy to implement progressive overload from one session to another and had enough rest between sets, on average 2-3 minutes between circuits, to allow near complete recovery of the phosphocreatine system before the next high intensity set. By contrast, the loading intensity of plyometric exercises tends to be less in comparison and the ground reaction forces in a plyometric exercise typically range from 1.5 to 3 times body weight, whereas heavier resistance training ranged from 2 to 5 times body weight or greater, and despite its effectiveness in producing a large strength gain, it was not found to generate the same level of mechanical tension required for maximal strength capacity.

Exercise 4.3: Why Plyometric Training Favoured Speed

The velocity specific nature of training adaptation is reflected by the clear speed advantage of plyometrics; the between group effect size was very large. Sprinting involves generating force over a very short ground contact time (0.08 - 0.12 seconds per step) and plyometric exercises are designed to train the rate of force development within this time window. Plyometric training is also believed to promote motor unit firing rates and recruitment of motor units appropriate for rapid acceleration, and to increase the efficiency of the stretch shortening cycle to allow greater elastic storage and return during ground contact via the tendons and connective tissue. It did increase speed significantly, but that was because the circuit group was getting more general strength adaptations, and because the time under tension in a typical resistance repetition is 1-2 seconds, compared to the <0.2 second ground contact time in a sprint stride, that is a major factor in the size of the speed gains that were seen in the circuit group.

4.4.1 Plyometric Training Favoured Agility

Agility performance requires the same qualities of rapid force production principles that are emphasized by plyometric training, along with the added requirement to decelerate, re-orient and reaccelerate through the many directional changes in the T-test. It is likely that the greater improvement noted amongst the plyometric group is due to exercises that closely simulate the high velocity, short ground contact requirements of change of direction movement being more directly transferred to the agility field as compared to exercises that are primarily designed for slower, higher load resistance. This finding is consistent with the overall literature of plyometric training for power and speed related outcomes, which has generally found greater effects with plyometric protocols on these specific outcomes than with strength training alone.

4.5 Interpreting the Findings Together

None of this can be taken as evidence that any one of the above methods, overall, is better than the other. Instead, the trend for each of the three outcomes is in favor of the training specificity principle, which states that adaptations are most closely related to the specific demands placed on the neuromuscular system during training. If a hockey conditioning programme is focused on one method it is unlikely that the other quality domain will be included. However, a periodized approach where the focus is to train circuit type resistance training in one phase followed by plyometric training in another phase (such as resistance training before the plyometric phase) may be a more complete approach than either of the two alone and, as noted above, this was not explicitly tested in this study and remains an inference rather than a tested fact.

The results obtained were compared with the existing literature.

These results are in line with previous studies in other sports, such as comparing circuit training and plyometric training in state level lawn tennis athletes, and complement the general evidence base for Plyometrics training for power and speed development to a hockey specific sample. In the present study, the two methods are directly compared within one trial, three related but distinct performance domains are measured instead of only one, and effect sizes are reported, thus enabling the practical, not only statistical, magnitude of the differential effects to be judged.

4.7 Limitations

There are some caveats to be taken into account when interpreting these results. The baseline difference between groups, however, and the fact that the primary between group analysis was based on change scores not absolute post-training scores, should be taken with a pinch of salt with regards to the strength specific conclusion; a design with the same baseline across all three outcomes would further validate the strength specific conclusion. While this sample size of 15 per group offers sufficient power for the large effects found here, it is not sufficient for the smaller or moderate effects, and a larger sample would increase power and generalizability. Findings might not be applicable to female athletes, junior or masters age athletes, or those with a different training background, as participants comprised male hockey players from one facility with one range of playing experience. The eight week intervention period was long enough to observe a significant change, but not long enough to be a training year, and it is uncertain whether the differential pattern observed in this study would continue to become more distinct or more similar as training lengthened. It should be noted that the training volume was not formally compared between the 2 protocols so it is difficult to separate the strength advantage of circuit training from the potential differences in training volume between the two protocols. A single test (the 1RM squat, 50 metre sprint, T-test) was used to evaluate each of the outcome domains, with a larger assessment battery and/or sport specific performance measures (e.g. skating speed or match derived measures) providing a more comprehensive picture of how these gains are reflected in competition. Lastly, analysis was not adjusted for multiple comparisons, and sleep, nutrition or motivation – among other potentially confounded factors – were not formally incorporated in the analysis that might unconfound training response by differing between groups.

4.8 Practical Applications

The implications for practitioners who are creating conditioning programs for hockey players are quite simple, if not foolproof. If the main focus of the training block is to develop maximal lower body strength, then a circuit based resistance approach seems to provide a greater stimulus. A plyometric training approach seems to provide a greater stimulus where the emphasis is to develop the ability to run in a straight line or to change of direction. If most hockey players require a certain amount of each of these qualities, then a programme that has specific times or sessions devoted to each of these methods, but does not rely on just one, will likely benefit the development of players better than either of these methods alone.

4.9 Future Research

More research is needed to establish if the differential pattern reported in this study persists after 12-16 weeks or beyond of training; if the combined circuit and plyo training protocol results in more balanced gains across all three qualities than either circuit or plyo training alone; and if the same 'differential' is observed for female hockey players, younger and older groups of players, and players with differing baseline strength training experience. To understand the mechanisms behind the differential adaptations described here, studies that include sport specific performance outcomes and studies that use a neuromuscular or biomechanical measure like electromyography or force plate analysis would be useful.

5. Conclusion

Circuit training and plyometric training significantly increased strength, speed and agility in a group of hockey players over an 8 week period, although the two training methods did not achieve the same benefits in the same areas. All between group differences were large and circuit training had greater gains in maximal strength and plyometric training had greater gains in sprint speed and agility. The findings agree with the training specificity principle and provide a utilisation guide for coaches and sports physiotherapists to choose or combine conditioning techniques based on the quality of performance they seek when designing a hockey training programme.

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