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Impact of Three Weekly Sessions of Complex versus French Contrast Training on Physical and Physiological Responses in Field Hockey Players: A Randomized Control Trial

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Abstract

This investigation aimed to shed light on the potential benefits these training methods can offer athletes attempting to improve their abilities in their game on the field. The complex training group (CMT), the French contrast training group (FCT), and the active control group (ACG) comprised 15 male field hockey players (Total 45 field hockey players) with an average age of 19.42±1.18 years. These players were randomly allocated to three equal groups. There were 36 training sessions in each training group over three months, with CMT and FCT training interventions being carried out thrice weekly. Participants in the ACG group went through their daily hockey practice regimen. In physical outcome measures, there were no significant differences in speed across groups (p=0.280), but significant variations were seen with time (p<0.01) and when groups and time were combined (p<0.01). Significant differences were seen for Change of direction (COD) and muscular endurance (ME) between groups (p<0.01) across time (p<0.01) and in the interaction between groups and time (p<0.01). In physiological outcome measures, anaerobic power (AP), vital capacity (VC), and VO2 max showed significant changes between groups (p<0.01) over time (p<0.01) and in the interaction between groups and time (p<0.01). In contrast, resting heart rate (RHR) showed no significant variations between groups (p=0.317), either across time (p=0.662) or in the interaction between groups and time (p=0.052). It concluded that CMT and FCT enhanced hockey players' COD, ME, AP, VC, and VO2 max. The FCT group outperformed the CMT group, proving its usefulness in improving athletic performance.

Keywords: *anaerobic power, complex training, French contrast training, vital capacity, VO2 max*

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Introduction

Hockey is a team sport requiring various equipment, involving unpredictable movement patterns influenced by the dynamic and longer match condition (McGuinness et al., 2017) . During the match, field hockey players engage in high-speed running, quick directional changes, and accelerations, utilizing strategic offensive and defensive maneuvers within confined spaces to optimize performance and secure the competitive success (McGuinness et al., 2020). The field hockey game has seen a substantial increase in the physical demands placed on players over the previous ten years. Particularly challenging on the lumbar spine and lower limbs are the distinctive flexed hip/trunk postures, rapid speed changes, and quick directional shifts characteristic of this exercise (Beddows et al., 2020). For much of the game, players must possess the following physical skills: power, endurance, muscular strength, and dynamic balance (Ramasamy et al., 2022). Any disruption to these activities during play will increase a player's risk of many injuries and reduce their effectiveness (Stokes et al., 2020). Suggestions from previous narrative and systematic reviews and meta-analyses have highlighted the significance of the treatment options by improving physiological and physical outcomes and lowering several injury risk variables in a variety of sports populations (Dolci et al., 2020; Lesinski et al., 2020; Moscatelli et al., 2023; Ramirez-campillo et al., 2021, 2022; Saeterbakken et al., 2022; Thiele et al., 2020; Vasconcelos et al., 2020; Vincent et al., 2022), which includes resistance and plyometric training interventions. In recent times, strength and conditioning coaches and trainers have been increasingly embracing these training methods in order to enhance the athletic performance of their athletes (Ramirez-campillo et al., 2021; Saeterbakken et al., 2022) especially the combination of both in the same training (Oliver et al., 2024). Some earlier studies referred to complex training (CMT) as an alternative term for combining plyometric and resistance training in a single workout session, which was becoming increasingly popular among the experts (Ojeda et al., 2016).

By analyzing fitness testing results, sports scientists and strength and conditioning professionals can better grasp their athletes' present fitness profiles. It is possible to use this information to build a training program that corresponds to each player's requirements, including the requirements of their playing position (Pešič et al., 2024; Turner et al., 2019). A strong aerobic capacity and the ability to undertake repeated high-intensity efforts while simultaneously accurately performing difficult stick and ball skills are two primary performance markers associated with top-level competition (Lombard et al., 2021). As with many individual and team sports, the length of the competition makes aerobic endurance more crucial for the participants, but there are also a lot of sprint and power actions that play a role in hockey competition victory. Due to the influence of stick swing speed and players' ability to change direction, sprint and agility talents are crucial for competitive success in hockey. Consequently, in field hockey training, training regimens that increase an athlete's strength and speed are frequently used in addition to endurance training (Güllich, 2014).

The concept of 'complex training' refers to a training mode that combines one set of strength training with a similar set of plyometric exercises in the same training session and is thought to improve the quality of the plyometric training stimulus. Combining biomechanically comparable workouts is beneficial for boosting force production and dynamic power rate through improved neuromuscular control. High-intensity resistance training prepares the body for plyometrics by affecting neuromuscular, hormonal, metabolic, and psychomotor aspects. This method promotes neural adaptations that enhance physical abilities (Ali et al., 2017). A study by Kanniyan and Syed (2013) emphasizes that the results demonstrated a significant improvement in all evaluated variables compared to the control group for both the CMT and contrast training groups. Throughout a 10-week training session, the CMT group improved more than the contrast training group in several areas, such as speed and muscle endurance, even though the contrast training group also showed notable advantages in resting heart rate (RHR) and cardiorespiratory endurance. CMT's ability to increase the power of lighter exercises is believed to be due to PAP (Robbins, 2005).

CMT refers to varying movement velocity or load between sets or exercises within a session to improve slow and fast force expression. There are four types of CMT: contrast training, ascending training, descending training, and French contrast training (FCT), which involves performing a series of exercises (Cormier et al., 2022)with a combination of both CMT and contrast training (Michael et al., 2022), entails performing a series of exercises in a single session in a specific order. These exercises include things like heavy compound exercises (resistance exercises), lighter exercises (plyometric exercises), light-to-moderate load compound exercises that maximize movement speed (also externally loaded power exercises), and an assisted plyometric exercise (Gould, 2021). The FCT Method is one of the many CMT approaches that have been presented in order to have the most significant possible impact on the post-activation performance enhancement (PAPE) phenomena (Rebelo et al., 2023; Türkarslan & Deliceoğlu, 2024) even though PAP and PAPE are connected (Villalon-gasch et al., 2022), it is possible to consider them to be two distinct phenomena. This is because the processes that cause PAP are distinct from those that produce PAPE. Electrostimulation is the source of PAP, characterized by an increase in the efficiency of contractions due to a more optimal coupling of actin and myosin (Chen et al., 2017).

On the other hand, PAPE is associated with various factors, including but not limited to conditions such as the temperature of the muscle, the amount of water present in the muscle fibres, and the number of motor units that are activated (Blazevich & Babault, 2019). As a result, their effects may manifest at varying periods and degrees of intensity (Zimmermann et al., 2020). Previous research has only conducted a limited number of studies that have studied the impact of CMT on the physical and physiological variables (Kanniyan & Syed, 2013), especially on hockey players (Rathi et al., 2023; Thapa et al., 2023). Some of them explore the influence of FCT on agility (Salam & Sherif, 2020), speed (Türkarslan & Deliceoğlu, 2024), maximal strength and power (Rebelo et al., 2023) and some of the other physical variables (Elbadry et al., 2019; Welch et al., 2019). No experiment has been carried out in the past that has discriminated between the effects of CMT and FCT on physical and physiological characteristics among field hockey players. Hence, the researcher aimed to explore the influence of CMT and FCT on physical and physiological variables among field hockey players and determine which training intervention has highly influenced those variables over 3-months of intervention.

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Methods

Ethical approval

All of the participants in this study were provided with information on the aims and general procedures of the whole research project, and they voluntarily consented to participate in the study by signing a written consent form that the committee authorized. This was done to ensure that the scientific findings obtained from this study were reliable. The study was conducted by the declaration of Helsinki (World Medical Association, 2013) and received approval from the institutional ethics committee at Pondicherry University (Approval No. HEC/PU/2023/05/07-08-2023).

Participants

Fifty male hockey players from Union Christian College in Aluva, India, provided written consent and agreed to participate in this study. One of the inclusion criteria was five years of playing experience in field hockey, and two years of resistance training and plyometric experience were fixed. Players with a history of musculoskeletal injury were omitted from this study according to the exclusion criteria. In this study, five hockey players were removed prior to the initial test due to a history of pre-existing musculoskeletal injury. The researcher utilized the G*Power 3.1.9.7 software Franz Faul developed at the University of Kiel in Germany to determine the appropriate sample size. During the calculation, the following variables were taken into consideration: effect size for within-between interaction in repeated measures ANOVA: three groups, two measurements, and a priori: compute required sample size - given, power, desired power (1-ß error) =0.80, alpha error <0.05, non-sphericity correction =1, effect size (f) of 0.25, the correlation between repeated measures =0.5, and effect size (f) of 0.25. According to the results of the computation of the sample size, a minimum of 42 participants would be necessary in order to attain statistical significance in the context of the study (Chovanec & Gröpel, 2020). Given the possibility of individuals dropping out of the study, a slightly higher sample size of 45 male participants was considered for this study. To assess the power (1-ß error) with 45 participants, post hoc: compute achieved power-given sample size, and effect size was tested using G*Power. The output parameter shows that the power (1-ß error) =0.83, which is increased by 0.03. After the inclusion and exclusion criteria, the selected participant's (n=45) age was 19.47±1.16, height: 1.69±0.07, weight was 64.16±4.98, and body mass index (BMI) was 22.44±1.26. No dropouts were observed after or during the training program.

Study design (Experimental approach to the problem)

A 3x2 randomized controlled trial was conducted over three months to examine the effects of CMT and FCT on selected parameters in field hockey players. The participants were classified into three groups, each comprising fifteen participants. The CMT group carried out the Complex training intervention, while the FCT group carried out the French contrast training intervention. Both intervention groups participated in three sessions per week over 3-months of intervention, and participants received ample recovery between sessions. The active control group (ACG) performed no exercises beyond the regular field hockey training. Demographic data were obtained before the training program and familiarization session started. Participants completed two weeks of familiarization sessions, comprising CMT and FCT activities, and one session for the testing process. One repetition maximum (1 RM) test was conducted at least one week before baseline testing. During familiarization sessions, participants performed squats, box jumps, bench presses, a 1 kg medicine ball overhead wall throw for CMT training and squats, and box jumps, weighted jumps, band-assisted vertical jump and bench presses, a 1 kg medicine ball overhead wall throw, push press, and band assisted push-ups for FCT training. These were helpful for training prescriptions and providing the participants with a better understanding of the training program. After completing the 1 RM test for each resistance training exercise, baseline tests (Time 1) were evaluated for each of the variables chosen for the study. One day before the baseline test (Time 1), the participants were instructed to refrain from indulging in any form of strenuous activity and to consume a meal that they regularly consume. End line test (Time 2) was used to assess after the commencement of 3 months of CMT and FCT training intervention. The semantic representation of the investigation explains the sample sizes in different stages (Figure 1).

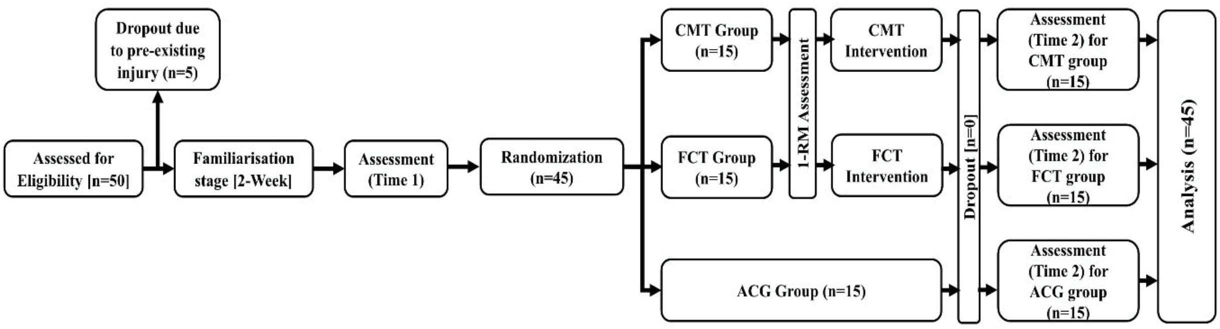

Figure 1. Semantic Representation

Intervention

CMT and FCT groups have completed three sessions per week, and 36 training sessions were given for each treatment group. Each treatment group performed standardized warming-ups and cooling down specific training programs for each group. Warming ups include general and specific for toning the muscles to perform the specific training program (CMT and FCT). CMT and FCT training were given to the subjects based on the training mentioned in the narrative review by Cormier et al. (2022). Every participant began their resistance training (high load activity) in CMT and FCT training with an intensity level of sixty per cent throughout the first few weeks of the program. From the first to three weeks, the intensity of the training ranged from sixty to seventy per cent; from the fourth to six weeks, it was sixty to seventy-five per cent; from the seventh to ninth weeks, it was seventy to eighty per cent; and from the tenth to twelve weeks, it was seventy-five to eighty-five per cent. For plyometric training (low load activities) in CMT and FCT training, first to three weeks, the intensity of the training fixed to a 12-inch box (box height) for lower extremities and l kg weight (medicine ball) for upper extremities; in the fourth to six weeks, it was an 18-inch box for lower extremities and 3 kg weight for upper extremities; in the seventh to ninth weeks, it was 24-inch box for lower extremities and 5 kg weight for upper extremities; and in the tenth to twelve weeks, it was 24 inch box for lower extremities and 5 kg weight for upper extremities. For the FCT group weighted plyometric exercise (3rd exercise), 30-40 per cent of 1 RM was fixed for 3- months, and assisted plyometrics (4th exercise) sets and repetition progressively increased. The appropriate recovery time was provided between each set and workout.

Load measurement

The 1RM test was frequently used to assess the individualized training intensities of the participants (Kumar et al., 2024). Prior to every evaluation, the participants went through a familiarization session. Additionally, general and specific warm-up, which lasted for ten to fifteen minutes, was performed before each evaluation. The weight was gradually increased to five kilograms to accomplish the 1 RM in a maximum of five attempts. There was a four-minute break in between each 1 RM effort. Spotters with experience secured the safety. The training loads for CMT and FCT were set as a percentage of each participant's 1RM to maximize strength and power gains.

Outcome measures

The outcome measures employed in this investigation provide extensive supporting data for the study's results. Metrics like speed, COD, and ME are classified as physical outcome measures. This study's physiological outcome measurements included AP, RHR, Vital capacity (VC), and $VO_{2\ max}$. In the morning before and after 3-months of intervention, a baseline (Time1) assessment and an end-line (Time2) assessment were used to look at all the outcome measures for this study. Participant height was measured using a standard stadiometer (MCP 2m/200CM Roll Ruler Wall Mounted Growth Stature Meter), weight was assessed with a digital weighing machine (HD-93), and body mass index was calculated using the formula: weight (kg) / height (m^2).

In physical outcome measures, the speed was tested with a widely used test 50m dash, which was measured in seconds (Bartosz et al., 2024; Zabaloy et al., 2021). Individualized warm-ups were followed by two 50-meter sprints on an outdoor track, with a 5 to 10-minute break. Experienced sprinters used individualized warm-ups to optimize performance and prevent injuries (Martín-Fuentes & van den Tillaar, 2022). The subjects started each sprint in a split stance, with one hand on the floor and the other behind the line, which is commonly utilized in training. Three timers were used for each attempt, and a hand stopwatch(Thapa et al., 2023) (NIVIA JS 609 Digital Stop Watch, Freewill Sports Pvt. Ltd., India) was used to obtain measures of the speed of the participants. The interclass correlation coefficient (ICC) for test-retest reliability was 0.95 (95% confidence Interval [CI]: 0.861–0.984, Coefficients of variation [CV]: 4.8% presented in table 3.

The Change of direction (COD) was evaluated using the Illinois agility test, an acceptable tool for evaluating the COD, measured in seconds (Pauli et al., 2023). The field is 10 m long and 5 m wide between start and finish positions. Four cones were positioned in the centre of the testing area, 3.3 m apart. Four cones indicated the beginning, end, and two turning places. Individualized warm-ups were followed by one trial on a specific field, with ample recovery given between trial and test. The individuals began the test lying prone, hands at shoulder level. The trial began with the "go" instruction, prompting the individuals to run as quickly as possible. The trial ended when the players crossed the finish line without knocking down cones (Cao et al., 2020). The best time from three trials was utilized for analysis (Andrašić et al., 2021). Hand stopwatch (NIVIA JS 609 Digital Stop Watch, Freewill Sports Pvt. Ltd., India) used to record the COD. The interclass correlation coefficient (ICC) for test-retest reliability was 0.98 (95% confidence Interval [CI]: 0.943–0.994, Coefficients of variation [CV]: 5.3% presented in table 3.

Finally, muscular endurance (ME) was tested with a sit-up test (Cho et al., 2024). Participants were told to lie supine with both hands folded behind their heads and legs at a 45-degree angle (Jeong & Chun, 2021). Each time the participants contacted their knee and returned to a supine posture, it was counted as one successful repetition (Zhang et al., 2021). The maximum number of repeats was timed for one minute. The interclass correlation coefficient (ICC) for test-retest reliability was 0.87 (95% confidence Interval [CI]: 0.635–0.959, Coefficients of variation [CV]: 5.8% presented in table 3.

In physiological outcome measures, the stair run test developed by Margeria Kalamen is recognized as one of the most widely used techniques for determining Anaerobic power (AP) (Cabre et al., 2024). The Margaria Kalamen stair run power test measures the time between the third and ninth steps. Participants completed a standard aerobic warm-up, stretching, and three submaximal stair runs. Participants started 6 meters from the stair base. Upon receiving the start signal, participants sprint and take three steps on the third, sixth, and ninth steps to ascend as quickly as possible. A stopwatch records the time from the third to the ninth step, beginning when the foot contacts the third step and finishing when it touches the ninth step, each step approximately 17.5 inches (Morse & Biggerstaff, 2024). Three test trials with pauses of 2-3 minutes each were allowed. The power output was calculated by the formula $P=(W*D)9.8/t$. P= Anaerobic power, W= body weight, D= vertical distance (3rd to 9th step), 9.8= gravity (constant), t= time taken (3rd to 9th step) (Pramod & K, 2023). The interclass correlation coefficient (ICC) for test-retest reliability was 0.98 (95% confidence Interval [CI]: 0.963–0.996, Coefficients of variation [CV]: 10.9% presented in table 3.

Resting heart rate (RHR) was tested with the manual radial palpation method. Because the pulse rate is identical to the heartbeat, the radial palpation approach is the most straightforward and widely utilized method, measured in numbers per minute (Cooney et al., 2010). The test was administered in the morning before any activities. The subject was sitting and resting for a minimum of five minutes when the RHR was measured. Using the tips of the index and middle fingers, find the radial artery on the thumb side of their wrist (Motimath

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& Rajan, 2020). Feel the pulse, count the beats for thirty seconds, then multiply by two to get beats/ minutes. To prevent variations in the subject's RHR, the researcher ensured that the subject remained quiet during the test. The interclass correlation coefficient (ICC) for test-retest reliability was 0.94 (95% confidence Interval [CI]: 0.834–0.982, Coefficients of variation [CV]: 2.8% presented in table 3.

Vital capacity (VC) was tested with a spirometer, measured in litres (Fabrin et al., 2023). The participants received comprehensive verbal instruction in this test before taking the exam. The participants were instructed to inhale deeply through their clipped nostrils and then exhale forcefully into the spirometer's opening. Participants had to ensure that their mouths and the spirometer's opening were tightly sealed during the test. There were three trials for each contestant. VC score was determined by taking the best of the three. The spirometer was thoroughly inspected each time in preparation for the following trial. The interclass correlation coefficient (ICC) for test-retest reliability was 0.95 (95% confidence Interval [CI]: 0.861–0.981, Coefficients of variation [CV]: 6.8% presented in table 3.

Finally, the $VO_{2\ max}$ was tested using the Queens College step test (Salehi et al., 2017). The step test was carried out from a height of 16.25 inches (Aryal et al., 2020). The stepping was done for three minutes, with a rate of twenty-four steps per minute stated. After finishing the work, the carotid pulse rate was monitored from the fifth to the thirtieth seconds of recovery. The 30-second pulse rate was translated into beats per minute. Finally, the $VO_{2\ max}$ score was calculated using the following equation: $VO_{2\ max}$ = 111.3- (0.42 x pulse rate beat/min). The interclass correlation coefficient (ICC) for test-retest reliability was 0.96 (95% confidence Interval [CI]: 0.909–0.990, Coefficients of variation [CV]: 6.8% presented in Table 3.

Statistical analysis

The Shapiro-Wilks test was used to evaluate if the data were normal after all the data had been tabulated using Microsoft Excel. Intraclass correlation coefficients were computed to ascertain the measured variables' inter-measurement reliability. In order to make sure there was no significant difference between the groups, the baseline assessment parameters of the participants (age, weight, height, and body mass index) were determined using one-way ANOVA and the Levene test. The intra-class correlation coefficients (ICCs) were used to evaluate the test-retest reliability of all tests, but only for the ACG. In terms of reliability, the inter-rater correlation coefficient (ICC) across trials and assessors was evaluated as follows: excellent (>0.9), good (0.75–0.9), moderate (0.5–0.75) and poor (<0.5). A paired sample t-test was used to compare the changes after 3- months of intervention with baseline for each of the three groups and all outcome measures. Cohen's d values, which were classified as trivial: 0 to 0.2; small: 0.21 to 0.6; moderate: 0.61 to 1.2; large: 1.21 to 2.0; very large: 2.01 to 4.0; nearly perfect: >4.01 (Ndlomo et al., 2023), were used to quantify the magnitude of changes between Time 1 and Time 2 assessment. A 3x2 (group x time) mixed design analysis of variance for repeated measures test was used to assess the changes of three groups for all outcome measures. This test measured the effects of time (Time 1 and Time 2), group (CMT, FCT, and ACG), and interaction (group x time). The Bonferroni post hoc test was utilized to identify group differences accurately. Furthermore, the two-way repeated measures ANOVA test yielded the partial eta-square (η_p^2). The effect size, or partial eta-square, was employed to ascertain the extent of the variation. The interpretations for a big are (≥0.14), a medium is (0.06-0.14), and a small is (≤0.06). Pairwise comparisons were applied with the Bonferroni post hoc test. In order to display the statistical significance, a level of 0.05 was set. All statistical analysis was done using the statistics package for social science software version 22.0.

Results

Table 1 shows the baseline characteristics of the two intervention groups (FCT and CMT) and the control group (ACG). There was no discernible difference in the participants' weight (p=.368), height (p=.281), or age (p=.827). Kolmogorov-Smirnov and Shapiro-Wilk tests were used to determine whether the participants' characteristics were normal.

Table 1. Characteristics of participants

Characteristics	CMT Mean (SD)	FCT Mean (SD)	ACG Mean (SD)	p
Weight	64.73(4.33)	65.07(6.46)	62.67(3.72)	.368
Height	1.70(.075)	1.71(.061)	1.67(.040)	.281
Age	19.47(1.19)	19.60(.986)	19.33(1.34)	.827
BMI	22.53(1.54	22.30(1.48)	22.49(.613)	.869

Table 2 demonstrates that the characteristics of the participants had Test of Homogeneity of Variances with the p values of p=.099 for weight, p=.138 for height, p=.209 for age, and p=.053 for body mass index, all of which were higher than the significance level of 0.05 (p>0.05). Same as Table 1, the Table 2 results show that the observed population has a uniform distribution for each experimental group (CMT, FCT, and ACG)

Table 3 presented that the evaluated tests' intra-class correlation coefficients (ICC) varied from 0.87 to 0.98, while the coefficients of variation (CV) ranged from 2.8 to 10.9%.

Table 2. Tests of Homogeneity for baseline characteristics of participants

Characteristics	Levene Statistic	df1	df2	sig
Weight	2.440	2	42	.099
Height	2.079	2	42	.138
Age	1.627	2	42	.209
BMI	3.156	2	42	.053

Table 3. Intraclass correlation coefficients (ICCs) for relative reliability and coefficients of variation for absolute reliability

Outcome Measures	ICC	95%CI	CV
Speed	0.95	.861-.984	4.8%
COD	0.98	.943-.994	5.3%
ME	0.87	.635-.959	5.8%
AP	0.98	.963-.996	10.9%
RHR	0.94	.834-.982	2.8%
VC	0.95	.861-.984	6.8%
$VO_{2\,max}$	0.96	.909-.990	6.8%

Table 4 displays the results of the Kolmogorov-Smirnov and Shapiro-Wilks tests used to determine the normality of the outcome measures (Speed, COD, ME, AP, RHR, VC, and $VO_{2\,max}$). The Shapiro-Wilks and Kolmogorov-Smirnov tests revealed that all outcome measure data were normally distributed.

Table 4. Tests of normality

Outcome measures	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Speed	CMT	.142	15	.200	.924	15	.223
	FCT	.113	15	.200	.941	15	.389
	ACG	.152	15	.200	.934	15	.314
COD	CMT	.164	15	.200	.918	15	.178
	FCT	.133	15	.200	.926	15	.236
	ACG	.183	15	.190	.899	15	.093
ME	CMT	.212	15	.069	.910	15	.134
	FCT	.141	15	.200	.937	15	.350
	ACG	.162	15	.200	.932	15	.291
AP	CMT	.178	15	.200	.909	15	.130
	CNST	.163	15	.200	.946	15	.469
	ACG	.209	15	.076	.910	15	.134
RHR	CMT	.167	15	.200	.931	15	.279
	FCT	.217	15	.056	.937	15	.343
	ACG	.168	15	.200	.955	15	.601
VC	CMT	.185	15	.178	.900	15	.096
	FCT	.212	15	.069	.917	15	.175
	ACG	.202	15	.100	.882	15	.050
$VO_{2\,max}$	CMT	.140	15	.200	.913	15	.153
	FCT	.211	15	.071	.923	15	.217
	ACG	.142	15	.200	.924	15	.223

Table 5 displays the repeated measure analysis of variance on speed, COD, ME, AP, RHR, VC, and $VO_{2\,max}$ over two times. There were significant changes in speed between time ($p<0.01$, η_p^2=.461) with a large effect as well as between groups ($p<0.01$, η_p^2=.330) with a large effect. However, there were no significant changes between groups (p=.280, η_p^2=.059) with a large effect. COD had significant changes between group ($p<.001$, η_p^2=.476), time ($p<.001$, η_p^2 =.778), and group x time ($p<.001$, η_p^2=.669) with large effect. ME had significant changes between group ($p<.001$, η_p^2=.417), time ($p<.001$, η_p^2=.838), and group x time ($p<.001$, η_p^2=.700) with large effect. AP had significant changes between group ($p<.001$, η_p^2=.507), time ($p<.001$, ES=.876), and group x time ($p<.001$, η_p^2=.754) with large effect. VC had significant changes between group ($p<.001$, η_p^2 =.546), time ($p<.001$, η_p^2=.825), and group x time ($p<.001$, η_p^2=.692) with large effect. $VO_{2\,max}$ had significant changes between group ($p<0.01$, η_p^2 =.240), time ($p<.001$, η_p^2=.727), and group x time ($p<.001$, η_p^2=.565) with large effect. Finally, RHR showed no significant difference between group, time and group x time at 0.05.

When considering the paired sample t-test presented in a table, speed had a significant difference in CMT ($p<0.01$, d=1.03) with a moderate effect and FCT ($p<.001$, d=1.31) group with a significant effect. However, the ACG group showed no significant difference ($p>0.05$). COD had a significant difference in CMT ($p<0.05$, d=.579) with a small effect and FCT ($p<.001$, d=1.45) group with a significant effect, but the ACG group did not show any significant difference ($p>0.05$). ME had a significant difference in CMT ($p<.001$, d=2.35) with a substantial effect and FCT ($p<.001$, d=3.44) group with a very

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Table 5. Repeated measures ANOVA

Outcome measures	Group	Time 1 (SD)	Time 2 (SD)	Group (effect)	Time (effect)	Group x time (interaction)
				P (ηp2) 95%CI		
Speed	CMT	7.36(.377)	7.04(.180)	.280 (059)	.000** (.461)	.000** (.330)
	FCT	7.36(.380)	6.97(.183) ▲			
	ACG	7.32(.331)	7.33(.304) ▲			
COD	CMT	18.61(1.02)	17.63(1.15)	.001** (.271)	.000** (.331)	.000** (.276)
	FCT	18.61(1.08)	16.54(1.10) ▲			
	ACG	18.65(1.01)	18.72(.983) ▲			
ME	CMT	39.87(2.45)	47.53(4.34)	.000** (.417)	.000** (.838)	.000** (.700)
	FCT	40.73(2.68)	51.53(3.44)▲			
	ACG	40.33(2.61)	40.93(2.71) ▲			
AP	CMT	1072.81(91.90)	1425.76(104.23)	.000** (.507)	.000** (.876)	.000** (.754)
	CNST	1075.27(130.80)	1531.10(110.32) ▲			
	ACG	1073.18(96.30)	1099.75(112.71) ▲			
RHR	CMT	74.27(2.49)	73.73(2.25)	.317 (.053)	.662 (.005)	.052 (.131)
	FCT	74.27(2.37)	73.47(1.92)			
	ACG	74.53(3.07)	75.47(2.33)			
VC	CMT	3.83(.243)	4.51(.194)	.000** (.546)	.000** (.825)	.000** (.692)
	FCT	3.81(.273)	4.73(.158) ▲			
	ACG	3.77(.263)	3.81(.252) ▲			
$VO_{2\,max}$	CMT	39.31(2.51)	43.93(1.81)	.003* (.240)	.000** (.727)	.000** (.565)
	FCT	39.26(2.62)	46.17(1.75) ▲			
	ACG	39.76(3.05)	40.04(2.80) ▲			

**Significant at .001, *Significant at 0.05, ▲ Significant difference with control 0.05

large effect, but the ACG group did not show any significant difference (p>0.05). AP had a significant difference in CMT (p<.001, d=2.69) with a substantial effect and FCT (p<.001, d=4.46) group with a nearly perfect effect. However, the ACG group showed no significant difference (p>0.05). VC had a significant difference in CMT (p<.001, d=2.87) with a substantial effect and FCT (p<.001, d=2.86) group with a very large effect, but the ACG group did not show any significant difference (p>0.05). $VO_{2\,max}$ had a significant difference in CMT (p<.001, d=1.63) with a large effect and FCT (p<.001, d=2.85) group with a very large effect, but the ACG group did not show any significant difference (p>0.05). RHR did not show any significant difference between all the three groups. The magnitude of the effect is presented in Figure 2.

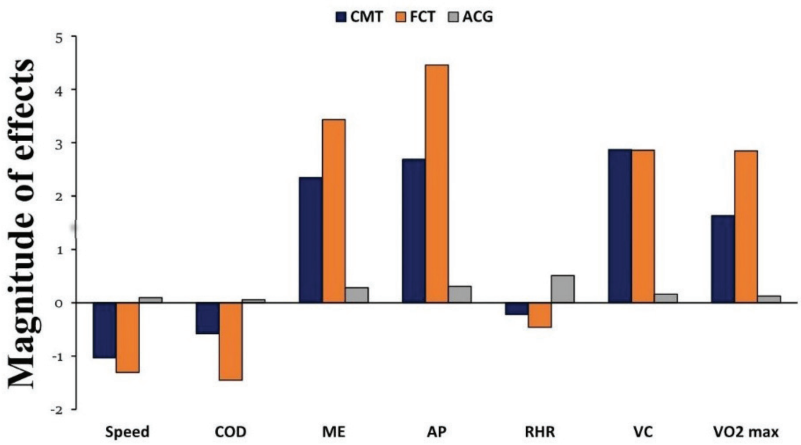

Figure 2. Magnitude of effects on Time 1 to Time 2 for the selected outcome measures

When considering the one-way analysis of variance, time 1 assessment of all the outcome measures did not show any significant difference at the 0.05 level. Time 2 assessment on speed, COD, ME, AP, VC, and $VO_{2\,max}$ significantly improved in both training interventions (CMT and FCT). However, RHR did not show any significant improvement in both training interventions (CMT and FCT) and the ACG group.

When considering the Bonferroni post hoc test (table 7), the FCT group showed significantly higher improvement in COD, ME, AP, VC, and $VO_{2\,max}$ when compared to the CMT group. Moreover, FCT and CMT groups significantly improved speed, COD, ME, AP, VC, and $VO_{2\,max}$ at p<.001, and RHR at .05 levels.

Table 6. Paired t-test

Outcome measures	Group	df	T-Ratio	p	Cohen's d
Speed	CMT	14	3.991	.001*	1.03
	FCT	14	5.056	.000**	1.31
	ACG	14	.372	.716	0.10
COD	CMT	14	2.243	.042*	.579
	FCT	14	5.61	.000**	1.45
	ACG	14	.222	.828	.057
ME	CMT	14	9.092	.000**	2.35
	FCT	14	13.303	.000**	3.44
	ACG	14	1.090	.294	0.28
AP	CMT	14	10.417	.000**	2.69
	CNST	14	17.267	.000**	4.46
	ACG	14	1.191	.253	0.31
RHR	CMT	14	.845	.413	0.22
	FCT	14	1.780	.097	0.46
	ACG	14	1.974	.068	0.51
VC	CMT	14	11.129	.000**	2.87
	FCT	14	11.075	.000**	2.86
	ACG	14	.627	.541	0.16
$VO_{2\,max}$	CMT	14	6.323	.000**	1.63
	FCT	14	11.028	.000**	2.85
	ACG	14	.495	.628	0.13

*Significant at 0.05, **significant at 0.001.

Table 7. Post Hoc Comparison

Outcome measures	Groups		Mean difference	SE	P_B	95% Confidence Interval for Difference	
						Lower Bound	Upper Bound
Speed	CMT	FCT	.072	.060	.702	-.077	.222
	CMT	ACG	-.304	.060	.000**	-.454	-.154
	FCT	ACG	-.376	.060	.000**	-.526	-.227
COD	CMT	FCT	1.090	.399	.028*	.094	.2.087
	CMT	ACG	-1.084	.399	.029*	-2.080	-.087
	FCT	ACG	-2.174	.399	.000**	-3.171	-1.177
ME	CMT	FCT	-3.286	1.066	.011*	-5.948	-.625
	CMT	ACG	6.984	1.059	.000**	4.342	9.627
	FCT	ACG	10.271	1.058	.000**	7.630	12.911
AP	CMT	FCT	-104.088	34.882	.014*	-191.162	-17.015
	CMT	ACG	326.204	34.881	.000**	239.134	413.273
	FCT	ACG	430.292	34.882	.000**	343.220	517.364
RHR	CMT	FCT	.267	.600	1.000	-1.232	1.765
	CMT	ACG	-1.589	.601	.035*	-3.088	-.089
	FCT	ACG	-1.855	.601	.011*	-3.355	-.356
VC	CMT	FCT	-.235	.070	.005*	-.409	-.061
	CMT	ACG	.683	.070	.000**	.509	.858
	FCT	ACG	.918	.070	.000**	.744	1.093
$VO_{2\,max}$	CMT	FCT	-2.250	.695	.007*	-3.985	-.516
	CMT	ACG	4.076	.696	.000**	2.338	5.814
	FCT	ACG	6.326	.697	.000**	4.587	8.066

*Significant at 0.05, **significant at 0.001.

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Discussion

The present study aimed to investigate the effects of three weekly training sessions of CMT and FCT on the physical and physiological outcomes measures of field hockey players, and the secondary aim of the study compared the effects of three weekly training sessions of CMT versus FCT on physical and physiological outcome measures of field hockey players. The results revealed significant improvements in physical performance measures, including speed and COD, as well as physiological parameters such as AP, VC, and $VO_{2\ max}$. Additionally, it was discovered that the FCT had improved more in all of the selected physical outcome measurements, including speed and COD, as well as the majority of the physiological outcome measurements, including AP, VC, and $VO_{2\ max}$.

CMT and FCT responses on physical measures

The results of the present study reveal that CMT and FCT significantly improved speed, COD, and ME in physical outcome measures compared to the control group. One of the main outcomes of the present study was consistent with earlier CMT studies in field hockey players (Koca & Recvan, 2023; Thapa et al., 2023). Athletes can acquire the precise physical traits essential for best performance by concentrating on high-intensity, short-duration workouts that simulate the demands of actual match play. These activities include linear sprinting, agility, and maximal isokinetic strength. This method is consistent with the findings presented by Thapa (2023) and lends credence to the idea that strategic supplemental training treatments can bring about considerable enhancements in field hockey players. Specific neuromuscular adaptations may be responsible for performance improvement in the CMT and FCT groups. These adaptations may have resulted in an improved stretch-shortening cycle (SSC), increased motor unit recruitment, firing frequency, intra- and inter-muscular coordination, and alterations in structure that assist with the ability to produce the greater force from the muscle (Cormier et al., 2020). The results of Koca and Recvan (2023) suggest that the resistance training, which was applied three days a week for eight weeks and consisted of a strength training program with an intensity of 50–70% 1 RM and free weight exercises, core exercises, and resistance band exercises, significantly increased the muscular strength and ME of both male and female field hockey players. Some of the findings from earlier research align with the current study's results, which were conducted with a different population (Ali et al., 2019; Kumar et al., 2023; Nasrulloh et al., 2022). Ali et al. (2019) reveal that after participating in a training program that lasted for six weeks, football players experienced increased agility and speed due to CMT. Likewise, a comparison was made by Kumar et al. (2023) between the effects of load-equated two and three-complex contrast training sessions per week on several measures of physical fitness. Compared to the complex contrast training, which was two sessions per week, the complex contrast training, which was three sessions per week, resulted in much better improvements in speed and COD.

Further promoting the activation of fast-twitch muscle fibres, this force-velocity relationship optimization may aid in maximizing athletic performance like sprints and COD speed (Cormier et al., 2022). The study by Nasrulloh et al. (2022) explores that Archery athlete's ME is significantly increased by weight training using the compound set approach, which consists of an intensity of 60-80% 1 RM, 3-4 sets, and 15-25 reps. Therefore, weight training with the compound set approach over eight training weeks may significantly improve an archery athlete's strength and ME. This study found that increased muscle endurance following 3-months of intensive training. Improved neuromuscular efficiency helps the nervous system activate muscles and coordinate (Hammami et al., 2019; Josef, 2018). Resistance workouts develop muscular fibres, causing muscle hypertrophy and sustained muscle activity(Currier et al., 2023). Enhanced motor unit synchronization and activation lead to increased motor unit recruitment (Grgic et al., 2021). Muscles adapt to carry more weight for longer durations, increasing endurance (Rathi et al., 2023). The above factors may have contributed to this present study's excellent outcomes.

According to the current research findings, the FCT led to considerable gains in terms of speed, COD, and ME when compared to the CMT in terms of assessment of physical outcomes. Although there is a paucity of published material on FCT for hockey athletes, the findings presented here are consistent with those of earlier research carried out on a variety of sports populations that share comparable traits or characteristics (Türkarslan & Deliceoğlu, 2024). When applied to professional soccer players, the FCT program can potentially boost speed throughout a training program that lasts for three weeks (Türkarslan & Deliceoğlu, 2024). The FCT for ten weeks increased the power and performance of complex skills for football players. These skills include speed and skill performance (receiving and running with the ball, receiving, dribbling passing, receiving, dribbling shooting)(Salam & Sherif, 2020). In order to achieve this, football players must have efficient speed, trunk strength, and agility abilities (França et al., 2022; Saeterbakken et al., 2022; Viran et al., 2022). Among the four different CMT strategies offered to have the best potential influence on the PAPE phenomenon is the FCT Method (Rebelo et al., 2023; Türkarslan & Deliceoğlu, 2024). They are targeting four components of the force-velocity relationship. That is, in the precise order: maximum strength, speed-strength, strength-speed, and maximum speed, respectively. The goal is to elicit a PAPE with the contrasting nature of loading/contraction types (Cormier et al., 2022). Some studies have explored that PAPE protocols show performance benefits in agility tests and sprint tests (Escobar Hincapié et al., 2021; Thapa et al., 2020).

CMT and FCT responses on physiological measures.

The findings of the current research indicate that both CMT and FCT led to substantial improvements in physiological outcome measures such as AP, VC, and $VO_{2\ max}$ when compared to the group that served as the control. RHR did not show any significant difference between the treatment group and the control group. Regarding those outcome measures, FCT demonstrated a greater degree of improvement than CMT. Published research on FCT for hockey players lacks physiological outcome measures (K V et al., 2024). The study by K V et al., (2024) indicates that over the period of 12-week FCT intervention (36 trining sessions) effectivly enhances the AP, and VC. Moreover, the results shown here align with other studies conducted on different populations (Chang et al., 2022; Ingle et al., 2006). Chang et al. (2022) imply that eight weeks of classical resistance training substantially improved AP for healthy college students.

Similarly, Ingle et al. (2006) found that CMT increased the average AP throughout a twelve-week intervention. It might be the consequence of High-load activity may increase calcium in the muscle fibre's myoplasm, activating the myosin light chain kinase, which phosphorylates the light chains and promotes actin-myosin cross-bridges, which potentiates lower-load activity (Cormier et al., 2022). One of the studies that Ağirbaş and Karakurt (2023) carried out was to investigate the impact that static strength training using a Tera-Band for the upper extremities had on the ability of the lungs to breathe. It revealed that static strength training performed with a Tera-Band for the upper extremities affected the respiratory capacities of elite boxers, such as their forced vital capacity (Ağirbaş & Karakurt, 2023). Similarly, the forced vital capacity increased after six weeks of plyometric training in aerobic gymnasts (Cuce et al., 2021).

Regarding $VO_{2\ max}$, Chovanec and Gröpel (2020) reported that the resistance training program resulted in physiological adaptation, which manifested itself as an increase in $VO_{2\ max}$ following the intervention that lasted for eight weeks for the training program (Chovanec & Gröpel, 2020). In CMT and FCT training, high-intensity efforts are combined with incomplete rest intervals (Cormier et al., 2022). This combination results in a more significant strain on the circulatory system and an improvement in the efficiency with which oxygen is utilized. Because of the fatigue that results, the body is forced to adapt by improving its cardiorespiratory function and increasing the amount of oxygen uptake to meet the increased demands (Kayhan et al., 2024). These physiological changes support higher levels of athletic performance, leading to increased vital capacity and voluntary oxygen consumption ($VO_{2\ max}$) (Monnerat et al., 2020). This may be the reasonable rationale for improving vital capacity and $VO_{2\ max}$ following the systematic implementation of CMT and FCT training intervention.

Additionally, the current study revealed that the CMT and FCT were unsuccessful in improving the RHR compared to the ACG. According to the findings of research conducted by Rathi et al. (2023), complex-descending training over six weeks does not result in a substantial reduction in RHR (Rathi et al., 2023). According to one of the Mata analyses, strength training does not substantially influence the RHR (Reimers et al., 2018). The athletes had previously surpassed the targeted threshold by continuous engagement, which is the most plausible explanation for the result (Rathi et al., 2023).

Limitation

A few restrictions should be taken into consideration regarding this study. Due to the limited amount of information available in this sector, comparing the present findings with those of previous FCT research conducted in hockey is not feasible. This study, on the other hand, will serve as a foundation for further research on hockey players since it presents original and innovative evidence. Additionally, the duration of the training intervention was restricted to twelve weeks. More extended research beyond three months may be required to assess the long-term adaptations in hockey athletes. Despite considerable gains being shown in the CMT and FCT groups, one of the outcome measures, RHR, did not show any significant decline. The third limitation is that the sample size for this research needed to be more significant. A higher sample size may be necessary in order to validate the findings that have been obtained. Finally, data about biochemistry or haematology needs to be collected. These data would give additional insights into the biological elements of the training, which could increase the evidence of the interconnection of the selected outcome measures and the effect of the specified training interventions.

Practical application

Within the context of field-based team sports, the practical implications of our study findings are pertinent for fitness experts and coaches interested in optimizing exercise programmes to improve physical fitness and overall health through physiological markers. As a result of the fact that both CMT and FCT displayed substantial improvements in speed, COD, and ME, it is evident that adopting either training modality into a daily exercise programme can successfully create favourable changes in overall fitness and development in sport-specific skills. This understanding can be helpful for fitness experts when they are developing individualized exercise programmes to improve physiological markers so that they can attain cardiorespiratory health. Furthermore, coaches and strength and conditioning trainers may utilize this information to offer suggestions for athletes looking to enhance their general health, particularly those who participate in team sports. Data can justify these recommendations.

Conclusion

The potential for physical and physiological outcome measures was investigated to improve field hockey players following a 3-month CMT or FCT training plan. After completing a 3-month CMT and FCT training course, we conclude that participants in both training groups improved more in speed, direction changes, and muscle endurance (compared with ACG). After completing a 3-month CMT and FCT training program, we conclude that individuals in both training groups improved more in VC, AP, and $VO_{2\ max}$ in physiological end measures (when compared with ACG). The ACG and the two-intervention group's RHR did not alter significantly. Moreover, when comparing the FCT group to the CMT group, it was revealed that the FCT group had improved more in all of the chosen physical outcome measures and most of the physiological outcome measurements, except RHR.

Consequently, if boosting COD speed, ME and VC, AP, and $VO_{2\ max}$ are targets, practitioners and coaches may choose CMT and FCT programs. Finally, trainers, coaches, and athletes who wish to enhance their routines are advised to try FCT. Such integration facilitates the intended modifications in physiological and physical factors beyond CMT training, significantly improving hockey players' overall performance and success.

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Conflicts of interest

The authors declare that there are no conflict of interest.

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