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# Acute Effects of the French Contrast Method and Post Activation Potentiation on 3 × 3 Basketball Game Demands and Thermal Asymmetry Responses

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**Abstract:** This study aimed to determine the acute effects of the French contrast method (FCM) and post-activation potentiation (PAP) protocols on 3 × 3 basketball game demands and thermal asymmetry in male basketball players and to compare these effects between protocols. Eighteen male basketball players (mean ± SD; age: 21.7 ± 1.5 years, 10.6 ± 1.9 years of experience) visited the laboratory four times, 72 h apart. The players participated in three different protocols (baseline: 3 × 3 game; FCM + 3 × 3 game; PAP + 3 × 3 game; respectively). The players' internal and external loads were monitored, game profiles were analyzed, and thermography was applied during the protocols. The results revealed that FCM and PAP did not significantly differ in internal load; however, the significant highest total distance and distance in band 2 during the 3 × 3 basketball game was after the FCM. The 1-point attempt was significantly higher after the FCM, and turnover was significantly higher after PAP. Significant thermal asymmetry was observed in the abdominals and lower back after the FCM and PAP. The results of this study provide coaches and practitioners with detailed information regarding the game demands that can be used to improve the playing profile of 3 × 3 basketball players.

**Keywords:** 3 vs. 3; game-related statistics; FCM; PAP; thermal imaging

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## 1. Introduction

Three × three basketball is a high-intensity sports discipline that requires highly developed aerobic and anaerobic capacities to play successfully [1–3]. The fact that the game format and playing area are more limited than those of 5 vs. 5 basketball [4] suggests that the game demands of 3 × 3 basketball are also different. Compared with 5 vs. 5 basketball, 3 × 3 basketball has a shorter shot time (12 s) and fewer players (3 + 1 substitute players), the same weight but a smaller diameter ball, a smaller field size (11 × 15 m), and particularly high-speed acceleration (ACC), which results in a relatively higher physiological response than 5 vs. 5 basketball [5,6]. In 3 × 3 basketball, the 10-minute game time includes sprints, fast plays [7], change of direction (CoD) [8], and high intensity [9].

The internal and external loads of athletes are determined through monitoring [10–13], which has been frequently used in recent years to follow the training and game demands [13], and depending on the training load, whether an athlete has absorbed the training is determined by monitoring the skin temperature via thermography [14]. Infrared thermography has recently become more popular in terms of providing insights into heat production and distribution in exercise physiology [15–18], and in recent years, it has become a widely used method to monitor the training responses and injury risks

of athletes [19–21]. While it is known that a 1 °C increase in muscle temperature during short-term exercise can lead to improvements in performance from 2% to 5% [22,23], and an increase in muscle temperature is associated with improved performance and that an increase as much as 0.3–0.9 °C can contribute to improved neuromuscular performance [24], whether thermal asymmetry occurs after performance enhancement protocols during warm-up may be an important indicator to evaluate in terms of injury risk. Recording bilateral skin temperature differences (i.e., thermal asymmetry) can be used to detect potential injury risk and measure physical performance [19,25]. On the other hand, the weaknesses and strengths of the opponent and the own team are determined through game analysis [26], and training programs are specified by determining the external and internal loads of the game.

A 3 × 3 basketball game is characterized by an average of 28 shot attempts, 12.3–15.4 rebounds, approximately 1 block, 3.9–6.6 turnovers per game with ~15% standing and walking, ~44% low-intensity activity, ~17% moderate activity, and ~24% high-intensity activity (with ~7 RPE) [7]. Montgomery and Maloney [2] reported that male 3 × 3 basketball players covered an average of 867.0 ± 220.8 m and 46.6 ± 10.3 $m \cdot min^{-1}$ during a game.

As 3 × 3 basketball games are generally played in a tournament style, and since athletes play 2–3 games a day over 2 or 3 days [2], defining the 3 × 3 basketball discipline in detail in terms of cumulative fatigue resulting from many consecutive games is crucial, and including practices that maximize performance in games is critical [7,27]. Thus, athletes who aim to achieve maximum performance by taking advantage of various neuromuscular, metabolic, and psychological changes during games may apply different warm-up routines [28,29].

As in every sports discipline, the main aim of 3 × 3 basketball is to increase the game performance of athletes. Although technical-tactical and strength-conditioning training are applied to improve the performance of athletes [30], methods such as PAP [31], and FCM have recently emerged as acute performance enhancement protocols [32–34]. PAP protocols, often added after a routine warm-up, are reported to improve performance with an increase in explosive neuromuscular capacity following a performance-enhancing exercise [31] and can improve subsequent performance above and beyond the warm-up [24]. On the other hand, FCM, which is basically based on the PAP [35], is another performance enhancement protocol that allows for the restoration of adenosine triphosphate (ATP) levels and increases in strength, speed, power, and anaerobic capacity, created with appropriate rest periods to enable high-quality movement strategies [32–34]. For example, complex training, another pre-game performance enhancement technique, may require a set of box jumps immediately followed by a set of high-load squats, while contrast training instead requires the athlete to perform a set of high-load squat repetitions and sets of the same exercise, alternating with light-load squat repetitions [34,36]. FCM training includes a heavy compound exercise, a plyometric exercise, a light-to-moderate load compound exercise that maximizes movement speed (i.e., external power), and a plyometric exercise [36]. The main idea in FCM training is to use four consecutive phases to stimulate the athlete's physiological responses and train along the force–velocity curve [34]. Evidence from previous research suggests that PAP and FCM improve performance in activities involving anaerobic power [31,37–39]. However, to the best of the authors' knowledge, no research has investigated the acute effects of applying these protocols before a 3 × 3 basketball competition on game demands and thermal asymmetry. We hypothesize that the PAP and FCM protocols used for pre-game warm-up strategy and performance enhancement would increase external load metrics such as jumping, sprinting, distance covered in high-speed, and total distance in 3 × 3 basketball and create thermal asymmetry through a

significant increase in skin temperature. Therefore, this study aimed to determine the acute effects of the FCM and PAP protocols on the 3 × 3 basketball game demands and thermal asymmetry in male basketball players and compare the effects of these protocols. For this purpose, in this current study, we completed measurements including internal and external load monitoring, game analysis, and thermal imaging in three different sessions (baseline: 3 × 3 game; FCM + 3 × 3 game; PAP + 3 × 3 game, respectively) to determine the effects of FCM and PAP interventions as a warm-up strategy and a performance enhancement protocol on game demands in basketball players.

## 2. Materials and Methods

### 2.1. Experimental Approach to the Problem

The study was conducted using a randomized, repeated measures, cross-sectional design. Players were randomly divided into six teams, each consisting of three players, according to player position. Each team had one guard and two forwards. In addition, to normalize the game conditions and keep the opponent standards constant, the teams were matched by drawing lots. After this match, the teams competed with the same opponent throughout the three measurement sessions, which included 3 × 3 basketball games. To control for circadian changes, players participated in the measurements at the same time of day, without performing vigorous lower extremity exercise in the previous 48 h, without consuming any stimulants or alcohol within 12 h before the measurement session, and were called to the gym four times, 72 h apart, in accordance with the protocols. To limit the environmental factors, players completed their 3 × 3 basketball games indoors and without spectators. In addition, no external tactical or motivational feedback was given by the researchers. Players completed their games with the same team and at the same time throughout all measurement sessions. All protocols and thermal imaging were supervised by the same researchers. In addition, all games were managed by the same referees to standardize the decision-making mechanism.

### 2.2. Participants

Eighteen male basketball players participated in this study voluntarily. The inclusion criteria were (a) having at least 7 years of basketball experience, (b) being an active licensed athlete in professional basketball leagues, (c) having participated in a 3 × 3 basketball tournament at least once before, (d) playing guard or forward positions, (e) participating in basketball training regularly at least five days a week, and (f) having experienced strength training regularly for at least one year. Athletes who had a musculoskeletal system injury or underwent surgery within the previous six months were not included in the study. All protocols within the scope of the study were explained to the athletes, and informed consent was obtained from all participants before starting the study. The research was approved by the Local Ethics Commission (Research Code: 2023-862) and was conducted in accordance with the Declaration of Helsinki.

### 2.3. Study Design

In the first measurement session, the players' characteristics were recorded, and the one repetition maximum (1 RM) back squat was determined according to the test protocol of the National Strength and Conditioning Association [40]. After this visit, the loads in the PAP and FCM protocols were calculated for each athlete according to the 1 RM. The second session was the baseline protocol, which consisted of a warm-up and a 2-minute rest interval after the warm-up, followed by a countermovement jump (CMJ), a 3-minute rest interval, and then a 3 × 3 basketball game. RPE data were collected before warm-up, after CMJ, and after the 3 × 3 basketball games, and thermal images were collected after

warm-up and after the 3 × 3 basketball games. The players completed the FCM protocol in the third session and the PAP protocol in the fourth session after warm-up, and then they were asked to jump and play a 3 × 3 basketball game as in the baseline protocol (Figure 1).

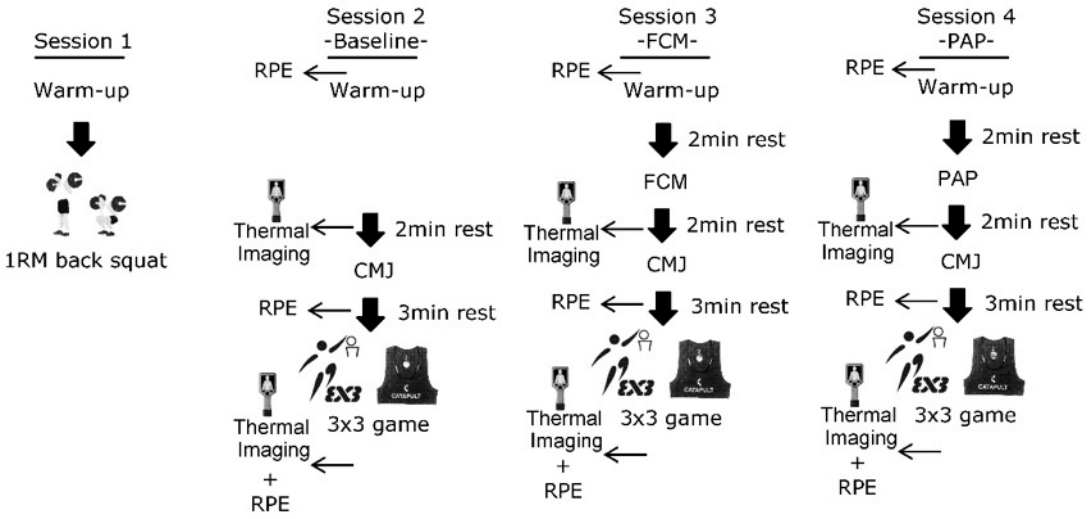



**Figure 1.** Study design.

*2.4. Procedures*

*Body height and body mass.* A stadiometer with ±1 mm precision was used to measure the players' body height (Seca 213, Seca, Hamburg, Germany), and a mechanical scale was used to determine body mass (Seca 761, Seca, Hamburg, Germany).

*Warm-up.* Before the protocols, the players performed the same warm-up protocol at each visit, consisting of 5-minute jogging and ball warm-up, a 3-minute dynamic warm-up consisting of a series of dynamic stretching movements covering 15 m, and 2-minute static stretching movements, respectively.

*Internal load.* The rate of perceived exertion (RPE) was determined using the 10-point Borg scale [41] for internal load. The players were informed of this scale during their first measurement visit. Responses from the players were taken verbally, and the RPE was recorded.

*Thermal imaging.* Thermal images were measured with a FLIR ONE® Gen 3 (FLIR ONE, FLIR Systems, Wilsonville, OR, USA) Apple Lightning connector-type calibrated thermal camera, which according to the specifications has an accuracy +/−3 °C or +/− 5%, equipped with an 80 × 60 sensor with a pixel size of 17 µm and a thermal sensitivity of 150 mK [42,43]. The acclimatization period to determine skin temperature was 10 min, and the TISEM checklist was used to verify that factors that could affect thermographic measurements were taken into account [44]. The FLIR ONE® Gen 3 (FLIR ONE, FLIR Systems) mobile application was used to evaluate the images. The camera was placed 1 m away from the players and held perpendicular to their body parts. Images were recorded in a controlled environment, where no one could disturb the measurement at a distance of 5 m and where there was no other equipment. During the measurements, the players were asked to take off their clothes, and their images were taken in a standing position with only their boxers on. Temperature reference points were taken from nine regions, namely the gastrocnemius for the calf, hamstrings, quadriceps femoris, rectus abdominis for the abdominals, thoracolumbar fascia for the lower back, triceps brachii, biceps brachii, pectoralis major, and deltoids for the shoulder, separately on the right and left sides of the body. The ambient temperature during the tests was 19 °C throughout all sessions, and the players were limited to the same type of clothing throughout the protocols. Thermal

imaging recorded thermal asymmetries in degrees Celsius and exported them to a Microsoft Excel spreadsheet.

*CMJ.* The jump height was measured with an Optojump (Optojump, Microgate, Bolzano, Italy) via the CMJ testing protocol. CMJ was completed by the players by quickly bending down to 90° knee flexion, with their hands-free, and then immediately jumping as high as possible and then landing on the ground again. The participants were asked to jump twice, and the highest value was recorded in cm.

*FCM and PAP protocols*. The FCM protocol consists of four movements and three sets in total. The FCM protocol is as follows: one repetition of an isometric squat (90° knee angle) with 85% of 1 RM (lasting for three seconds), 20 s of rest, three drop jumps from a height of 50 cm, 20 s of rest, three dynamic squats (90° knee angle) with 50% of the players' body mass, 20 s of rest, and three hurdle jumps (hurdle height is 50 cm and distance between each hurdle is 1.5 m) [38]. The rest interval between sets is 5 minutes. The PAP protocol consists of three repetitions and one set of back squats (90° knee angle) with 90% 1 RM.

*3 × 3 basketball game.* 3 × 3 basketball games were played in accordance with the FIBA 3 × 3 official game rules. However, some modifications were made by the researchers. The games were played over a single 10-minute period, as stated in the regulations. Playtime was not stopped throughout the game, and if the ball went out, the ball was fed by the researchers to avoid wasting time. The games were officiated by two referees. In the case of a foul during shooting, no free throws were allowed, and the ball was started with a check-ball from the top. The teams were made up of three players, and substitute players were not included so that the load per player did not change for each game and could be determined the same for everyone, and rest intervals did not alter performance. In this way, the players remained active constantly without ever leaving the game. The teams were not allowed to use the time-out rights specified in the rules and were allowed to compete actively for 10 minutes.

*External Load.* A Catapult Vector S7 (CatapultSports, Melbourne, VIC, Australia), a local positioning system (LPS) tracking device, was used to determine the external load. The system features IMU technology consisting of a three-axis accelerometer, gyroscope, and magnetometer, providing inertial movement analysis (IMA) at a sampling rate of 100 Hz. In previous studies, IMU system validity has been demonstrated in team sports [45–48] and has been widely used in basketball games and training to determine the external load metrics of players [49,50]. The external load metrics included total distance, ACC count, ACC distance, deceleration (DEC) count, DEC distance, maximum velocity and distance in velocity bands, rating of high-intensity effort (RHIE) count, jumping (total jumps, jump count in the low-medium-high band), and CoD (low-medium-high velocity) count.

*Game analysis.* All games were recorded with the help of a tripod using an iPhone 14 Pro Max smartphone that can record 60 Hz and 4 K video per second. Game analysis was completed by the researchers via the manual notational analysis method. The game analysis parameters consisted of 2-point made (2P), 2-point attempt (2PA), 2-point% (2P%), 1-point made (1P), 1-point attempt (1PA), 1-point% (1P%), assist, turnover, steal, and block.

### 2.5. Statistical Analyses

For descriptive statistics, the means and standard deviations (SDs) of the variables were calculated. The normality of the data distribution was assessed using the Shapiro–Wilk test. A paired sample t-test was used to compare the parameters pre- and post-game, and repeated measures ANOVA was used to compare each session's responses. All pair-wise multiple comparison procedures (Tukey test) were used to determine which groups the difference occurred. Effect size was classified using Cohen's d [51] according to the following scale: trivial < 0.2, small 0.2–0.5, medium 0.5–0.8, and large > 0.8. Effect sizes for

repeated measures ANOVA were classified using the partial eta squared ($\eta_p^2$) according to the following scale: trivial $\leq$ 0.01, small = 0.01, medium = 0.06, and large $\geq$ 0.14 [52]. Statistical analysis was performed via SigmaPlot 11.0 software (Systat Software, Inc., San Jose, CA, USA). The significance level was 0.05.

## 3. Results

The characteristics of the participants were as follows: mean ± SD; age: 21.7 ± 1.5 years, height: 187.8 ± 6.9 cm, body mass: 85.9 ± 8.3 kg, and 10.6 ± 1.9 years of basketball training experience. The 1 RM back squat was 135.6 ± 20.6 kg.

The pre-warm-up, pre-game, and post-game RPEs of the male basketball players were significantly different in all protocols ($p < 0.001$), and the highest RPE occurred in the post-game. Additionally, the pre-warm-up RPE was significantly different between the baseline and PAP (F = 4.496, $\eta_p^2$ = 0.209 [large], $p$ = 0.006), and between the FCM and PAP (F = 4.496, $\eta_p^2$ = 0.209 [large], $p$ = 0.044). Pre- and post-game RPE were not significantly different between the protocols (Table 1).

**Table 1.** RPEs of basketball players pre-warm-up, pre-, and post-3 × 3 basketball game following the baseline, FCM and PAP protocols.

| | Baseline | *p* * | FCM | *p* * | PAP | *p* * | *p* ** |
|---|---|---|---|---|---|---|---|
| Pre-warm up | 2.3 ± 0.9 | <0.001 | 2.5 ± 1.3 | <0.001 | 3.1 ± 1.6 | <0.001 | <0.006 [a–c], <0.044 [b,c] |
| Pre-game | 4.7 ± 1.3 | | 4.6 ± 1.9 | | 4.6 ± 1.8 | | 0.975 |
| Post-game | 7.4 ± 1.8 | | 7.1 ± 1.4 | | 6.9 ± 1.5 | | 0.562 |

Data are presented as the mean ± SD. [a]: Baseline protocol, [b]: FCM protocol, [c]: PAP protocol. *p* *: Intra-group comparison, *p* **: Inter-group comparison, $p < 0.05$.

For the in-game analyses, 1PA increased significantly after the FCM compared with the baseline (F = 4.570, $\eta_p^2$ = 0.212 [large], $p$ = 0.006), and the highest 1PA was observed in the 3 × 3 basketball game after the FCM. However, significantly higher turnover was found in the 3 × 3 basketball game after the PAP than after FCM (F = 4.796, $\eta_p^2$ = 0.220 [large], $p$ = 0.004). Although the highest 2PA was determined in the baseline 3 × 3 basketball game, the highest 2P%, 1P, assist, and block in the post-FCM game, and the highest steal in the post-PAP game, this difference was not significant. The highest score in rebounds was achieved in the game after the FCM and PAP (Table 2).

Following the baseline protocol, thermal asymmetries in different regions were not significantly different pre- and post-3 × 3 basketball game. However, after the 3 × 3 basketball game following the FCM, the thermal asymmetry in the abdominals ("large" ES = 1.149, $p$ = 0.006) and lower back regions ("medium" ES = 0.686, $p$ = 0.020) was significantly higher than that in the pre-game. In addition, following the PAP, the post-3 × 3 basketball game's thermal asymmetry in the abdominals ("medium" ES = 0.766, $p$ = 0.034), lower back ("large" ES = 0.888, $p$ = 0.009), and hamstring regions ("large" ES = 0.685, $p$ = 0.038) was significantly higher than that pre-game. Pre-game thermal asymmetries were not significantly different between the protocols. However, thermal asymmetry after the 3 × 3 basketball game following the PAP was significantly lower in the calf region than after the game following the other protocols (baseline vs. PAP, F = 58.066, $\eta_p^2$ = 0.356 [large], $p$ = 0.009; FCM vs. PAP, F = 223.018, $\eta_p^2$ = 0.329 [large], $p$ = 0.009). The highest thermal asymmetry in the calf region occurred in the post-game following the FCM (Table 3).

**Table 2.** The 3 × 3 basketball game analysis after the baseline, FCM, and PAP protocols.

| | Baseline | FCM | PAP | *p* |
|---|---|---|---|---|
| 2P | 1.6 ± 1.5 | 1.6 ± 1.7 | 1.2 ± 1.0 | 0.573 |
| 2PA | 5.2 ± 3.8 | 4.7 ± 4.2 | 4.2 ± 2.9 | 0.232 |
| 2P% | 30.0 ± 25.9 | 30.6 ± 29.2 | 28.1 ± 27.4 | 0.622 |
| 1P | 3.1 ± 2.5 | 3.7 ± 3.2 | 3.2 ± 2.5 | 0.470 |
| 1PA | 5.4 ± 4.4 | 7.4 ± 4.7 | 6.8 ± 3.5 | 0.006 [a,b] |
| 1P% | 47.2 ± 28.8 | 45.7 ± 26.7 | 45.2 ± 24.2 | 0.966 |
| Rebound | 5.7 ± 2.3 | 6.2 ± 2.6 | 6.2 ± 2.3 | 0.770 |
| Assist | 1.4 ± 1.3 | 1.7 ± 2.0 | 1.3 ± 1.4 | 0.640 |
| Turnover | 1.2 ± 1.3 | 0.7 ± 1.1 | 1.8 ± 1.1 | 0.004 [b,c] |
| Steal | 0.3 ± 0.5 | 0.3 ± 0.5 | 0.8 ± 0.9 | 0.075 |
| Block | 0.1 ± 0.3 | 0.4 ± 0.9 | 0.3 ± 0.8 | 0.554 |

Data are presented as the mean ± SD. [a]: Baseline protocol, [b]: FCM protocol, [c]: PAP protocol. 2P: 2-point made, 2PA: 2-point attempt, 2P%: 2-point%, 1P: 1-point made, 1PA: 1-point attempt, 1P%: 1-point%. *p* value indicates the inter-group comparison, $p < 0.05$.

**Table 3.** Thermal asymmetries of the basketball players pre- and post-3 × 3 basketball game following the baseline, FCM, and PAP protocols.

| | | Baseline | *p* * | FCM | *p* * | PAP | *p* * | *p* ** |
|---|---|---|---|---|---|---|---|---|
| Quadriceps femoris | Pre | 0.27 ± 0.25 | 0.175 | 0.28 ± 0.25 | 0.095 | 0.33 ± 0.24 | 0.823 | 0.493 |
| | Post | 0.36 ± 0.35 | | 0.41 ± 0.40 | | 0.36 ± 0.35 | | 0.792 |
| Pectoralis major | Pre | 0.37 ± 0.22 | 0.712 | 0.40 ± 0.19 | 0.064 | 0.38 ± 0.25 | 0.235 | 0.927 |
| | Post | 0.51 ± 0.51 | | 0.64 ± 0.48 | | 0.57 ± 0.65 | | 0.166 |
| Biceps brachii | Pre | 0.43 ± 0.33 | 0.194 | 0.51 ± 0.27 | 0.864 | 0.51 ± 0.47 | 0.758 | 0.742 |
| | Post | 0.61 ± 0.49 | | 0.48 ± 0.45 | | 0.54 ± 0.38 | | 0.669 |
| Abdominals | Pre | 0.33 ± 0.33 | 0.067 | 0.30 ± 0.26 | 0.006 | 0.27 ± 0.29 | 0.034 | 0.807 |
| | Post | 0.54 ± 0.40 | | 0.69 ± 0.40 | | 0.59 ± 0.53 | | 0.401 |
| Shoulder | Pre | 0.49 ± 0.47 | 0.187 | 0.36 ± 0.40 | 0.119 | 0.33 ± 0.30 | 0.107 | 0.389 |
| | Post | 0.72 ± 0.52 | | 0.54 ± 0.38 | | 0.59 ± 0.63 | | 0.585 |
| Triceps brachii | Pre | 0.51 ± 0 40 | 0.548 | 0.39 ± 0.27 | 0.162 | 0.50 ± 0.29 | 0.925 | 0.370 |
| | Post | 0.58 ± 0.37 | | 0.56 ± 0.41 | | 0.51 ± 0.51 | | 0.813 |
| Lower back | Pre | 0.27 ± 0.33 | 0.106 | 0.26 ± 0.22 | 0.020 | 0.20 ± 0.16 | 0.009 | 0.570 |
| | Post | 0.38 ± 0.35 | | 0.50 ± 0.46 | | 0.41 ± 0.30 | | 0.457 |
| Calf | Pre | 0.28 ± 0.29 | 0.284 | 0.33 ± 0.31 | 0.236 | 0.27 ± 0.28 | 0.934 | 0.674 |
| | Post | 0.37 ± 0.22 | | 0.41 ± 0.33 | | 0.27 ± 0.29 | | 0.009 [a–c] |
| Hamstrings | Pre | 0.37 ± 0.27 | 0.826 | 0.44 ± 0.29 | 0.130 | 0.25 ± 0.20 | 0.038 | 0.054 |
| | Post | 0.39 ± 0.28 | | 0.33 ± 0.34 | | 0.40 ± 0.24 | | 0.642 |

Data are presented as the mean ± SD. [a]: Baseline protocol, [b]: FCM protocol, [c]: PAP protocol. *p* *: Intra-group comparison, *p* **: Inter-group comparison, $p < 0.05$.

The total distance covered by the basketball players in the 3 × 3 basketball game after the baseline protocol was 714.3 ± 84.1 m, that after the FCM was 731.4 ± 93.8 m, and that after the PAP was 688.5 ± 104.7 m. The ACC count was highest after the baseline protocol, the ACC distance (average 43.5 ± 18.8 m) and the DEC distance (average 9.2 ± 5.3 m) were highest in the game after the FCM, and the DEC count was highest after the FCM and PAP (8.7 ± 5.7 and 8.7 ± 6.0, respectively) (Figure 2). The total distance after the FCM was significantly higher than that after the PAP ($F = 17.358$, $\eta_p^2 = 0.480$ [large], $p = 0.024$).

Although there were quantitative differences in the ACC count, ACC distance, DEC count, and DEC distance between the protocols, these differences were not significant ($p > 0.05$).

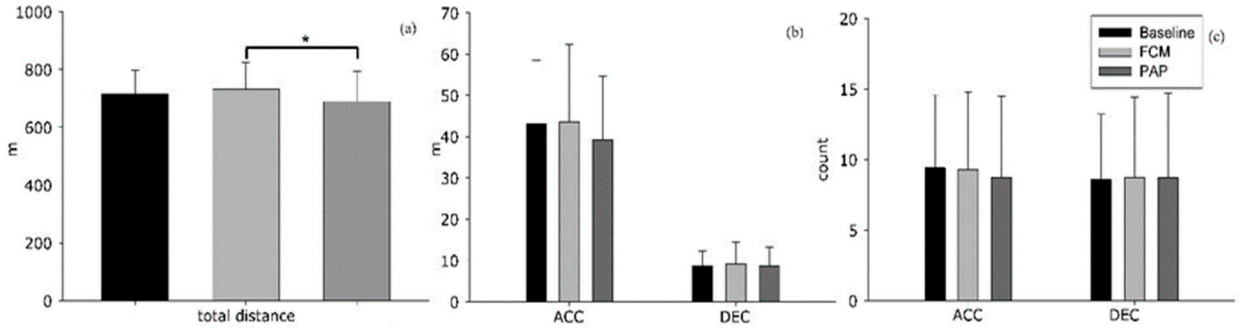



**Figure 2.** The total distance (**a**), ACC and DEC distance (**b**), and ACC and DEC counts (**c**) of the basketball players during the 3 × 3 basketball game following the baseline, FCM, and PAP protocols. *: $p < 0.05$.

Among the 3 × 3 basketball games played following the different protocols, the highest maximum velocity was after the baseline protocol (average 15.8 ± 1.4 km/h), followed by the PAP (average 15.3 ± 1.3 km/h), and after the FCM (average 15.2 ± 1.9 km/h), respectively. After the baseline protocol, players reached the highest distance in band 1 (after the baseline protocol, FCM, and PAP; average 70.5 ± 10.3 m, 61.1 ± 9.7 m, 58.5 ± 10.8 m, respectively), which was the lowest velocity band (distance covered at 0–<20% of the maximum velocity), and after the FCM, players recorded the highest distance in band 6 (average 62.5 ± 44.0 m), which was the highest velocity band (distance covered at = 100% of the maximum velocity) (Figure 3).

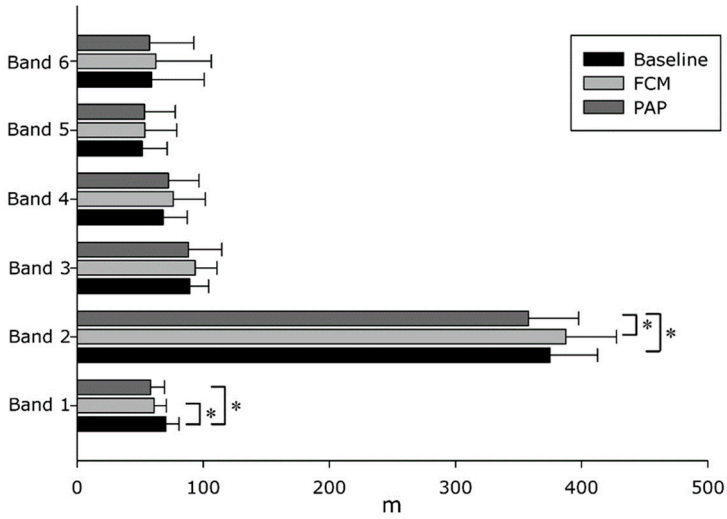



**Figure 3.** The distance in velocity bands of the basketball players during the 3 × 3 basketball game following the baseline, FCM, and PAP protocols. *: $p < 0.05$.

In the 3 × 3 basketball game, the total distance after the baseline protocol in velocity band 1 was significantly higher than that after the FCM and PAP (baseline vs. FCM: F = 17.500, $\eta_p^2 = 0.480$ [large], $p < 0.001$; baseline vs. PAP: F = 17.638, $\eta_p^2 = 0.480$ [large], $p < 0.001$). In velocity band 2, the total distance after the baseline protocol and FCM was significantly higher than after the PAP (baseline vs. PAP: F = 17.203, $\eta_p^2 = 0.480$ [large], $p = 0.020$, FCM vs. PAP: F = 17.222, $\eta_p^2 = 0.480$ [large], $p < 0.001$). In all games, the highest total distance was in band 2, and the highest RHIE count was after the baseline protocol (4.8 ± 1.2), followed by after the PAP (4.7 ± 1.9) and FCM (4.5 ± 1.4), respectively. Although

the total distance in velocity bands 3–6 and the RHIE count were quantitatively different between games after different protocols, this difference was not significant.

The highest total jumps (average 21.2 ± 6.9 jumps) and the highest jump count in the low (average 4.1 ± 3.2 jumps) and medium bands (average 13.6 ± 5.5) were in the 3 × 3 basketball game following the baseline protocol. The highest jump count in the high band was in the game after the FCM (average 4.6 ± 3.8 jumps) (Figure 4a). The CMJ heights performed after different protocols—also before the game—were not significantly different between the groups (baseline, FCM, and PAP average 44.6 ± 6.1, 44.7 ± 5.8, 46.0 ± 6.6 cm, respectively). Most jumps were in the medium band (20–40 cm). Jump counts in the 3 × 3 basketball game after different protocols were not significantly different between groups in any jump metrics ($p > 0.05$).

The highest CoD left-high count was after the FCM (average 2.7 ± 1.9), and the highest CoD right-high count was after the baseline protocol and FCM (average 2.1 ± 1.9 and 2.1 ± 1.5, respectively). The highest CoD left and right counts were at low velocity in all protocols (baseline, FCM, and PAP, respectively; CoD right-low: 39.1 ± 12.9, 40.6 ± 10.8, 37.1 ± 8.4; CoD left-low: 38.8 ± 9.9, 37.2 ± 9.3, 38.1 ± 8.3). The CoD count was not significantly different between the groups in any parameter in the 3 × 3 basketball game after the different protocols ($p > 0.05$, Figure 4b).

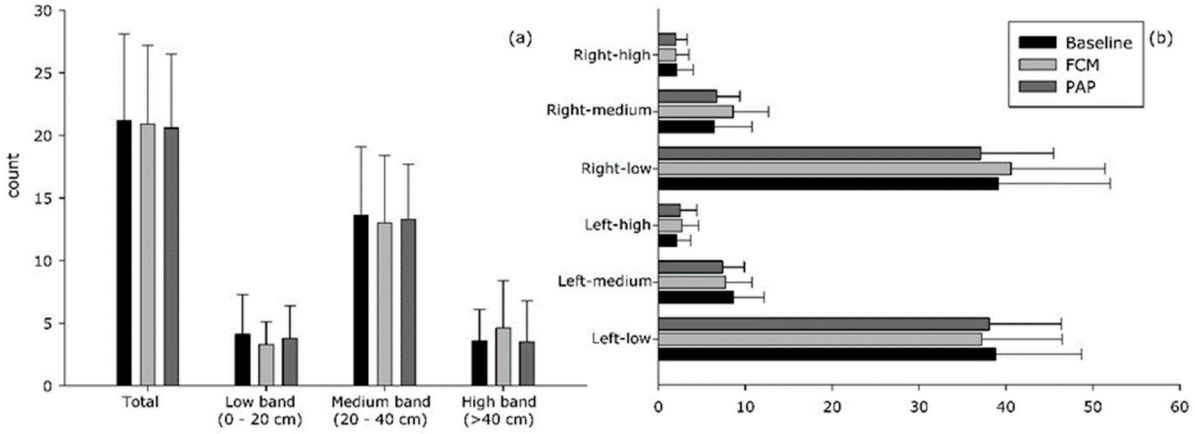



**Figure 4.** The jump counts (**a**) and CoD metrics (**b**) of the basketball players during the 3 × 3 basketball game following the baseline, FCM, and PAP protocols.

## 4. Discussion

The aim of this current study was to determine the acute effects of the FCM and PAP protocols on the 3 × 3 basketball game demands and thermal asymmetry in male basketball players and compare the effects of these protocols. We hypothesized that the FCM and PAP protocols applied before a 3 × 3 basketball game would have an acute significant effect on the game demands and thermal asymmetry. The first main finding is that the highest significant total distance in the 3 × 3 basketball game was after the FCM, and after all protocols, the total distance was covered mostly in band 2 (distance at 20–<40% of the maximum velocity), and the highest significant value in this distance was reached after the FCM, and the jump and CoD counts were not significantly different in the game after three different protocols. The second main finding is that 1PA was significantly higher in the 3 × 3 basketball game following the FCM, and turnover was significantly higher following the PAP. The third main finding is that although significant thermal asymmetry did not occur after the baseline protocol, significant thermal asymmetry was observed in the abdominals and lower back after the FCM and PAP, and additionally in the hamstring muscle group after the PAP.

Previous research indicates that 3 × 3 basketball games are completed at higher RPE than 5 vs. 5 matches [27], and male players have higher RPE than female players [53]. In general, RPE in international 3 × 3 basketball games has been reported to be between 5.7 and 6.3 [7,54], 4.3 ± 2.0 in group games, and 7.7 ± 1.6 in the final round [53]. The findings of our study confirm the relatively higher RPE compared to previous studies. Notably, the lowest RPE was obtained following the PAP. This result may be due to the protocol order. PAP was the third protocol, which can be explained by the possibility of the better adaptation of players to the game structure. The lower RPE in the 3 × 3 basketball game after PAP than after FCM may also have been affected by the higher volume of the FCM.

Although 3 × 3 basketball has grown exponentially in popularity over the past decade and has recently become an Olympic sport, the scientific literature focused on depicting the profile of 3 × 3 basketball players is limited [6]. In our research, the highest 1PA was in the 3 × 3 basketball game after the FCM, and this finding was significantly higher than that after the baseline protocol. However, significantly higher turnover was found after the PAP than after the FCM. Previous studies examining most international tournaments have shown that in a 3 × 3 basketball game, 28 shots are attempted [7], the 1PA is 13.7–29.4, the 2PA is 8.9–15.9 [55,56], the 1P (average per game: 7.6–11.9; [55,56]) and 1P% (39–50.8%; [7,57]) are higher than 2P (average per game: 2.1–4.4, [55,56]) and 2P% (19–25%; [7,57]), turnover is 3.9–29.4 [7,56], and block is approximately 1 per game [7]. The reason why the 1P, 2P, rebounds, and turnovers in our research were lower than those in previous studies is that in our research, the average was taken with the game profile analysis data of only one player from each team (i.e., player-based analysis). However, data on the total shots, rebounds, turnovers, assists, steals, and blocks for a team in a game have not been provided. Therefore, this difference may be due to the data analysis method used. After multiplying the data in the 3 × 3 basketball game by three where we used only three unchanging players in the game, the data reached values similar to those of previous studies. On the other hand, the highest 2P%, 1P, assist, block, and 1PA in the game after FCM and the highest steals in the game after PAP showed that the FCM protocol is the more preferable protocol in terms of the game profile.

We detected significant thermal asymmetry in the abdominals and lower back regions after the FCM and PAP, and additionally in the hamstrings after the PAP compared to the pre-game. However, although the pre-game thermal asymmetries were not different between groups following the three different protocols, there was significant thermal asymmetry in the calf region after the game. The highest thermal asymmetry in the calf region occurred after the 3 × 3 basketball game following the FCM, whereas the lowest asymmetry occurred after the game following the PAP. After the FCM, the thermal asymmetry was 0.39 °C in the abdominals, 0.24 °C in the lower back, and after the PAP, the thermal asymmetry was 0.32 °C in the abdominals, 0.21 °C in the lower back, and 0.25 °C in the hamstrings. These significant asymmetry differences were within the range that [21] classified as a "follow-up" thermal asymmetry of 0.3 °C–0.4 °C and did not entail any preventive intervention or risk situations. It is suggested that recording the bilateral skin temperature differences can be used to detect potential injury risk as well as measure physical performance [25], and muscle injuries have been found to be reduced in elite athletes with a load reduction intervention only in cases where thermal asymmetry is detected [21]. Therefore, the fact that different protocols applied in warm-up do not create severe asymmetry is an important finding in terms of the applicability of these protocols. A 20-minute warm-up routine in adult basketball players has been shown to increase muscle temperature, but this benefit is lost after a period of inactivity following a warm-up of high-level basketball, leading to a reduction in certain aspects of athletic performance [58].

Although exercise-induced muscle temperature increase is frequently reported as one of the explanations for the acute performance effects of PAP, this has not been directly evaluated in studies on the phenomenon of increased performance after PAP. It is well-known that an increase in muscle temperature is associated with improved athletic performance and that an increase of up to 1 °C can contribute to improved neuromuscular performance [24]. However, no study has been found investigating the acute effects of the FCM protocol on skin temperature in athletes. In our study, the significant higher thermal asymmetry finding in the calf region after FCM compared to the other protocols may have occurred due to the muscles that perform activation/contraction in the FCM protocol. On the other hand, the high load, low volume, and shorter application time in the PAP protocol (significant thermal asymmetry in the abdominals, lower back, and hamstring) may have created thermal asymmetry in more regions compared to the FCM (significant thermal asymmetry in the abdominals and lower back) in the pre- and post-tests.

In the 3 × 3 basketball game, the total distance after FCM was significantly higher than that after PAP. The ACC count was highest in the game after the baseline protocol, the ACC and DEC distances were highest in the game after the FCM, and the DEC count was highest in the game after the FCM and PAP. Three × three basketball is a highly dynamic sport characterized by high workloads over a relatively short period [59], with an average total distance per game of 771 m, with the longest distance being just under 1 km [60]. The results of Lukic and Kamasi's [60] research were similar to the total distance (average 688–731 m) data from our study. In male basketball players, 44 DEC and 34 ACC counts per game were reported [54]. There may be two reasons why this study's ACC and DEC counts were higher. The first is that we presented player-based data analysis in our research, and the second is that the above research included data from elite players in international competitions. Our study participants were not players competing in international tournaments, which may have affected the performance metrics. However, the main purpose of this research was not to determine the 3 × 3 basketball game demands; our main purpose was to investigate the acute effects of different protocols used in warm-up on the 3 × 3 basketball game demands. In addition, to standardize the acute effect in the game after all protocols, we limited the game time to 10 min, without using game pauses and not performing foul shots. These manipulations may have affected the total distance and the ACC and DEC counts during game pauses. On the other hand, it is a remarkable finding that the total distance after the FCM in the 3 × 3 basketball game was significantly higher than that of the PAP.

The highest maximum velocity was in the baseline protocol (average 15.8 ± 1.4 km/h), followed by the PAP (average 15.3 ± 1.3 km/h) and the FCM (average 15.2 ± 1.9 km/h), respectively. Willberg et al. [27] reported that the maximum velocity of a 3 × 3 basketball game for male players was 17.7 km/h. In fact, considering that the maximum sprint time was increased by 6.36% in the repeated sprint test performed 4 minutes after a half squat at 5RM, similar to the PAP, in male basketball players [61], it can be seen that these interventions can be used to improve performance, but according to the results of our research, it should not be neglected that strength training interventions aimed at improving performance in warm-up, such as FCM and PAP, reduce the maximum speed. However, it is also important to consider whether there is a similar or different effect on other demands in the game.

After the baseline protocol, the players reached the highest distance in the lowest velocity band, band 1 (distance covered at 0–<20% of the maximum velocity), and after the FCM, the players reached the highest distance in the highest velocity band, band 6. In band 2 (distance covered at 20–<40% of the maximum velocity), the distance after the baseline protocol and FCM was significantly higher than that after the PAP. The velocity band with the greatest distance covered was band 2 in all games, and the highest RHIE was

after the baseline protocol, followed by the PAP and FCM, respectively. The majority of 3 × 3 basketball games (43–75% of playing time) involve low-intensity activity [7,27,62,63]. In our research, the greatest distance covered was in band 2, confirming previous research. In addition, the fact that a higher distance was reached after the FCM compared with the baseline protocol in band 6, which is the distance covered at 100% of the maximum velocity, and that the PAP reached lower data than the baseline protocol in this band may be an important indicator for preferring the FCM.

We obtained a higher CMJ height after the FCM and PAP compared with the baseline value. Although the highest increase was observed after the PAP (+1.4 cm), this increase was not significantly different. Previous studies have reported that FCM significantly increases the CMJ height both acutely [38] and chronically [33,35,64]. Post-PAP jump height findings are contradictory. It can be seen that the jump height increased significantly after the PAP [24,37] and there was no significant effect [65–67]. Therefore, further research is needed to confirm our findings. We reached the highest jump count in the high band (>40 cm) in the game after the FCM. Interestingly, these data accompanied the acute effect of the FCM, which reached its highest value in total distance and band 6. In the game following the PAP, the lowest total jump count and the lowest high band jump count were obtained. Researchers noted that in the 3 × 3 basketball game, there were between 21 and 56 jumps, and the highest jump was reached between 20 and 40 cm [2,27,54,68]. In our research, confirming previous studies, the highest jumps were in the medium band (20–40 cm).

CoD metrics in the 3 × 3 basketball game following different protocols were not significantly different between the groups. The highest count in the CoD left- and right-high was after the FCM. The highest CoD left and right counts were at low velocity in all protocols. To the best of the authors' knowledge, no research has examined the CoD during a 3 × 3 basketball game after the FCM and PAP. Although no previous studies have investigated the effect of FCM only on CoD, some studies have investigated the acute effect of an isolated CoD test after the PAP. A review emphasized that linear ACC increased after PAP, the CoD improved by 1.16–2.27%, and 90% 1RM load had an improving effect on CoD [69]. Using an isolated CoD test in the study above provides information on the detection of performance increases in the selected motoric feature. However, it should be noted that the effect that players cannot transfer on their in-game performance cannot be ignored and that no significant difference was found in the CoD after either FCM or PAP in our study.

There are several limitations in our research. One of these is the sample size. In future studies, comparing the study's findings with a larger sample size may indicate an important result. Another limitation is that the game time was not stopped, and foul shots were not performed in our research. However, we performed this intervention so that the game could be restricted to the standard 10 minutes on each of the three separate protocol days. Another limitation is the lack of substitute players. Although player substitutions are preferred in 3 × 3 games, no substitute players were used in the research design due to the invariance of all measurement protocols or the provision of the same standard and the fact that the external load data would not be affected due to changing game times. Additionally, we presented the external load and game analysis findings per player. While previous studies often presented the total data per game, we focused on the effects of interventions on the players' external loads and game analysis in the 3 × 3 basketball game. We included only male basketball players in our study. We recommend that further studies be conducted on female players to examine the acute effects of the FCM and PAP protocols on game demands and thermal asymmetry and even investigate gender differences.

As a result, we determined that the FCM and PAP did not create a significantly different internal load compared with the baseline protocol, the significant increase in 1PA after the FCM was accompanied by a significant increase in turnover after the PAP, a significant higher total distance was achieved after the FCM, and the lowest significant data was in velocity band 2 (20–<40%) after the PAP in this study. Additionally, we found that significant thermal asymmetry occurred in the abdominals and lower back regions (in addition to the hamstrings in the PAP) after the FCM and PAP. We observed that after different protocols, jumps were in the medium band (20–40 cm) of the majority of the 3 × 3 basketball games, and although there was a quantitative increase in CMJ height after FCM and PAP (the largest increase was after PAP), this increase was not significantly different. We also found that the FCM and PAP protocols had no acute significant effects on jumping or CoD during the 3 × 3 basketball games. In addition, although there was no significant difference, we reached the highest quantitative data in the parameters of distance in velocity band 6 (distance covered at 100% of maximum velocity), jump count in the high band (>40 cm), and CoD count at high velocity after the FCM. Therefore, in light of the findings obtained above, it can be said that the FCM is the more preferred protocol by coaches, players, athletic performance trainers, and practitioners in the warm-up phase in order to increase the total distance and high-intensity activity counts in the 3 × 3 basketball game. In addition, the acute effect on the 3 × 3 basketball game demands can be examined after some modifications, such as choosing different types of movements in the protocols, changing the game's start time after the protocol, and differentiating the number of sets applied in the protocols. Moreover, considering that players in 3 × 3 basketball tournaments usually play 2–3 games in a day, using these protocols before each game or before a selected game (first or last, etc.) and evaluating the acute effect will also provide a different perspective. We also recommend investigating the chronic effects of the FCM and PAP protocols applied regularly for a long period of time on the game demands.

## 5. Conclusions

Previous research has shown that the FCM and PAP protocols acutely enhance performance [24,37,38]. However, no previous research has determined the effects of using the FCM and PAP as a warm-up strategy before a 3 × 3 basketball game on the game demands and thermal asymmetry responses. The results of this current study revealed that the FCM and PAP do not significantly differ in internal load; however, FCM improves the game demands on external load (maximum total distance after FCM, highest distance in maximum velocity band, highest jump count in high band, and highest CoD count at high velocity) and game analysis (increase in 1PA after FCM). In the 3 × 3 basketball game played following the FCM and PAP, no preventive intervention or risk situations occurred in terms of thermal asymmetry. Therefore, strength and conditioning coaches, players, and practitioners should consider using the FCM to increase the total distance and high-intensity activity counts in the 3 × 3 basketball game.

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**Data Availability Statement:** The raw data supporting the conclusions of this article will be made available by the authors on request.

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