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Determining the Relationship between Physical Capacities, Metabolic Capacities, and Dynamic Three-Point Shooting Accuracy in Professional Female Basketball Players

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Abstract: Three-point shooting plays an important role in determining the outcomes of basketball games and could be relevant for player selection. However, there has been little research into the relationship between basketball players' physical capacities, metabolic capacities, and three-point shooting accuracy, particularly among female players. The aim of this study was to examine the relationship between physical capacities, metabolic capacities, and dynamic three-point shooting accuracy in female professional basketball players. Twelve female professional basketball players from the Women's Chinese Basketball Association (WCBA) league (age: 19.04 ± 1.31 years, height: 181.33 ± 4.90 cm, playing experience: 7.83 ± 1.7 years) were recruited for this study. Pearson correlations and multiple linear regression analysis were run to assess the relationship between physical capacities, metabolic capacities, and dynamic three-point shooting. Results showed that coordination, balance, core strength, and relative average power were positively correlated with three-point shooting accuracy ($r > 0.58$, $p < 0.05$), while no other variables showed significant correlations. The current study suggests that coaching staff should consider coordination, balance, core strength, and anaerobic capacities when selecting players as well as in their training periodization if three-point shooting accuracy is considered relevant.

Keywords: basketball skills; physical fitness; basketball testing; dynamic shooting; shooting accuracy

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1. Introduction

From the perspective of metabolic capacities, basketball is a highly intermittent, aerobic–anaerobic sport [1]. Specifically in female basketball, players average 5215 ± 314 m per game, including walking (456 ± 20 m), jogging (1517 ± 93 m), running (1850 ± 13 m), and sprinting (925 ± 184 m) [2]. Additionally, authors have further pointed out that players perform 35 ± 11 jumps, 49 ± 17 sprints and 58 ± 19 high-intensity runs. Researchers have highlighted that aerobic capacity can aid in the faster resynthesis of phosphocreatine during intermittent high-intensity exercise, which is a key determinant of high-level basketball performance [3], and also that anaerobic capacity has a greater impact on basketball players' performance [4]. Specifically, the ability to produce repetitive explosive efforts, such as jumps, accelerations and decelerations, and changes of direction, are all critical elements in the efficient movement process with and without the ball, directly affecting game performance [5] as well as player selection [6].

On the other hand, understanding the specific physical capacities required by basketball competition is the foundation for designing appropriate training [7,8]. Several studies have reported that physical capacities play an important role in determining basketball players' performance. Studies investigating the importance of strength for basketball players have reported that good lower extremity strength is positively associated with motor control and coordination of the lower limb joints, thus influencing the players' ability to perform sprints, changes of direction, and jumps [9–11]. Similarly, Ferioli et al. investigated the difference in players' physical capacities regarding different divisions of the NCAA basketball league, finding that players in Division I performed better in peak power output and absolute peak force than those in Divisions II and III [12]. Additionally, as part of strength, many studies have highlighted the important role of core strength [1,13]. As the core connects the upper and lower parts of the body, proper core strength is essential to transfer forces in complex, multiplanar movements that involve both the upper and lower extremities. Furthermore, recent research has found a strong positive correlation (r = 0.837, $p = 0.003$) between vertical jump ability in elite female players and their shooting performance [14]. Likewise, a study by Maria Garcia-Gil et al. found a strong correlation ($p < 0.05$) between T-drill test performance in 41 female basketball players in the Spanish league, and their overall on-court performance, as measured by a composite score (PIR/min) of points, rebounds, assists, and missed shots [15]. Importantly, the core is essential for balance and postural control [1,13], which help players maintain motor control even under the influence of physical contacts, which are frequent in the basketball game. Furthermore, previous studies have shown that players with better speed, agility, and jump capacities have substantial advantages in competition scenarios such as rebounding, blocking, and shooting [16].

While the physical and metabolic capacities of basketball players have been extensively researched, less effort has been made to understand the relationships they have with specific performance aspects, such as shooting. With the development of modern basketball, the trends of three-point popularity have greatly changed the game. In recent years, many National Basketball Association (NBA) teams have emphasized more three-point shooting attempts as an essential part of preparing for the game [17]. Game-related statistics showed that three-point field goal attempts/field goal attempts (%) (3PA/FGA (%)) have increased in the NBA at an average annual rate of 0.6% over the past 40 years, indicating that three-point shooting is becoming more and more important in high-level basketball games. Furthermore, Stavropoulos et al. reported that, in the 2019 Men's Basketball World Cup, assists, two-point field goal percentage, and three-point field goal percentage were the key factors determining the outcome of the game [18]. The increase in usage of three-point shots in modern basketball has been fostered by data science approaches, which collectively found that three-point shooting from certain spots of the court is a more efficient option than two-point shooting [19].

From a physical perspective, shooting from the three-point area requires faster releasing speed and maintaining the proper flight angle and shot direction [19], which might be related to high specific physical capacities. From a physiological perspective, one study showed that players' three-point shooting performances decrease at higher intensities (80% of the peak heart rate) compared to lower ones (20% of the peak heart rate) [20], which suggests that players should be trained for shooting tasks during physiologically demanding game scenarios. To our knowledge, the relationship between physical capacities, metabolic capacities, and three-point shooting has not been deeply analyzed. Given the importance of three-point shooting in modern basketball, coaches and researchers are quite interested in the matter [21]. However, previous research has mainly focused on technical skills, with little information available on how physical and metabolic capacities relate to three-point shooting accuracy, especially in dynamic shooting tasks that resemble the game scenarios. Therefore, the aim of this study was to examine the relationship between physical capacities, metabolic capacities, and dynamic three-point shooting in female professional basketball players. Identifying the most important physical and metabolic capacities associated with three-point shooting might have considerable practical significance for player selection and training periodization in high-level basketball players.

2. Materials

2.1. Participants

Twelve female basketball players (age: 19.04 ± 1.31 years, body height: 181.33 ± 4.90 cm, body fat: 24.38 ± 2.71%, playing experience: 7.83 ± 1.7 years) participated in the study. All players played in the Women's Chinese Basketball Association league (WCBA) (the top national league). Players' training plans featured skills and team ball trainings of around 12.5 h per week (5 days × 2.5 h/day), while physical conditioning accounted for 10 h a week (5 days × 2 h/day). To avoid the interference of fatigue on testing, players were asked to restrain from training sessions one day before testing. All players had no illnesses or injuries. A detailed explanation of the study procedures was provided, and players gave written informed consent prior to the testing procedure. The Beijing Sport University Ethics Committee approved the study, which was performed following the ethical standards of the Declaration of Helsinki (code: 2023036H).

2.2. Procedures

Players' physical and metabolic capacities and three-point shooting were assessed over 3 days. Before the start of each testing day, all players had a 10 min warm-up for physical and metabolic capacity tests consisting of 5 min jogging and 5 min dynamic stretching. For the shooting test, the warm-up consisted of 5 min jogging, 5 min dynamic stretching, and 5 min casual shooting. On the first day, the one-repetition maximum (RM) deep squat, one-RM bench press, 20 m sprint, lane agility test, vertical jump, Functional Movement Screen (FMS), plank support, and supine static tests were conducted. The aforementioned tests were selected since the one-RM deep squat, one-RM bench press, and vertical jump test can evaluate players' strength [22], and the 20 m sprint test and lane agility test are important to determine the speed and agility, respectively [23,24]. Additionally, many studies have used the FMS, plank, and supine static tests to measure players' coordination, core stability, and body control ability [25,26]. Furthermore, on day 1, body height and mass were measured using an ultrasound meter [27] (Tanita WB-380, Tokyo, Japan), and body fat percentage was obtained through an electronic body composition device (Tanita RD545, Tokyo, Japan) [28]. The 20 m sprint and vertical jump height were measured using a SmartSpeed Timing Gate System (Fusion Sport, Queensland, Australia) and a Kistler three-dimensional force measuring platform (Kistler 9260AA, Winterthur, Switzerland), respectively. Their reliability and validity have been confirmed by previous studies [29–31]. The FMS consists of 7 movement patterns: deep squat, hurdle step, inline lunge, shoulder mobility, active straight-leg raises, trunk stability push-up, and rotary stability. The scoring criteria are rated on a scale of three, two, one, and zero, respectively. Three is given if the individual can perform the movement without any compensations according to the established criteria; two is given if the individual can perform the movement but must utilize poor mechanics and compensatory patterns to accomplish the movement; one is given if the individual cannot perform the movement pattern even with compensations; and zero is given if the individual has pain during any part of the movement. The participants were allowed to try three times for each movement pattern, and the best performances were chosen [32]. Additionally, the one-RM deep squat, one-RM bench press, 20 m sprint, plank test, supine static test, and lane agility test (Figure 1) were performed under the guidance of previous studies [6,26,33].

On the second day, the maximum oxygen uptake, peak power, peak power relative value, average power, and average power relative value were examined. Previous studies have confirmed that oxygen uptake is considered to reflect athletes' aerobic capacity, and peak power, peak power relative value, average power, and average power relative value are considered to reflect athletes' anaerobic capacity [34,35]. To evaluate players' aerobic capacity (metabolic capacity), a Lode treadmill (Lode Valiant Ultra 450, Groningen, The Netherlands) was used, connected with the cardiopulmonary function testing system (Cortex, Leipzig, Germany), to measure players' maximal oxygen consumption using the direct measurement test. Participants completed an incremental treadmill test starting at

7–12 km/h with 1% slope and increasing by 1 km/h every 3 min until volitional exhaustion. VO_2 was measured during the last 60 s of each 3 min stage, and the highest VO_2 value obtained during the test was recorded as the participant's VO_2max [36,37]. Anaerobic capacity was evaluated using the 30-second Wingate Test, performed on a cycle Ergometer (MONARK894E, Vansbro, Sweden) [38].

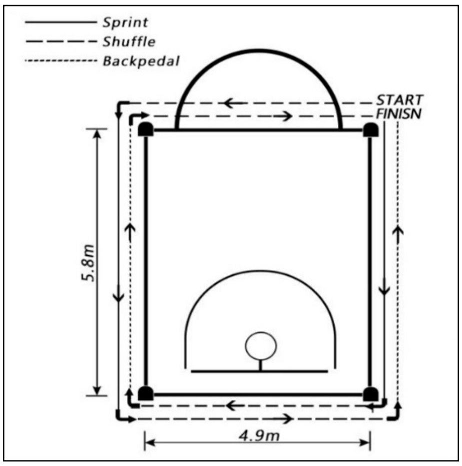

Figure 1. Layout of lane agility test.

On the third day, 90 s (s) dynamic three-point shooting was examined. The shooting test is presented in Figure 2. Players dribbled the ball in any direction from the start area to the three-point line, performing a three-point shot. Then, they ran to catch the rebound and dribbled out of the three-point line to attempt another three-point shot. Players were asked to repeat this for 90 s. All players were encouraged to catch the rebound at full speed to take as many shots as possible. A backboard clock (ZJS-3C, JinLing, Zhangjiagang, China) was used to count 90 s. Each player executed the test two times (i.e., after all players executed the three-point shooting one time, players executed a second time in the same order as the first time), and the best performance was recorded. The 90 s dynamic three-point shooting results were used to determine the shooting accuracy since it is similar to the game situation in which players execute shooting off the dribble frequently. Additionally, this shooting test is used to evaluate players' shooting skills in the WCBA and CBA (China Basketball Association) drafts.

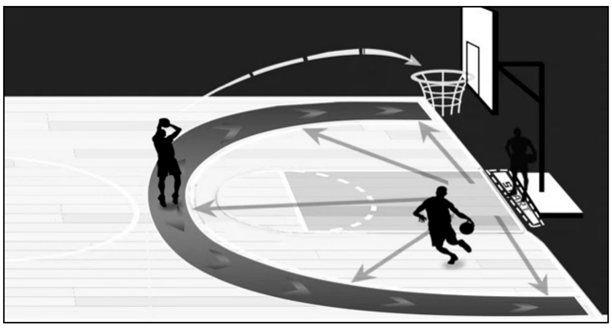

Figure 2. Layout of 90 s dynamic three-point shooting test.

2.3. Statistical Analysis

Descriptive statistics (mean ± standard deviations) were calculated. The assumption of normality was confirmed through the use of the Shapiro–Wilk test. The Pearson correlation coefficient (r) measures the strength and direction of the linear relationship between two variables, ranging from −1 to +1. According to previous studies, the following ranges are commonly used to interpret the strength of the correlation,: negligible (0.00–0.10), weak

(0.10–0.39), moderate (0.40–0.69), strong (0.70–0.89), and very strong (0.90–1.00) [39,40]. Multiple linear regression analysis was carried out to assess the relationship between physical capacity, metabolic capacity, and three-point shooting accuracy.

In order to detect the multicollinearity of independent variables, the variance inflation factor (VIF) was used [41]. The VIF showed a high degree of multicollinearity between the value of 1 RM bench press and the supine static test (VIF > 5). Therefore, the 1 RM bench press was removed. Stepwise regression analysis was used to identify the collinearity of variables, and the result showed that there were multicollinearity issues between the values of peak power and relative peak power and between the values of average power and relative average power. Therefore, the values of peak power and value of average power were removed. Statistical significance was set at $p < 0.05$, and calculations were performed using SPSS (version 26).

3. Results

The descriptive statistics of physical capacities, metabolic capacities, and dynamic three-point shooting are presented in Table 1. Mean value, standard deviation (Sd), minimum value, and maximum value were calculated for all variables.

Table 1. Descriptive statistics of physical capacities, metabolic capacities, and three-point shooting.

Variables	Mean	SD	Minimum	Maximum
Age (y)	19.04	1.31	16.75	21.17
Height (cm)	181.33	4.90	175.00	192.00
Weight (kg)	71.01	4.99	63.50	81.90
Body fat rate (%)	24.38	2.71	20.10	29.60
Training experience (y)	7.83	1.70	5.00	11.00
FMS	14.75	2.42	10.00	18.00
20 m Sprint (s)	3.40	0.10	3.24	3.58
Lane agility test (s)	13.08	0.58	12.27	14.19
Vertical Jump (cm)	53.08	4.08	47.00	60.00
1 RM bench press (kg)	55.33	6.30	43.00	65.00
1 RM deep squat (kg)	90.67	13.97	65.00	115.00
Supine static test (s)	132.67	28.96	96.00	180.00
Plank support test (s)	210.67	56.65	156.00	322.00
Maximum oxygen uptake (mL/kg/min)	46.75	3.19	42.00	53.00
Relative peak power (w/kg)	9.50	0.61	8.23	10.18
Relative average power (w/kg)	7.18	0.63	5.87	7.81
Average power (w)	508.64	47.16	419.97	592.18
Peak power (w)	673.61	54.23	587.75	768.97
Dynamic three-point shots made (n)	10.42	1.44	8.00	13.00

The results of the Pearson correlation coefficients and multiple linear regression analyses between physical capacities and dynamic three-point shooting accuracy are shown in Table 2 and Figure 3. The seven physical capacity variables (FMS, 20 m sprints, lane agility test, 1 RM deep squat, vertical jump, plank support test, and supine static test) were included in the multiple regression analysis due to multicollinearity issues. The multiple linear regression analysis showed that the adjusted R^2 was 0.335, explaining the 33.5% variation in dynamic three-point shooting accuracy. Additionally, the FMS score was significantly correlated with dynamic three-point shooting accuracy ($r = 0.632$, $p < 0.05$, 95% CI [0.000 to 0.875]). Furthermore, the performance of plank support was significantly correlated with the dynamic three-point shooting performance ($r = 0.584$, $p < 0.05$, 95% CI [−0.001 to 0.888]). However, no significant correlation was found between 1 RM bench press, 1 RM squat, 20 m sprint, supine static test, vertical jump, and dynamic three-point shooting ($p > 0.05$).

Table 2. The results of Pearson Correlation Coefficients and Multiple Linear Regression analyses between physical capacities and dynamic three-point shooting accuracy (N = 12).

Variables	r (95% CI)	SIG (Two Tailed)	β	VIF
FMS	0.632 (0.000 to 0.875) (moderate)	0.027 *	0.894	3.661
20 m Sprint (s)	−0.084 (−0.760 to 0.647) (negligible)	0.795	−0.521	3.523
Lane agility test (s)	−0.133 (−0.721 to 0.771) (weak)	0.680	−0.007	2.590
1 RM deep squat (kg)	0.107 (−0.378 to 0.616) (weak)	0.741	0.346	4.326
Vertical Jump (cm)	0.194 (−0.323 to 0.691) (weak)	0.545	−0.37	2.865
Plank support test (s)	0.584 (−0.001 to 0.888) (moderate)	0.046 *	0.710	2.445
Supine static test (s)	0.373 (−0.126 to 0.793) (weak)	0.232	−0.620	4.485
Model summary	Adjusted R^2 = 0.335		DW = 2.064	

Note: * r = Pearson's product-moment correlation coefficients; 95% CI = 95% confidence interval; SIG = significant difference; β = standardized coefficient; R^2 = adjusted coefficient of determination; * = statistical significance of $p < 0.05$; VIF = variance inflation factor.

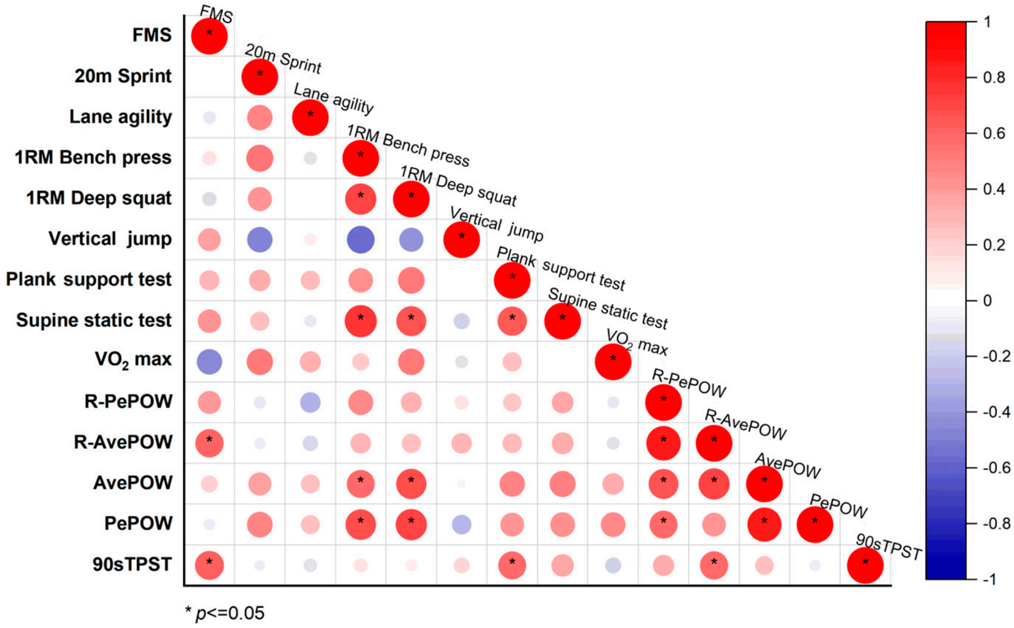

Figure 3. The results of Pearson correlation analysis between physical capacities, metabolic capacities, and three−point shooting. Note: FMS = Functional Movement Screen; 1 RM Bench press = 1 repetition maximum bench press; 1 RM deep squat = 1 repetition maximum deep squat; VO_2 max = maximal oxygen consumption; R−PePOW = relative peak power; R−AvePOW = relative average power; AvePOW = average power; PePOW = peak power; 90 s TPST = three−point shooting test; * = $p < 0.05$.

On the other hand, the results of Pearson correlation coefficients and multiple linear regression analyses between metabolic capacity and dynamic three-point shooting are shown in Table 3 and Figure 3. After removing independent variables due to multicollinearity issues, three metabolic capacities (maximal oxygen consumption, relative peak power, and relative average power) were included in the multiple regression analysis. The multiple linear regression analysis showed that the adjusted R^2 was 0.313, explaining 31.3% of the dependent variable's variation. Furthermore, the relative average power was significantly correlated with dynamic three-point shooting performance (r = 0.596, $p < 0.05$, 95% CI [−0.156 to 0.898]). However, there was no significant correlation between maximal oxygen consumption and average peak power ($p > 0.05$).

Table 3. The results of Pearson correlation coefficients and multiple linear regression analysis between metabolic capacities and dynamic three-point shooting accuracy (N = 12).

Variables	r (95% CI)	SIG (Two Tailed)	β	VIF
Maximal oxygen consumption (mL/kg/min)	0.044 (−0.499 to 0.474) (negligible)	0.891	0.894	1.014
Relative Peak Power (w/kg)	0.34 (−0.584 to 0.773) (weak)	0.279	−0.521	4.375
Relative Average power (w/kg)	0.596 (−0.156 to 0.898) (moderate)	0.041 *	−0.007	4.372
Model summary	Adjusted R^2 = 0.313	D-W = 2.406		

Note: * r = Pearson's product-moment correlation coefficients; 95% CI = 95% confidence interval; SIG = significant difference; β = standardized coefficient; R^2 = adjusted coefficient of determination; * = $p < 0.05$; VIF = variance inflation factor.

4. Discussion

Three-point shooting is a key performance indicator in basketball [42], and the increase in usage of three-point shots in modern basketball has been collectively reported by data science approaches [19]. However, there has been little research into the relationship between basketball players' physical capacities, metabolic capacities, and three-point shooting accuracy, particularly among professional female players, which is a population that, generally, has received less attention compared to their male counterparts. The aim of this study was to determine the relationship between basketball players' physical capacities, metabolic capacities, and dynamic three-point shooting accuracy. The results of the current study showed that there was a significant positive correlation between coordination and balance (assessed with FMS, r = 0.632, moderate), core strength (plank support test, r = 0.584, moderate), and dynamic three-point shooting accuracy. Furthermore, anaerobic capacity (relative average power, r = 0.596, moderate) was highly correlated with dynamic three-point shooting accuracy. Differently, there were no significant correlations between three-point shooting and absolute strength (1 RM bench press and squat), agility, speed, aerobic capacity (VO_2 max), anaerobic peak power, relative peak power, or average power.

Previous studies have reported that the FMS test can effectively evaluate coordination, body control, and flexibility [25,43,44]. Researchers further mentioned that lower FMS scores may lead to unbalanced muscle strength in basketball players, which can negatively affect shooting technique [45,46]. This study found a large, positive correlation between the FMS test score and dynamic three-point shooting accuracy, indicating that better coordination and body control contributed to three-point shooting accuracy. A study by Apaak et al. [47] investigated the relationships between physical fitness variables and shooting performance among basketball players, which demonstrated a positive relationship between coordination and dynamic shooting performance (dynamic free throws and dynamic two-point shots). These findings are consistent with current results, which suggest that coordination is associated with improved shooting accuracy. Therefore, it appears that coordination and motor control have relevant associations with three-point shooting, an important key performance indicator in basketball.

Differently, there were no correlations between dynamic three-point shooting and squat, bench press, 20 m sprint, and vertical jump. A previous study reported that as shooting distance increases, the lower extremity needs to produce more force to accelerate the ball speed, and the upper extremity must adjust the motion to maintain balanced and stable shooting, which requires good coordination [48]. This also corresponds to our finding that shooting is a technical skill depending mostly on motor control/coordination instead of pure physical capacity. To this end, this study suggests that coaching staff need to design appropriate coordination and body control training to enhance the stability and coordination of all joints and muscles.

The Pearson correlation coefficient analyses showed a large, positive correlation between the plank support test and dynamic three-point shooting accuracy. Previously, Chen et al. [49] showed that an 8-week core strength intervention improved free throw accuracy by 14.0% and dynamic shooting accuracy by 36.2% in collegiate male basketball players. Furthermore, Liu [50] divided 40 college male basketball players into a core strength training (experimental) group and a traditional strength training (control) group. After 12 weeks, dynamic shooting accuracy in the core strength training group increased by 32.8%, which was higher than that of the traditional strength training group. The role of the core is essential in whole-body movements, as it integrates and bypasses forces from distal segments. Additionally, basketball competitions feature intense physical contact, which can impair players' shooting technique [51]. Therefore, it is important for players to have proper core strength to maintain balance and stabilize the body when shooting. Similarly, Liu [52] noticed that the body's vestibular sensation, proprioception, and central nervous system's ability to regulate muscles are significantly improved as core strength improves, which can effectively improve players' dynamic balance ability, which is required for three-point shooting.

It has been suggested that anaerobic capacity is a more critical factor in a basketball game than aerobic capacity [53], seen by Supej et al. as an "anti-fatigue" ability in determining jump height and shooting biomechanics when shooting from a long distance [54]. The current study found that players with higher relative average power have better dynamic three-point shooting accuracy. In terms of the shooting test in this study, players were asked to take as many shots as they could while running to pick up the ball after each shot, a task that required high anaerobic endurance. This finding is in line with Pojskic et al. [55], who also found that the relative anaerobic power, as measured in an anaerobic sprint test, was positively correlated with dynamic three-point shooting accuracy. The authors further concluded that players with good anaerobic endurance can reduce the negative effects of fatigue on shooting accuracy. Additionally, studies have pointed out that elite basketball players can adjust the shooting motion by modifying shooting height and biomechanical factors when they are fatigued, in order to maintain a higher shooting efficiency [56–58]. Regarding the other metabolic capacities assessed, there was no significant correlation between maximal oxygen uptake and dynamic three-point shooting. A possible explanation for this might be that the 90 s dynamic three-point shooting test is relatively short, requiring less aerobic metabolism energy supply but more anaerobic supply [59]. Since basketball games are characterized by intense phases of activity relying on anaerobic metabolism, the current study suggests combining anaerobic endurance training with shooting drills in order to effectively improve shooting efficiency in real-game settings [6].

5. Limitation

This study has some limitations. Firstly, due to the small sample size, the results need to be interpreted with caution as the findings might not translate across skill levels, ages, and genders, which is a potentially significant limitation that should be further investigated. Additionally, physical demands and physiological responses during the dynamic three-point shooting were not monitored. Future studies are recommended to include the physical demands (e.g., accelerometry) [60] and physiological responses [61] during testing, such as blood lactic acid and heart rate, to better analyze and interpret the correlation between physical demands, metabolic capacities, and shooting performance. Furthermore, the shooting test in this study is just one type of three-point dynamic shooting. In the future, other dynamic shooting techniques should be investigated, such as catch and shoot, or a combination of catch and dribble shots.

6. Conclusions

The purpose of the current study was to determine the relationship between physical capacities, metabolic capacities, and dynamic three-point shooting. In terms of physical capacity, this study has shown that dynamic three-point shooting was significantly correlated with coordination, balance, and core strength. In terms of metabolic capacity, this study found that relative average power was significantly correlated with dynamic three-point shooting. However, there were no significant correlations between strength, speed, agility, aerobic capacity, and dynamic three-point shooting. The findings of this study suggest that developing the coordination, balance, core strength, and relative average power of female basketball players may help improve their dynamic three-point shooting accuracy. Basketball practitioners and directors might consider testing players' coordination, balance, core strength, and relative average power capacities since three-point shooting is important for success in basketball [62].

Author Contributions: F.L., X.M. and M.Z. contributed to the conception and design of the study. T.R. and P.S. collected the data and performed data analysis. M.Z. and F.L. wrote the first draft of the manuscript. P.S., T.R. and T.V. made critical revisions of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of Beijing Sport University (ethical code 2023036H, approval date 13 March 2023.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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