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Optimal Joint Angles of a Free Throw Shot in NCAA Division II Women's Collegiate Basketball Players

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Optimal Joint Angles of a Free Throw Shot in NCAA Division II Women's Collegiate Basketball Players

by

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Abstract

The purpose of the present study was to analyze the free throw shooting form of NCAA Division II women's basketball collegiate athletes. Joint angles of the wrist, elbow, shoulder, hip, knee, and ankle were assessed in the sagittal plane to identify differences between proficient ($\geq$ 80%) and non-proficient (< 80%) shooters, along with differences between made and missed free throw shots. Fourteen healthy athletes (19.9 ± 1.5 yrs.) completed four sessions of 25 free throw attempts for a total of 100 attempts per athlete and video data on each of the six joint angles was examined in both the preparation and follow-through phases. Proficient ($\geq$ 80%) free throw shooters had more hip flexion, along with less wrist extension, elbow flexion, knee flexion, and ankle dorsiflexion than non-proficient (< 80%) shooters in the preparation phase. Proficient shooters also have more hip extension, and less wrist flexion, elbow extension, knee extension, and plantarflexion than non-proficient shooters in the follow-through phase. Greater shoulder extension at the preparation phase was found to be significant ($p \leq 0.014$), and less knee extension at the follow-through phase approached significance ($p \leq 0.064$) between made and missed free throw shots in this population. Results from this study have potential to be applied to coaching cues and form correction at the free throw line in basketball athletes.

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I would like to thank my chairperson, Dr. Kyle Reason, for his guidance throughout this entire process. Completing this thesis was met with its challenges, but Dr. Reason was there to answer any questions or clarify any confusion I had. His passion for education and dedication to his students is second to none. Dr. Reason gave me the courage to learn and grow through this process, and I am grateful for the opportunity to work with him.

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I would also like to thank Jessica Hartmann for her expertise in athletics and women's basketball. As a former player and current coach at St. Cloud State, Jessica added insight to the data collection process. Jessica is an incredible mentor and provided me with productive feedback on my work.

Finally, I would like to take the time to thank the St. Cloud State women's basketball team members and coaches for allowing me to work with them. Because of their cooperation and excitement for this study, valuable information was found and can be applied directly to the future success of their program. Without their participation, this process would not be possible.

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Chapter I: Introduction

With 27.1 million people playing in 2021 (Broughton, 2022), basketball has become a popular sport on the world stage as well as within the United States. Particularly, women's basketball has grown in popularity as collegiate athletes continue to provide a national platform with increased viewership (Elchlepp, 2023). According to Next College Student Athlete Sports (Women's college basketball teams, 2023), there are more than 1,000 active women's basketball teams in the National Collegiate Athletic Association (NCAA). Among the 1,000+ NCAA women's teams, there was a standout NCAA Division I championship game in the 2022-23 season that reached 9.95 million viewers on ABC network, resulting in a 95.2% year-over-year viewership increase (NCAA women's final four, 2023). As Doherty (2023) has mentioned, the 2023 NCAA Division I Elite Eight games' viewership increased by 43% from the 2022 tournament. Major increases in viewership exemplifies the highest level of competition in collegiate women's basketball is gaining traction, yet there is a gap in literature when it comes to studying female basketball players.

Team success (measured by number of wins per season) can be attributed to the number of points scored in any given game (Okazaki et al., 2015). As a result, the ability to shoot the ball accurately can further impact a team's chances of winning. Particularly, optimal joint angle biomechanics of a shot are important to enhance the overall accuracy, as it has been shown to impact the overall trajectory of the ball (Kelmendi et al., 2021). In basketball, often times, a singular point can determine the outcome of the game, therefore, a crucial shot for a team's success is the free throw (Toma, 2017). According to Ammar et al. (2016) the free throw shot is completed without the presence of a defender and allows the offense to score uncontested points.

Because of the absence of any external factors such as a defender, the free throw shot is often thought to be a simpler shot to make compared to its jump shot counterpart, with NCAA Division II women's basketball teams' free throw attempts accounting for an average of 12 points per game in the 2022-23 season (NCAA.com, 2023). Even so, only 47 of the 294 NCAA Division II women's basketball teams shot over 75% from the free throw line in the 2022-23 season. Two of those 47 teams included the national champion and national runner-up teams, both of which ranked in the top 15 for free throw percentage (NCAA, 2023).

Toma (2017) contributes free throw misses to athletes underperforming in high-pressure scenarios with results suggesting free throw percentages decreased within NCAA women's basketball by 2.25 percentage points when less than 30 seconds remained in a game. Another author believes that angular velocity at varying joint angles can be attributed to the success or failure of a shot (Okubo & Hubbard, 2015). Angular velocities of the shoulder, wrist, and elbow work in conjunction to determine how one joints angular velocity impacts the others. Specifically, larger angular velocities in the shoulder joint have frequently been accompanied by an increase in the angular velocity magnitude of the elbow to produce an accurate trajectory of the ball after it is released (Okubo & Hubbard, 2015). By using a two-dimensional computer simulated arm model and geometric calculations, researchers have estimated optimal release conditions based on ball release speed, angle, and backspin, yet results concluded no singular combination of joint angles was deemed most successful (Okubo & Hubbard, 2015).

While psychological factors and joint angular velocity have shown to play a key role in determining the success of a free throw shot, another possible technique used to analyze potential success is to assess kinematic differences. As another branch of biomechanics, kinematics are often used to analyze the motion of an object (Oxford languages, 2023), particularly used in this case to assess degree changes within specific joint angles. Ammar et al. (2016) suggest that knee angle has the largest impact on free throw success, specifically with higher prevalence of made shots utilizing a joint angle of 160.6 degrees of flexion compared to 158.2 degrees for missed shots. Cabarkapa et al. (2021) found that proficient (> 70% makes) shooters averaged 108.5 degrees of knee flexion, 71.9 degrees of elbow flexion, 147.6 centimeters of elbow height, and 7.9 degrees of elbow angle. Proficient shooter data was then compared to non-proficient (< 70% makes) shooters averaging 117.9 degrees of knee flexion, 80.5 degrees of elbow flexion, 153.5 centimeters of elbow height, and 19.8 degrees of elbow angle (Cabarkapa et al., 2021).

However, due to a shot's complexity, joint angles utilized throughout the total duration of free throw shot cannot be limited to a single frame. Therefore, it is common for the free throw shot to be broken down into two distinct phases to assist in a better understanding of the impact of various movement patterns on shot success. Specifically, the biomechanics of jump shots have been split into either three phases (preparation, release, and follow-through) (Irawan & Prastiwi, 2022), or five phases (preparation, ball elevation, stability, release, and inertia) (Okazaki et al., 2015). However, when analyzing a free throw, the jump is not included and therefore can be simplified into two phases (preparation and follow-through) (Kelmendi et al., 2021). The preparation phase occurs when athletes are set in a stance prior to any shot movement (Figure 1A). Athletes in this phase are at their relative maximal point of flexion in the elbow, hip, knee, and ankle, while also at their relative maximal extension in the wrist and shoulder joints prior to the upward shooting motion. The follow-through phase is the final pose athletes hold immediately following the release of the ball from the hand. In this phase, basketball players have shifted the elbow, hip, knee, and ankle into extension, while the wrist and shoulder move into flexion immediately following the release of the ball (Figure 1B).

Although there are several different approaches to determining optimal biomechanical impact on the accuracy of a free throw, joint angles remain important for analysis. Since the naked eye cannot calculate angular velocity or joint angles, video analysis can produce information that interprets significant differences within joint angles to allow coaches to correct form in their athletes (Ammar et al., 2016). Due to the increased need for representation of female athletes in literature, the primary purpose of this study was to apply previous research modalities on joint angle biomechanics to an NCAA Division II women’s basketball team while looking at the impact of joint angle differences between proficient (≥ 80%) and non-proficient (< 80%) free throw shooters in the preparation and follow-through phases. The secondary purpose of this study was to analyze joint angle differences between made and missed free throw shots at the preparation and follow-through phases.

Chapter II: Methods

Participants

Fourteen NCAA Division II women's basketball players between the ages of 18 and 22 participated in this study. Using a sample size calculator (Dhand & Khatkar, 2014) it was determined *a priori* that 13 participants would be sufficient to achieve a desired power of 0.8, using a moderate-high effect size, and an alpha level set at 0.05 when using differences in knee joint angle between misses and makes (Ammar et al., 2016) as the primary dependent variable. All participants were actively rostered on the St. Cloud State University women's basketball team. All procedures were approved by the university institutional review board and followed all ethical guidelines for research with human subjects. Written informed consent was obtained prior to data collection. To be included in this study, athletes must have been free of injury and cleared by the St. Cloud State University sports medicine staff to fully compete in practices and games. Anthropometric data was taken for each participant using a stadiometer for height (cm) (Portable Mechanical Stadiometer-HM200P, Charder Medical, Taichung City, Taiwan) and a column scale (seca 700, seca, Hamburg, Germany) for body mass (kg).

Table 1

Anthropometric Data for Participants (n = 14)

Variables	Average
Age (yr)	19.9 ± 1.5
Experience (yr)	13.3 ± 2.4
Height (cm)	178.7 ± 6.6
Mass (kg)	73.8 ± 9.2

Note: Values are means and standard deviations.

Procedures

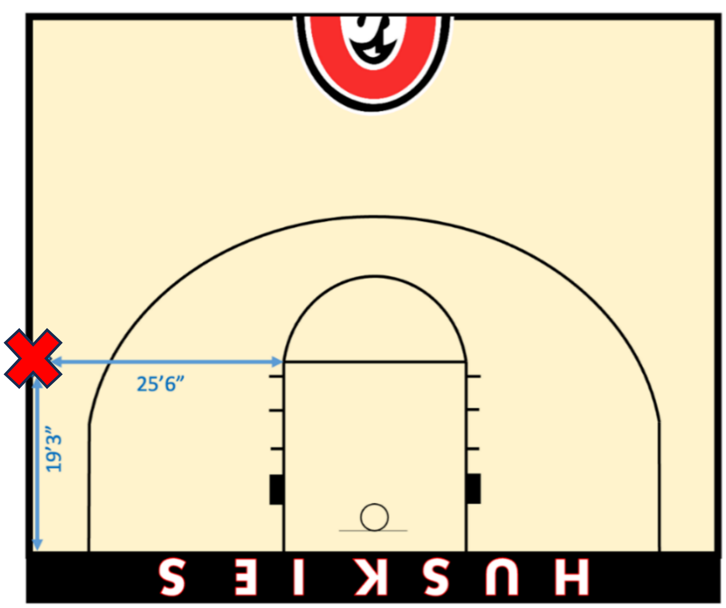
Participants reported to the gymnasium on four occasions and completed 10 warmup free throw shots prior to their 25 free throw attempts at each visit. Each participant completed one hundred free throw attempts using the standard free throw line (Figure 2). For this study, six joint angles were assessed: wrist, elbow, shoulder, hip, knee, and ankle. Analysis of the free throw shot attempts were separated into two phases, the preparation phase, and the follow-through phase. Each individual attempt was recorded using an iPad Air (iPad Air 4^{th} generation, Apple, Cupertino, CA) video camera and tripod facing the sagittal plane of each player. The camera was placed 19 feet, 3 inches onto the basketball court from the baseline, and 25 feet, 6 inches to the side of the lane line. Precise camera location was marked with tape on the court to ensure consistency between trials (Figure 2). The success of individual shot attempts was recorded in the video frame to compare data between makes and misses at each of the phases. Joint angle data and success of the free throw shot in both preparatory and release phases were assessed using artificial intelligence biomechanical technology and integrated software (SportsVision Learn to Compete Platform, SportsVision AI, Minneapolis, MN, US).

Figure 1

Phases of the Free Throw Shot: (A) Preparation Phase (B) Follow-Through Phase

Figure 2

Court Diagram for Video Camera Setup



Statistical Analysis

Using SPSS (v28) data was analyzed and reported as means and standard deviations. Data was analyzed for normality using a Shapiro-Wilk test and was considered acceptable if $p > 0.05$. Data was also analyzed for skewness and kurtosis and deemed acceptable if statistic value was less than 2 times the SEM. Separate independent samples t-test were used to determine differences between joint angles of the wrist, elbow, shoulder, hip, knee, and ankle, when comparing misses and makes for both the preparation and follow-through phases of the free throw shot. An independent t-test was utilized as joint angles between made and missed shots varied and were therefore treated as separate groups of data. Additionally, independent samples t-test were used to compare joint angles of the wrist, elbow, shoulder, hip, knee, and ankle between proficient shooters and nonproficient shooters during the preparation and follow-through phase of the free throw shot. For the present study, individuals who made ≥ 80% of attempted shots were classified as proficient (PS) and those who made < 80% of attempted shots were classified as non-proficient (NPS).

Chapter III: Results

Proficient vs Non-proficient

Anthropometric data for participants are represented in Table 1. Participants completed a total of 1,423 free throw shots. Due to researcher error, 5 of the 14 participants shot 4 more free throw attempts, and 1 participant shot 3 more free throw attempts over the required 100. This was due to a miscount in the attempts, and participants were asked to err on the side of caution and attempt more free throws to meet the minimum of 100. 81% (1,154) of the total shots were makes, and 19% (269) of the total shots were misses. 10 of the 14 participants shot at or above 80% during these trials and were identified as PS, and 4 individuals shot below 80% (three at 77% and one at 62%) and were classified as NPS. Significant differences ($p < .001$) were found when comparing joint angles of the wrist, elbow, hip, knee, and ankle between PS and NPS in both the preparation and follow-through phases (Table 2). No significant differences were found between PS and NPS in either the preparation or the follow-through phase for the shoulder joint ($p > 0.5$).

Makes vs Misses

When comparing joint angles for made and missed shots, significant differences were not found at the preparation phase in the wrist, elbow, hip, knee, and ankle joints ($p \geq 0.18$). However, there was a significant difference in the shoulder joint angle between made and missed shots ($p \leq 0.014$). Furthermore, the follow-through phase of the free throw shot found no significant differences between made and missed free throw shots at the wrist, elbow, shoulder, hip, and ankle joints ($p \geq 0.5$). However, the knee joint angle approached significance between makes and misses ($p \leq 0.064$) (Table 3).

Table 2

Joint Angle Differences between Proficient (≥ 80%) and Non-proficient (≤ 80%) Free Throw Shooters at the Preparation and Follow-through Phases

	Preparation Phase			Follow-Through Phase		
Joint Angles	**PS (n = 1018)**	**NPS (n = 405)**	**Effect Size**	**PS (n = 1018)**	**NPS (n = 405)**	**Effect Size**
Wrist	138.6 ± 21.1	125.2 ± 10.7*	.71	124.4 ± 17.3	121.1 ± 14.4*	.20
Elbow	81.2 ± 17.2	75.0 ± 13.2*	.38	191.2 ± 40.0	200.5 ± 24.9*	-.26
Shoulder	46.8 ± 15.3	46.5 ± 7.8	.02	118.4 ± 34.5	120.6 ± 19.0	-.07
Hip	140.4 ± 13.7	147.8 ± 7.0*	-.61	185.3 ± 4.4	183.7 ± 4.0*	.38
Knee	133.0 ± 10.9	130.1 ± 7.7*	.28	174.7 ± 6.4	178.6 ± 10.4*	-.51
Ankle	68.2 ± 4.6	65.2 ± 4.7*	.63	82.5 ± 4.2	92.0 ± 22.3*	-.76

Values are means and standard deviations; * denotes significance (p < .001) at that specific joint angle; PS = proficient shooters, NPS = non-proficient shooters.

Table 3

Joint Angle Differences between Made and Missed Free Throw Shots at the Preparation and Follow-through Phases

	Preparation Phase			Follow-Through Phase		
Joint Angles	**Makes (n = 1154)**	**Misses (n = 269)**	**Effect Size**	**Makes (n = 1154)**	**Misses (n = 269)**	**Effect Size**
Wrist	135.1 ± 19.9	133.4 ± 18.9	-.09	123.3 ± 16.8	124.0 ± 15.8	.04
Elbow	79.2 ± 16.2	80.5 ± 17.5	.08	193.9 ± 36.3	193.7 ± 38.0	.01
Shoulder	46.3 ± 13.7	48.5 ± 12.8*	.17	119.2 ± 30.0	118.4 ± 34.4	.01
Hip	142.3 ± 12.7	143.2 ± 12.3	.07	184.8 ± 4.4	185.0 ± 4.2	.04
Knee	132.1 ± 10.2	132.5 ± 10.2	.05	175.7 ± 8.2	176.7 ± 6.7†	.13
Ankle	67.3 ± 4.8	67.4 ± 4.9	.03	85.1 ± 13.3	85.5 ± 12.0	.03

Values are means and standard deviations; * denotes significance (p = 0.01) at that specific joint angle; † denotes approaching significance (p = 0.06) at that specific joint angle.

Chapter IV: Discussion

The ability to accurately shoot a free throw shot in the sport of basketball has been shown to contribute to team success (Okazaki et al., 2015). Research suggests accurate shot mechanics require optimal joint angle execution throughout the shot (Ammar et al., 2016). However, despite women's basketball programs exponential growth, there is a lack of female collegiate athlete representation in the literature. Male and female basketball players may differ in strength and height, leading to potentially different shot forms, emphasizing the need for this population to be studied. Therefore, the primary purpose of this study was to assess differences in various joint angles between PS (≥80%) and NPS (<80%) shooters. While the secondary purpose of this study was to analyze joint angle differences between made and missed free throw shots.

Results of the present study show a significant difference in joint angles of the wrist, elbow, hip, knee, and ankle in both the preparation and follow through phases when comparing PS and NPS (Table 2). Cabarkapa et al. (2021) also found significant differences between PS (≥70%) and NPS (<70%), yet results found in the population of recreational males were opposite of the present study. In the present study, less knee flexion was associated with higher accuracy (PS 133.0; NPS 130.1; $p < .001$) and the findings of Cabarkapa et al. (2021) suggest that greater knee flexion was reflective of higher accuracy (PS 108.5; NPS 117.9; $p < .05$). Similar comparisons and opposing values are shown within the elbow joint angle, where less elbow flexion was associated with higher accuracy in the present study (PS 81.2; NPS 75.0; $p < .001$) and Cabarkapa et al. (2021) suggests greater elbow flexion was representative of higher accuracy (PS 71.9; NPS 80.5; $p < .05$). The discrepancy between studies could possibly be explained by strength and height disparities between genders, or potentially that recreational males had been taught to release the ball at a different angle than the women's basketball players, requiring more knee and elbow flexion to get the ball into the hoop. Although Cabarkapa et al. (2021) suggests that 70% is the threshold of PS compared to NPS, only one subject in the present study shot below 70%. Furthermore, 126 of the top 250 NCAA Division II women's basketball players (who played in 75% of total team games) shoot at or above 80% (NCAA, 2023). Therefore, it was determined that for this population, a threshold of 80% more accurately reflects PS vs NPS.

Significant differences were found at five of the six joint angles assessed, with the shoulder being the only joint angle unchanged between PS and NPS. This is potentially due to the shoulder joint being a critical component in overall shot trajectory, and without it, ideal release angle cannot be achieved (Okubo & Hubbard., 2015). Although each individual athlete has their own unique form, PS may have muscle memory and are therefore able to replicate a shooting motion that can attain the desired trajectory of a shot potentially leading to higher accuracy. Influencing factors on the height and angle at which the ball is released involves joint angles and velocities of the upper and lower extremities. Each independent joint angle impacts the overall kinematics of the shot, and the combination of such joint angles play a key role in the assessment of PS and NPS (Ammar et al., 2016). More specifically in the present study, greater range of motion within the hips (45 degrees in PS vs 36 degrees in NPS) throughout the free throw movement was shown in PS, which allows for more upward movement of the trunk throughout the course of the shot, therefore possibly impacting the shots overall trajectory. However, less range of motion within the wrist (98 degrees in PS vs 114 degrees in NPS) elbow (110 degrees in PS vs 125 degrees in NPS), knee (42 degrees in PS vs 48 degrees in NPS), and ankle (104 degrees in PS vs 117 in NPS) joints has shown to be more favorable in PS in the present study. NPS moved through a total larger range of motion at these joints (wrist, elbow, knee, & ankle), potentially impacting the trajectory of the shot, whereas less total range of motion can be characteristic of accurate free throw shooters.

While analysis between PS and NPS has found significance at multiple joint angles, comparison between made and missed free throw shots were also seen to have an impact. The results of the present study show the shoulder joint to be significant ($p = 0.01$) in the preparation phase and the knee joint to approach significance ($p = 0.06$) in the follow-through phase (Table 3). These findings differ at the shoulder joint from the values found between PS and NPS, yet the knee joint significance is similar to those found in previous research. Ammar et al. (2016) found knee joint angle to be the significant ($p < 0.05$) when comparing made and missed free throw shots and suggests knee joint angle to be the most correlated with free throw success (i.e., makes and misses) throughout the trials ($r = 0.64$). Although Ammar et al. (2016) assessed total joint angle movement throughout the course of the shot (i.e., knee flexion to knee extension), the present study has found the knee joint angle may only impact the success of a free throw shot in the follow-through phase. The differences at the knee joint in the present study comparing makes and misses are consistent with those between PS and NPS, where a made shot ends with a softer extension at the knee just after the ball is released.

When analyzing the data as a whole and comparing makes vs misses rather than PS and NPS, made free throw shots showed a lower joint angle (more extended) for the shoulder in the preparation phase. Although the data suggests a 2.2-degree difference is statistically significant, the effect size is very small and therefore is not clinically significant in this setting. However, the lack of variation at the shoulder joint could be due to how these players have been taught to successfully release the ball to get it to the hoop. While the success of the free throw shot is dependent on all other joint angles as well, without the shoulder, the upward motion and ideal release angle is not possible. Okubo and Hubbard (2015) mention the importance of the shoulder joint and how it impacts the vertical component (or upward motion) and therefore the trajectory of the shot. Cabarkapa et al. (2021) also discusses that shoulder angle does not have a significant difference between made and missed shots within their PS (≥ 70%), yet mentions the shoulder angle can still impact velocity, release angle, and overall results at the free throw line. Furthermore, this group of individuals in the present study have been playing basketball for 13.3 ± 2.4 years (Table 1) and are therefore potentially aware of the trajectory necessary to shoot the ball accurately.

Despite the four NPS being responsible for ~ 40% of the missed free throw attempts, the team success at the free throw line under these conditions resulted in 81% made shots. This data suggests the accuracy of these athletes, as the threshold was determined to be 80%, and is higher than those of subjects in previous studies (Cabarkapa et al., 2021). As athletes participating at the NCAA at the Division II level, this level of accuracy is to be expected, yet is not always replicated in game situations. Further studies should assess these parameters of joint angle differences in real-game pressure scenarios. It should also be noted that the joint angles at each phase do not consider the velocity or speed at each joint, which can also impact the distance and rate at which the ball is loaded and released for each attempt.

Limitations

The present study confirms a limitation of game-like scenarios not being represented well, as these athletes were completing data collection on their home court without the presence of fans. Real-life scenarios of games may include a much larger crowd, outside noises, game-situation pressures, or the discomfort of shooting a free throw on a different hoop in a different gymnasium (Toma, 2017). Another limitation is that these free throws were completed after the athlete had adequate recovery time from practice or competition, and therefore did not replicate the in-game scenario of fatigue that basketball athletes experience. This was a known limitation in order to ensure consistency between all subjects and free throw attempts. Furthermore, the subjects completed 10 warmup free throw shot attempts, followed by 25 recorded free throw attempts for each session. It was the researcher's decision that 10 warmup shot attempts were sufficient for the athletes to get into their shot mechanic rhythm, regardless of makes or misses, because in live game situations athletes are not granted any warmup attempts. Finally, the present study was limited to a single camera angle in the sagittal plane and did not account for any extra movement in the frontal or transverse planes. As seen in Cabarkapa et al. (2021), the frontal plane of view can assess limb deviation from the midline throughout the course of the free throw shot. Results from this study found significance within the forearm angle where PS had less forearm deviation from the midline compared to NPS (PS 7.9; NPS 19.8; $p < .05$). Further research within the present population could analyze variation of joint angles in the frontal plane.

Chapter V: Conclusion

The results of the current study suggest that proficient NCAA Division II women's basketball free throw shooters have greater hip flexion, along with less wrist extension, elbow flexion, knee flexion, and ankle dorsiflexion in the preparation phase. Furthermore, these athletes also exhibit greater hip extension, along with less wrist flexion, elbow extension, knee extension, and plantarflexion in the follow-through phase. The results also suggest that lower shoulder positioning during the preparation phase and less extension at the knee joint in the follow-through phase was associated with more made free throw shots in NCAA Division II women's basketball athletes.

The data collected in this study can be used in a variety of ways other than that of the present study. Subject data can be used to compare the teams' most accurate free throw shooter to their least accurate free throw shooter and analyze joint angle differences. Likewise, the made free throw shot data points could be assessed by noticing variance within one joint in a shot attempt and how it impacts the other joint angles throughout the course of the shot. To the authors knowledge, this is the first study assessing NCAA Division II women's basketball athletes in this scenario. Further research should continue to assess high-caliber athletes in game scenarios to assess if joint angles or environmental pressure has more of an impact on their success at the free throw line. The aim of the present study was to assess free throw shooting form to be able to apply coaching cues to enhance player performance. Results suggest consistent differences in joint angles between PS and NPS. Coaches may use this information to provide coaching cues to correct form in NPS.

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Appendix A

Participant Informed Consent

INFORMED CONSENT
ST. CLOUD STATE UNIVERSITY

Title of Project: Optimal Joint Angles During a Free Throw Shot in Division II Women's Collegiate Basketball Players
Primary Investigator: Mattea Peplinski
The following information is provided to inform you about the research project and your participation in it. Please read this form carefully and feel free to ask any questions you may have about this study and the information given below. You will be given an opportunity to ask questions, and your questions will be answered. Also, you will be given a copy of this consent form. You must be 18 or older to participate.

PURPOSE OF RESEARCH STUDY
The purpose of this study is to analyze the impact of various joint angle differences between made and missed free throw shot attempts at the preparation and follow-through phases in division II collegiate women's basketball players.

PROCEDURES OF STUDY

1) Report to the lab and complete this consent form. These forms will be used to evaluate the safety of your participation as well as your willingness to participate. The information will be kept confidential. It is important that you answer these questions accurately and completely. If you have any questions, please ask. Any questions you may have about your participation or the forms you complete are welcomed and will be answered to your satisfaction.

2) You will be asked to complete 4 trials of 25 recorded free throw shot attempts:
    a. 100 total recorded free throw shot attempts.
    b. Descriptive data (age, height, and weight) will be measured at the beginning of the first session.

YOU SHOULD NOT VOLUNTEER IF YOU:
1. **ARE NOT CLEARED FOR PRACTICE AND/OR COMPETITION AT THE TIME OF DATA COLLECTION**
2. **IF YOU ARE UNDER 18 YEARS OF AGE**

The trials will be completed on 4 separate days and will be as follows:
- A) Free Throw Attempts: During these trials you will complete 10 un-recorded free throw attempts, followed by 25 recorded free throw attempts using the standard free throw line. You will be recorded via an iPad video camera placed facing the sagittal plane of your dominant shooting arm. Once your 25 recorded attempts are completed, you will schedule your next visit with the principal investigator.

PARTICIPATION RISKS AND DISCOMFORTS

Potential risks for this study are minimal. There are no additional risks associated with the study other than those already associated with your current participation in collegiate athletics.

COVID-19 RISKS AND PRECAUTIONS

Due to the need for your physical presence at the research site, and face to face interaction with the researchers. There is a risk that you may be exposed to COVID-19 and the possibility that you may contract the virus. Please review the Information on COVID-19 for Research Participants that is attached to this consent document. To minimize your risk of exposure we will routinely sanitize all equipment and surfaces between participants. Furthermore, research's assisting in metabolic cart set up will wear protective gloves during this process.

EXPECTED BENEFITS OF PARTICIPATION

By participating in this study, you will gain valuable information about your shooting biomechanics. Information gathered during data collection may be used by your coaches to assist in optimizing your shooting accuracy.

RIGHT TO WITHDRAW

It is your right to withdraw from the study at any point for any reason. Withdrawing from the study will not adversely affect you in any manner. You should also understand that the investigator might require you to withdraw from the study. If you wish to withdraw at any point during the study please contact the Principal Investigator, Mattea Peplinski [redacted] or Dr. Kyle Reason (kyle.reason@stcloudstate.edu)

CONFIDENTIALITY

After initial data collection, your name will not be associated with this data. Data will be kept secure at all times in a secure, password-protected SharePoint server. No publication or other public material will carry your name as a subject, and data collected for this research will not be distributed to others for future research.

VOLUNTARY CONSENT & WHOM TO CONTACT FOR FURTHER INFORMATION

If you have any problems or questions on the study procedures, you can contact the primary investigator, Mattea Peplinski or the faculty advisor, Dr. Kyle Reason. If you have any questions regarding your rights as a participant or if you feel that you have not been treated fairly, please contact IRB Chair, William Collis-Prather (wccollisprather@stcloudstate.edu).

I have read the above and freely and voluntarily agree to participate in the study described above. I understand that I can terminate participation at any time without penalty or prejudice.

Print your name: ________________________________

Signature: __________________________ Date: ___________________

Witness: ____________________________ Date: ___________________

Appendix B: IRB Notification

INSTITUTIONAL REVIEW BOARD (IRB)
720 4th Avenue South AS 101, St. Cloud, MN 56301-4498

November 28, 2023

Mattea Peplinski
mattea.peplinski@stcloudstate.edu

Faculty Mentor: Kyle Reason

The Institutional Review Board has reviewed your protocol to conduct research involving human subjects.

Project Title: Optimal Joint Angle during a Free Throw Shot in Division II Women's Collegiate Basketball Players

Your project has been: Approved

IRB PROTOCOL DETERMINATION: Expedited

SCSU IRB#: 57433451

1st Year Approval: 11-28-2023 **1st Year Expiration:** **11-27-2024**
2nd Year Approval: **2nd Year Expiration:**
3rd Year Approval: **3rd Year Expiration:**

Please read through the following important information concerning IRB projects .

- The principal investigator assumes the responsibilities for the protection of participants in this project. Any adverse events must be reported to the IRB as soon as possible (ex. research related injuries, harmful outcomes, significant withdrawal of subject population, etc.).
- The principal investigator must seek approval for any changes to the study (ex. research design, consent process, survey/interview instruments, funding source, etc) by completing an IRB Modification/RevisionequestForm:https://webportalapp.com/webform/irb_modification_request_form
- The IRB reserves the right to review the research at any time.
- Expedited and full board review projects are up for annual renewal (1 year from your approval date, or on the expiration date listed on the approval stamp) and the principal investigator is required to report the status of the project prior to the expiration date by completing one of the following:
  ◦ Continuing Review Form: Request to extend the project as either subject recruitment/enrollment continues or data collection continues and the project has not concluded. https://webportalapp.com/webform/irb_continuing_review_form
  ◦ Final Report Form: Indicate project completion as data collection is complete (data anaylsis may continue). You will receive an email reminder approximately one month in advance of the expiration date. https://webportalapp.com/webform/irb_final_report
  NOTE: if a report form is not submitted timely, the protocol will be closed and a new submission will be required.
  • Approved consent form(s) and recruitment document(s) display the formal SCSU IRB stamp which is indication of official approval and lists expiration dates. These are the forms to be used during the project study. If arenewal is requested and approved, new consent forms will be officially stamped and reflect the new approval and expiration dates.

Feel free to contact the IRB for assistance at 320-308-4932 or email ResearchNow@stcloudstate.edu and reference the SCSU IRB number when corresponding for expedited response. Additional information can be found on the IRB website https://www.stcloudstate.edu/irb/default.aspx.

Sincerely,
IRB Chair:
William Collis-Prather
[signature]
Program Director
Applied Clinical Research

IRB Institutional Official:
Dr. Claudia Tomany
[signature]
Associate Provost for Research
Dean of Graduate Studies