

# Statistical Model for Muscle Memory in Basketball

Benedict Al E. Candia, Englevert P. Reyes, Rigil Kent Sevileno, & Jan Hector Y. Obando  
University of San Jose – Recoletos

**Abstract:-** The purpose of this investigation is to present a statistical model to find the dominant skill of the ten National Basketball Association (NBA) superstars that portray muscle memory from the NBA Regular Season 2014-2018. Training and work-outs of every NBA superstar are identified to determine what constitutes muscle memory. This study used descriptive statistics (mean, standard error of the mean, and standard deviation), time series plot, and multiple linear regression to create a reliable model for the ten outstanding player rankings in the NBA. The independent variables within the regression equation included field goal percentage (FG%), three-point percentage (3P%), free-throw percentage (FT%). The free-throws and field-goals have a consistent average throughout the years and positively contribute to scoring. While, as the player gets older, injuries and fatigue are the factors that affect the three-points performance of a player. Hence, the NBA player's offensive training and work-outs are identified to provide a valuable tool. The person-concerned must take into consideration the science and the various parameters which improve a certain offensive skill of an athlete. And for coaches, athletes, and physical education instructors, it would be better if all their training related to the improvement of basketball offensive skills must be closely-based on the training and workouts provided in this study.

**Keywords:-** Anatomical Movement, Muscle Groups, Offensive Skills & Muscle-Memory.

## I. INTRODUCTION

Basketball is played by numerous countries in the world (Duke, 2016). Hence, National Basketball Association (NBA) produced the greatest players of all time (Mertz et al, 2016). And, the first sports league to reach a billion followers/fans (NBA Communications, 2016). The muscle memory plays a significant role in the basketball offense. Professional athletes used systematic programs that constitute muscle memory. This study intends to provide evidence for muscle memory.

Basketball costs a lot of energy expenditure, where the nature of the game involves continuously shifting steps, running fast breaks and applications of basketball offensive techniques, to include lay-up, shooting, and high-speed play, aerobic and anaerobic energetic processes (Maud and Foster, 2006; Araujo, 2014). The desired outcome of basketball shooting came from release, speed, angle, and backspin in

connection with the lower body (Smith, 2019). The free-throw shooting is the most fundamental and significant skill, where metabolic intensity, fatigue and game pressure can affect the athlete's free-throw performance in an actual game (Padulo et al, 2015). Dunking is a way of scoring a field goal, a player should improve his vertical leap in order to reach the ring (Hall, 2019). Lay-up is almost alike with a dunk; however, the ball is released up in the air, using the fingers. A player is only limited to create two steps in making a legal lay-up (Barry, 1988). And, one should maintain balance and high vertical leap, and proper grip of the ball released near to the ring (Nin et al, 2016). Eligibly, these following basketball movements and activities constitutes muscle memory. In this case, muscle memory plays a vital role in having an efficient shooting percentage (Felkel, 2015). The Free throw, field-goal and three-points shooting efficiency can be developed through a constant training and repetition. The National Council of Educational Research and Training (NCERT, 2016), define "sports training" as a systematic process based on scientific principles to enhance the skills and to achieve best-level performance in a particular sport. In the context of Basketball, Offense is an attack made by a player to the ring (interchangeably called rim or basket) in an attempt to score a point. Offensive scorings are two-point field goals, free-throw, and three-points (Erčulj, 2015). Point Guard (PG), Shooting Guard (SG), Power Forward (PF), Small Forward (SF), and Center (C), and each has different game-related statistics and positions in a basketball game (Sampaio et al, 2006). Each player's position has roles and physiological characteristics (OSTOJIC et al, 2006). By this, it will assess how muscle memory was developed, and seen in basketball athletes. Hence, each assigned position of every player has training programs that enhance their muscle memory. PG the leader of the team and sets the play for a better offense and show defensive pressure in the basketball court (Trninic et al, 1997). The PG creates higher percentage in scoring three-point, two-point and free-throw, and usually the faster among the four. SG is the one who performs the best shooting in three-point line and the best defender (Sampaio et al, 2006). The SF usually has an aggressive ball-handling, making cuts to the basket to create a two-point shot. The PF and the Center have the roles of defending, blocking shots for a possible score from the opponent and make rebounds. The Center is usually the tallest and heaviest player between PG, SG and SF (Pojskic, 2014). Usually the center has the ability to have a higher score in two-point field goal through lay-up and dunk. Guards and forwards have a higher percentage of shooting free-throw as opposed to the centers, who has a low

percentage in free-throw shooting (Ibañez, 2015).

No single athlete can imitate a unique shooting style similar to an NBA player. An NBA player’s anatomical movement may undergo significant analysis to perform a beautiful and successful shooting (Fensin & Lucey, 2017). Furthermore, Filipinos are relatively shorter in height compared to the players from several foreign countries; to name a few: China, the United States of America (USA), Spain, Brazil, South Korea (Lasco, 2018). The height of an athlete is a physical attribute that provides advantages in playing basketball for additional chances of rebounding and creating a closer shot (Antolihao, 2015). In the Philippines, basketball is arguably one of the most patronized sporting events and paved the way for several opportunities to athletes of the sport. One of the infamous lines Filipino athletes always say is “tatangkad din ako” (I will grow taller). This statement implies that despite the physical disadvantages such as height, wingspan, and athleticism, Filipinos could still compete and go toe-to-toe against competitors in the game of giants (Antolihao, 2015). There are only limited studies about determining muscle memory through game statistics. And, no systematic researches that provide a tool for the development of muscle memory in all the basketball offensive skills.

This study aims to provide information to students, athletes, trainers, and coaches on the importance of muscle memory and to which muscle groups are needed to develop, to enhance basketball skills. Moreover, providing the training in enhancing the basketball skills used by basketball superstars is beneficial to coaches, physical education instructors, and players respectively. With the aforementioned, a functional approach to analyze the anatomical movement of a professional player will provide a valuable tool for the practitioners (Hossner, 2015).

**II. CONCEPTUAL AND THEORETICAL FRAMEWORKS**

The anatomical movements are the correct movement pattern demonstrated by an athlete. Every offensive skill demonstrated by a basketball player is analyzed to create the correct anatomical movements. To be a good offensive player, it requires different skills and proper anatomical movements (Krause & Nelson, 2018). Moreover, the correct form and repetitiveness of demonstrating offensive skills in basketball will give familiarity and mastery of the movement (Klunick, 2017). Hence, coordination of the muscle groups is essential in performing a correct free-throw, field-goal, and three-point shooting form.

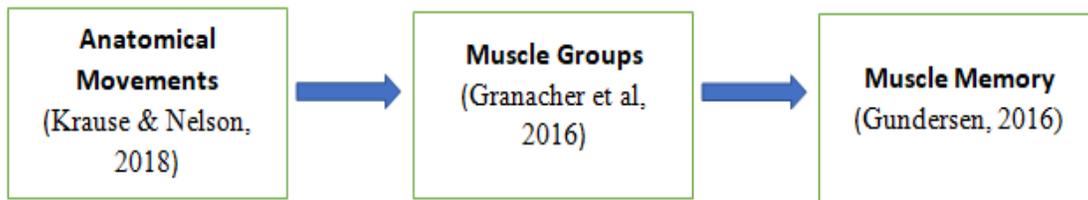


Figure 1. Diagrammatic sequence of muscle memory development

The coordination of different muscle groups is used in demonstrating the basketball offensive skills. And, different trainings enhance every muscle groups needed to provide sufficient force and energy in executing the skills (Granacher et al, 2016). Meanwhile, weights and calisthenic training are essential keys to developing the total muscles of the players. Calisthenics training is done through lifting its body weight, which gives more energy expenditure, and body function. (Machado et al, 2017). Hence, High Intensity Interval Training (HIIT), is one example of calisthenic training. On the other hand, weights training used specific gym equipment, and give maximum strength, muscle tone, and athleticism used in competitive sports performance (Baechle & Earle, 2019). These work-outs are used to attain the best basketball

physique and body condition.

In connection, muscle memory is seen through repetition and familiarity of the movements. Furthermore, the nucleus of a muscle cell will grow faster when subjected to overload exercises and early strength training (Gundersen, 2016). Hence, the proper reinforcement and monitoring of basketball training with the consistency of performing the exercises will develop muscle memory at an early age (Aoki et al, 2017). After the mastery of movements without a conscious effort, and working out the muscle groups to enhance the strength, imminently muscle memory is developed. Moreover, when the information is given, determined and saved it will have a long-term memory.

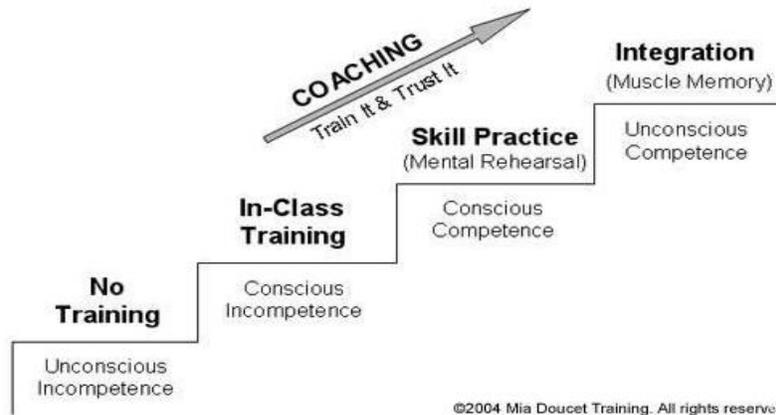


Figure 2. Development of muscle memory through training and practice (adapted from “The Four Levels of Teaching” by Martin Broadwell, 1969

An individual who lacks training in basketball starts as someone who does not know how to play basketball nor understand the skills required basketball. He cannot determine how he would fare if he plays basketball since skill and knowledge deficits remain unknown. He is said to be on the first level, Unconscious Incompetence (No Training).

When the individual becomes aware or recognizes the deficits, he has in playing basketball, and understands the importance of learning basketball, he now moves in the second level known as Conscious Incompetence (In-class Training). In this level, committing several mistakes and correcting those mistakes is vital to the learning process, such that if one does not learn the correct shooting technique in the initial phase, he might develop the wrong muscle memory for shooting.

The third level is Conscious Competence (Skill Practice), where the individual already knows how to execute the skills related to basketball. The individual takes as many chances as he can to practice the skills, put conscious effort when executing the skills, and develop high-level focus or concentration.

After much frequent practice, the individual develops a high level of proficiency that he can perform the skill so easily and unconsciously. Doing the skill becomes like his second nature. When the skill is repeated over a long period of time, muscle memory is developed in the individual which allows him to perform the skill even with unconscious effort. This is the final level known as Unconscious Competence (Integration).

**III. DESIGN AND METHODOLOGY**

This study utilizes a quantitative approach, specifically correlational design. Correlational design, which is exploratory and explanatory in nature, investigates the nature of relationships among the variables (Sousa, Driessnack, & Mendes, 2007). This study is also considered retrospective

since “the outcome of interest has already occurred at the time the study is initiated” (Salkind,2010).

The data in this study are the so-called box scores statistics of NBA players which were extracted from the official website of the NBA (stats.nba.com). Box-score statistics are a standard set of statistics recorded for almost all professional basketball games. In this paper, the main subjects of interest are the top 10 best performing players of the NBA games from 2014 to 2018. The determination of the top 10 was based on the overall standing/rank of the players in offensive skills throughout the five seasons. Being the finest and most superior athletes in their field, they were used as models in this study. Although box-score provides all offensive and defensive skills performance of an athlete, this paper only examines the three major offensive skills: free throws, 2-point field goals, and 3-point field goals, since a player’s shooting success rate, is logically indicative of muscle memory.



As shown in Fig. 3, total points are obtained from the three offensive skills scores – 2-point field goals, 3-point shots, and free throws. It can be noted that in the actual data, a player should have at least a hundred attempts to rule out that his success shots were not because of chance. When the scores

made by a player show consistency, his shooting skill then is indicative of muscle memory, which is established from repetitive training and physical conditioning.

**IV. RESULTS AND DISCUSSION**

Data used were the prominent players’ box scores taken from the official NBA website. Analyses of the data were conducted using descriptive statistics (mean, standard error of the mean, and standard deviation), time series plot, and multiple linear regression.

Table 1 Means, standard errors of the mean and standard deviations of basketball offenses of 10 NBA players from 2014-2018

Variable	N	N*	Mean	SEMean	StDev
Free Throws	5	0	0.83483	0.00986	0.02204
Field Goals	5	0	0.46828	0.00322	0.00720
ThreePoints	5	0	0.38101	0.00377	0.00843

Table 1 above shows the mean scores, standard errors of the mean, and standard deviations. The mean scores indicate the average success rate (number of successful shots over total number of attempts) of 10 prominent players in the last 5 seasons of the NBA games (2014-2018). The number of attempts made by each player is estimated to be at least 100 to prove that their success rate is a product of skill and not of luck or chance. Free throws obtained the highest mean score (M = 0.83) which shows that free throw is the most accurate shooting offense and most consistent in terms of muscle memory. Free throw being an unimpeded form of shot is considered the easiest among the players (Padulo, et al, 2015). Results further suggests that free throw is the most practiced of all the three offensive skills in basketball. Field goals (M=0.468) and three-point shots (M=0.381) got below 50% average success rate. Compared to free throws, these two offensive shots involve blocks and steals which contribute to the difficulty in achieving points when using these two.

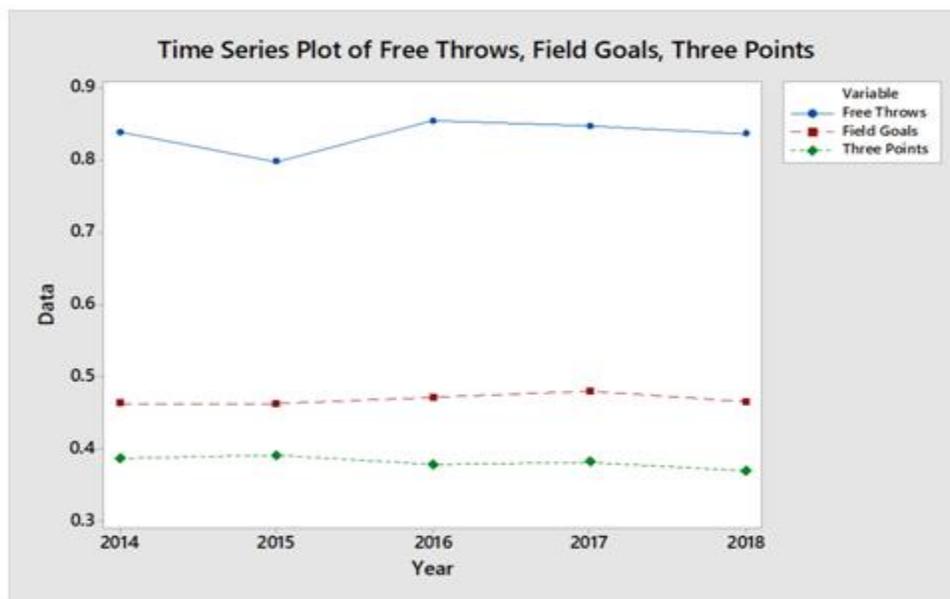


Table 2. Time Series Plot of Free throws, Field Goals and Three Points

The time series plot above shows the trends of players’ performance in each of the offensive skills from year 2014 to 2018 in the NBA games. Free throws, which is situated at the top of the plot, indicate a significant drop in 2015. Looking at the scores of each of the players, player E contributed majorly on this drop with 24% success rate only in free throws. ESPN News reported player E’s shoulder dislocation and subsequent surgery during the said season (McMenamin, 2015). If player E’s score on this is removed from the data, it can be observed that free throws relatively have a consistent success rate over a period of 5 years. Field goals are found to have no significant changes of scores, while three-point shots have marginally significant downward trend over the course of 5 NBA seasons.

PLAYERS	FG TOTAL POINTS	3 POINTS TOTAL	FREE-THROW TOTAL PTS.
A	6386	4734	1537
B	6988	1809	2434
C	7050	4047	2955
D	7022	1773	1758
E	2768	2190	1001
F	5676	2031	1736
G	6342	3789	1985
H	6254	3759	815
I	5562	2274	1227
J	4386	1398	1358

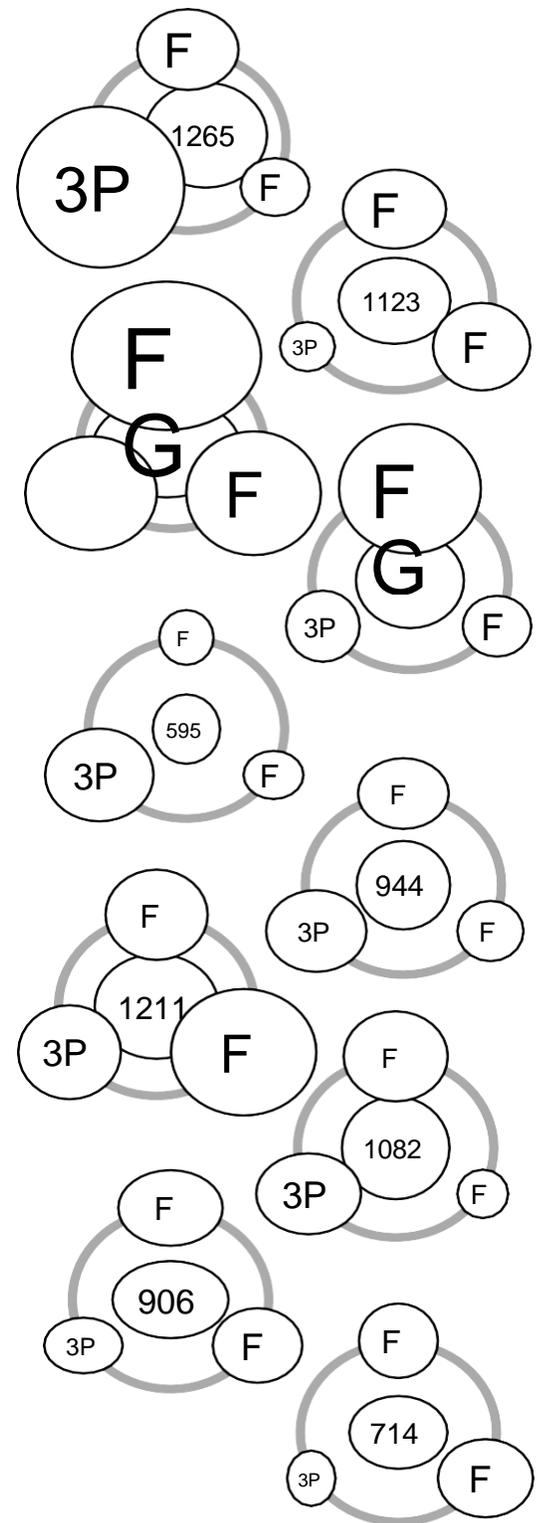


Table 3. Radial cycle model of the offensive skill's total points.

The radial cycle model shows a vivid illustration of the highest points. Hence, the bigger the circle, the higher the offensive score, and determining their specific roles and training are significant to assess every player's performance. In portraying the muscle memory, player A in point guard position shows the highest points of 4734 in three-point shooting and second of the highest total points. While player C is second to the highest three-points and got the highest 14052 points in field-goals and 2955 points in free-throw shooting. Among all the NBA superstars, player C got the highest total of 14052 offensive points withing the past five seasons. The profiling of every players offensive skills is used to analyze the highest contributor when it comes to portraying the muscle memory in basketball.

Table 4. Regression equations of each player and overall based on their success rates in basketball offenses against the total point contribution

PLAYER	REGRESSION EQUATION
A	TOTAL POINTS = 35809 – 7594 FG % + 27240 3P% - 45434 FT%
B	TOTAL POINTS = -14144 + 30069 FG % - 14396 3P% + 7514 FT%
C	TOTAL POINTS = -82876 + 115779 FG % - 120118 3P% + 90465 FT%
D	TOTAL POINTS = 8113+ 6893 FG % - 5505 3P% - 6726 FT%
E	TOTAL POINTS = 85 + 16919 FG % - 9019 3P% + 3109 FT%
F	TOTAL POINTS = -31989 + 5197 FG % - 3615 3P% + 37026 FT%
G	TOTAL POINTS = -10712 + 12598 FG % + 8541 3P% + 4933 FT%
H	TOTAL POINTS = -995 + 4586 % - 13131 3P% + 7708 FT%
I	TOTAL POINTS = -5771 – 5859 FG % + 10812 3P% + 6962 FT%
J	TOTAL POINTS = -20474 + 24379 FG % - 1888 3P% + 12702 FT%
OVERALL	TOTAL POINTS = -169 + 476 FG % + 1665 3P% + 1240 FT%

Table 2 reveals the regression equations upon analyzing each of the players' success percentages vis-à-vis total points contributed. Further, the regression equations reveal the weights of each offensive skill for every player; thereby disclosing the dominant skill of each player. Player C as the first rank and followed by player A are classified under three-point shooter since their three-point scores obtained the greatest contribution to their total points accumulated. Player C as the first rank, followed by players A, F, J and H are free-throw shooters since regression equations show largest coefficients on their free throws. The remaining players B, D, E, G and I are found to be excelling in 2-point (short and mid-range) field goals based on the weights in their regression equations. In the overall total points, field goals ( $\beta=476$ ) and free throws ( $\beta=1240$ ) appear to contribute positively, and the three-point shots ( $\beta=1665$ ) positively affect the total points.

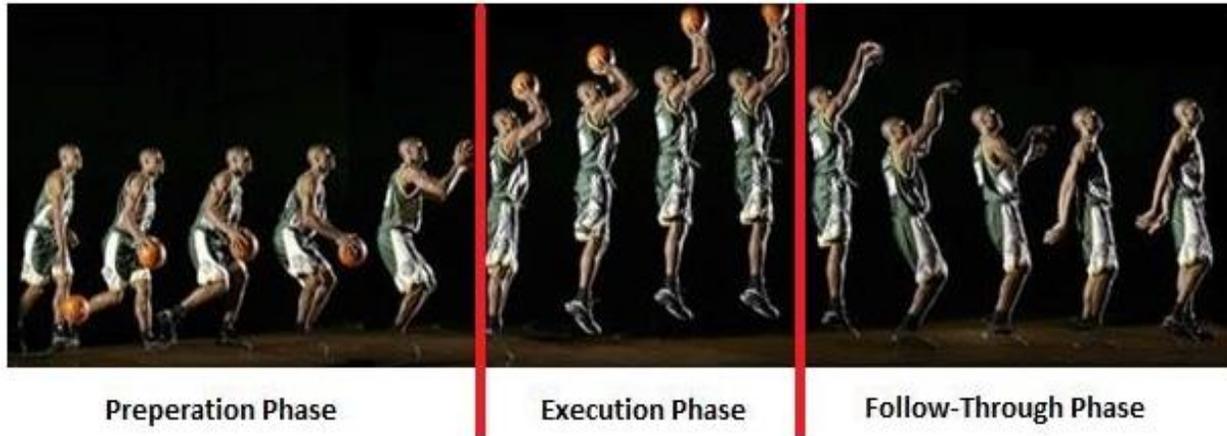
The overall regression equation shows that three-points shooting contributes the highest score in basketball and the key in winning a game. However, in corroboration of the time series finding, the performance of three-point shooting deteriorates due to the said physical factors over time. Furthermore, this entails that basketball players prefer to demonstrate three-point shooting because it is the highest points contributor. However, the consistency of offensive attempts over made shots show the skill percentage of every basketball player to demonstrate muscle memory. Apparently, in time series it shows that the weakness of three-point shooting is most probably caused by the age of the players. This means that the said offensive skill diminishes as years progress, and also by the long-range distance involved in a three-point shot. In order of strength of muscle memory, free throws come in first, followed by field goals, and three-point the last.

Table 5 Regression equations of each player and overall based on their success rates in basketball offenses against the total point contribution

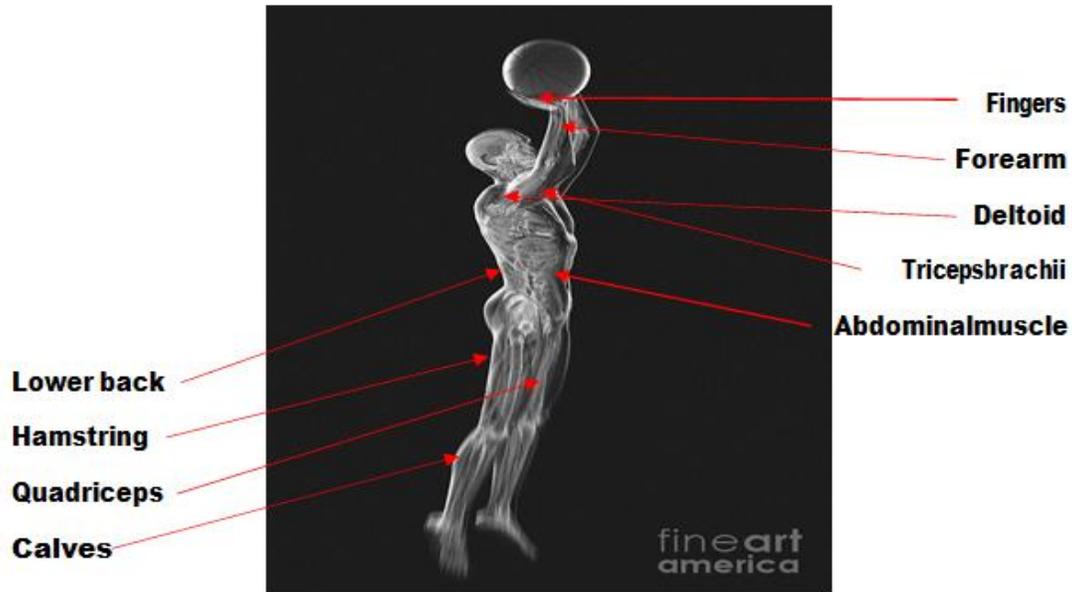
PLAYERS	DOMINANT SKILL	MUSCLES INVOLVED	TRAINING PROGRAM/DRILLS
A, C	Three Points	Abdominal muscle Deltoids Finger Forearm Hamstring Lower back Quadriceps Triceps brachii Calves	“Beat the Ogre” (Adding 4 more shots, for every missed shot) 3-point Shooting with Defender 3-points on every angle Mobility, Calisthenics, Lightweight Training Pull-up 3-point Jumper Repetitive 3-point Shooting
F, J, H, I, J	Free Throws	Abdominal muscle Deltoids Finger Forearm Hamstring Lower back Quadriceps Triceps brachii Calves	Training Program: Classic Weightlifting/CrossFit Training Explosive Training Mobility and Lightweight Training Pre-game Shooting Repetitive Free Throw Shooting
B, D, E, G	Field Goals	Abdominal muscle Calves Deltoid Biceps Triceps Forearm Gluteus maximus Hamstring Hand Lower back Quadriceps	Aggressive Drive to the Basket Attack the Basket Classic Weightlifting Close-range Floaters and Hook Shots Coast to Coast 3-point Shooting Coast to Coast Shooting x Layup CrossFit Training Mid-range and Close-range Jumpshots Mid-range and Close-range Scoring Mobility, Lightweight Strength Training Pre-game Shoot-around Repetitive Free Throw Shooting

Table 6. Building up Muscle Memory in Basketball Offense

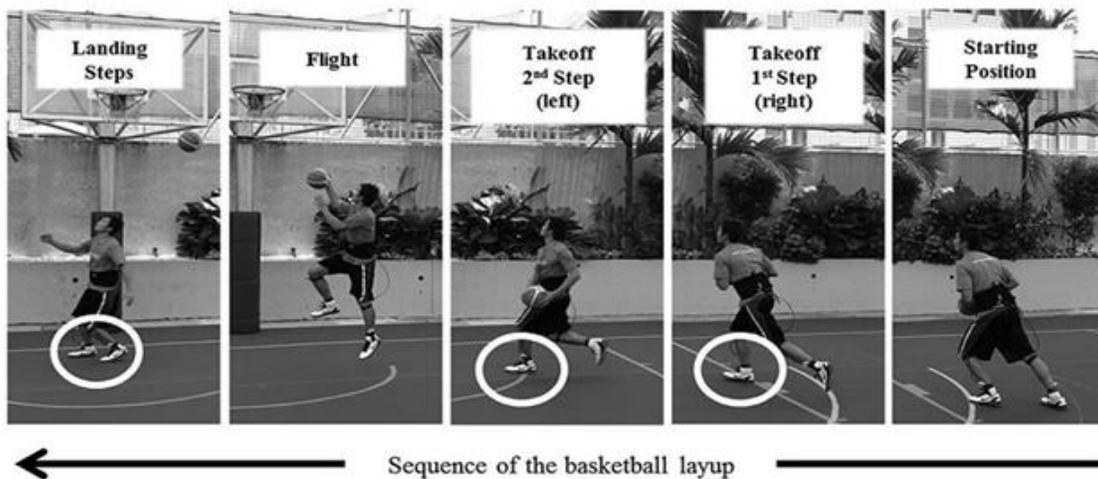
**Basketball Shooting:**



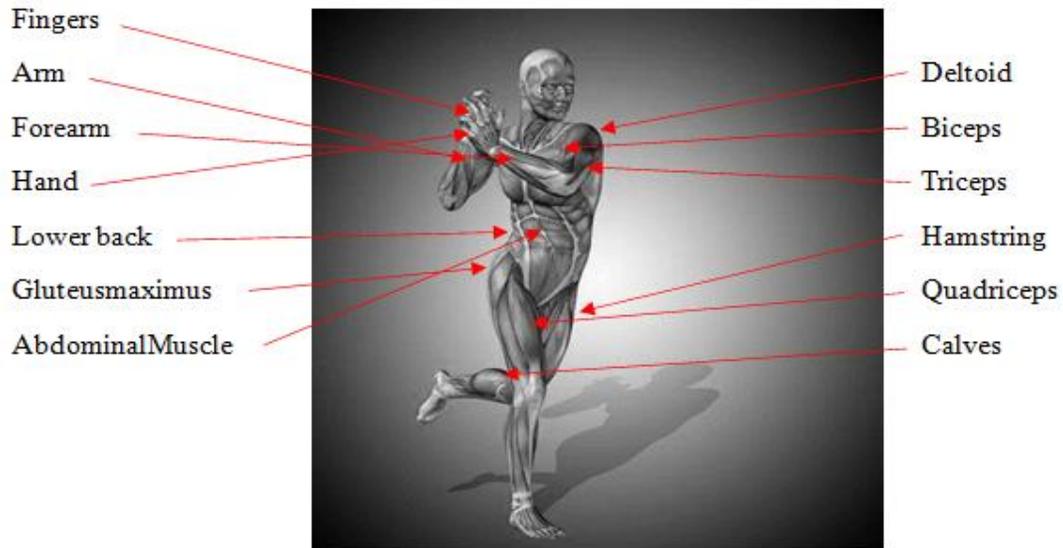
- A. *Preparation Phase:* Hold the ball using the fingers (Dominant hand), and the other hand will serve as the support for the ball, while raising the head focusing on the ring. The knees are slightly bended to create a maintaining balance and sufficient force.
- B. *Execution Phase:* Executing a vertical leap while lifting the ball upward. The dominant arm should be on the right-angle position. Head focusing on the target. The force usually starts from the lower extremities going up to the upper extremities.
- C. *Follow-Through Phase:* Force should come from the dominant arm and the fingers will release the ball smoothly, maintaining its position towards the ring. Proper landing of both feet is required to have a balance and support for the body.



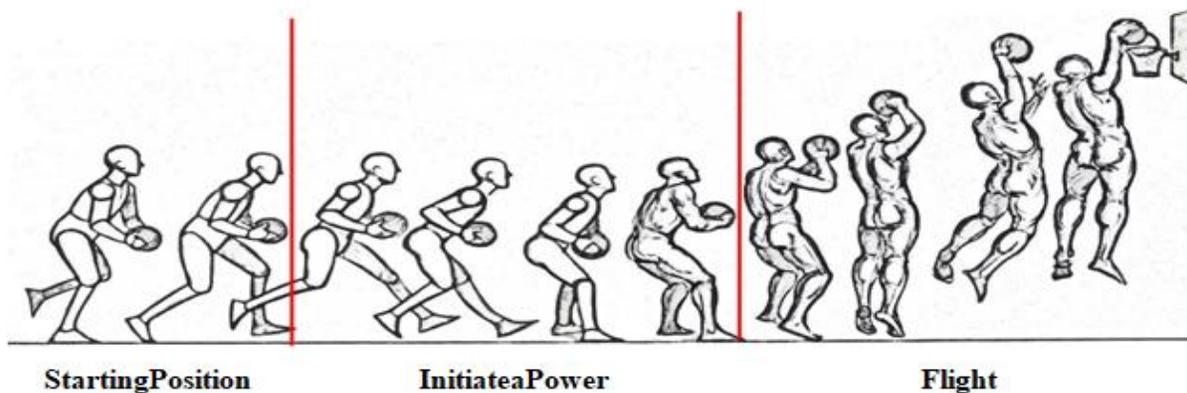
**Basketball Lay-up:**



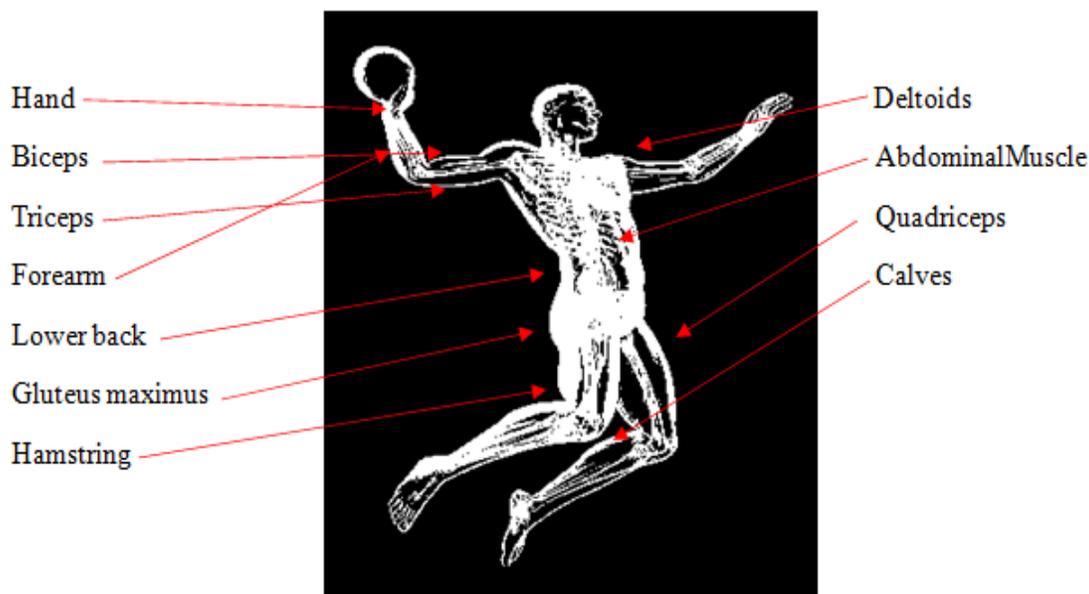
- A *Starting Position:* One should hold the ball, maintaining a proper grip using the fingers, and bend the lower body to create balance and strength.
- B *Takeoff 1<sup>st</sup> step (Right or Left):* Create two legal steps in executing a lay-up, and exert force on the lower body through bending the knees while holding the ball with both hands.
- C *Flight:* Exert force on the leg to execute a vertical leap, the ball is lifted up on the air while holding it with the fingers. Coordination of upper and lower body is used to have a successful movement. Afterwards, the ball is released towards the ring with finger roll (using of fingers).
- D *Landing:* Proper landing of both feet is required to have a balance and support for the body to avoid injuries.



**Basketball Dunk**



- A. *Starting Position:* In executing a dunk a player is limited to establish two steps (Right or Left) towards the ring. A player should hold the ball tightly with both hands, while the head is focusing on the ring.
- B. *Initiate a Power:* Coming from the lower extremities, a force is made from the lower muscle groups in order to create a maximum power in performing a vertical leap. The strength should start from the lower extremities towards the ground, and going up to the upper extremities.
- C. *Flight:* The body hangs up in the air, while lifting the ball using the upper muscle groups, and uses the hand to put the ball inside the ring. Coordination of both upper and lower extremities are needed in executing a dunk.
- D. *Landing:* Proper landing of both feet is required to have a balance and support for the body to avoid injuries.



## V. CONCLUSION

In performing the basketball offensive skills, one should master the movement pattern that enables the muscles to familiarize the movement through constant repetitions and training. In every action, specific muscle groups involved are needed to be enhanced through work-outs that results to the development of muscle memory. Using descriptive statistics, timeline series plot, and multiple regression, the results show that the dominant skill of every player in their respective basketball position, was a product of muscle memory that is developed over time, and not by luck. Hence, free-throw shooting has the highest and consistent average, followed by the two-point field goals that positively contributes in scoring. Three-points as the highest score contributor for winning a basketball game, yet the first offensive skill to fade as a player ages, and it is found to be the weakest among all types of offensive skills in terms of muscle memory, and it deteriorates over time.

The muscle memory remains on a player for as long as possible, retaining the ability to score offensively. But in the prevalence of injury and fatigue caused by aging, the three-point average is the most affected and the weakest among offensive skills. This entails that due to these factors, the muscle groups deteriorate its performance, and the movement of demonstrating the three-point shooting is affected. Through that, specific offensive skill trainings and muscle work outs of the ten NBA players are identified to provide a valuable tool in developing the offensive performance and body condition of basketball players. This is significant to enhance basketball offensive skills and being consistent in performing throughout the years.

## RECOMMENDATION

This study aims to help students, athletes, coaches to further understand the science of basketball offensive skills. Specifically, the study dwells on the movements that contribute to the success of the execution of the fundamentals of the sport, e.g., shooting, lay-up, dunk, three points. And in terms of the success and efficiency of an athlete's performance, every person-concerned must take this as a guide to cultivate and improve the athlete's offensive skills. The person-concerned must take into consideration the science and the various parameters which improve a certain offensive skill of an athlete. Free-throw shooting and two-point field goals as the most fundamental in basketball offense should be mastered first before going to three-points skill. In terms with the three-point shooting, the physical condition of a player should be maintained through a prescribed muscle work-out and skills training to have a consistent performance.

In this study, it emphasized the importance of muscle memory concerning the mastery and success of offensive skills. For future researchers, it would be best to emphasize how muscle memory contributes to the cognitive enhancement of an athlete vis-à-vis the coordination of mind-body aspect on a long-term basis. On a technical standpoint, future researchers must also take into consideration the following offensive skills that easily become frail over time. In doing so, it will serve as a preemptive measure against injuries of any kind. And for coaches, athletes, and physical education instructors, it would be better if all their trainings related to the improvement of basketball offensive skills must be closely-based on the trainings and workouts provided in this study.

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