Lior Laver · Baris Kocaoglu
Brian Cole · Amelia J. H. Arundale
Jeffrey Bytomski · Annunziato Amendola
Editors

Basketball Sports Medicine and Science

European Society of Sports Traumatology, Knee Surgery & Arthroscopy
ESSKA
European Society of Sports Traumatology, Knee Surgery & Arthroscopy
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Springer

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Foreword by Coach Mike Krzyzewski

Basketball is one of the most popular sports in the world. Certainly, it has evolved significantly since Dr. James Naismith placed a peach basket on an elevated track in December 1891.

For most of my life, I have been blessed to play or coach this game, including the last 45 years at the highest levels as a head coach serving Army, Duke, and USA Basketball. Of course, our sport has always revolved around the "TEAM" concept at its core. The best basketball teams are formed by many individuals from different backgrounds, successfully working together toward a shared set of values and a common goal.

Those teams are comprised not only of players and coaches but also strong support staffs, including medical personnel, many of whom you will hear from—and hopefully learn from—in this book.

Certainly, high-end performance is contingent on physical health and well-being. We fully understand that our physicians, physical therapists, athletic trainers, performance specialists, and strength and conditioning coaches are integral to the ultimate success of our teams.

At Duke, we are fortunate to have two of the contributors of this book—Dr. Ned Amendola and Dr. Jeff Bytomski—on our medical team. We believe in them. We trust them, and we have incorporated many of their ideas into both our medical preventative and rehabilitation strategies. We have experienced significant injury reductions in recent years. On a daily basis, we utilize data of our players' workloads in a sophisticated approach to reduce the physical stress on our team. And, in some other cases, we simply adhere to some common sense advice from our medical team to facilitate preventative care.

While we know and trust Ned and Jeff implicitly, the other editors of this book—Lior Laver, Baris Kocaoglu, Brian Cole, and Amelia J. H. Arundale—are equally as accomplished. There is so much to learn from all of them as they will provide the most comprehensive source for basketball's medical caregivers.

As we know, basketball has evolved significantly, including the medical care provided to athletes around the globe. That basketball medical community, which is so critical to the effectiveness and success of our teams, continues to advance as well. I look forward to using some of the concepts in this book to further advance our program. You can too.

Mike Krzyzewski
Duke Basketball Head Coach since 1980
Winner of 5 NCAA championships, 12 Atlantic Coast Conference (ACC) regular season championships, and 15 ACC Tournament championships
USA Basketball Senior National Team Head Coach 2005–2016
Five-time Olympic Gold Medal winner – 1984, 1992 (assistant coach); 2008, 2012, 2016 (head coach)
Two-time FIBA World Cup Gold Medal winner – 2010, 2014
Member of the Naismith Memorial Basketball Hall of Fame

Foreword from the ESSKA Leadership

After Handball and Football, ESSKA's Third Sport-Specific Book—On Basketball Medicine and Science!

ESSKA is proud to expand its book collection with this dedicated book about basketball. It follows the spirit of the European Sport Medicine Associates (ESMA), the fourth section of ESSKA which is fully dedicated to the entire spectrum of sports medicine. After a book on handball medicine and science as well as return to sports aspects in football, this book is the third demonstration of the sport-specific "global vision" ESSKA wishes to promote. ESSKA believes that clinicians and scientists should always have this holistic view in mind when they take care of their athletes. Multi- and interdisciplinary thinking is of utmost importance for the understanding of sports injuries, their prevention, best treatment, and return to sports and performance.

Basketball is undoubtedly one of the most physically demanding team sports and requires a wide variety of different skills. Playing basketball involves a unique assembly of injury risks and related health problems. Therefore, the medical and health care of every basketball team and each player requires an unusual combination of knowledge and skill by every health professional involved. The current book not only provides a deep scientific and clinical foundation of knowledge but addresses every aspect of the health and medical care required in the sport.

What is it that makes basketball so special? It is a fast speed and intense game, with specific player morphotypes and hence some particular biomechanical aspects including very high lever arms in the upper and lower extremities, repetitive jumping with high impact loading on the ankle and knee joints, repetitive loading of the spine through the pelvis, and extreme pivoting elements in this sport which is played on very adherent surfaces. These are some specificities of basketball which lead to characteristic joint loading and frequent subsequent injuries. The game of basketball exposes the players to a very wide panel of injuries from the head and neck to the ankle and foot, as well as the psychological implications of playing a high-profile competitive sport.

The current book provides a compilation of topics representing an excellent tool for coaches, physiotherapists, sports physicians, and scientists as well as orthopedic surgeons—essentially providing a unique perspective for all

basketball personnel—from basic science topics, team building and preparations, injury management and rehabilitation, injury prevention, the special needs of unique and specific groups as well as psychological aspects. It will help the entire "professional perimeter" of the team to strategize, prepare, and address the various aspects involved in the medical coverage of a basketball team's competition program from the preseason screening through the entire season.

The book provides an overview of a basketball player's predisposing constitutional abilities to become a "competitive player," the differences between the various levels of play in basketball and the practical translation of these aspects in terms of physical abilities. The book also provides a strong foundation of knowledge in biomechanics, physiology, endocrinic changes and nutrition as well as other basic essential factors in order to design adequate training programs including important relevant aspects of injury prevention.

Management of sports trauma and life-risking situations begins with good preparation, and these aspects of assembling the medical team and preparing for the various scenarios in basketball are specifically highlighted in the book. Management of trauma and injuries is addressed on all its aspects, from its occurrence and initial management on the court through following management phases and rehabilitation and onto surgical management when necessary. It is important to emphasize that various sports often differ, apart from common types of injuries, in injury management and return to sports aspects which are relevant and specific for each sport, and even the optimal surgical technique and approach (i.e., graft choices for knee ligament reconstructions, surgical techniques for shoulder dislocations, surgical management options in ankle injuries or Achilles tendon ruptures) for a basketball player may differ from the optimal technique in football players, fencers, or in martial arts. Therefore, clinicians would hopefully benefit from this book and gain more knowledge in aspects which would aid in their injury management and decision-making.

The book provides an overview of the state-of-the-art rehabilitation approaches and programs for return to play, injury prevention concepts and programs and load management strategies, as well as valuable and practical tools for implementing these important elements. Finally, the book provides special focus on the psychologic aspects of this fascinating sport as well as a special focus on the retired basketball player.

ESSKA is proud to have such an outstanding team of authors contributing to this project. This book is also unique as it is a first-time collaboration between ESSKA and our good friends from the American Orthopaedic Society for Sports Medicine (AOSSM), coming together as two of the world's leading orthopedic sports medicine organizations to provide a concise state-of-the-art overview of sports medicine and science in basketball. Over the last years, ESSKA has worked intensively to strengthen the bonds between the two societies. It is with great pleasure that we see this work come to fruition in this huge project.

This book will undoubtedly raise the level of the ESSKA community as high as a basket hoop, and we can say that our great roster of authors, under the leadership of lead editors Lior Laver and Baris Koacoglu along with co-editors Ned Amendola, Brian Cole, Jeff Bytomski, and Amelia J. H. Arundale, have shown great team work from the first JUMP-BALL to produce this outstanding SLAM DUNK of a book !!!

Lyon, France — David Dejour
Luxembourg — Romain Seil
Geneva, Switzerland — Jacques Menetrey
December 2019

Preface

Since its invention in 1891 by Dr. James Naismith, basketball has become one of the most popular sports in the world, with an ever-growing popularity and a constant evolution. When all one needs to play is a ball and a basket, the popularity of the game is no surprise as well as the wide spectrum of participants from kids, "weekend warriors," amateurs, and onto professional players. Expansions/extensions such as streetball (street basketball) and 3 × 3 basketball (soon to become an Olympic sport) are rapidly attracting more and more participants worldwide. The game itself has become extremely fast pace, with rule changes to accommodate this evolution. These changes, along with the growing numbers of participants worldwide, have brought a growing number of injuries and have thus emphasized the constant need for proper physical and medical coverage and attention for the athletes playing the game.

Basketball is a team sport, and team work is essential for success not only on the court but off the court as well. From the players, coaching staff, logistical staff, and onto the medical staff—team work is the key for a successful team and any successful initiative in the sport. Preparing a book for publication is no different and requires a great team effort.

For this purpose, an excellent multidisciplinary group of individuals has joined forces to form an elite team of authors—each a leader in his own field—in order to produce a unique achievement in the field of basketball medicine, sports medicine, and sports science.

Our goal was to create a comprehensive educational source not only for basketball medical caregivers and scientists but also for all basketball personnel, made easily available and accessible to provide answers in whichever aspect of their interest (physicians, PTs, ATs, rehabilitation specialists, conditioning trainers, and coaches). Our hope is that this source would also serve as a link between the different disciplines and modalities involved in basketball care, creating a common language and improving communication within the team staff and environment.

The unique group of people assembled for this project will undoubtedly bring a great passion not only to the game of basketball but also an equal level of scientific passion. With the help and collaboration of the ESSKA Publications department and in collaboration with the American Orthopaedic Society of Sports Medicine (AOSSM), our aim is that these "ingredients" would combine to produce a result that would be concise and practical as well as innovational and would improve the medical care in basketball

worldwide. We hope that this project would serve as a starting point and a fertile ground for collaboration across the sport of basketball in terms of research and initiatives to improve players' safety and medical care in the future as well as evolve alongside with the evolution of the game.

Tel-Aviv, Israel — Lior Laver
Istanbul, Turkey — Baris Kocaoglu
Chicago, USA — Brian Cole
Brooklyn, USA — Amelia J. H. Arundale
Durham, USA — Jeffrey Bytomski
Durham, USA — Annunziato Amendola

A Word from the Editors/ Acknowledgments

Over the years, we have been fortunate to be surrounded and supported by great medical staff, physicians, physical therapists, athletic trainers, performance specialists, and strength and conditioning coaches. As with any team, leadership, communication, and collaboration are essential to optimize results. Every one of us has learned tremendously from this environment and these interactions, and we are thankful for the professionals we have been fortunate to be around over the years. These professionals have made us better over the years and they still do. This accentuates the importance of teamwork, which is true not only on the field but off the field as well.

Preparing a book for publication is no different and requires a great team effort. A passionate team of international authors have come together to realize this important project and to produce a unique achievement in the fields of basketball, sports medicine, and sports science. An experienced and diverse team of experts, including orthopedic surgeons, primary care team physicians, and rehabilitation specialists, all covering different levels and leagues, from European basketball, college basketball, and the NBA, all came together for this project. We thank all the authors for the time, efforts, dedication, and passion invested in this project.

Editing such an extensive book requires a great effort in order to put together an end product which provides a balanced view and an adequate stage for the various topics covered, while maintaining a structured flow of content which will be useful and easy to navigate through for everyone.

We would especially like to thank and acknowledge Prof. Jon Karlsson, KSSTA editor-in-chief, for his support of this project as well as his contribution as associate section editor in the "basketball injuries" section (Part IV), and Dr. Ron Gilat, for his contribution as associate section editor in the "basketball injuries" section (Part IV).

This book is also a first of its kind collaboration between ESSKA and AOSSM, bringing together two of the world's leading Orthopedic sports medicine societies. We would like to thank the leadership of both societies for their tremendous support and vision.

While the game of basketball is similar in its essence all over the world, resources also vary between levels of play and not every team can afford the medical and scientific support available at the highest levels. There is a great need for a relevant and reliable basketball-specific source to guide appropriate management of injuries and health problems, as well as to provide a strong frame for scientific and medical support in basketball—wherever it is

played. Our aim with this book was to address this need. The resulting content of the book provides the most comprehensive educational source for basketball medical caregivers, scientists, and all associated basketball personnel.

Our experience has taught us over the years that while knowledge and education are extremely important, leadership is essential for building a strong, sustainable, and successful medical team, and we tried to portray these elements throughout this book. This project was put together by a group of authors that is committed to excellence. Together, they have produced a practical and innovative source of high scientific quality relating to their beloved sport aimed to improve the medical care in basketball worldwide.

We are extremely proud of the end product, and we hope this would be a great impetus to increase the support for basketball science and to improve medical services across the sport.

Sincerely,

Lior Laver, MD
Baris Kocaoglu, MD
Brian Cole, MD
Amelia J. H. Arundale, PT, PhD, DPT, SCS
Jeff Bytomski, DO
Annunziato Amendola, MD

Basketball Sports Medicine and Science - Introduction

Basketball has grown over the years to become one of the most popular sports in the world. One can find a basketball hoop in the backyards of homes and schools in every continent and every corner of the world. History was made in a cold early December day in 1891, when Canadian James Naismith [1], a physical education professor at the International Young Men's Christian Association (YMCA) Training School [2] in Springfield, Massachusetts, USA, nailed a peach basket onto a 10-foot (3.0 m) elevated track, to keep his gym class students active on a rainy day. His purpose was to invent an indoor game to keep his students occupied and at proper levels of fitness during the long New England winters. No doubt, the journey and evolution the game has undergone in over a century have been tremendous.

The new game quickly gained popularity and developed, spreading through schools, colleges, and universities across North America and professional basketball developed soon after. By the 1920s, there were hundreds of men's professional basketball teams all over the United States. In 1946, the Basketball Association of America (BAA) was formed and later, in 1949, merged with the National Basketball League (NBL) to form the National Basketball Association (NBA). By the 1950s, basketball had also become a major college sport. In 1967, the American Basketball Association (ABA) emerged and operated alongside the NBA, until the ABA-NBA merger in 1976 to form current day's NBA, which is the leading professional basketball league in the world in terms of popularity, salaries, talent, and level of competition.

At the international scene, FIBA (International Basketball Federation) was formed in 1932, and originally only oversaw amateur players. Its acronym was derived from the French title: Fédération Internationale de Basket-ball Amateur, and thus "FIBA." Men's basketball was officially first included at the Berlin 1936 Summer Olympics. The first FIBA World Championship for men, now known as the FIBA Basketball World Cup or "Mundobasket," was held in Argentina in 1950. Three years later, in 1953, the first FIBA World Championship for women, now known as the FIBA Women's Basketball World Cup, was held in Chile. Although women's basketball was popular from the very beginning, it was officially added to the Olympics only in 1976, in Montreal, Canada.

Popular national and continental leagues have emerged over the years in Europe (the "Euroleague" is considered the second-best professional league in the world, after the NBA), Australia, Central and South America, Asia, and

Africa. Today, the global popularity of the sport is reflected in the many nationalities represented in the NBA and the Euroleague, including players from all over the world.

The NBA-backed Women's National Basketball Association (WNBA) was only established in 1997; however, amateur and professional women's basketball leagues, both national and continental, have existed worldwide for many years.

The popularity of the game of basketball has enjoyed a substantial growth in recent years. In addition, the development of the game's "siblings" and derivates such as wheelchair basketball, street basketball (streetball) and 3 × 3 basketball, as well as "show basketball" (i.e., the Harlem Globetrotters) and "slamball" has helped spread the game even more, reaching out to all layers of the population worldwide.

Concurrently with the continuous development of the game and the increased focus on performance optimization in elite sports, significant progress took place in basketball with regard to parameters such as technique, tactics, and intensity, as well as the physical aspect. Over the years, the professional side of the sport has developed as well, alongside the evolution of the game rules, which helped turn it into a fast and very dynamic game, contributing to its attractiveness and growing popularity.

The popularity of the game is shared between genders and is evident in both the men's and women's game at all age groups, which unfortunately is still rarely seen in many other sports, and the women's game received a substantial boost since the establishment of the WNBA.

The future of basketball appears very bright. FIBA now counts 213 national federations worldwide under five confederations, making it one of the biggest international sports federations (www.FIBA.basketball). The introduction of 3 × 3 basketball as an Olympic sport, and the development of wheelchair basketball over the years, which has opened a window into Paralympic sports, is already helping spread the game even more, reaching out to all layers of the population worldwide. With the growing evolution and involvement of the media and social media in the sports, as well as the growing emphasis on fan engagement, the game of basketball is drawing more attention worldwide. Professional leagues for men and women draw thousands of spectators in Europe, Asia, and South America and Australia, and apart from the world and continental championships for national teams, continental club competitions in Europe (i.e., Euroleague and FIBA European champions league), NBA, WNBA, and NCAA for men and women annually feature the world's best teams, competing for substantial prize money and national/international prestige. Finally, the evolution of the game of basketball on all its aspects over the last century has made it the exciting, popular sport it is today. Undoubtedly, the next 100 years will bring ongoing evolution; however, in the meantime, the status of basketball as one of the most popular and exciting sports worldwide is assured.

The evolution and changes the game has undergone over the years have also influenced the physiologic demands of the game as well as the injury profile in the sport, which has emerged as one of the most injury-prone ball sports. The growing need for an appropriate medical and scientific envelope

to support the game became evident over the years; however, the epidemiologic profile of injuries in the sports was lacking, especially when compared to football (soccer), a fact portrayed quite distinctively in the much lower number of epidemiologic studies in basketball compared to football. Even so, over the years high-quality scientific research has been done in basketball, contributing not only to the sport itself, but providing great scientific merit for other sports as well.

Over the years, basketball has emerged as one of the most demanding team sports with regard to the variable skills involved and physical demands. Additionally, participation in the sport of basketball involves a unique constellation of injury risks and related health problems. Therefore, the health and medical care of every basketball team and each individual player requires a special and unique collection of knowledge and skill by the involved medical and health professional. This book aims not only to provide a deep scientific and clinical foundation for basketball professionals, covering every aspect of the health and medical care needed around the sport. This includes basic science topics, medical team assembly and related preparations, injury management and rehabilitation, injury prevention, understanding the special needs of unique and specific groups as well as psychological aspects—all are addressed and covered extensively.

This unique project compiles the work of the top international experts in the field of basketball medicine and basketball science. It is the most comprehensive scientific source to date, aiming to aid and guide medical and all scientific personnel around the sport of basketball, and hopefully will be the reference and starting point of many other joint projects aimed to develop the medical and scientific support for the game in the coming years.

Lior Laver
Baris Kocaoglu
Brian Cole
Amelia J. H. Arundale
Jeff Bytomski
Annunziato Amendola

References

1. The Greatest Canadian Invention. CBC News. Archived from the original on December 3, 2010.
2. YMCA International—World Alliance of YMCAs: Basketball: a YMCA Invention. www.ymca.int. Archived from the original on March 14, 2016. Retrieved March 22, 2016.

Contents

Part I

Basic and Applied Sciences

1 Physical and Anthropometric Characteristics of Basketball Players

Jay R. Hoffman

1.1 Introduction

The popularity of basketball as an international sport has been well-publicized over the past 20 years. Although the rules differ across the various professional and amateur leagues, the sport itself is predominantly played as a high-intensity, strength/power event. Previous descriptions of the physiology of basketball had suggested that the intensity of the game was dependent upon coaching strategy [1, 2]. However, changes in rules and character of the game (e.g., requirement of a shot clock and greater reliance on exploiting the defense to offense transition) have provided a more specific physiological requirement for success. In 1996, Hoffman and colleagues [3] in a 4-year study of elite male college basketball players indicated that components of anaerobic ability (i.e., speed, vertical jump, and agility) were strong predictors of playing time, while a high aerobic capacity was reported to have a negative relationship with playing time. Although additional studies examining performance predictors of playing time are limited, subsequent research has tended to support the importance of strength/power and anaerobic ability to basketball playing performance (e.g., often comparing starters to nonstarters, or different levels of play). Pojskic et al. [4] noted the importance of explosive power and anaerobic capacity as determinants of shooting performance, and a recent study by Garcia-Gil and colleagues [5] in elite female Spanish basketball players indicated that height, wing span, body fat, and time in T-Drill test were significant predictors of playing performance. A recent investigation examining data obtained from the National Basketball Association (NBA) Draft Combine reported that anthropometric measures (specifically values relating to length) were the best predictors of future basketball performance, followed by upper-body strength [6].

Fact Box
Components of anaerobic performance (i.e., speed, vertical jump, and agility) are strong predictors of playing time, while endurance capacity has a negative relationship with playing time.

This chapter will focus on the physical and anthropometric characteristics of basketball players and the relationship that these measures have to basketball performance. When possible, comparisons between positions and leagues will be done. Although focus of discussion will be based upon recent literature, historical perspectives will be provided when appropriate.

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1.2 Physical Attributes of the Basketball Player

This section will examine the contribution of various components of fitness and how they impact the basketball player. Data will be discussed relative to both sex and league. In addition, professional basketball will not be grouped together, but rather data from players participating in the NBA will be separated from the results of professional basketball players participating in various teams across the International Basketball Federation (FIBA).

1.2.1 Aerobic Capacity

The maximal oxygen consumption (VO_2max) of male basketball players has been reported to range from 49.8 mL kg min^{-1} to 63.4 mL kg min^{-1} [7–11]. These investigations focused on National Collegiate Athletic Association (NCAA) Division II, European and Tunisian professional players. Interestingly, it has been suggested that changes in rules relating to the shot clock (reduction in time allowed to shoot the ball from 30 to 24 s) and moving from two halves to four quarters resulted in a need for greater aerobic capacity [9]. Although evidence is limited, Cormery and colleagues [9] in a 10-year examination of male basketball players playing in the top French professional league reported that the aerobic capacity of guards increased from 51.0 ± 1.6 mL kg min^{-1} in athletes before the year 2000 to 63.4 ± 2.7 mL kg min^{-1} in athletes playing after the year 2000. No changes in aerobic capacity were noted in forwards and centers during the same time span. In contrast to previous reports [1], guards appeared to have a greater aerobic capacity than either forwards or centers in collegiate and professional level basketball in both men [8, 12, 13] and women [14]. Whether an increase in aerobic capacity among certain positions in basketball is related to changes in the physiological needs of basketball is not clear. Evidence to date, although limited, suggests that aerobic capacity is not a predictor of playing time or performance in elite male basketball players [3].

In contrast to the relationship reported between aerobic capacity and basketball performance in men, aerobic capacity has been suggested to be associated with basketball performance in women [15]. However, as previously indicated investigations examining the relationship between aerobic capacity and basketball performance in both men and women are scarce in the past decade. Interestingly, Ben Abdelkrim and colleagues [7] reported that aerobic capacity was related (r = 0.67) to high-intensity activity during a basketball game in Tunisian male basketball players. Whether this is a function of the Tunisian basketball league or a global trend is not well understood. Further research is needed in this area.

1.2.2 Anaerobic Power

Components of anaerobic performance (i.e., speed, vertical jump, and agility) have been demonstrated to be strong predictors of playing time in elite male college basketball players [3]. Power performance in basketball players is most often assessed via a vertical jump. Jump tests are reported as jump height or jump power. The latter test can be performed either on a force plate or predicted from vertical jump height [16]. Different methods of vertical jump assessment have made it difficult to compare between studies or to develop normative data [1].

Studies in the past 10–15 years have been consistent in demonstrating that vertical jump performance can differentiate between starters and nonstarters in NBA players [17] and NCAA Division I women [18], and between different levels of play [12, 19]. A recent study by Spiteri and colleagues [19] indicated that the countermovement jump was able to differentiate between players of different competitive leagues in women's basketball. Basketball players in the Women's National Basketball Association (WNBA) jumped significantly higher (34.8 ± 3.3 cm) than athletes in the Australian Women's Basketball League (WNBL) and NCAA Division I women's basketball (30.6 ± 3.9 cm and 32.0 ± 5.1 cm, respectively). Significant differences have also been reported between positions. Guards tend to jump significantly higher than centers and

power forwards in men [8, 11, 13], but these positional differences may not be seen in women, especially at lower levels of play [20]. However, vertical jump power expression is significantly greater in centers than guards [11, 13], which likely reflects the greater mass seen in these players. However, this difference is lost when power is expressed relative to body mass [8].

Examination of vertical jump data in NBA players reveals interesting results. Figure 1.1 provides a perspective of standing reach height, vertical jump height without a step (preparation step), and maximal vertical jump height with a step. NBA players are only ~44 cm below the baskets rim when standing with their arms outstretched; however, centers are only ~26 cm below the rim. The average NBA player jumping without a step will be ~29 cm above the rim and will be 42 cm above the rim when jumping with a step. It can be clearly seen that much of the NBA game is played "above the rim." Interestingly, jump height or power has not been demonstrated to be an effective predictor of performance in NBA basketball players [6]. However, that could simply be a function of the exceptional level of jumping ability in most NBA players.

Fact Box

Evidence from the standing reach and vertical jump height of the NBA players clearly indicates that much of the NBA game is played above the rim!

Position comparisons in players participating in the NBA combine from 2000 to 2015 are depicted in Table 1.1. This data was obtained from the NBA Draft Combine (http://stats.nba.com/draftcombine/). Standing reach height is significantly different between positions. The standing reach height of point guards was less than all other players, the standing reach height of shooting guards was less than all forwards and centers, while the standing reach height of small forwards were less than both power forwards and centers. Finally, the standing reach height of power forwards was less than centers. When examining total height achieved from a jump with and without a step, results indicated that point guards achieved a total jump height lower than all other positions. Although the total height achieved from jumping by shooting guards was significantly greater than point guards, it was significantly lower than all other positions. No differences were noted in total height achieved from no step and maximum vertical jump height in forwards and centers. Interestingly, when comparing relative jump height between positions (jump height − standing height), no significant differences were observed between positions in either jump height with a step or without a step. Figure 1.2 depicts the range of average jump height (no step or maximal jump height) with standard deviation for 16 years of NBA combine testing. The highest average maximal jump heights have been observed in the last 3 years of the reported testing (2013–2015), in which average maximal jump heights ranged from 89.6 to 91.6 cm, and average jump height with no step ranged from 76.3 to 77.6 cm.

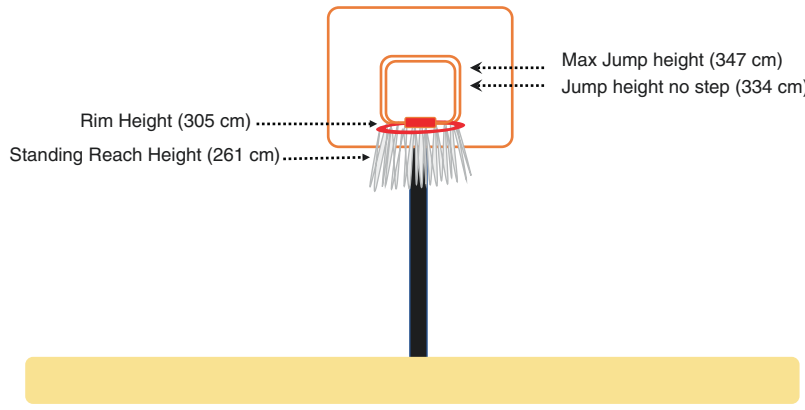

Fig. 1.1 Standing reach height, vertical jump height without a step, and maximal vertical jump height with a step in relation to backboard and rim height in NBA basketball players

Table 1.1 NBA Combine jump, strength, and speed performance between 2000 and 2015

Position	*N*	Standing reach (cm)	No step jump height (cm)	Max jump height (cm)	NO step VJ (cm)	Max VJ (cm)	BP reps (185)	3/4 Sprint speed (s)
Point guards	203	245. 4 ± 7.6[a]	320.5 ± 8.6[a]	335.0 ± 10.2[a]	74.9 ± 7.6[a]	89.7 ± 9.1[a]	8.6 ± 5.2[a]	3.21 ± 0.10[a]
Shooting guards	202	256.5 ± 5.8[b]	332.2 ± 8.1[b]	345.9 ± 8.1[b]	75.7 ± 7.4[a]	89.4 ± 8.1[a]	9.9 ± 5.3[a]	3.24 ± 0.10[a]
Small forwards	191	265.4 ± 6.1[c]	339.9 ± 7.1[c]	352.8 ± 8.4[c]	74.7 ± 7.9[a]	87.6 ± 8.9[a]	10.3 ± 5.3[a]	3.28 ± 0.12[a]
Power forwards	259	271.3 ± 5.3[d]	343.7 ± 7.1[c]	354.3 ± 8.1[c]	72.4 ± 6.9[a]	83.3 ± 7.6[a]	13.0 ± 5.7[a]	3.33 ± 0.13[a]
Centers	145	278.9 ± 5.6[e]	347.2 ± 7.9[c]	357.1 ± 7.6[c]	68.6 ± 7.9[a]	78.5 ± 7.9[a]	11.7 ± 5.4[a]	3.42 ± 0.14[a]

Different letters indicate a significant difference

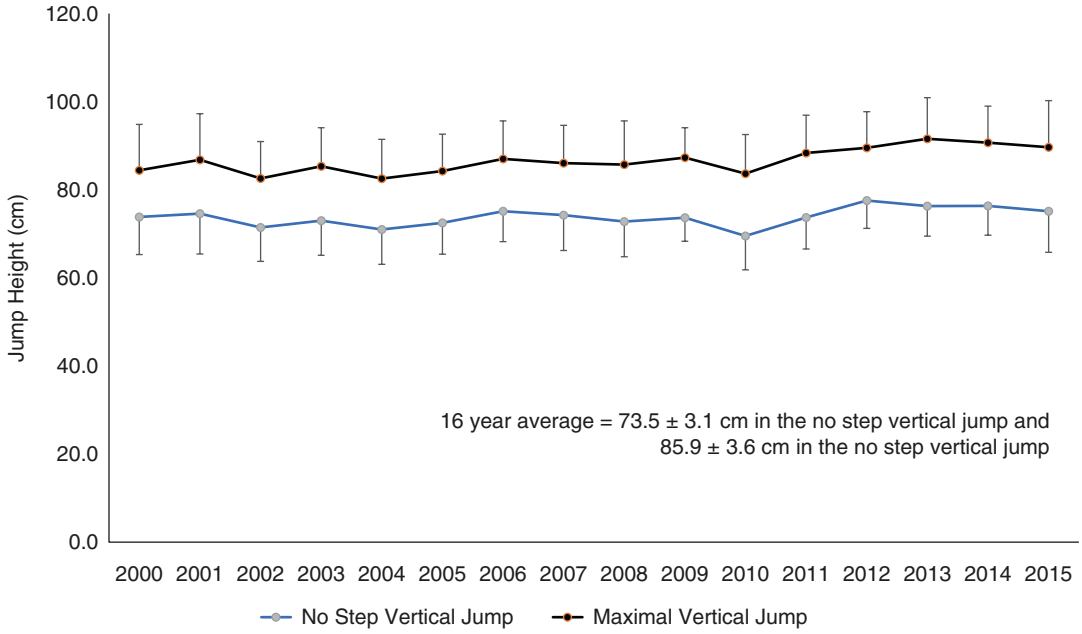

Fig. 1.2 No step and maximal jump height between 2000 and 2015 in professional basketball players participating in the NBA Combine

1.2.3 Strength

Examination of the literature in the past 10–15 years has found a paucity of data reporting maximal strength in college or professional basketball players. It is surprising considering that maximal squat strength (1-RM squat) has been reported to be a strong predictor of playing time in NCAA Division I male basketball players [3]. Hoffman and Maresh [2] reported that the average 1-RM squat in NCAA Division I male athletes was 152.2 ± 36.5 kg. In a position by position analysis in NCAA Division I basketball players, Latin and colleagues [21] indicated that collegiate forwards (161.9 ± 37.7 kg) were significantly stronger than centers (138.1 ± 32.1 kg) but similar to guards (151.1 ± 35.5 kg). Lower body strength has been suggested to be important for "boxing-out" and positioning during a basketball game [1]. An investigation by Köklü and colleagues [12] comparing first and second division Turkish professional players suggested that isokinetic leg extension and leg flexion strength was unable to differentiate players between the two divisions of basketball play.

Interestingly, the only recent publication that has reported 1-RM strength in collegiate basketball players assessed the front squat and hang (power) clean in both men and women NCAA Division II players [22]. The explosive action of the hang clean and its ability to integrate strength, explosive power, and neuromuscular coordination among several muscle groups suggest that this exercise has similarity to many of the actions common to basketball players [1], and may be a more appropriate exercise to assess in basketball players than the squat. Thus, improving strength in this exercise may provide for a better transfer of strength to the basketball court. Hang clean strength in NCAA Division II men was recently reported to be 44.0 ± 6.1 kg and 23.7 ± 2.7 kg in women [22]. Previously, Latin and colleagues [21] reported maximal strength in the power clean to be 99.2 ± 15.2 kg (range 59.0–137.3 kg) in NCAA Division I male college basketball players, with forwards (105.1 ± 16.9 kg) being significantly stronger than guards (94.5 ± 13.0 kg) but not centers (99.8 ± 13.7 kg).

In a previous discussion of the physiology of basketball, Hoffman [1] indicated that bench press strength was the most common strength testing measure reported in basketball players. This was despite a poor relationship (*r*'s from −0.04 to 0.14) reported between playing time and upper-body strength [3]. Maximal bench press strength in NCAA Division I college basketball players was reported to be 102.7 ± 18.9 kg [2], with no differences noted between positions (Latin and colleagues [21]). Ben Abdelkrim and colleagues [7] indicated that the 1-RM bench press strength in Tunisian first division basketball players was 92.1 ± 8.3 kg. Recent research has suggested that upper-body strength may be a moderate predictor of future NBA performance [6]. Figure 1.3 provides the average number of repetitions performed by basketball players invited to the NBA combine between the years 2000 and 2015. The average number of repetitions performed was 10.8 ± 5.6. This is equivalent to a 1-RM bench press of 115.6 kg [23]. Table 1.1 provides a position by position comparison of the number of repetitions performed in the 185 lb bench press

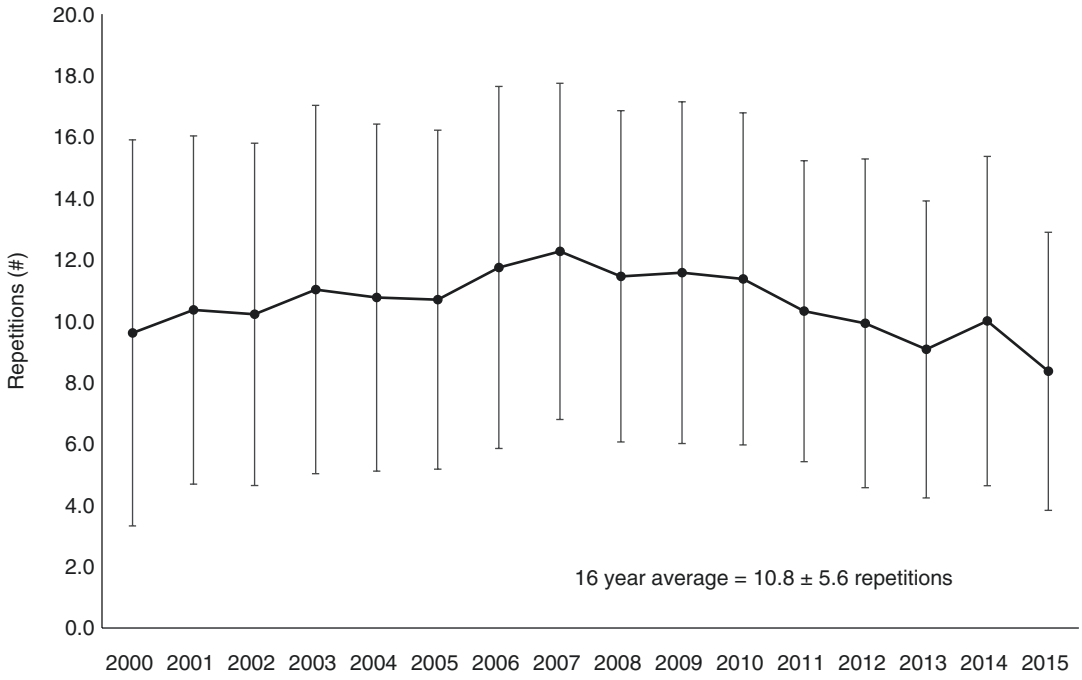

Fig. 1.3 Number of repetitions performed in the 185 lb (84.1 kg) Bench Press test in professional basketball players participating in the NBA Combine (2000–2015)

test. Although power forwards performed the greatest number of repetitions, they were not significantly different than those observed for any other position, and no significant differences in repetitions performed were noted between any position. However, these results should be interpreted in an appropriate context as lower body strength (i.e., 1-RM squat) was not examined or compared in these athletes.

1.2.4 Speed and Agility

Initial research with elite college basketball players indicated that speed (30 m) was a significant predictor of playing time [3]. Speed has also been demonstrated to differentiate between different levels of play in some studies [12, 24] but not all [5, 19, 20]. Ben Abdelkrim and colleagues [7] reported that sprint speed (either 10 m, 20 m, or 30 m) was not related to high-intensity performance in basketball, while sprint performance did not predict future performance in the NBA, as determined from actual basketball performance during the players initial competitive season [6]. Figure 1.4 depicts 3/4 court sprint speed in athletes participating in the NBA combine from 2000 to 2015. The average sprint speed during this 16-year period was 3.29 ± 0.14 s. No significant changes from this mean were seen at any time. It is likely that sprint speed of these athletes was similar and at a high level to limit this fitness component being an effective predictor of future basketball performance. It is likely when there is a greater variability of performance that sprint speed may be a better predictor.

There does appear to be differences in sprint speed comparisons between positions. Although speed does not appear to be significantly different between positions in basketball players participating in the NBA combine (see Table 1.1), point guards were 0.2 s faster than centers in the 3/4 court sprint (~21.5 m). Others have reported that guards are significantly faster than centers in male Spanish U-15 players, but not in U-16 or U-17 players [25]. Others have also indicated that guards are faster than centers in Turkish men [12], Belgian men [8], and English women basketball [20]. The distances used for assessment in these latter studies were 5-, 10-, and 20-m.

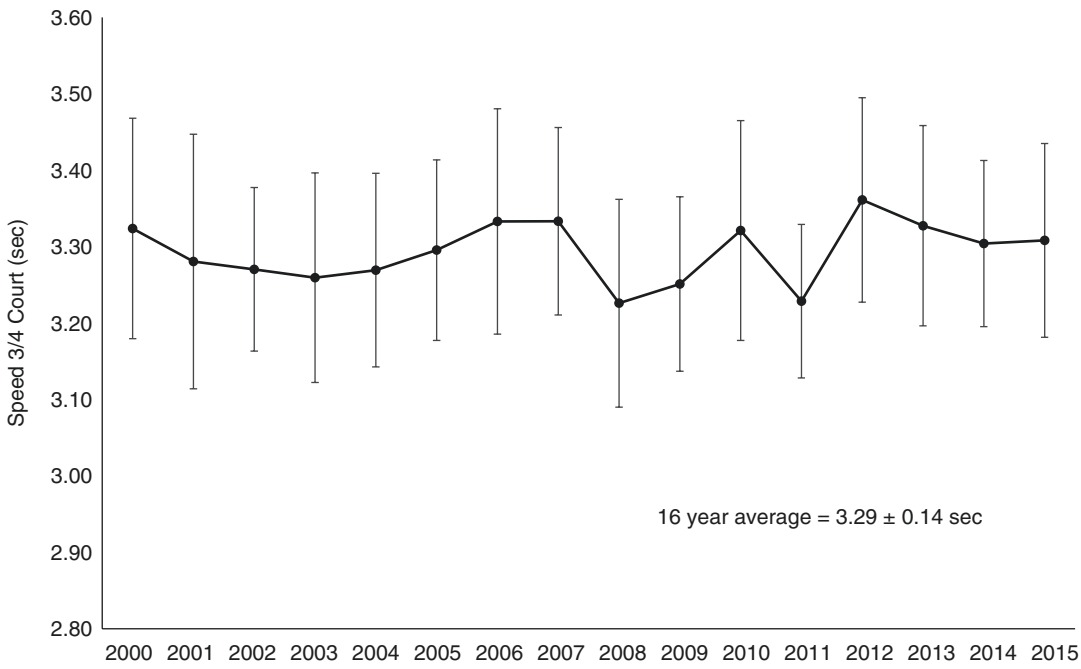

Fig. 1.4 Speed (3/4 court) of professional basketball players participating in the NBA Combine (2000–2015)