DYNAMIC BALANCE AND BASKETBALL PLAYING ABILITY

Thesis

Presented to the Graduate Council of
Texas State University-San Marcos
in Partial Fulfillment
of the Requirements

for the Degree

Master of EDUCATION

by

Michael L. Hobbs, B.S.

San Marcos, TX

December 2008

DYNAMIC BALANCE AND BASKETBALL PLAYING ABILITY

Committee Members Approved:

____
Lisa K. Lloyd, Chair

____
Kevin McCurdy

____
Eric A. Schmidt

Approved:

____
J. Michael Willoughby
Dean of the Graduate College

DEDICATION

I would like to dedicate this thesis to my parents, brothers, sister, and friends who supported the accomplishment of my dream of receiving my master's degree. Mom and Dad, you taught me what unconditional love and sacrificing for the good of others are about. I could have not made it through everything without your love and support. Furthermore, I could not have done this without the support of the coaching staff and basketball players from the 2007-08 Texas State basketball team and most especially their strength and conditioning coach, Leo Seitz. In addition, I could not have achieved this without my greatest motivators, those who said I could not or would not. I would also like to recognize Dr. Robert Pankey who introduced me to the idea for my thesis.

ACKNOWLEDGEMENTS

I would like to thank my chair, favorite professor, and mentor, Dr. Lisa Lloyd. There is not enough time left, nor space on this page to express my thanks to her. She kept me moving forward no matter how scared I was to progress. She has presented me with opportunity after opportunity to participate in research, teach, and most importantly, learn. She is an incredible person, and without her help and guidance I truly do not know where I would be or what I would be doing. My thanks also go out to Dr. Eric Schmidt for his patience and his many hours of editing assistance and explanations. I am truly a better writer for it. I want to thank Dr. Kevin McCurdy for his advice and guidance on balance and reliability. It was imperative to the completion of my thesis. I could not have done this without the Texas State University-San Marcos basketball team and staff, especially Leo Seitz. I would like to express my gratitude to Mary Jo Bush for all her help fixing computers and installing SPSS. A special thanks goes out to Carolyn Clay for helping me in a million different ways, a million different times. This would not be possible without her and her army of interns

None of this would have been possible without my parents' patience, love, and support. To my siblings, thank you for your encouragement and constant, though sometimes feigned, interest. I also want to thank all my friends, especially Trey Hutton, and the Texas State University-San Marcos faculty members for their help and encouragement. Finally, I would like to thank all of my subjects, because without you and your time, there would be no thesis.

I'm sure I have forgotten to thank several people, so thank you to everyone I have forgotten to thank. This is what any determined person can do with the incredible help and support I received.

This manuscript was submitted on February 24, 2008.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

ABSTRACT

DYNAMIC BALANCE AND BASKETBALL PLAYING ABILITY

by

Michael L. Hobbs, B.S.

Texas State University-San Marcos

December 2008

SUPERVISING PROFESSOR: LISA K. LLOYD

Limited research suggests that dynamic balance is associated with athletic performance (7). However, its relation to BPA has not been identified. Based on the definition of dynamic balance (33) and the required motor skills associated with high levels of BPA (32), dynamic balance is likely to affect BPA. The purposes of this research are to compare the dynamic and static balance of: 1) collegiate basketball players versus novice basketball players, 2) collegiate basketball starters versus non-starters, and 3) collegiate basketball players with the most playing time versus those with the least playing time. Ten collegiate basketball players and 12 novice basketball players completed three tests of dynamic balance: the athlete 1-leg stability test using the Biodex Balance System SD (BBS SD), the Johnson Modification of the Bass Test of Dynamic Balance (JMBT), and the Stork Stand Static Balance test (SSSB). The results of this study showed that for the three tests: 1) the male college basketball players did not score significantly better than the novice basketball players; 2) the male college basketball starters did not score significantly better than the male college basketball non-starters; and 3) the male college basketball players with most minutes played did not score significantly better than the male college basketball players ($p \geq 0.05$). Results from this study indicate that neither dynamic nor static balance, as measured by three general tests of balance, are tests that can be used to determine BPA of college basketball players.

CHAPTER 1

COMPARISON OF DYNAMIC BALANCE AMONG DIVISION I COLLEGE STARTERS, NON-STARTERS, AND NOVICE BASKETBALL PLAYERS

Common goals of competitive collegiate basketball programs are to identify, recruit, and enroll players who possess a high level of basketball playing ability (BPA), while also improving these players BPA with the most effective conditioning methods and techniques. Consequently, identifying factors associated with the highest levels of BPA is imperative. However, due in large part to the varying methodologies employed in previous studies (2-8, 10-13, 15-19, 21-23, 25-26, 28-30), factors associated with BPA have yet to be clearly identified. The factors that were looked at varied widely from anthropometric measures (e.g., weight, height), to performance measures (e.g., vertical jump, leg power), to basketball specific measures (e.g., playing time, skills tests). Individuals were qualified as having greater BPA by: 1) playing college basketball as opposed to being a non-athlete; 2) being a starter as opposed to a non-starter; or 3) being one of the five players with the most minutes played as opposed to the rest of the team.

Previous studies have compared measures of performance: 1) across sports (4, 5, 7, 13, 16, 19, 21, 26, 28); 2) between basketball athletes versus non-athletes and basketball starters versus non-starters (10, 15, 16, 21, 26); 3) among basketball players of varying ages (2-4, 6, 23) and skill levels (8, 23, 30); and 4) among players with most and least minutes played (15). In studies comparing basketball players to non-athletes, several factors, such as height (10, 16, 21, 26, 28), sitting height (16, 21),body weight (16, 21, 28), lean body weight (10, 21, 28), speed (10, 16, 21), power (10, 16), and agility (10, 16), appear to be related to BPA. However, in studies comparing basketball players to athletes from different sports (4, 5, 7, 13, 16, 19, 21, 26, 28), basketball starters versus non-starters (15), basketball athletes with most and least minutes played (15), and basketball players of varying ages (2, 3, 4, 6, 23) and skill levels (8, 23, 30), anthropometric measurements have been the only factors consistently associated with BPA. For example, in studies comparing athletes across different sports, basketball players tended to be taller than soccer (16), volleyball (13, 26), baseball (16), football (5), and handball players (4). Furthermore, basketball players tended to be leaner than handball (4) and football players (5).

In light of this previous research, the association between BPA and anthropometric measures is clear, while the association between BPA and performance measures (e.g., speed, agility, power, and muscular strength) remains unclear. Contributing to this lack of clarity is the fact that previous studies on BPA have varied in methodology and assessed only a limited number of motor-skill related measures. Consequently, research investigating the association of other motor-skill related measures (e.g., dynamic balance in particular) with BPA is warranted.

The literature is bereft as to the association between dynamic balance and BPA. Dynamic balance is a skill-related component of physical fitness that involves the maintenance of equilibrium while moving (33) and, as such, is becoming an integral component of strength and conditioning regimens (24, 31). Since basketball involves abrupt and intense changes in direction, as well as high frequencies of starting, stopping, and physical contact (32), it is reasonable to expect that BPA may be associated with the ability to maintain balance while moving. shooting, dribbling, etc. Despite this, only one study has investigated the relationship between BPA and dynamic balance (7). In this study, dynamic balance measurement scores of female basketball players were compared to female soccer and gymnastic athletes. The results showed that female basketball players had lower dynamic balance scores than soccer players and similar dynamic balance scores to gymnasts. Despite these findings, this study may be of limited usefulness, as no comparisons were made between athletes and non-athletes, or between starters and non-starters within each sport.

Though the potential validity of using the previously noted anthropometric and to a lesser extent, common performance measures, in predicting BPA has been demonstrated, no research has investigated whether dynamic balance is an important factor in BPA. Thus, the purposes of this research are to compare the dynamic and static balance of: 1) collegiate basketball players versus novice basketball players, 2) collegiate basketball starters versus non-starters, and 3) collegiate basketball players with the most playing time versus those with the least playing time. Based on the definition of dynamic balance (33) and the required motor skills associated with high levels of BPA (32), it is hypothesized that dynamic balance will be greater in: 1) collegiate basketball players versus non-athletes, 2) collegiate basketball starters versus collegiate non-starters, 3) collegiate basketball athletes with most minutes versus least minutes. The results of this study may increase both the use of dynamic balance assessments when evaluating BPA, as well as the incorporation of dynamic stability training in the strength and conditioning programs of competitive collegiate basketball programs.

Methods

Approach to the Problem

Limited research suggests that dynamic balance is associated with athletic performance (7). However, its relation to BPA has not been identified. Based on the definition of dynamic balance (33) and the required motor skills associated with high levels of BPA (32), dynamic balance is likely to affect BPA. To begin to better understand the effect of dynamic and static balance on BPA, the current study compared dynamic and static balance among collegiate and novice basketball players. Specifically, this study determined whether significant differences in performance on the Biodex Balance System SD (BBS SD) dynamic balance test existed between: 1) collegiate basketball players and non-athletes, 2) starters and non-starters, and 3) players with most and least minutes played. Since it is unlikely that many strength and conditioning programs have access to laboratory equipment for assessing dynamic balance, this study also determined whether performance on this laboratory test was associated with performance on two commonly used field tests of balance: the Johnson Modification of the Bass Test of Dynamic Balance (JMBT) and the Stork Stand Static Balance test (SSSB) (20).

Subjects

Twenty-four men (19 - 29 years of age) volunteered to participate in this study. Twelve athletes (20.5 ± 1.3) were recruited from a university men's basketball team and 12 novice basketball players (23.8 ± 2.9) were recruited from physical education/physical activity classes at the same university. To be included in the study, the non-athletes must have played varsity basketball at the high school level. Potential subjects were excluded if they had been diagnosed with a concussion in the 12 weeks prior to the study, and/or were currently: 1) participating in a structured balance training program; 2) suffering from a lower extremity injury; or 3) experiencing vestibular (e.g., vertigo) or visual problems (e.g., blind in one eye) (9). During testing, one basketball player was injured and, thus, did not complete the study, and one basketball player, who began the study, did not complete testing for no apparent reason. Results from the remaining subjects were used in the final data analysis. Descriptive data (n=22) of the sample used for statistical analyses are provided in Table 1.

After providing a detailed description of testing procedures, written consent was obtained from each subject. This investigation was submitted to and approved by the university's Institutional Review Board.

Instrumentation

A calibrated physician scale (Detecto Scale Co., Jericho, NY) was used to obtain height and weight. The Biodex Balance System SD (BBS SD) was used to quantify each participant's ability to maintain dynamic stability on an unstable surface (Biodex Medical Systems, Shirley, New York). The unstable surface was a circular platform that moved along the anterior-posterior and medial-lateral axes simultaneously, allowing up to twenty degrees of platform tilt. The stability of the platform could be varied by adjusting the level of resistance in the springs located under the platform. Spring resistance levels range from one (least stable) to eight (most stable). Based on a previously applied protocol (9), a spring resistance level of two was initially selected for use in the current study. However, based on the inability of a pilot group to sustain balance long enough to complete one trial at levels two and three, a spring resistance level of four was employed in the study. The BBS SD provided an overall stability index, which was the mean platform displacement in inches while standing on one leg for 20 seconds.

The reliability of the BBS SD has never been tested. However, multiple studies have demonstrated that the previous model, the Biodex Balance System (BBS), is reliable (r = .64-.89) (14). In preparation of the current study, reliability was determined by the test-retest method using data collected on university students. Seventy male (n=48) and female (n=22) participated in this pilot study. Age (m=22.41years, r=19-29 years), height (m=67.91 in, r= 61.75-76.00), weight (m=166.60 lb, r=111-284 lb). The data taken showed the BBS SD to have a moderate level of reliability on both the right leg (r= 0.653) and left leg (r= 0.676).

Testing Procedures

Subjects visited the laboratory on three separate occasions. During their initial visit, subjects: 1) were given testing instructions based on the American College of Sports Medicine guidelines (1); 2) read and signed a consent form; 3) completed a health appraisal; 4) were measured for height and weight (in exercise clothes and without shoes); and 5) practiced the laboratory and field stability tests. In addition, limb dominance was determined by asking which leg each subject preferred to use when kicking a ball (19).

During the initial visit, foot placement on the platform was determined separately for each subject's dominant (D) and non-dominant (ND) leg. Specifically, each subject was instructed to stand with his dominant leg on the locked platform of the BBS SD. The subject was then instructed to position his foot in such a way that enabled him to maintain a balanced position. This foot position was recorded. To ensure consistency of foot placement throughout all trials, the recorded foot placement was used for all tests involving the dominant leg. These exact procedures were also repeated for the non-dominant foot. Once placement for each foot was determined, each subject participated in a familiarization test. Specifically, the BBS SD test consisted of three, 20-second trials separated by 10-second recovery periods. During each trial, the subject first placed his dominant foot at the pre-recorded position on the locked platform. The subject then stood with his dominant leg on the platform while holding the non-dominant leg in a comfortable, knee-flexed position. When ready, the platform was released and the subject was asked to maintain his balance for 20 seconds. To assist in maintaining balance, the subject was permitted to move his arms. If balance could not be maintained for 20 seconds, then the trial was terminated. The subject was given a chance to recover and the trial was repeated. Testing procedures were repeated for the dominant leg two more times, with 10-second rest periods between each trial. This familiarization testing protocol was then repeated for the non-dominant leg.

Throughout the familiarization protocol, the BBS SD handrails were used during and between trials but not during actual testing. Also, during testing, the instrument panel was covered to prevent the subject from obtaining performance feedback from the BBS SD (9). For each trial, an Overall Stability Index (OSI) score was determined by the BBS SD. The OSI score represents the variance of foot platform displacement in degrees from level with the platform base. A high number indicates greater motion and difficulty with maintaining a stable platform while a low number indicates less motion and greater ability to maintain a stable platform (9). For data analysis, the average of the three OSI scores was used.

Subjects were also familiarized with the two field tests. Like the laboratory test, the subjects were assessed individually. For the JMBT (20), eleven pieces of tape (1” X ¾”) were placed in the pattern shown in Figure 1. When ready, the subject: 1) stood with the right foot on the starting mark and the left foot elevated; 2) leapt to the first tape mark, landed on the ball of the left foot, and attempted to hold this position for 5 seconds; 3) leapt to the second tape mark, landed on the ball of the right foot, and attempted to hold for 5 seconds; and 4) continued to the other tape marks, alternating feet and attempting to hold a steady position for 5 seconds. The test scoring was as follows: 1) 5 points for landing successfully on the tape mark (tape completely covered by foot); 2) 1 point for each second (up to 5 seconds) the steady position was held on the tape marks. A maximum of 10 points per tape mark and 100 points for the test could have been earned. The subject was not rewarded the 5 points for landing at a given mark if any of the following landing errors occurred: 1) failing to stop upon landing; 2) touching the floor with any part of the body other than the ball of the landing foot; or 3) failing to completely cover the tape mark with the ball of the foot. In the case of a landing error, the correct balance position was assumed and held for a maximum of 5 seconds. If the subject landed successfully on the tape mark but committed any of the following errors before completing the 5-second count, the point count was immediately stopped: 1) touching the floor with any part of the body other than the ball of the landing foot; or 2) failing to hold the landing foot steady while in the steady position. If one of the previous errors mentioned occurs, the subject was required to return to that mark and leap to the next mark.

To perform the SSST (20), each subject stood on his dominant foot, with his opposite foot against the inside of the supporting knee, and both hands on his hips. At the start signal, the subject raised the heel of the dominant foot from the floor and attempted to maintain balance as long as possible. The trial ended if the subject either moved his hands from his hips, the ball of the dominant foot moved from its original position, or if the heel touched the floor. During testing, the test administrator counted aloud and recorded the seconds the subject was able to balance. Each subject performed this test three times, with only the best time used in data analysis. Rest time between trials was between 5 and 10 seconds, depending on how quickly the subject was able to regain his balance. Standard protocol for implementing this test suggests stopping the test once a subject achieves the norm for above average (i.e., 37 seconds). However, since this study involved well-trained athletes, the test was halted after 60 seconds. Only one subject performed this test for 60 seconds.

After the familiarization session, each subject was scheduled to return to the laboratory for testing no sooner than 24 hours and no later than 7 days. The testing order for all subjects was: 1) Stork test (Right leg, left leg), 2) JDBT, and 3) Biodex Test (Right leg, left leg). During visit 2, each subject completed the Stork test and JDBT, separated by one to two minute rest period. Each subject was then scheduled to return within 24 to 48 hours to complete the Biodex. The testing sessions used the same methodology as the familiarization session. The dominant and non-dominant leg of each subject was tested during the Stork test and the Biodex test.

Statistical Analyses

To determine whether groups differed in height and weight, an independent samples t-test was performed. The dependent variables used in data analysis were the OSI score, the best time recorded during the SSST, and the score on the JMBT. An independent samples t-test was also utilized to determine whether differences in OSI, SSST, and JMBT scores existed between: 1) basketball players and non-athletes, 2) starters and non-starters, and 3) players with most minutes and least minutes. The Statistical Package for the Social Sciences for Windows

15.0 (SPSS, SPSS Inc, Chicago, IL) was used for all statistical analyses. All tests were conducted with an alpha level of .05.

Results

Table 1 reports both the anthropometric and balance scores of the novice and college basketball players. Independent samples t-tests revealed that there was a significant difference between the two groups in height ($p < .05$), but not for any of the other anthropometric measures tested: 1) weight ($p = .15$), 2) BMI ($p = .50$), 3) Biodex-R ($p = .16$), 4) Biodex-L ($p = .88$), 5) Biodex-D ($p = .14$), 6) Biodex-ND ($p = .97$), 7) Stork test-D ($p = .50$), 8) Stork test-ND ($p = .58$), and 9) JDBT ($p = .44$).

Table 2 compares the starters and nonstarters' anthropometric and performance scores from the Biodex, stork test and JDBT. Independent samples t-tests revealed there were no significant differences between the starter and non-starter groups for any of the variables: 1) height ($p = .59$), 2) weight ($p = .26$), 3) BMI ($p =.31$), 4) Biodex-R ($p = .52$), 5) Biodex-L ($p = .22$), 6) Biodex-D ($p = .49$), 7) Biodex-ND ($p = .27$), 8) Stork test-D ($p = .29$), 9) Stork test-ND ($p= .25$), and 10) JDBT ($p = .16$).

Table 3 compares the anthropometric and balance scores of the five individuals with the most minutes played to the rest of the players. Four of the five individuals with the most minutes played were starters. An independent samples t-test revealed there were no significant differences between the two groups for any of the variables: 1) height (p = .89), 2) weight (p = .67), 3) BMI (p =.51), 4) Biodex-R (p = .94), 5) Biodex-L (p = .41), 6) Biodex-D (p = .81), 7) Biodex-ND (p = .19), 8) Stork test-D (p = .68), 9) Stork test-ND (p= .40), and 10) JDBT (p=.22).

Discussion and Conclusions

The results from this study contribute to the literature by showing that neither the dynamic nor static balance tests used discriminate between levels of BPA of college basketball players. Other tests of balance may better determine BPA. Previous research has demonstrated that certain anthropometric and performance measures are correlated with playing ability in various sports (2-8, 10-13, 15-19, 21-23, 25-26, 28-30). While certain variables (e.g. age, height, weight, speed, power, muscular strength, and muscular endurance) have been extensively studied (2-8, 10-13, 15-19, 21-23, 25-26, 28-30), balance has not. Furthermore, from a thorough review of the literature involving the investigating of the relationship between playing ability and performance measures, most of these studies have involved athletes from sports other than basketball. The limited research involving basketball players has shown greater height (10, 16, 21, 26, 28), seated height (16, 21), body weight (16, 21, 28), lean body weight (10, 21, 28), upper body power (16, 21), lower body muscular endurance (10), lower body muscular strength (21), speed (10, 16, 21), and agility (10, 16) to be related to increased BPA. However, no known studies have investigated the correlation of dynamic balance and BPA.

One study that investigated the relationship between BPA and dynamic balance measured dynamic balance scores of female basketball players and compared them to female soccer and gymnastic athletes at the collegiate level (7). The results showed that female basketball players had lower dynamic balance scores than soccer players and similar dynamic balance scores to gymnasts. In that study, however, no comparisons were made between athletes and non-athletes, starters and non-starters, or players' with the most and least minutes.

In studies comparing basketball starters versus non-starters and basketball players with most minutes played versus least minutes played, the following anthropometric and performance measures were significantly different between groups: 1) age (4), 2) height (4, 30), 3) weight (4, 8, 30), 4) body composition (4, 8), 5) vertical jump (8, 15), 6) lower body power (8, 15), 7) speed (15), and 8) agility (15). In these studies, for instance, starters were older, taller, weighed more, had lower body fat, a greater vertical jump, greater lower body power, were faster, and more agile than non-starters. Furthermore, basketball players playing the most minutes had greater vertical jump height, were faster, had better acceleration, and greater leg strength than basketball players playing the least minutes. While limited, these studies suggested that BPA is correlated with strength, power, agility, and speed. The present study showed no difference in either dynamic or static balance between college basketball starters and non-starters or college basketball players with the most minutes played and the least minutes played.

Due to the nature of BPA, differences were expected in dynamic balance, but not necessarily in static balance. The unexpected lack of findings in this study with regard to dynamic balance may be due to: 1) the level of spring resistance, or 2) the limitation of test specificity. Different results might be obtained with an increased level of instability. Researchers have suggested that balance is not a general motor ability, but rather task-specific (27). For example, Tsigilis et al. (27) found no correlation between a laboratory test (stabilometer) for dynamic balance and three field tests (i.e., JMBT, the Balance Beam Speed Test 1, and Balance Beam Speed Test 2). Since the four different tests of dynamic stability were not correlated, the results suggest that the tests measured different aspects of dynamic balance. Thus, to determine differences in dynamic balance between differing levels of BPA, a test must be used or created to assess the aspects of dynamic balance specific to basketball. The development of such a test might be useful in identifying, recruiting, and enrolling players who possess a high level of BPA.

This exploratory study is not without additional limitations or potential confounders, including sample size, number of trials performed, subjects being tested on only one level, time of year data was collected, and the true BPA of the subjects. Specifically, the small sample size and the low number of trials performed per test may have contributed to the null findings. Furthermore, since the basketball players were tested two weeks after the end of their season, fatigue could have resulted in lower scores. Lastly, the BPA itself may not have been too different between the two groups employed in this study (i.e., college basketball athletes and college non-athletes). If the basketball players were recruited from collegiate teams consistently ranked in the top ten, then the BPA would have been much greater than the comparison group.

Despite the lack of findings in the present study, dynamic stability, as it relates to the maintenance of equilibrium while moving, would logically be expected to have an effect on a playing ability, especially for sports in which athletes are moving, turning, twisting, jumping, stopping, cutting, accelerating, and decelerating (32). Thus, research on dynamic stability should continue to be conducted. In light of the fact that dynamic balance is integral to BPA, at least in theory, future studies should determine the specific aspects of dynamic balance used in basketball. If specific aspects of dynamic balance are identified, future studies should then create basketball-specific tests of dynamic balance. Furthermore, future studies should employ larger sample sizes, test dynamic balance over a period of seasons and at different times in the season, and determine whether differences exist by positions (e.g. guard, forward, and center) and/or by experience (e.g., senior versus junior, number of years lettered, and number of games played.)

Practical Application

The results of this study showed that: 1) the male college basketball players did not score significantly better than the novice basketball players on the Biodex, Stork test, and the JDBT; 2) the male college basketball starters did not score significantly better than the male college basketball non-starters on the Biodex, Stork test, and JDBT; and 3) the male college basketball players with most minutes played did not score significantly better than the male college basketball players with fewer minutes played on the Biodex, Stork test, and JDBT. Results offer strength and conditioning coaches working with Division I basketball athletes a better understanding of the effect of dynamic balance on BPA and the ability of these current tests to determine BPA. With this understanding, coaches may be able to optimize their current training programs. Because dynamic balance, as measured by general tests of dynamic balance, may not be a key factor in BPA, coaches may consider eliminating, or at least limiting, time dedicated to training his/her players' dynamic balance.

While this study was unable to detect a relationship between BPA and dynamic balance, results may be used to guide the future exploration of whether BPA is correlated to specific tests of dynamic balance in basketball players. Specific tests rather than general tests of dynamic balance, including those employed in this study (i.e., Biodex, Stork test, and JDBT), may be more likely to discriminate between different levels of BPA. In theory, since basketball requires the maintenance of equilibrium while moving, specific tests of dynamic balance should be developed and utilized in the identification of whether a true relationship exists between BPA and specific aspects of dynamic balance.

References

1. American College of Sports Medicine. Guidelines for Exercise Testing and Prescription (7th Ed.). Philadelphia: Lippincott Williams & Wilkins, 2006.

2. Apostolidis, N., G.P. Nassis, T. Bolatoglou, and N.D. Geladas. Physiological and technical characteristics of elite young basketball players. *The Journal of Sports Medicine and Physical Fitness*. 44(2):157 - 162. 2004.

3. Bale, P. Anthropometric, body composition, and performance variables of young elite female basketball players. *The Journal of Sports Medicine and Physical Fitness*. 31(2):173 – 177. 1991.

4. Bayios, I.A., N.K. Bergeles, N.G. Apostolidis, K.S. Noutsos, and M.D. Kodkolou. Anthropometric, body composition, and somatotype differences of Greek elite female basketball, volleyball, and handball players. *The Journal of Sports Medicine and Physical Fitness*. 46:271 – 280. 2006.

5. Berg, K. and R.W. Latin. Comparison of physical and performance characteristics of NCAA Division I basketball and football players. *Journal of Strength and Conditioning Research*. 9(1):22 – 26. 1995.

6. Berg, K., D. Blanke, and M. Miller. Muscular fitness profile of female college basketball players. *The Journal of Orthopedic and Sports Physical Therapy*. 7(2):59 – 64. 1985.

7. Bressel, E., J.C. Yonker, J. Kras, and E.M. Keath. Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. *Journal of Athletic Training*. 42(1):42- 46. 2007.

8. Brooks, M.A., L.W. Boleach, and J.L. Mayhew. Relationship of specific and nonspecific variables to successful basketball performance among high school players. *Perceptual and Motor Skills*. 64:823 – 827. 1987.

9. Cachupe, W.J.C., B. Shifflett, L. Kahanov, and E.H. Wughalter. Reliability of Biodex Balance System measures. *Measurement in Physical Education and Exercise Science*. 5(2):97 – 108. 2001.

10. Gillam, G.M. Identification of anthropometric and physiological characteristics relative to participation in college basketball. *National Strength and Conditioning Association Journal*. 7(3):34 – 36. 1985.

11. Gocentas, A. and A. Landor. Dynamic sport-specific testing and aerobic capacity in top level basketball players. *Papers on Anthropology XV*. 55 – 63. 2006.

12. Greene, J.J., T.A. McGuine, G. Leverson, and T.M. Best. Anthropometric and performance measures for high school basketball players. *Journal of Athletic Training*. 33(3):229 – 232. 1998.

13. Hakkinen, K. Maximal force, explosive strength and speed in female volleyball and basketball players. *Journal of Human Movement Studies*. 16:291 – 303. 1989.

14. Hinman, M.R. Factors Affecting Reliability of the Biodex Balance System: A Summary of Four Studies. *Journal of Sport Rehabilitation*. 9(3):240-252. 2000.

15. Hoffman, J.R., G. Tenenbaum, C.M. Maresh, and W.J.Kraemer. Relationship between athletic performance tests and playing time in elite college basketball players. *Journal of Strength and Conditioning Research*. 10(2):67 – 71. 1996.

16. Ko, B. and J. Kim. Physical fitness profiles of elite ball game athletes. *International Journal of Applied Sports Science*. 17(1):71 – 87. 2005.

17. LaMonte, M.J., J.T. McKinney, S.M. Quinn, C.N. Bainbridge, and P.A. Eisenman. Comparison of physical and physiological variables for female college basketball players. *Journal of Strength and Conditioning Research*. 13(3):264 – 270. 1999.

18. Latin, R.W., K. Berg, and T. Baechle. Physical and performance characteristics of NCAA Division I male basketball players. *Journal of Strength and Conditioning Research*. 8(4):214 – 218. 1994.

19. Mayhew, J.L., M.G. Bemben, D.M. Rohrs, F.C. Piper, and M.K. Willman. Comparison of upper body power in adolescent wrestlers and basketball players. *Pediatric Exercise Science*. 7:422 – 431. 1995.

20. Miller, D.K. Balance. In T. Dorwick, V. Malinee, L. Huenefeld. *Measurement by the Physical Educator: Why and How Fourth Edition.* (pp. 122-124). New York: McGraw-Hill Higher Education.

21. Morrow, J.R., W.W. Holser, and J.K. Nelson. A comparison of women intercollegiate basketball players, volleyball players, and non-athletes. *Journal of Sports Medicine.* 20:435 – 440. 1980.

22. Ostojic, S.M., S. Mazic, and N. Dikic. Profiling in basketball: Physical and physiological characteristics of elite players. *Journal of Strength and Conditioning Research*. 20(4):740 – 744. 2006.

23. Sallet, P., D. Perrier, J.M. Ferret, V. Vitelli, and G. Baverel. Physiological differences in professional basketball players as a function of playing position and level of play. *The Journal of Sports Medicine and Physical Fitness.* 45(3):291 – 294. 2005.

24. Santana, J.C. Stability and balance training: Performance training or circus acts? *Strength and Conditioning Journal*. 24(4):75 – 76. 2002.

25. Smith, H.K. and S.G. Thomas. Physiological characteristics of elite female basketball players. *Canadian Journal of Sports Science.* 16(4):289 – 295. 1991.

26. Toriola, A.L., S.A. Adeniran, and P.T. Ogunremi. Body composition and anthropometric characteristics of elite male basketball and volleyball players. *Journal of Sports Medicine*. 27:235 – 239. 1987.

27. Tsigilis, N., Zachopoulou, E., and T. Mavridis. Evaluation of the specificity of selected dynamic balance tests. *Perceptual and Motor Skills*. 92(3) Pt. 1 827 – 833. 2001.

28. Tsunawake, N., Y. Tahara, K. Moji, S. Muraki, K. Minowa, and K. Yukawa. Body composition and physical fitness of female volleyball and basketball players of the Japan inter-high school championship teams. *Journal of Physiological Anthropology and Applied Human Science*. 22:195 – 201. 2003.

29. Vaccaro, P., J.P. Wrenn, and D.H. Clarke. Selected aspects of pulmonary function and maximal oxygen uptake of elite college basketball players. *Journal of Sports Medicine*. 20:103 – 108. 1980.

30. Viviani, F. The somatotype of medium class Italian basketball players. *The Journal of Sports Medicine and Physical Fitness*. 34(1):70 – 75. 1994.

31. Williardson, J. Core Stability Training: Applications to Sports Conditioning Programs. *Journal of Strength and Conditioning Research.* 21(3):979-985. 2007.

32. Guide to Coaching Basketball.com. http://www.guidetocoachingbasketball.com/motion.htm. Accessed December 15, 2007.

33. The President's Council on Physical Fitness and Sports. Department of Health and Humans Services. Definitions of Health, Fitness, and Physical Activity. http://www.fitness.gov/digest_mar2000.htm. Accessed February 10, 2007.

CHAPTER 2

Literature Review of Anthropometric and Performance Characteristics of Basketball Athletes

Because of the lucrative nature of sports in both the amateur and professional, high performing athletes are highly sought and valued. Many of the professional sport organizations had revenues of billions of dollars in 2006 including the NFL (5.86 billion), NBA (3.13 billion), NHL (2.2 billion), and MLB (5.2 billion) (MLB). The lucrative nature of professional sports is also evidenced by the fact that many professional athletes earn millions of dollars each year to play sports such as on average: NFL (1.4 million, MLB (2.7 million, NBA (5.215 million, NHL (1.46 million) (79). Many universities and colleges also received large profits through their athletic programs including University of Texas (42 million), University of Michigan (37 million), and University of Florida (32 million) in the 2005-06 fiscal year (78). Because of the vast sums of money to be earned by these organizations and collegiate programs it is beneficial to be able to identify higher performing athletes early on. Teams able to identify the athletes most likely to be successful should in turn give themselves the best chance to be successful. It can also help to ensure that finite resources such as money, time, and scholarships are not wasted on an athlete which will not be successful. One way of identifying/measuring potential performance has been by measuring anthropometric and physiological characteristics

It is generally recognized that different anthropometric and performance characteristics are required to be successful in different sports. Consequently, recent research has been focused on identifying the characteristics which are beneficial for participating in specific sports. Over the last three decades there has been an accumulation of physiological and anthropometric measurements (2-77). Many different types of measurements, such as age, professional experience, height, weight, lean body weight, fat weight, somatotype, muscular strength (bench press and squat), muscular endurance (push ups and squat thrusts), body fat, hemoglobin levels, hematocrit levels, forced vital capacity, forced expiratory volume, VO_2max, heart rate max, vertical jump (height and power), fast twitch muscle fiber percentage have been taken in these studies. Identification of requirements that increase performance in a specific sport could aid the coach, trainer, and/or athlete in creating a proper training program for that sport. To illustrate this point, if agility and acceleration were identified as components which help determine basketball performance, exercises which improve these would be included in the training program. Exercises which enhance other, less helpful components could be omitted since the adaptations would not increase performance. Recognition of these qualities could also assist the coaching staff in player selection, potential, and helping to diagnose individual player weakness. This would also help in selection of proper offensive and defensive roles (28).

There has been much research done to determine the anthropometric and performance characteristics of different athletes. These are shown in Table 4.

Barker et al. (5) assessed 59 Division IAA scholarship football players' performance, physical and personality factors, and football playing ability. The players were categorized according to position, strength level, race, and starter/nonstarter status. The players were ranked by the offensive coordinator, defensive coordinator, and the strength and conditioning coach. The rankings were averaged for analysis. Starters were shown to have significantly higher 1-RM, vertical jump power, and static vertical jump power. This suggests starters are stronger and more powerful than nonstarters. No significant difference was found between starters and nonstarters for any running performance variable.

One study by Heller et al. (34) looked at the physiological profiles of male and female taekwondo black belts. It concluded that physiological and kinanthropometric parameters do not, in general, correlate strongly with taekwondo performance. The results suggest that, even in this group of relatively homogeneously trained male and female competitors, a multifactorial approach may be helpful in selecting or differentiating more and less successful competitors. The successful taekwondo competitors tended to demonstrate low body fat percentage, high anaerobic abilities, elevated aerobic fitness, strength, and flexibility. Pulmonary function variables and height of vertical jump appear to be of little importance.

Young et al. (77) studied one Australian Football League (AFL) club. Starters and nonstarter results were compared and defenders, forwards, and mid-fielders results were compared. Starters were significantly older, more experienced, and better in measures of leg power, sprinting speed, and the distance covered in the Yo Yo intermittent recovery test compared to the nonstarters. Even though the starters were superior to the nonstarters in lower and upper body strength, vertical jump, and predicted VO_2 max, the differences were non-significant. It was concluded that some fitness qualities can differentiate between starters and nonstarters in at least one AFL club.

The aim of the study by Lee et al. (42) was to compare physiological and anthropometric measures of successful mountain bikers and professional road cyclists. The mountain bikers were significantly lighter and had lower body fat percentage. The mountain bikers produced higher power outputs relative to body mass at maximal exercise, at the lactate threshold, and during the 30 minute time-trial. VO_2 max relative to body mass was significantly higher in the mountain bikers. The results indicate that high power-to-weight characteristics are important for success in mountain biking.

Mujika and Padilla (52) examined 24 male professional road cyclists in order to determine their anthropometric and maximal and submaximal physiological characteristics. Male professional road cyclists were shown to have very high aerobic capacities, both at maximal and submaximal exercise intensities. It was also found that given anthropometric characteristics play a major role in the resistance a cyclist must overcome to generate movement, laboratory-based physiological measurements should be scaled in relation to body dimensions to assess road cycling performance. Also time trial specialists seem to have an overall performance advantage over the other groups of cyclists in all types of terrain and riding conditions. Finally, heart rate monitoring has been shown to be a useful tool to determine exercise intensity and load during time trial and mass-start competition, by relating racing values with laboratory-based maximal and submaximal reference values.

Another study quantified changes in training volume, organization, and physical capacity among Norwegian rowers winning international medals between 1970 and 2001 (21). This study found that over the last three decades, the maximal aerobic capacity of international medal winners in rowing appears to have increased by more than 10%. During this same time period annual training volume has increased 20% with the largest increase occurring during the winter period. Large increases in basic endurance training at intensities clearly below the first lactate turn point have been utilized. Training at high intensities, at or above race pace (105-115% VO_2 max) has been de-emphasized compared to the 1970s. Greater emphasis has been placed on training at intensities requiring 90-95% of VO_2 max most often in the form of long interval bouts lasting 4-8 min. Finally, repeated periods of altitude training, consisting of 14-21 day stays at ~2000 meters above sea level has become a common practice, although the benefits of repeated altitude among well-trained athletes remain undocumented. This study supports and provides a historical context for data from elite endurance athletes suggesting that the optimal training organization for maximal performance is a polarized model of training with about 75% of training performed well below the lactate threshold and 15-20% well about that intensity.

Sawyer et al. (61) studied the relationship between football playing ability (FPA) and selected anthropometric and performance measures were determined among NCAA Division I football players. Football playing ability (determined by the average of two defensive coaches' rankings if the subject was a defensive player or two offensive coaches' rankings if the subject was an offensive player) was significantly correlated with vertical jump (VJ) in all groups (offense, defense, and position groups of wide receiver-defensive back, offensive linemen-defensive linemen, and running back-tight end-linebacker). Eleven of 50 correlation (groups of variables), or 22%, were important for FPA. Five of the 11 relationships were related to VJ. Forward stepwise regression equations for each group explained over half of the criterion variable, FPA, as indicated by the R^2 values for each model. Vertical jump was the prime predictor variable in the equations for all groups. The findings of this study are discussed in relation to the specificity hypothesis. Strength and conditioning programs that enable football players to develop forceful and rapid concentric action through plantar flexion of the ankle, as well as extension of the knee and hip, may be highly profitable.

Although it is difficult to determine specific physiological and functional characteristics which determine success, understanding the profile of successful players could give coaches, trainers, and exercise scientists a better working knowledge of this particular group of athletes (56) and might be helpful to improve the functional ability of the athletes. These specific programs could be used to enhance playing performance and possibly reduce injury (41).

There has been some research done to determine the anthropometric and physiological characteristics of basketball athletes. These studies are shown in Table 5.

From these studies, factors underlying athletic performance have been identified. For basketball, in particular, limited studies suggest that height, arm length, and leg power may perhaps be factors integral to basketball playing ability. In a study by Ko and Kim (37), among elite athletes from four sports (soccer, volleyball, basketball, and baseball), basketball players tended to score among the highest in seated and standing height, chest circumference, body weight, and number of sit-ups performed and among the lowest in the 50-m run, the side-step test, and sit-and-reach test. Moreover, when compared to non-athlete, physical education majors, basketball players scored significantly different on all measures. In a study comparing Division I basketball and football players, Berg and Latin (7) found that, when compared to football players, basketball players were taller, lighter, and scored lower on the following measurements: 1) body fat percentage, 2) vertical jump, 3) vertical jump power, 4) absolute and relative bench press, and 5) absolute and relative squat. In a study by Bayios et al. (6) of Greek elite female basketball, volleyball, and handball players, basketball player were found to be significantly taller, heavier, higher in height weight ratio, lower in percent body fat, higher in fat free mass, and lower in sum of skin folds than handball players. They also had significantly lower body height, lower height weight ratio, higher BMI, higher body fat percentage, higher fat mass, and higher skin fold sum than the volleyball players. Toriola et al. (69) found, when looking at elite male basketball and volleyball players and 20 non-athletes, the basketball players were significantly taller and larger humerus diameter than the volleyball players and non-athletes and had significantly lower percent body fat than the non-athletes. Hakkinen revealed in a study between ten female volleyball and nine female basketball players of the same competitive level that the basketball players had significantly higher percent body fat, lower maximal vertical jumping height in the squat jump and the counter movement jump, and lower maximal throwing velocity of the upper body extremity with three different masses of the ball.

Gilliam (28) measured thirteen members of the male basketball team and fourteen physical education majors in order to identify the physiological (Table 6) and anthropometric characteristics (Table 7) which are necessary for participating in college basketball. There were three anthropometric characteristics which were found to be significantly contributing to participation. The basketball players were 10.53 cm taller and 9.39 kg heavier in body weight. The basketball players were also found to have a lower endomorphy value according to the Heath-Carter value. There were also physiological characteristics which were shown to contribute to basketball ability. The athletes (2.33 s)were shown to be superior to the P.E. majors (2.45 s) in acceleration (time elapsed between initial movement and crossing the finish line 15 yards away); maximum speed, 5.29 s to 5.71 s respectively, (time taken to cover a distance of 50 yards after 15 yards running start; agility, 10.80 s to 11.39 s respectively, (time taken to complete right-boomerang run); power, 154.12 kgm/sec to 135.20 kgm/sec respectively, (vertical jump distance and total body weight); and muscular endurance, 58.54 to 38.07 respectively, (number of squat thrusts).

Latin et al. (41) examined 45 NCAA Division I male basketball teams totaling 437 players were surveyed about their height, weight, strength, speed, power, agility, body fatness, and aerobic capacity and those results are shown on Table 8 . Comparisons were made among players based on their position, guard, forward, and center. The positions differed on all variables except bench press, 1.5 mile run, and agility. Guards were the shortest, lightest, had the lowest body fat percentage, and had the best vertical jump, speed, strength relative to body weight, and the best mile run performance. Centers were the tallest, heaviest, had the highest body fat percentage, and worst agility, 40-yd dash, and mile run times.

Hoffman et al. (35) examined the relationship of athletic performance tests, player evaluations by coaches, and playing experience relative to playing time in 29 male Division I college basketball players over a 4 year period and the results are shown on Table 9 and 10. The most prominent predictor was the coach's evaluation of the player, which explained 56 to 86% of the playing time variance. Following each season, the head coach compared each one to the other players on the team (Q1) and to the other Div. I basketball players they played against (Q2). Physical fitness evaluations and playing experience explained an additional 6 to 20% of playing time variance. In the 1988/89 season, vertical jump added 19% to the explained variance to player evaluation to predict playing time. During the 1989/90 season the contribution of 1-RM squat, sprint, vertical jump, and agility added 14% to the variance. In the 1990/1991 season squat, endurance, sprint, vertical jump, and agility added only 6% adjustments to the variance. During the 1991/92 season these physiological components added 10% to the explained variance of playing time. When the player evaluations and playing experience were excluded and the physical fitness measurements in the original regressions were regressed together for each season, they accounted 81, 64, 77, and 67% of the playing time, respectively, for each season. As was expected by the authors, the major determinant of playing time was the coach's evaluation of the player's ability. It is logical that a coach will play those who display greater basketball skills and can use them with their team. The authors do note that at this level of play, skill level among these athletes may be very similar. Because of this the difference in playing time may be determined by athletic ability (strength, speed agility), which may enhance a player's basketball performance. In this study there were several instances in which two players at the same position had very high ability ratings. The one who displayed greater athletic skills, as determined by their performance on the fitness tests had more playing time. The tests that entered into the regression equation still added significantly to the explained variance of playing time, though there was a large shared variance between the performance tests and player evaluations. The athlete's playing experience did not differ significantly during this study. However, experience level did enter into the regression equation during years 1 and 4. This may be due to the number of freshmen on the team during those two years (5 and 6 respectively) compared to the other years (4 and 2 respectively). Vertical jump, height, speed, and agility were shown to be consistent correlators to playing time. Vertical jump height was a strong predictor in each of the four regression equations, while speed and agility were moderate predictors in three.

Ko and Kim (37) tested a total of 113 male elite ball game athletes from the Korea Armed Forces Athletic Corps and 49 non-physical education major collegiate students which served as the athletes' age-matched counterparts were recruited. The breakdown of subjects is shown in Table 11.

The anthropomorphic and physiological characteristics of elite basketball players were identified as superiority of height, sitting height, weight, chest circumference, arm power, abdominal muscle endurance, leg power, aerobic capacity, speed, and agility. Though they were not significantly greater than all the athletes in all these characteristics, they had the greatest mean in all of them and were significantly greater than the age-matched college students in all these tests. The results for these tests are shown in Table 12 and the significance or lack of is shown in Table 13.

The Levene Homogeneity Analysis revealed that all the variables except height, seated height, basketball throwing, and sit-ups were homogenous. Group differences were found in all the variables measured, so the means of the variables which were assumed to be homogenous were compared using Scheffe's test, and the means of variables which were not assumed to be homogenous were compared using Dunnet T3.

Ostojic et al. (56) profiled the structural and functional characteristics of elite Serbian basketball players and the results are shown on Table 14. The subjects came from five men's basketball teams. All these teams competed in the professional First National League, which consists of 10 basketball squads and won 5 first places in the 2002-2003 season. Eight of these players were members of the National Olympic team and seven athletes played in the NBA. Overall measurements were taken from 60 players. Players were categorized into their positional roles of guards, forwards, and centers. Guards were older and more experienced, whereas centers were taller and heavier than the other two positions and forwards had significantly higher height and weight than guards. Centers had more body fat and lower estimated VO_2max than the guards and forwards. Lastly, the highest heart rate frequencies during the last minute of the shuttle run test were significantly lower in guards than in forwards and centers and vertical jump power was significantly higher in centers as compared with guards. These results show a strong relationship between body composition, aerobic fitness, anaerobic power, and the positional roles in elite basketball players.

Morrow et al. (51) sampled 330 college females with 110 being students only, 110 being collegiate basketball players, and 110 being collegiate volleyball players and the results are shown on Table 15. When compared to volleyball players, basketball players were taller, ran more slowly, had longer arms wider biiliac width, and greater leg strength. When compared to non-athletes the basketball athletes had greater lean weight, fat weight, height, sitting height, arm length, biacromium width, biiliac width, leg press, and bench press and a lower 10 yard sprint.

Tsunawake et al. (70) studied the body composition and physical fitness of the female volleyball and basketball players of the Japan Inter-high School Championship Teams and the results are shown on Table 16 and

17. There were 12 volleyball players, 11 basketball players, and 46 non-athletes involved in this study. Basketball players were significantly taller; heavier; had larger chest and abdominal girth; larger hip circumference; smaller tricep, subscapular, abdominal, supra-iliac, thigh, and knee skinfold thickness. They also had less percent body fat, fat mass, fat mass to height and greater body density, fat-free mass, and fat-free mass to height. There was no significant difference observed in any measured item of the physique, skinfold thickness, or body composition between basketball player and volleyball players. However, basketball players had significantly higher ventilatory maximum, VO_2 max, and O_2 debt max than volleyball players.

The study by Brooks et al. (12) showed a dichotomy between what coaches perceive as rating criteria for basketball players and what separated the good from the bad teams. These results are shown on Table 18. The best single predictor of playing ability in the coaches' viewpoint was jumping ability. The higher a player could jump the greater ability he was perceived to have by coaches. However, the best team was identified by better ball-handling skills, shooting accuracy, and greater knowledge of the game than the poorest team.

In a study by Greene et al. (31), the male subjects were significantly taller and heavier, while the females had a significantly higher percentage of body fat. There was no significant differences found for ankle plantar flexion and dorsiflexion, but the females had significantly more inversion and eversion range of motion. Analysis of medial longitudinal arch type found females to have a higher percentage of pronated arches and males have a higher percentage of supinated arches. Performance testing revealed that the males were able to jump significantly higher and run the 25-yard shuttle run and 20-yard sprint significantly faster than the female subjects. There was no significant difference between the groups for single-limb balance time. These results are shown on Table 19.

Gocentas and Landor (30) tested eight competitive male basketball players and the results are shown on Table 20. The athletes performed incremental exercise test on a cycle ergometer. Aerobic fitness (VO_2 max), maximal heart rate (HR max), oxygen pulse at the peak of cardiopulmonary test (Oxy Pulse), respiratory quotient (RQ), minute ventilation at the peak of exercise (VE max), and power output at the peak of cardiopulmonary test (W max). Mean heart rate and peak heart rate was during 3.5 minutes shooting exercise, which was recognized as basketball-specific. Such basketball-specific exercise was performed during real practices twice within four weeks. There was a strong correlation of oxygen pulse with the first mean and peak intensity basketball-specific exercise and with the exercise repeated after four weeks. The study established correlation between the heart rates achieved during aerobic performance testing and the sport-specific exercise test: lower heart rate during the sport-specific exercise test was related to higher aerobic performance. The correlation is permanent as determined by repeated exercise test. Basketball players have to develop aerobic performance (general endurance) allowing for better economy in sport-specific activities and acceleration of recovery from anaerobic loads.

Thirteen members of the University of Maryland basketball team were assessed for pulmonary function and maximal oxygen uptake at the peak of the 1977 competition season (71) and the results are shown on Table 21. Forced vital capacity (FVC), forced expired volume in one second ($FEV_{1.0}$), maximum voluntary ventilation (MVV) were tested on day one and maximal pulmonary ventilation (VE max), maximum oxygen uptake (VO_2 max), and maximum heart rate (HR max) were determined on day two. When compared with normative data, it was concluded that participation in basketball may provide some advantage in pulmonary function and that these athletes, as a group, cannot be characterized as having superior aerobic power.

The objectives of the study by Smith and Thomas (67) were to assess physiological components considered important to game performance in female players selected to the national basketball team roster in 1988 or 1989, and to use this information to describe the team and positional profiles. Data obtained from maximal treadmill tests, anthropometry, sprints, isokinetic dynamometry, and other tasks reflected those qualities of elite players and is shown on Table 22. In relation to previously reported data, the athletes were generally taller, heavier, and had higher maximal aerobic power than international and college players of 7 to 10 years ago. The data can also be used to identify target standards for current and prospective team members.

The purpose of the Berg et al. (8) investigation was to describe the body composition, peak torque, peak torque ratios, and relative and absolute muscle endurance in the ankle, knee, shoulder and elbow of 13 female college basketball players. (Table 23-24) The results showed that 1) these subjects were taller, heavier, and leaner than untrained females of the same age; 2) the flexors were stronger than the extensors at each joint and at each velocity tested with the exception of the right elbow; 3) the right-left difference in peak torque ranged from 0.2 to 12.4% with the mean difference across all joints and all velocities 3.0%; 4) flexor:extensor ratios varied with the velocity of the movement; and 5) relative muscle endurance was greatest in the shoulders and least in the knee while absolute muscle endurance was greatest at the knee and lowest at the ankle.

Bale's study (4) determined the physique and body composition of young female basketball players and to examine these variables in relation to their playing position. These results are shown on Table 25. Eighteen members of the under seventeen England Basketball squad were measured on twenty different anthropometric sites form which somatotype and body composition were calculated. Four performance measures, vertical jump, anaerobic power, right and left grip strength and laterality were also measured. The variables of the basketball players grouped according to playing position were then compared statistically using ANOVA. Centers had the largest measures of physique and body composition followed by the forwards and the guards. These differences were significant, particularly between the centers and the guards. The centers were much taller, had longer limb lengths, hip widths, and were more muscular.

In the study by Sallet et al. (59) a total of 58 players were divided into first (Pro A) and second division (Pro B) groups. The sample was also divided into centers, forwards, and guards. Many physical differences, most notably size, exist between players as a function of their playing position. But these differences have no relationship to the level of play of professional players. General aerobic capacity is fairly homogenous between playing position and level of play, even if there are observable VO_2 max differences due to inter-individual profiles. On the other hand, anaerobic capacity seems to be a better predictor of playing level even though it is not clear whether such capacity comes from specific training in Pro A, or from an initial selection criterion. These results are shown on Table 26.

The aim of the Apostolidis et al. (2) study was to a) describe the physiological and technical characteristics of elite young basketball players, and b) to examine the relationship between certain field and laboratory test among these players. The results are shown on Table 27. These players presented a moderate VO_2max and anaerobic power. The significant correlation between mean power and certain field tests indicate that these tests could be used for the assessment of anaerobic capacity of young basketball players.

While research assessing the anthropometric and performance characteristics of basketball is available to a small extent, one characteristic that has received much less attention in the literature is dynamic balance. Dynamic balance is a skill-related component of physical fitness that relates to the maintenance of equilibrium while moving (80). It would seem logical that a sport which involves a great deal of starting, stopping, changing of direction, and contact would benefit measuring an athlete's ability to maintain balance while moving. Scientific data has shown the efficacy of an unstable training environment. One recent study showed increased core muscle recruitment during an abdominal curl when performed in an unstable environment versus a stable surface (60). Research has also shown the efficacy of using unstable training environment when rehabbing the ankle complex (60). Training under a vibratory stimulus, which can be seen as a form of an unstable training environment, has also been shown to enhance performance parameters, such as vertical jump (60). Santana concludes that it is beneficial to incorporate a measured amount of balance training (using an unstable training environment) with any power program to help direct and control the size and power the program would provide (60). Athletic trainers would benefit from knowing which athletes require more balance training to reduce musculoskeletal injuries (11). In Bressel's study basketball players had the inferior balance scores and inferior balance scores may be a strong predictor of future ankle sprains (11), athletic trainers may find it useful to prescribe more balance training to basketball players (11).

While one study (11) has assessed the dynamic balance of female basketball, soccer, and gymnastic athletes, that study only compared scores on dynamic balance among female college athletes competing or training in soccer, basketball, and gymnastics. As stated earlier basketball players had the lowest dynamic balance scores of the three groups, but were only significantly lower than soccer players. This could be explained because soccer players often perform single-leg reaching movements outside their base of support during passing, receiving, and shooting, although no direct evidence supports this (11). The scores on dynamic balance in this study, however, were only compared to scores of other athletes. In other words, no comparisons were made between athletes and non-athletes, or between starters and non-starters.

Though the potential validity of using anthropometric and performance measures in both predicting basketball playing ability and developing a proper strength and conditioning program for basketball players has been demonstrated, no research has included assessments on dynamic balance. Dynamic balance, if correlated with basketball ability, could be used to 1) aid recruiters in identifying basketball players with the greatest potential, and 2) assist strength and conditioning coaches with developing a comprehensive training program specific to the skills required for basketball. The purposes of this research are to determine 1) if a significant difference between non-athletes and elite basketball players on measurements of dynamic balance exists, and 2) if there is a correlation between performance on dynamic balance tests and starter/non-starter status?

Appendix A

Informed Consent

Consent Form for Participation in Comprehensive Dynamic Stability (Dynamic Balance) Testing

Department of Health, Physical Education, and Recreation, Texas State University

INTRODUCTION AND PURPOSE OF COMPREHENSIVE TESTING

You have been asked to participate in a study to assess your dynamic stability. Your dynamic balance will be evaluated in the Biomechanics Lab at Texas State University-San Marcos (TXSTATE) with the use of a Biodex Balance System SD. Your participation is voluntary. Read this form and ask questions about anything if you do not understand before you decide that you want to participate. Michael Hobbs will be the primary researcher and can be reached by phone at 512-245-3569 and by email at mh1115@txstate.edu.

PROCEDURES

Depending on your answers to your health history questionnaire, you may participate in the components of the laboratory evaluation mentioned above. You must first:

Fill out a form about your health history (Using the Human Performance Laboratory Health Appraisal Form Attached)

Be measured for body weight & height.

Be measured for your Overall Stability Index with the Biodex Balance System SD.

POTENTIAL RISKS OR DISCOMFORTS

* **There is little physical risk with this experiment because there is no active exercise involved. However, because we are measuring dynamic balance on the Biodex Balance System SD (BBS SD), there is always some degree of risk for falling due to the movable platform and temporary imbalance that the BBS SD has during the testing protocol. The BBS has hand rails and the co-investigators will be providing spot support to provide safeguards that will be in place to insure that you will not fall, suffer from imbalance or become injured. You will be standing in place while being measured for dynamic balance. You will not be placed on a treadmill or any exercise equipment and you may simply stop at any time when being evaluated**.

* **The tests in this investigation are standard screening tests to dynamic stability and are commonly performed in a human performance laboratory or clinical examination. Subject records and results will remain anonymous.**

* **There are no psychological, social or legal risks associated with these evaluations**.

* To ensure your safety, you must tell us about your current health and health history.

* **If you have diabetes, you must obtain physician approval before participating in investigation.**

* Your personal information will be kept confidential. Your file will be kept in a cabinet stored in the Principle Investigator’s office. The Principle Investigator may use this information to evaluate all subjects’ dynamic balance and determine if dynamic balance affects basketball ability.

POSSIBLE BENEFITS

The results from this investigation may help you:

- **Learn about your dynamic balance.**
- **Learn if your dynamic balance affects your ability to play basketball.**

CONFIDENTIALITY

Your records will be kept private as much as the law requires. If you give us permission, your information may be shared with your health care provider. Personal information will be stored in a file cabinet in Michael Hobbs' Office for five years, after which, it will be destroyed. We will ask for additional written consent from you if this data will be used for other research purposes.

The results of the dynamic balance testing may be shared for scientific purposes but we will not give your name. When the results of the research are shared, no information will be included that would negate subject confidentiality.

TERMINATION OF TESTING

You are free to decide if you would like to take part in testing. If you choose not to take part, it will not prejudice your relations at Texas State University in any way. Also, should you choose to participate, you are free to discontinue participation at any time. In addition, the Principle Investigator may end your participation in testing without your consent if he believes that you may be in danger (i.e., based on physical symptoms experienced during the evaluations such as increased heart rate, breathing difficulty, etc.).

AVAILABLE SOURCES OF INFORMATION

For questions you may have about your rights as a participant in this evaluation, please consult with:

Principle Investigator: Michael Hobbs

Phone Number: 512-245-3569

Pertinent questions about the research and research participants' rights, and research-related injuries to participants, should be directed to the IRB chairperson, Dr. Lisa Lloyd, and to the OSP Administrator, Ms. Becky Northcut.

AUTHORIZATION

"I have read and understand this consent form. Questions concerning these procedures have been answered to my satisfaction by the Principle Investigator. I agree to participate in testing. I understand that I will receive a copy of this form. I voluntarily choose to participate, but I understand that my consent does not take away any legal rights in the case of negligence or other legal fault of anyone who is involved in this study. I further understand that nothing in this consent form is intended to replace any applicable Federal, state, or local laws. I also understand that I may withdraw from this study at any time without penalty."

Client's Name (Printed): ________________________

Date: ____________

Client's Signature: ________________________

Date: ____________

Principle Investigator's Signature: ________________________

Date: ____________

Inclusion Questions

1. Are you participating in a balance training program outside of your typical training?	**Yes**	**No**
2. Do you have a lower extremity injury?	**Yes**	**No**
3. Do you have a vestibular problem (e.g., vertigo)?	**Yes**	**No**
4. Do you have any visual problems (e.g., blind in one eye)?	**Yes**	**No**
5. Have you had a concussion in the 12 weeks prior to this study?	**Yes**	**No**

If you answer yes to any question, you will not be able to participate in this study.

If no, get ankle injury history.

1. Previous ankle injury	**Yes**	**No**
2. Left ankle	**Yes**	**No**
3. Right ankle	**Yes**	**No**

Left ankle injury/time since injury

Right ankle injury/time since injury

Health Appraisal

Human Performance Laboratory – Texas State University

Do you have a physician in town? **Name:**		
Yes	**No**	**History of Heart Disease – Have you experienced:**
❍	❍	A heart attack? If so, when?
❍	❍	Heart surgery? If so, when?
❍	❍	Cardiac catherization? If so, when?
❍	❍	Coronary angioplasty (PTCA)? If so, when?
❍	❍	Pacemaker/implantable cardiac defibrillator/rhythm disturbance? If so, when?
❍	❍	Heart valve disease? If so, when was it diagnosed?
❍	❍	Heart failure? If so, when?
❍	❍	Heart transplantation? If so, when?
❍	❍	Congenital heart disease? If so, when was it diagnosed?
Yes	**No**	**Current Health Status**
❍	❍	Do you have diabetes? If so, when was it diagnosed?
❍	❍	Lung disease? If so, when was it diagnosed?
❍	❍	Asthma? If so, when was it diagnosed?
❍	❍	Kidney disease? If so, when was it diagnosed?
❍	❍	Liver disease? If so, when was it diagnosed?
❍	❍	If you are a female, are you pregnant or do you think that you might be pregnant?

Yes	No	Symptoms – Do you:
❍	❍	Experience chest discomfort with exertion?
❍	❍	Experience unreasonable breathlessness or unusual fatigue at rest, with mild exertion, or during usual activities?
❍	❍	Experience dizziness, fainting, or blackouts?
❍	❍	Take heart medications? If so, what kind?
❍	❍	Experience difficulty breathing when lying flat or when asleep?
❍	❍	Experience ankle swelling?
❍	❍	Experience forceful or rapid heartbeats?
❍	❍	Experience numbness in legs or arms from time to time?
❍	❍	Have a known heart murmur?

If you answered yes to any of the questions above, you will need to receive physician approval before you can participate in fitness testing. Do you have a physician that we send a copy of the medical referral form to or would you like for me to set up an appointment at the Student Health Center?

(Office Use Only) Action taken if client answered yes:

Medical Referral form completed, and client was instructed to make an appointment with his/her physician or seek medical services at the Student Health Center (245-2161).

No action. Client declined to participate.

Yes	No	Cardiovascular risk factors:
❍	❍	Do you smoke or have you quit smoking within the last 6 months?
❍	❍	Have you been diagnosed with high blood pressure or do you take blood pressure medication?

❍	❍	Have you been diagnosed with high cholesterol levels, or do you take cholesterol-lowering medication?
❍	❍	Has a close blood relative experienced a heart attack, heart or blood vessel surgery, or sudden death from a heart attack or stroke before age 55 (father, brother, or son) or age 65 (mother, sister, or daughter)?
❍	❍	Have you been diagnosed with high blood sugar, or do you take medicine to control your blood sugar?
❍	❍	Are you physically inactive (i.e., do you get less than 30 minutes of physical activity on at least 5 days per the week)?
❍	❍	If you are a male, are you 45 years or older? If you are a female, are you 55 years or older?
❍	❍	If you are a female, have you had a hysterectomy?
❍	❍	If you are a female, are you postmenopausal?
(Office Use Only) Height: _____ Weight: _____ BMI: ______ Waist circumference: _____ %BF: _____		
		Other health issues that may warrant physician approval before engaging in physical activity.
❍	❍	Have you ever been told not to exercise by a health care provider?
❍	❍	Do you have problems with your muscles, bones, or joints?
❍	❍	Are you taking prescription medications? If so, please list:

Medication	**Dosage**

I certify that the information included on this form is correct.

______________ ______________________________________

Date Signature of Participant

______________ ______________________________________

Date Signature of Human Performance Personnel

(Office Use Only) Risk Status: ❍ 1. Low ❍ 2. Moderate ❍ 3. High
❍ Diabetes ❍ Heart Disease ❍ Lung Disease ❍ Kidney Disease ❍ Liver Disease ❍ Pregnant

References

1. American College of Sports Medicine. Guidelines for Exercise Testing and Prescription (7th ed.). Philadelphia: Lippincott Williams & Wilkins, 2006.

2. Apostolidis, N., G.P. Nassis, T. Bolatoglou, and N.D. Geladas. Physiological and technical characteristics of elite young basketball players. *The Journal of Sports Medicine and Physical Fitness*. 44(2):157 - 162. 2004.

3. Arnold, J.A., B. Brown, R.P. Micheli, and T.P. Coker. Anatomical and physiologic characteristics to predict football ability. *The American Journal of Sports Medicine*. 8(2):119 – 122. 1980.

4. Bale, P. Anthropometric, body composition, and performance variables of young elite female basketball players. *The Journal of Sports Medicine and Physical Fitness*. 31(2):173 – 177. 1991.

5. Barker, M. T.J. Wyatt, R.L. Johnson, M.H. Stone, H.S. O'Bryant, C. Poe, and M. Kent. Performance factors, psychological assessment, physical characteristics, and football playing ability. *Journal of Strength and Conditioning Research*. 7(4):224 – 233. 1993.

6. Bayios, I.A., N.K. Bergeles, N.G. Apostolidis, K.S. Noutsos, and M.D. Kodkolou. Anthropometric, body composition, and somatotype differences of Greek elite female basketball, volleyball, and handball players. *The Journal of Sports Medicine and Physical Fitness*. 46:271 – 280. 2006.

7. Berg, K. and R.W. Latin. Comparison of physical and performance characteristics of NCAA Division I basketball and football players. *Journal of Strength and Conditioning Research*. 9(1):22 – 26. 1995.

8. Berg, K., D. Blanke, and M. Miller. Muscular fitness profile of female college basketball players. *The Journal of Orthopaedic and Sports Physical Therapy*. 7(2):59 – 64. 1985.

9. Berg, K., R.W. Latin, and T. Baechle. Physical and performance characteristics of NCAA Division I football players. *Research Quarterly for Exercise and Sport*. 61(4):395 – 401. 1990.

10. Black, W. and E. Roundy. Comparisons of size, strength, speed, and power in NCAA Division 1-A football players. *Journal of Strength and Conditioning Research*. 8(2):80 – 85. 1994.

11. Bressel, E., J.C. Yonker, J. Kras, and E.M. Keath. Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. *Journal of Athletic Training*. 42(1):42- 46. 2007.

12. Brooks, M.A., L.W. Boleach, and J.L. Mayhew. Relationship of specific and nonspecific variables to successful basketball performance among high school players. *Perceptual and Motor Skills*. 64:823 – 827. 1987.

13. Burke, E.J., E. Winslow, and W.V. Strube. Measures of body composition and performance in major college football players. *Journal of Sports Medicine*. 20:173 – 180. 1980.

14. Cachupe, W.J.C., B. Shifflett, L. Kahanov, and E.H. Wughalter. Reliability of Biodex Balance System measures. *Measurement in Physical Education and Exercise Science*. 5(2):97 – 108. 2001.

15. Callister, R., R.J. Callister, R.S. Staron, S.J. Fleck, P. Tesch, and G.A. Dudley. Physiological characteristics of elite judo athletes. *International Journal of Sports Medicine*. 12(2):196 – 203. 1991.

16. Chapman, P.P., J.R. Whitehead, and R.H. Binkert. The 225-lb reps-to-fatigue test as a submaximal estimate of 1-RM bench press performance in college football players. *Journal of Strength and Conditioning Research*. 12(4):258 – 261. 1998.

17. Claessens, A.L., S. Hlatky, J. Lefevre, and H. Holdhaus. The role of anthropometric characteristics in modern pentathlon performance in female athletes. *Journal of Sports Sciences.* 12(4):391 – 401. 1994.

18. Daniel, M.L., B.S. Brown, and D. Gorman. Strength and anthropometric characteristics of selected offensive and defensive university level football players. *Perceptual and Motor Skills*. 59(1):127 – 130. 1984.

19. Davis, D.S., B.J. Barnette, J.T. Kiger, J.J. Mirasola, and S.M. Young. Physical characteristics that predict functional performance in Division I college football players. *Journal of Strength and Conditioning Research.* 15(1):115 – 120. 2004.

20. Deason, J., S.K. Powers, J. Lawler, D. Ayers, and M.K. Stuart. Physiological correlates to 800 meter running performance. *The Journal of Sports Medicine and Physical Fitness*. 31(4):499 – 504. 1991.

21. Fiskerstrand, A. and K.S. Seiler. Training performance characteristics among Norwegian International Rowers 1970 – 2001. *Scandinavian Journal of Medicine & Science in Sports*. 14:303 – 310. 2004.

22. Fleck, S.J., S. Case, J. Puhl, and P. Van Handle. Physical and physiological characteristics of elite women volleyball players. *Canadian Journal of Applied Sport Sciences*. 10(3):122 – 126. 1985.

23. Fry, A.C. and W.J. Kraemer. Physical performance characteristics of American collegiate football players. *Journal of Applied Sports Science Research*. 5(3):126 – 138. 1991.

24. Gabbett, T.J. Physiological and anthropometric characteristics of amateur rugby league players. *British Journal of Sports Medicine*. 34(4):303 – 307. 2000.

25. Gabbett, T.J. Physiological characteristics of junior and senior rugby league players. *British Journal of Sports Medicine.* 36(5): 334 – 339. 2002.

26. Garstecki, M.A., R.W. Latin, and M.M. Cuppett. Comparison of selected physical fitness and performance variables between NCAA Division I and II football players. *Journal of Strength and Conditioning Research*. 18(2):292 – 297. 2004.

27. Geithner, C. A., A.M. Lee, and M.R. Bracko. Physical and performance differences among forwards, defensemen, and goalies in elite women's ice hockey. *Journal of Strength and Conditioning Research*. 20(3), 500 – 505. 2006.

28. Gillam, G.M. Identification of anthropometric and physiological characteristics relative to participation in college basketball. *National Strength and Conditioning Association Journal*. 7(3):34 – 36. 1985.

29. Gleim, G.W. The profiling of professional football players. *Clinics in Sports Medicine*. 3(1):185-197. 1984.

30. Gocentas, A. and A. Landor. Dynamic sport-specific testing and aerobic capacity in top level basketball players. *Papers on Anthropology XV*. 55 – 63. 2006.

31. Greene, J.J., T.A. Mc Guine, G. Leverson, and T.M. Best. Anthropometric and performance measures for high school basketball players. *Journal of Athletic Training*. 33(3):229 – 232. 1998.

32. Hakkinen, K. Maximal force, explosive strength and speed in female volleyball and basketball players. *Journal of Human Movement Studies*. 16:291 – 303. 1989.

33. Hakkinen, K., M. Alen, and P.V. Komi. Neuromuscular, anaerobic, and aerobic performance characteristics of elite power athletes. *European Journal of Applied Physiology and Occupational Physiology*. 53(2):91 – 105. 1984.

34. Heller, J., T. Peric, R. Dlouha, E. Kohlikova, J. Melichana, and H. Novakova. Physiological profiles of male and female taekwondo (ITF) black belts. *Journal of Sports Science*. 16(3):243 – 249. 1998.

35. Hoffman, J.R., G. Tenenbaum, C.M. Maresh, and W.J. Kraemer. Relationship between athletic performance tests and playing time in elite college basketball players. *Journal of Strength and Conditioning Research*. 10(2):67 – 71. 1996.

36. Hollings, S.C. and G.J. Robson. Body build and performance characteristics of male adolescent track and field athletes. *The Journal of Sports Medicine and Physical Fitness*. 31(2):178 – 182. 1991.

37. Ko, B. and J. Kim. Physical fitness profiles of elite ball game athletes. *International Journal of Applied Sports Science*. 17(1):71 – 87. 2005.

38. Kollias, J., E.R. Buskirk, E.T. Howley, and J.L. Loomis. Cardiorespiratory and body composition measurements of a select group of high school football players. *The Research Quarterly*. 43(4):472 – 478. 1972.

39. Kory, R.C., R. Callahan, H.G. Boren, and J.C. Snyder. The veteran's administration army cooperative study of pulmonary function: I. Clinical spirometry in normal men. *American Journal of Medicine*. 30:243 – 258. 1961.

40. LaMonte, M.J., J.T. McKinney, S.M. Quinn, C.N. Bainbridge, and P.A. Eisenman. Comparison of physical and physiological variables for female college basketball players. *Journal of Strength and Conditioning Research*. 13(3):264 – 270. 1999.

41. Latin, R.W., K. Berg, and T. Baechle. Physical and performance characteristics of NCAA Division I male basketball players. *Journal of Strength and Conditioning Research*. 8(4):214 – 218. 1994.

42. Lee, H., D.T. Martin, J.M. Anson, D. Grundy, and A.G. Hahn. Physiological characteristics of successful mountain bikers and professional road cyclists. *Journal of Sports Sciences*. 20:1001 – 1008. 2002.

43. Lundy, B., H. O'Connor, F. Pelly, and I. Caterson. Anthropometric characteristics and competition dietary intakes of professional rugby league players. *International Journal of Sport Nutrition and Exercise Metabolism*. 16:199 – 213. 1006.

44. Mayhew, J.L., F.C. Piper, T.M. Schwegler, and T.E. Ball. Contributions of speed, agility, and body composition to naerobic power measurement in college football players. *Journal of Applied Sports Science Research*. 3(4):101 – 106. 1989.

45. Mayhew, J.L., M.G. Bemben, D.M. Rohrs, F.C. Piper, and M.K. Willman. Comparison of upper body power in adolescent wrestlers and basketball players. *Pediatric Exercise Science*. 7:422 – 431. 1995.

46. McDavid, R.F. Predicting potential in football players. *The Research Quarterly*. 48(1):98 – 104. 1977.

47. Meckel, Y., H. Atterbom, A. Grodjinovsky, D. Ben-Sira, and A. Rotstein. Physiological characteristics of female 100 metre sprinters of different performance levels. *The Journal of Sports Medicine and Physical Fitness*. 35(3):169-175. 1995.

48. Melrose, D.R., F.J. Spaniol, M.E. Bohling, and R.A. Bonnette. Physiological and performance characteristics of adolescent club volleyball players. *Journal of Strength and Conditioning Research*. 21(2):481 – 486. 2007.

49. Miller, T.A., E.D. White, K.A. Kinley, J.J. Congleton, and M.J. Clark. The effects of training history, player position, and body composition on exercise performance in collegiate football players. *Journal of Strength and Conditioning Research*. 16(1):44 – 49. 2002.

50. Millet, G.P., P. Dreano, and D.J. Bentley. Physiological characteristics of elite short- and long-distance triathletes. *European Journal of Applied Physiology*. 88:427 – 430. 2003.

51. Morrow, J.R., W.W. Holser, and J.K. Nelson. A comparison of women intercollegiate basketball players, volleyball players, and non-athletes. *Journal of Sports Medicine*. 20:435 – 440. 1980.

52. Mujika, I. and S. Padilla. Physiological and performance characteristics of male professional road cyclists. *Sports Medicine*. 31(7): 479 – 487. 2001.

53. Neumayr, G., H. Hoertnagl, R. Pfister, A. Koller, G. Eibl, and E. Raas. Physical and physiological factors associated with success in professional alpine skiing. *International Journal of Sports Medicine*. 24(8):571 – 575. 2003.

54. Noel, M.B., J.L. VanHeest, P. Zaneteas, and C.D. Rodgers. Body composition in Division I football players. *Journal of Strength and Conditioning Research*. 17(2):228 – 237. 2003.

55. Olson, J.R. and G.R. Hunter. A comparison of 1974 and 1984 player sizes, and maximal strength and speed efforts for Division I NCAA universities. *National Strength and Conditioning Association Journal*. 6(6):26 – 28. 1985.

56. Ostojic, S.M., S. Mazic, and N. Dikic. Profiling in basketball: Physical and physiological characteristics of elite players. *Journal of Strength and Conditioning Research*. 20(4):740 – 744. 2006.

57. Ready, A.E. Physiological characteristics of male and female middle distance runners. *Canadian Journal of Applied Sports Sciences*. 9(2):70 – 77. 1984.

58. Rundell, K.W. and D.W. Bacharach. Physiological characteristics and performance of top U.S. biathletes. *Medicine and Science in Sports and Exercise*. 27(9):1302 – 1310. 1995.

59. Sallet, P., D. Perrier, J.M. Ferret, V. Vitelli, and G. Baverel. Physiological differences in professional basketball players as a function of playing position and level of play. *The Journal of Sports Medicine and Physical Fitness*. 45(3):291 – 294. 2005.

60. Santana, J.C. Stability and balance training: Performance training or circus acts? *Strength and Conditioning Journal*. 24(4):75 – 76. 2002.

61. Sawyer, D.T., J.Z. Ostarello, E.A. Suess, and M. Dempsey. Relationship between football playing ability and selected performance measures. *Journal of Strength and Conditioning Research*. 16(4):611 – 616. 2002

62. Schmidt, W.D. Strength and physiological characteristics of NCAA Division III American football players. *Journal of Strength and Conditioning Research*. 13(3):210 – 213. 1999.

63. Secora, C.A., R.W. Latin, K.E. Berg, and J.M. Noble. Comparison of physical and performance characteristics of NCAA Division I football players: 1987 and 2000. *Journal of Strength and Conditioning Research*. 18(2):286 – 291. 2004.

64. Shields, C.S., F.E. Whitney, and V.D. Zomar. Exercise performance of professional football players. *The American Journal of Sports Medicine*. 12(6):455 – 458. 1984.

65. Sirota, S.C., G.A. Malanga, J.J. Eisschen, and E.R. Laskowski. An eccentric- and concentric-strength profile of shoulder external and internal rotator muscles in professional baseball pitchers. *The American Journal of Sports Medicine*. 25(1):59 – 64. 1997.

66. Smith, D.J., D. Roberts, and B. Watson. Physical, physiological and performance differences between Canadian national team and universiade volleyball players. *Journal of Sports Sciences*. 10(2):131 – 138. 1992.

67. Smith, H.K. and S.G. Thomas. Physiological characteristics of elite female basketball players. *Canadian Journal of Sports Science.* 16(4):289 – 295. 1991.

68. Stuempfle, K.J., F.I. Katch, and D.E. Petrie. Body composition relates poorly to performance tests in NCAA Division III football players. *Journal of Strength and Conditioning Research*. 17(2):238 – 244. 2003.

69. Toriola, A.L., S.A. Adeniran and P.T. Ogunremi. Body composition and anthropometric characteristics of elite male basketball and volleyball players. *Journal of Sports Medicine*. 27:235 – 239. 1987.

70. Tsunawake, N., Y. Tahara, K. Moji, S. Muraki, K. Minowa, and K. Yukawa. Body composition and physical fitness of female volleyball and basketball players of the Japan inter-high school championship teams. *Journal of Physiological Anthropology and Applied Human Science*. 22:195 – 201. 2003.

71. Vaccaro, P., J.P. Wrenn, and D.H. Clarke. Selected aspects of pulmonary function and maximal oxygen uptake of elite college basketball players. *Journal of Sports Medicine*. 20:103 – 108. 1980.

72. Vescovi, J.D., T.D. Brown, and T.M. Murray. Descriptive characteristics of NCAA Division I women lacrosse players. *Journal of Science and Medicine in Sport.* 10:334 – 340. 2007.

73. Viviani, F. The somatotype of medium class Italian basketball players. *The Journal of Sports Medicine and Physical Fitness*. 34(1):70 – 75. 1994.

74. Wade, G. Tests and measurements: Meeting the standards of professional football. *National Strength and Conditioning Association Journal.* 4(3):23. 1982.

75. White, J., J.L. Mayhew, and F.C. Piper. Prediction of body composition in college football players. *Journal of Sports Medicine*. 20:317 – 324. 1980.

76. Willford, H.N., J. Kirkpatrick, M. Scharff-Olson, D.L. Blessing, and N.Z. Wang. Physical and performance characteristics of successful high school football players. *American Journal of Sports Medicine*. 22(6):859 – 862. 1994.

77. Young, W.B., R.U. Newton, T.L.A. Doyle, D. Chapman, S. Cormack, G. Stewart, and B. Dawson. Physiological and anthropometric characteristics of starters and non-starters and playing positions in elite Australian Rules football: a case study. *Journal of Science and Medicine in Sport*. 8(3):333 – 345. 2005.

78. ESPN.com. College football. Available at: http://sports.espn.go.com/ncf/columns/story?columnist=gilmore_rod&id=2733624. Accessed September 7, 2007.

79. Plunkett Research Ltd. Industry statistics, trends, and in-depth analysis of top companies. Sports Statistics. Available at: http://www.plunkettresearch.com/Sports/SportsStatistics/tabid/273/Default.aspx. Accessed September 7, 2007.

80. The President's Council on Physical Fitness and Sports. Department of Health and Humans Services. Definitions of Health, Fitness, and Physical Activity. http://www.fitness.gov/digest_mar2000.htm. Accessed February 10, 2007.

Table 1.

Anthropometric and performance scores of novice and college basketball players.

Variable	Novice basketball players (n=12)	College basketball players (n=10)
Height (in)	70.6±2.4	73.8±4.1
Weight (lbs)	194.7±34.7	195.3±28.6
BMI	27.6±5.4	25.1±1.6
Biodex-R	11.9±3.3	12.4±2.7
Biodex-L	11.3±3.2	9.2±2.0
Biodex-D	12.1±3.1	12.3±2.8
Biodex-ND	11.2±3.4	9.2±2.0
Stork test-D	12.0±10.0	11.2±7.1
Stork test-ND	14.2±15.3	18.0±17.0
JDBT	81.3±14.1	81.9±9.6

Note. BMI= Body Mass Index, R= Right Leg, L=Left Leg, D= Dominant Leg, ND= Non-dominant Leg, and JDBT= Johnson Modification of the Bass Test.

*Significant difference in height between the groups, $p < .05$.

Table 2.

Anthropometric and performance scores of college basketball starters and non-starters.

Variable	College basketball starters (n=5)	College basketball non-starters (n=5)
Height (in)	75.8±4.2	71.8±3.3
Weight (lbs)	208.6±30.2	181.9±22.0
BMI	25.5±2.0	24.8±1.1
Biodex-R	13.6±2.5	11.2±2.4
Biodex-L	9.3±2.6	9.1±1.4
Biodex-D	13.6±2.5	11.0±2.5
Biodex-ND	9.3±2.6	9.2±1.5
Stork test-D	12.8±5.8	9.5±8.5
Stork test-ND	21.2±20.7	14.9±14.0
JDBT	84.4±11.1	79.4±8.3

Note. BMI= Body Mass Index, R= Right Leg, L=Left Leg, D= Dominant Leg, ND= Non-dominant Leg, and JDBT= Johnson Modification of the Bass Test.

Note. No significant differences between the two groups were observed in any of these tests.

Table 3.

Anthropometric and performance scores of college basketball with most minutes played and remainder of team.

Variable	Five players with most minutes played (n=5)	Remaining players (n=5)
Height (in)	74.0±4.9	73.6±3.8
Weight (lbs)	199.4±36.1	191.1±22.3
BMI	25.5±2.0	24.7±1.1
Biodex-R	12.5±2.7	12.3±3.0
Biodex-L	9.7±1.9	8.6±2.0
Biodex-D	12.1±3.2	12.6±2.6
Biodex-ND	10.1±1.7	8.4±2.1
Stork test-D	12.2±6.7	10.2±8.0
Stork test-ND	22.9±19.0	13.2±15.1
JDBT	85.8±9.6	78.0±8.7

Note. BMI= Body Mass Index, R= Right Leg, L=Left Leg, D= Dominant Leg, ND=Non-dominant Leg, and JDBT= Johnson Modification of the Bass Test. *Note*. No significant differences between the two groups were observed in any of these tests.

Table 4

Research on Anthropometric and Physiological Characteristics of Different Athletes

Author(s)	Subjects	Characteristics measured
Arnold et al.	56 NCAA Division I football players	Internal hip rotation, external hip rotation, tibial torsion, genu varum, hip abduction, knee extension, knee flexion, plantar flexion, time, horsepower, 40-yd dash, balance, height, and weight
Barker et al.	59 NCAA Division IAA football players	Age, body mass, height, % fat, 1-RM squat, relative strength, vertical jump, static vertical jump, vertical jump power index, static vertical jump power index, vertical jump takeoff velocity; static vertical jump takeoff velocity, squat reps at 70%, squat reps at 90%, total squat reps, squat load at 70%, squat load at 90%, total squat load, 5 yd dash, 10 yd dash, 300 yd dash, and 1.5 mile run
Berg & Latin	45 NCAA Division I basketball and 40 NCAA Division I football teams	Height, weight, % fat, fat free mass, vertical jump, power, 40-yd dash, bench press, bench/wt, squat, squat/wt, and power
Black & Roundy	11 NCAA Division 1 football teams (1,618 players)	Weight, 1-RM squat, 1-RM bench press, vertical jump, and 36.6 meter dash
Burke et al.	67 NCAA Division I football players	Fat mass, lean mass, bench press strength, squat strength, 40-yd dash, and 1-mile run
Callister et al.	18 male and 9 female nationally ranked judo athletes	Body composition, aerobic capacity , isokinetic elbow and knee flexor and extensor strength, muscle fiber size, and composition of the vastus lateralis
Chapman et al.	98 NCAA Division II football players	1 RM bench press and 225 lb rep to failure
Cheetham et al.	6 elite Canadian 800 meter runners	VO_2 max and anaerobic capacity

Table 4-Cont

Claessens et al.	65 female participants (54 participants, 11 reserves) at the IXth World Modern Pentathlon Championships, 1989	Body mass, lengths (biacromial), breadths (humerus), girths, skinfolds, somatotype, BMI, and body composition
Davis et al.	46 NCAA Division 1 football players	Height, weight, bench press, sit and reach, hang clean, % fat, 36.6-m sprint, vertical jump, and 18.3 shuttle run
Deason et al.	11 male track athletes	Body composition, VO_2max, running economy, 100 meter dash, 300 meter dash
Fleck et al.	1980 U.S. Women's National Volleyball Team and the collegiate players who composed the 1979 U.S. Women's University Games Volleyball Team	Age, height, weight, body composition, vertical jump, VO_2 max, heart rate max, and respiratory exchange ratio
Fiskerstrand & Seiler	28 international medal winning Norwegian rowers	Height, weight, VO_2 max, and 6 minute rowing ergometer
Fry & Kraemer	6 NCAA Division I, 7 NCAA Division II, and 6 NCAA Division III football teams	Bench press, squat, power clean, vertical jump, and 36.6m sprint
Gabbett	35 amateur rugby league players	Height, body mass, fat %, sum of four skinfolds, vertical jump, muscular power, speed (10 meter and 40 meter sprint), maximal aerobic power, match frequency, training status, playing experience, and employment related physical activity levels
Gabbett	150 junior and senior rugby league players	Body mass, vertical jump, muscular power, speed (10 meter, 20 meter, and 40 meter sprint), agility, and maximal aerobic power

Table 4-Cont

Garstecki et al.	26 NCAA Division I and 23 Division II football teams	Height, weight, bench press, squat, power clean, vertical jump, 40 yd dash, % fat, fat free mass, vertical jump power, bench/wt, squat/wt, and power clean/wt
Geithner et al.	112 University of Alberta women's ice hockey players	Age, weight, height, BMI, sitting height, leg length, thigh length, calf length, arm length, biepicondylar breadth, bicondylar breadth, biacromial breadth, bicristal breadth, androgyny, relaxed arm circumference, flexed arm circumference, thigh circumference, waist circumference, hip circumference, waist-hip ratio, tricep skinfold, subscapular skinfold, midaxillary skinfold, suprailiac skinfold, supraspinale skinfold, abdominal skinfold, bicep skinfold, mid-thigh skinfold, medial calf skinfold, & fat, endomorphy, mesomorphy, ectomorphy, vertical jump, 40-yd dash, cornering s-turn agility test, 6.10-m acceleration, modified repeat sprint skate test, blood lactate concentration, and VO_2 max
Gleim	51 professional football players	Height, weight, knee diameter, ankle diameter, elbow diameter, wrist diameter, bi-iliac diameter, bitroch diameter, biacromial, bideltoid, thigh circumference, arm circumference, arm circumference, chest circumference, waist circumference, 8 sites fat, % fat, total leg strength, upper body flexibility, lower body flexibility, total flexibility, vertical jump, chin-ups, dips, and 40-yd dash
Hakkinen et al.	4 powerlifters, 7 bodybuilders, and 3 wrestlers	Maximal isometric force/wt, isometric force production time (time to 30% force level), counter movement and squat jumps (at 0, 40, and 100 kg loads), anaerobic power in 1-minute maximal test, VO_2 max, fiber distribution, fiber areas, and area ratio of fast and slow twitch fibers in vastus lateralis
Hollings & Robson	38 elite young male track and field athletes	Vertical jump, Margaria stair run, and the Wingate Test

Table 4-Cont

Heller et al.	23 black belt taekwondo athletes (All members of the Czech national team)	Age, height, body mass, fat %, lean body mass, BMI, biacromial width, bicristal width, bitrochanteric width, biceps girth, thigh girth, calf girth, arm flexion strength, knee extension strength, hand grip strength, flexibility, vertical jump, upper and lower limb visual reaction time, vital capacity, during aerobic performance test (PWC-170, PWC, power output, power output/wt, VO_2 max, pulmonary ventilation, heart rate max, VO_2 max/heart rate max, lactic acid max, and ventilatory threshold), and during 30 second Wingate test (maximum anaerobic power, anaerobic capacity, fatigue index, and lactic acid peak)
Kollias et al.	27 high school football players	Age, height, weight, surface area, % fat, VO_2 max, ventilation max, heart rate max, and exercise time
Lee et al.	Australian nationally and internationally male cross-country mountain bikers (18) and road cyclists (30)	Age, height, body mass, skinfold sums, fat %, maximal power output, maximal power output/wt, VO_2 peak, peak ventilation, economy (power output/liter of oxygen), maximal heart rate, maximal lactate, maximal pH, D-max, D-max/wt, % maximal power output at D-max, % VO_2 max at D-max, lactate at D-max, and heart rate at D-max
Lundy et al.	74 professional rugby league players	Age, first grade games played, competed at State of Origin, competed internationally, height, weight, waist, waist-hip ratio, BMI, skinfolds sum, fat %, and somatotype
Mayhew	53 college football players	Age, height, weight, lean body mass, % fat, agility, 10-yd dash, 40-yd dash, bench press, power, and power/kg
Mayhew et al.	69 NCAA Division IAA football players and 73 NCAA Division II football players	Age, height, weight, 1 RM bench press, repetitions at 225 lb, 1 RM/lb, and %1 RM

Table 4-Cont

Mayhew et al.	35 untrained students, 28 resistance trained athletes, 21 college wrestlers, 22 soccer players, 51 football players, 35 high school students, 24 resistance-trained middle-aged men	Age, height, weight, 1-RM bench press, and 1-RM/kg
McDavid	67 college football players	McCloy Classification Index, power, strength, visual reaction time, auditory reaction time, agility, speed, and work
Meckel	20 female track athletes and10 recreationally trained females	Wingate Anaerobic Test, squat strength, fat %, reaction time, flexibility, VO_2 max, and running skill
Melrose et al.	29 adolescent girls who were members of a competitive volleyball club	Height, weight, age, BMI, fat %, lean body mass, fat mass, neck girth, shoulder girth, waist girth, abdominal girth, hip girth, mid-thigh girth, calf girth, bicep girth, forearm girth, moderate sit and reach, shoulder rotation, right isometric handgrip, left isometric handgrip, leg dynamometry, vertical jump, broad jump, one-minute sit-ups, T-test, shuttle, stork stand, serving speed, and spiking speed
Miller et al.	261 NCAA Division I football players	Bench press, back squat, power clean, vertical jump, 40-yd dash, 20-yd dash, height, weight, and % fat
Millet, et al.	15 elite male triathletes participating in the World Championships (9 short distance and 6 long distance)	Age, height, body mass, % fat, years of training, swim time, cycle time, run time, triathlon time, VO_2 max, heart rate max, peak power output, peak power output/wt, respiratory compensation point, cycling economy, run velocity, and net energy cost of 2 runs

Table 4-Cont

Mujika and Padilla	24 male professional road cyclists	Age, height, body mass, body surface area frontal area, maximal power output, maximal power output/wt, VO_2 max, heart rate max, peak blood lactate level, power at lactate threshold, VO_2 at lactate threshold, heart rate at lactate threshold, power at onset of blood lactate accumulation (obla), VO2 at obla, and heart rate at obla
Neumayr et al.	20 female and 28 male members of the Austrian WC Ski Team	Age, height, body mass, BMI, fat %, thigh circumference, aerobic power, muscle strength of the lower limbs
Noel et al.	69 NCAA Division II football players	Age, height, BMI, body density, fat free mass, and % fat
Olson & Hunter	13 NCAA Division I football teams	Height, weight, 40 yd sprint times, maximal bench press, maximal power clean, and maximal squat
Pratt	84 male high school students	Age, weight, % fat, lean body weight, strength, strength per body weight, strength per lean body weight, and flexibility
Ready	7 male and 5 female middle distance runners	Height, weight, % fat, VO_2max, maximal aerobic power, maximal aerobic power/wt, peak power during knee and ankle flexion and extension, peak power during knee and ankle flexion and extension/wt, hemoglobin, hematocrit, red blood cell count, mean corpuscular hemoglobin, and mean corpuscular volume
Rundell	11 male and 10 female biathletes (6 male and 6 female were top 10 U.S. ranked)	Treadmill run and double-pole lactate profile and VO_2 Peak tests, and a double-pole peak power test, 1993 National Points Rank, racing ski time, and shooting percentage from 1993 World Team Trials
Sawyer et al.	40 NCAA Division I football players	Height, weight, vertical jump power, 9.1 meter sprint, 18.2 meter sprint, pro-shuttle run, squat, bench press, power clean, and Olympic snatch
Schmidt	78 NCAA Division III football players	Age, height, weight, % fat, sit-ups, dips, 300-yd shuttle, vertical jump, pull-ups, bench press, hip sled, seated medicine ball, and sit and reach

Table 4-Cont

Secora et al.	37 Division I football teams (797 athletes)	Height, weight, 40 yd dash, vertical jump, % fat, bench press, squat, bench/wt, squat/wt, power, and fat free mass
Shields et al.	167 professional football players	Age, height, weight, % fat, lean weight, sit & reach, back arch, visual reaction time, auditory reaction time, VO_2 max, heart rate max, treadmill time, bench press, shoulder press, curl leg press, abdominal endurance, and grip strength
Sirtoa et al.	25 professional baseball players	Eccentric and concentric isokinetic tests at 60 and 120 degree/sec
Smith et al.	15 Canadian national and 24 universiade team volleyball players	% fat, VO_2 max, anaerobic power, bench press, 20 meter sprint time, and vertical jumping ability (block and spike jumps)
Stuempfle, et al.	77 NCAA Division III football players	Age, height, body mass, BMI, % fat, fat mass, fat free mass, and lean:fat ratio
Vescovi et al.	84 NCAA Division I women lacrosse players	Age, height, body mass, VO_2 max, 9.1 m sprint, 18.3 m sprint, 27.4 m sprint, 36.6 m sprint, countermovement jump, Illinois agility test, and Pro-agility test
Wade	7 NFL teams (150 football players)	Bench press, flexibility, vertical jump, and standing broad jump
White et al.	58 football players (1977 Northeast Missouri State University)	Age, height, weight, lean body mass, % fat, and density
Willford et al.	18 high school football players	Age, height, weight, % fat, fat-free mass, sum of 7 skinfolds, vertical jump, bench press, squats, 36.6-m sprint, flexibility, VO_2max, and heart rate max

Table 4-Cont

Young et al.	34 Australian Rules football players	Isokinetic peak torque in the right and left quadriceps and the right and left hamstrings, 3 repetition maximum (3RM) leg press, 3RM chin-ups, 3RM bench press, leg extensor power in squat jump, squat jump plus 40 kilos, countermovement jump, countermovement jump plus 40 kilos, drop jump off 40 and 80 cm box, 10m time, flying 30m time, vertical jump, VO_2 max, and yo yo

Table 5

Research on Anthropometric and Physiological Characteristics of Basketball Athletes

Author(s)	Subjects	Characteristics measured
Apostolidis et al.	13 elite level basketball players, all members of the Greek Junior's National Team who participated in the 6th Junior World Championship	Age, height, body mass, fat %, fat mass, VO_2 max, maximum heart rate, ventilatory threshold, maximum power output/wt, mean power output/wt, fatigue index, post-exercise blood lactate concentration, squat jump height, counter-movement height
Bale	18 female members of the under	Age, weight, height, sitting height,

	17 England Basketball squad	lower limb length, upper limb length, widths (shoulder, hip, humerus, femur, and extended hand), circumferences (chest, abdomen, relax arm, flexed arm, and calf), skinfolds (biceps, triceps, subscapular, suprailiac, anterior thigh, and medial calf), indexes (ponderal index, trunk width index, skelic index), somatotype (endomorphy, mesomorphy, ectomorphy), body composition (% fat, absolute fat, lean body weight), vertical jump, anaerobic power, right and left grip strength, and laterality quotant
Berg et al.	13 members of the 1982-83 women's basketball team at the University of Nebraska at Omaha	Age, height, weight, % fat, lean body weight, fat weight, and mean peak extension and flexion torque of both knees, shoulders, elbows, and ankles
Bressel et al.	34 NCAA Division I female athletes (soccer, n=11; basketball, n=11; gymnastics, n=12)	static balance and dynamic balance

Table 5-Cont

Brooks et al.	50 male high school basketball players	Age, height, weight, % fat, McCloy Index, vertical index, depth perception, hand reaction time, foot reaction time, shooting accuracy, dribbling, wall pass, and years on varsity
Gillam	13 members of the male basketball team and fourteen physical education majors at Jacksonville State University	Height, body mass, lean body mass, fat mass, % fat, somatotype, supine press, squat, push ups, squat thrusts, cardiovascular endurance, power, acceleration, maximum speed, agility, and flexibility
Gocentas & Landor	8 competitive male basketball players	Age, height, body mass, BMI, VO_2max, heart rate max, oxygen pulse at the peak of cardiopulmonary test, respiratory quotient, minute ventilation at the peak of exercise, and power output at the peak of cardiopulmonary test
Greene et al.	54 female and 61 male subjects from high school varsity basketball teams in Wisconsin	Age, height, weight, % fat, inversion, eversion, plantar flexion, dorsiflexion, single-limb balance time, vertical jump, pro agility run, 20-yd sprint
Hoffman et al.	29 NCAA Division I male basketball players	Height, weight, bench press, squat, agility, speed, vertical jump, and aerobic endurance

Table 5-Cont

Karpowicz	78 young basketball players (12.5-13.5 years)	Height, weight, BMI, skinfold measurements, somatotype, starting speed, speed, speed endurance, jumping ability, agility, reaction time, eye and hand coordination, pick-up strength, static strength, aerobic performance, dribbling, passing, slide step, and shooting
Ko and Kim	113 male elite ball game athletes from the Korea Armed Forces Athletic Corps (soccer, n=43; volleyball, n=15; basketball, n=22; baseball, n=33) and 49 non-physical education major collegiate students	Height, seated height, mass, chest circumference, % fat, push-up, basketball throwing, sit-up, half squat, standing long jump, 1600m run, 50m run, side-step test, and sit & reach
Lamonte et al.	46 Division I female basketball players	Height, weight, density, fat-free mass, % fat, vertical jump, peak absolute power, peak relative power, peak power relative to fat-free mass, absolute mean power, mean relative power, and mean power relative to fat-free mass

Table 5-Cont

Latin et al.	45 NCAA Division I male basketball teams (437 players)	Height, weight, % fat, fat-free mass, vertical jump, power, bench press, bench press/wt, power clean, power clean/wt, squat, squat/wt, 40-yd dash, 30-yd dash, "T" agility, 1-mile run, and 1.5 mile run
Morrow et al.	330 college women (110 non-athletes, 110 NCAA Division I basketball athletes, 110 NCAA Division I volleyball athletes)	Fat weight, lean weight, height, sitting height, arm length, biacromium width, biiliac width, 10 yard sprint, leg press, and bench press
Ostojic	5 professional Serbian men's basketball teams from the First National League	Age, professional experience, height, weight, body fat, hemoglobin, hematocrit, forced vital capacity, forced expiratory volume, estimated VO_2max, HR max, vertical jump height, vertical jump power, and fast twitch
Sallet et al.	58 French professional basketball players	Age, height, body mass, % fat, VO_2 max, maximal aerobic velocity, velocity at anaerobic threshold, 30 second all-out test (highest measure power, lowest measured power, fatigue index, maximal pedaling frequency)

Table 5-Cont

Smith and Thomas	31 athletes on the 1988 and 1989 Canadian National Women's Basketball Team rosters	Mass, height, sum of skinfolds, chest girth, abdominal girth, gluteal girth right thigh girth, VO_2 max, ventilation, "suicide" run times, left/right knee flexion/extension at 60 and 120 degrees
Tsunawake et al.	12 high school female volleyball players who won the 1989 Japan Inter-high School Meeting, 11 high school female basketball players who won the 1991 Japan Inter-high School Meeting, and 46 female high school students with no particular athletic background	Age, height, body mass, chest girth, abdominal girth, upper arm girth, thigh girth, lower leg girth, waist, hip, skinfold thickness, body composition, VO_2max, ventilation max, heart rate max, and O_2 debt max
Vaccaro	13 male members of the 1977 University of Maryland basketball team	Age, height, weight, forced vital capacity, forced expired volume in one second, maximum voluntary ventilation, maximal pulmonary ventilation, and heart rate max
Viviani	38 medium class Italian basketball players	Weight, height, endomorphy, mesomorphy, and ectomorphy

Table 6

Anthropometric Comparisons of Basketball Players and Nonparticipants

Variables		Basketball	Nonparticipants	t
Height (cm)		189.23±7.03	178.70±6.11	4.17
Total Body Weight (kg)		85.99±8.69	78.47±12.15	1.77
Lean Body Weight (kg)		74.37±7.32	64.98±7.15	3.28
Fat Weight (kg)		11.63±2.86	13.50±7.59	0.8
Body Fat (%)		13.46±2.75	16.60±6.00	1.66
Somatotype				
	Endomorphy	3.33±0.91	4.45±1.57	2.16
	Mesomorphy	4.04±0.92	4.56±1.22	1.2
	Ectomorphy	2.09±1.01	2.24±1.12	1.29

Values are means±S.D.

t= 2.06 for significance at $p<0.05$

Table 7

Physiological Comparisons of Basketball Players and Nonparticipants

Variables		Basketball	Nonparticipants	t
Muscular Strength (kg)				
	Supine Press	76.31±11.31	82.43±19.24	1.00
	Squat	115.31±18.01	104.21±21.03	1.47
Muscular Endurance (kg)				
	Push Ups	23.23±7.93	27.07±7.84	1.27
	Squat Thrusts	58.54±31.19	38.07±17.55	2.08
Cardiovascular (m)		2613.08±350.79	2392.29±377.29	1.57
Power (kgm/sec)		154.12±16.36	135.20±24.86	2.32
Speed (sec)				
	Acceleration	2.33±0.06	2.45±0.12	3.2
	Maximum	5.29±0.26	5.71±0.45	2.44
Agility (sec)		10.80±0.30	11.39±0.57	3.68
Flexibility (cm)		29.31±8.84	30.07±9.63	0.21

Values are means±S.D.

t= 2.06 for significance at $p<0.05$

Table 8

Comparison of Position Mean Scores

	Guards			Forwards			Centers		
Variable	*n*	M	SD	*n*	M	SD	*n*	M	SD
Height (cm)	185	187.4[a]	5.8	153	198.4[a]	3.8	90	205.5[a]	6.1
Weight (kg)	185	82.9[a]	6.8	152	95.1[a]	8.3	90	101.9[a]	9.7
Body Fat (%)	13	8.4[a]	3	89	9.7	3.9	53	11.2[a]	4.5
Fat-free Weight (kg)	113	75.8[a]	8.6	89	85.5[a]	8.1	53	90.4[a]	6.2
Vertical Jump (cm)	152	73.4[a]	9.6	124	71.4[b]	10.4	73	66.8[a,b]	10.7
Power (kgm/sec)	147	158.2[a]	16.5	121	178.5[a]	21.5	71	182.1[b]	16.6
Bench Press (kg)	149	100.8	17.6	120	104	21.5	73	104.4	17
Bench Press/weight (%)	145	121[a,b]	19.8	117	109.1[a]	20.6	71	103.1[b]	17.1
Power Clean (kg)	58	94.5[a]	13	43	105.1[a]	16.9	26	99.8	13.7
Power Clean/weight (%)	58	112.9[a]	14.9	43	107.6	13.5	26	98.5[a]	14.3
Squat (kg)	72	151.1	35.5	61	161.9[a]	37.7	36	138.1[a]	32.1
Squat/weight (%)	72	180.9[a]	45.4	61	167.8[b]	38.6	36	136.9[a,b]	33.2
40-yd dash (sec)	29	4.68[a]	0.2	31	4.84	0.29	17	4.97[a]	0.21
30-yd dash (sec)	18	3.68[a]	0.14	15	3.83	0.16	7	3.97[a]	0.21
"T" agility (sec)	9	8.74	0.41	12	8.94	0.38	6	9.28	0.81
1-mile (mile:sec)	65	5:31[a]	0:35	62	5:43	0:32	34	5:57[a]	0:38
1.5-mile (mile:sec)	20	9:49	1:14	17	9:38	1:24	13	9:41	1:34

Note. Statistical significance for variables based on *F* ratios, $p < 0.001$.

Means with same superscript significantly different, $p < 0.05$.

Table 9

Anthropometric Measures, Performance Tests, and Playing Experience (±SD)

	Ht (cm)	Wt (cm)	Bench Press (kg)	Squat (kg)	27-m sprint (sec)	Vertical Jump (cm)
1988/89	196.6	87.9	88.1	143.4	3.9	68.1
n=14	±10.4	±10.0	±14.5	±24.3	±0.18	±8.6
1989/90	197.4	91.2	97	145.9	3.96	66
n=15	±9.1	±10.9	±19.2	±24.4	±0.19	±6.9
1990/91	198.1	94.8	101.6	155.9	3.89	72.6
n=14	±9.4	±12.3	±20.2	±18.6	±0.16	±5.6
1991/92	197.9	91.9	102.1	-	3.89	67.3
n=15	±8.1	±10.1	±19.1		±0.18	±6.0

Table 9 continued

Anthropometric Measures, Performance Tests, and Playing Experience (±SD)

	Endurance- 2,414 -m run (sec)	Agility- T-test (sec)	Experience (yrs)
1988/89	582.6	9.11	2.1
n=14	±92.9	±0.46	±1.2
1989/90	557.9	8.94	2.1
n=15	±42.3	±0.34	±1.0
1990/91	617.8	9	2.9
n=14	±53.6	±0.45	±1.1
1991/92	574.9	9.15	2.3
n=15	±54.3	±0.41	±1.3

Table 10

Pearson Product Moment Correlation Between Playing Time and Physical Fitness Components, Player Ratings, and Experience

Variable		1988/89	1989/90	1990/91	1991/92
Athletic Performance					
Tests					
	1-RM Bench Press	0.03	0.02	-0.04	0.14
	1-RM Squat	0.16	0.52*	0.64*	-
	Agility (T Test)	-0.26	-0.30	-0.33	-0.30
	27-m Sprint	-0.62*	-0.45	-0.38	-0.24
	Vertical Jump	0.68*	0.41	0.35	0.58*
	2414-m run	-0.42	0.10	0.64*	0.63*
Player Evaluation					
	Q1	0.85*	0.86*	0.81*	0.84*
	Q2	0.81*	0.87*	0.84*	0.93*
Playing Experience		0.58*	0.09	0.13	0.31

$^{*}p \leq 0.05$

Table 11

Number of Subjects

Athletic Event	Number	Athletic Event	Number
Soccer	43	Basketball	22
Volleyball	15	Baseball	33
College Student	49		

Table 12

Means and Standard Deviations of Each Testing Variable

Variables	College Students	Soccer	Basketball	Volleyball	Baseball
Height (cm)	174.2±5.1	178.8±6.4	188.1±6.4	187.6±5.5	180.4±5.2
Seated Height (cm)	92.7±3.4	97.1±3.1	99.8±2.6	100.0±3.3	97.8±2.6
Body Weight (kg)	72.8±11.6	74.9±7.0	90.8±10.9	83.3±6.0	85.9±8.3
Chest Circumference (cm)	93.6±8.0	97.2±3.8	104.2±4.5	102.6±4.0	100.8±5.7
Body Fat (%)	16.1±4.9	13.0±2.8	18.2±3.5	15.2±2.3	17.0±2.7
Push-Up (times)	60.6±29.1	116.7±16.0	61.7±13.5	56.2±11.5	86.4±18.4
Basketball Throwing (cm)	661.1±113.5	1025.6±94.7	1346.1±90.8	1113.7±69.2	1004.2±84.7
Sit-Up (times/2 min)	67.7±20.6	97.2±10.9	94.4±16.0	93.9±11.0	88.0±11.9
Half Squat Jump (time /2 min)	107.2±39.6	144.0±27.1	125.4±25.4	84.5±12.0	117.2±18.1
Standing Long Jump (cm)	224.7±34.7	258.8±12.4	256.9±14.6	279.7±18.1	268.2±12.7

Table 12-Cont

1600m Running (sec/1600m)	465.5±77.7	311.0±22.0	354.1±38.2	357.5±31.9	357.3±34.4
50m Running (sec)	7.8±1.0	6.5±0.3	6.8±0.4	7.0±0.3	6.5±0.3
Side Step Test (times/20sec)	272±8.6	50.7±4.6	49.9±3.1	50.2±3.3	49.4±4.3
Sit & Reach (cm)	14.9±5.7	22.1±4.8	18.8±7.2	20.3±5.1	20.3±5.1

Table 13

Mean Differences of Physical Characteristics among Sport Events

Variables	Levene	F	post hoc test				
			College Student	Soccer	Basketball	Volleyball	Baseball
1	0.78	30.82*	a	a, b	c	c	b
2	0.77	31.82*	a	b	c	c	b, c
3	2.83*	21.45*	A	A	B	B	B
4	4.46*	17.55*	A	A	B	B	B
5	3.78*	11.18*	B, C	A	C	B	B, C
6	10.05*	52.34*	A	C	A	A	B
7	1.68	221.44*	a	b	d	c	b
8	5.72*	25.84*	A	C	B, C	B, C	B
9	3.91*	15.55*	B, C	C	B, C	A	B
10	9.99*	29.61*	A	B	B	C	C
11	10.27*	60.00*	C	A	B	B	B
12	6.04*	32.50*	C	A	A, B	B	A

Table 13-Cont

13	9.67*	129.79*	A	B	B	B	B
14	1.88	10.58*	a	b	a, b	b	b

Numbers in Variable Column are identical to Table 7.

* p<.05

a<b<c<d. Scheffe

A<B<C<D. Dunnett T3

Table 14

Characteristics of Elite Serbian Basketball Players

Variables	Guards n=20	Forwards n=20	Centers n=20	Total n=60	Range
Age (y)	25.6±3.2	21.4±2.8	23.2±3.2	23.4±3.5	16.8-32.4
Professional experience (y)	9.6±3.2	5.0±2.7	7.1±3.3	7.2±3.6	2.1-13.8
Height (cm)	190.7±6.0	200.2±3.4	207.6±2.9	1995.±8.2	180.3-220.5
Weight (kg)	88.6±8.1	95.7±7.1	105.1±11.5	96.5±11.2	75.6-121.2
Body fat (%)	9.9±3.1	10.1±3.2	14.4±5.6	11.5±4.6	3.1-20.4
Hemoglobin (mmol.L^{-1})	131.1±10.9	132.2±10.4	132.1±10.7	132.0±10.7	119.2-145.7
Hematocrit (%)	0.41±0.03	0.41±0.04	0.41±0.04	0.41±0.04	0.39-0.44
Forced vital capacity (L)	6.5±0.8	6.6±1.0	6.6±0.9	6.6±0.9	5.5-7.6
Forced expiratory volume in 1 s (L)	5.4±1.1	5.7±0.9	5.8±1.1	5.6±1.0	4.9-6.8

Table 14-Cont

Estimated VO_2max ($ml*kg^{-1}*min^{-1}$)	52.5±4.8	50.7±2.3	46.3±4.9	49.8±4.9	41.3-63.9
Hrmax ($b*min^{-1}$)	193±2	196±5	195±3	195±3	186-208
Vertical jump height (cm)	59.7±9.6	57.8±6.5	54.6±6.9	57.4±7.7	31.1-89.6
Vertical jump power (W)	1484.9±200.0	1578.6±137.5	1683.0±191.7	1582.1±193.6	1256.1-1889.5
Fast twitch (%) ∂	65.1±10.2	64.7±8.9	62.4±9.1	64.1±9.4	45.2-79.5

Values are expressed as mean±SD; HRmax = maximal heart rate obtained in the last minute of shuttle run test; VO_2max = maximal oxygen uptake.

∂ Estimated percentage of muscle fiber types (fast twitch) of leg extensor muscles.

† Statistically significant at $p < 0.01$ for guards vs. forwards

‡ Statistically significant at $p < 0.01$ for guards vs. centers

◊ Statistically significant at $p < 0.01$ for forwards vs. centers

Table 15

Univariate F Results and Standardized Discriminant Coefficients for Helmert Contrasts

	Athletes contrasted with non-athletes		Basketball contrasted with volleyball	
Dependent variable	F[a]	SDC[b]	F[a]	SDC[b]
Lean weight (kg)	251.95*	-0.48	0.54	0.39
Fat weight (kg)	13.71*	-0.07	0.08	0.26
Height (cm)	146.82*	0.19	1.70	0.62
Sitting height (cm)	37.10*	0.04	0.04	-0.08
Arm length (cm)	205.66*	-0.53	30.63*	-1.00
Biacromium width (cm)	127.94*	-0.05	0.82	0.20
Biiliac width (cm)	29.02*	0.03	12.29*	-0.31
10 yard sprint (sec)	186.00*	0.60	8.61*	-0.57
Leg press (kg)	62.91*	0.00	83.92*	-0.83
Bench press (kg)	107.56*	-0.07	8.32*	-0.21

[a]df=1 and 327

[s]tandardized discriminant coefficients

*p<.01

Table 16

Physical Characteristics of Female Volleyball and Basketball Championship Team Players in the Japan Inter-High School Meeting

	Volleyball (V)	Basketball (B)	Non-athletes (N)	Significance Level		
				V VS. N	B VS. N	V VS. B
Number	12	11	46			
Age (years)	17.4 ± 0.73	17.6 ± 0.88	17.7 ± 0.40	ns	ns	ns
Height (cm)	168.7 ± 5.89	166.5 ± 7.87	157.7 ± 5.11	***	***	ns
Weight (cm)	59.7 ± 5.73	58.8 ± 6.85	50.7 ± 6.42	***	***	ns
Chest girth (cm)	82.8 ± 4.34	83.9 ± 3.25	71.9 ± 5.84	***	***	ns
Abdominal girth (cm)	73.7 ± 4.43	72.1 ± 2.98	77.7 ± 5.41	*	**	ns
Upper arm girth (cm)	25.2 ± 2.04	24.5 ± 1.22	24.5 ± 1.97	ns	ns	ns
Thigh girth (cm)	53.9 ± 3.69	53.9 ± 2.44	52.3 ± 3.24	ns	ns	ns

Table 16-Cont

Lower leg girth (cm)		35.5 ± 1.95	35.7 ± 1.63	34.9 ± 3.91	ns	ns	ns
Waist (cm)		67.3 ± 4.04	64.8 ± 3.35	63.1 ± 4.41	**	ns	ns
Hip (cm)		90.9 ± 3.29	91.1 ± 4.35	87.6 ± 4.25	*	*	ns
Skinfold thickness							
	Triceps (mm)	16.3 ± 3.58	14.7 ± 4.03	17.9 ± 3.54	ns	*	ns
	Sub-scapular (mm)	12.1 ± 4.10	11.6 ± 3.75	14.2 ± 3.46	ns	*	ns
	Abdominal (mm)	14.5 ± 3.83	14.2 ± 3.75	20.7 ± 4.79	***	***	ns
	Supra-iliac (mm)	13.3 ± 4.21	10.9 ± 4.23	18.3 ± 5.57	**	***	ns
	Chest (mm)	10.9 ± 2.17	11.3 ± 3.79	12.4 ± 3.19	ns	ns	ns
	Thigh (mm)	23.4 ± 2.76	21.7 ± 5.50	29.1 ± 4.55	***	***	ns
	Knee (mm)	12.9 ± 3.96	11.0 ± 2.79	14.5 ± 3.63	ns	**	ns
	Mid-axillary (mm)	11.2 ± 3.60	9.3 ± 3.44	11.5 ± 3.41	ns	ns	ns

Table 16-Cont

Body composition							
	Body density (BD) (g/ml)	1.0564 ± 0.0080	1.0632 ± 0.0124	1.0440 ± 0.0092	***	***	ns
	Percent body fat (%Fat) (%)	18.4 ± 3.29	15.7 ± 5.05	23.8 ± 3.03	***	***	ns
	Fat mass (FM) (kg)	11.0 ± 2.46	9.4 ± 3.57	12.2 ± 2.59	ns	***	ns
	FM/Ht (kg/m)	6.5 ± 1.40	5.6 ± 2.05	7.7 ± 1.55	*	***	ns
	Fat-free mass (FFM) (kg)	48.6 ± 4.53	49.4 ± 5.08	38.7 ± 4.41	***	***	ns
	FFM/Ht (kg/m)	28.8 ± 2.42	29.6 ± 1.77	24.9 ± 3.39	***	***	ns

*p<0.05, **p<0.01, ***p<0.001, ns: not significant

Table 17

VO_2 Max and O_2 Debt Max of Female Volleyball and Basketball Championship Team Players in the Japan Inter-High School Meeting

		Volleyball (V)	Basketball (B)	Significance Level V VS. B
Number		12	11	
VO_2 max				
	Heart rate max (beats/min)	186.1 ± 9.20	187.5 ± 6.33	ns
	VE max (l/min)	101.2 ± 13.97	117.5 ± 9.22	**
	VO_2 max (l/min)	2.78 ± 0.32	3.32 ± 0.31	***
	VO_2 max (ml/kg*min)	46.6 ± 2.90	56.7 ± 4.17	***
O_2 debt max				
	O_2 debt max (l)	6.18 ± 1.15	7.92 ± 1.80	*
	O_2 debt max (ml/kg)	103.2 ± 12.40	134.3 ± 23.24	***

*$p<0.05$, **$p<0.01$, ***$p<0.001$, ns: not significant

Table 18

Demographic, Cognitive, and Psychomotor Characteristics of High School Basketball Players (n=50)

Variable	M	SD	Range
Age (yr.)	17	0.9	15.0-18.0
Height (in.)	73.1	3.2	67.2-79.5
Weight (in.)	167.1	23.1	129.0-223.5
% fat	13.5	2.7	8.2-20.9
McCloy Index	975.7	49.7	879-1095.0
Vertical Jump (in.)	23	2.7	17.0-29.5
Depth Perception	11.6	0.8	10.0-12.0
Hand Reaction Time (sec.)	0.158	0.01	0.13-0.19
Foot Reaction Time (sec.)	0.192	0.01	0.16-0.23
Shooting Accuracy	22.3	3.9	14.0-30.0
Dribbling (sec.)	8.9	0.4	8.2-10.2
Wall Pass	32.7	2.2	28.0-37.3

M= mean

SD= standard deviation

Table 19

Anthropometric and Performance Measures (Means and Standard Deviations (SD)) for High School Basketball Players

	Female		Male	
Variable	Mean	SD	Mean	SD
Age (y)	16.02	1.16	16.21	1.07
Height (cm)	166.19	7.42	182.34	7.59
Weight (kg)	61.54	8.68	74.95	12.02
Body fat (%)	20.45	4.65	11.98	4.3
Inversion (degrees)	36.25	6.98	31.95	6.63
Eversion (degrees)	16.54	3.98	14.52	4.59
Plantar flexion (degrees)	30.35	9.33	27.94	8.71
Dorsiflexion (degrees)	10.33	4.35	8.72	3.55
Single-limb balance time (s)	27.25	5.14	28.19	3.72
Vertical jump (cm)	46.36	5.59	64.01	10.82
Pro agility run (s)	6.14	0.32	5.63	0.31
20-yd sprint (s)	3.46	0.27	3.13	0.21

Table 20

Anthropometric Indices and Cardiopulmonary Testing Parameters of the Study Subjects

Variable	Mean ± SD	Range
Age (years)	22.63 ± 2.97	19 - 28
Height (cm)	200.13 ± 6.38	190 - 209
Body mass (kg)	93.88 ± 11.01	80.0 - 110.4
BMI	23.36 ± 1.49	21.04 - 25.18
VO_2 max (l/min)	4.33 ± 0.63	3.45 - 5.14
W max (W)	326.5 ± 37.66	279 - 381
HR max (bpm)	170.5 ± 12.94	152 - 193
VE max (l/min)	124.7 ± 9.74	109.8 - 144.1
Oxy Pulse (ml/bpm)	24.86 ± 5.68	18.5 - 34.1
RQ	1.13 ± 0.04	1.07 - 1.18

Table 21

Physical Characteristics, Pulmonary Function Measurements, and Maximal Exercise Measurements of Subjects

Variables	Centers n = 3	Forwards n = 5	Guards n = 5	Total mean	Range
Age (years)	20.14 ± 1.49	20.43 ± 1.61	19.58 ± 0.98	20.00 ± 1.27	18.08 - 22.58
Height (cm)	205.72 ± 0.03	197.10 ± 4.61	186.43 ± 6.37	194.99 ± 9.05	175.26 - 205.74
Weight (kg)	97.20 ± 7.04	92.79 ± 5.35	75.45 ± 4.35	87.13 ± 10.94	68.20 - 103.41
Body surface area (BSA) m^2	2.40 ± 0.06	2.27 ± 0.08	1.99 ± 0.05	2.19 ± 0.19	1.81 - 2.46
FVC (L)	6.88 ± 0.05	6.27 ± 0.25	5.86 ± 0.06	6.28 ± 0.44	5.78 - 6.88
% of predicted values *	105	101	104		
$FEV_{1.0}$ (L)	5.71 ± 0.14	5.29 ± 0.61	4.90 ± 0.06	5.28 ± 0.43	5.78 - 6.88
% of predicted values *	105	102	103		
MVV (L/min)	212.12 ± 18.46	204.92 ± 24.09	200.14 ± 26.58	203.41 ± 24.38	175.80 - 221.63
% of predicted values *	93	94	98		
Heart rate (beats/min)	187.66 ± 3.51	184.00 ± 9.60	184.60 ± 7.86	185.17 ± 7.21	173.00- 195.00
VE max (L/min)	170.83 ± 27.30	158.25 ± 8.99	149.76 ± 10.47	157.53 ± 15.61	139.00 - 198.50

Table 21-Cont

VO_2 max (L/min)	5.46 ± 0.48	5.39 ± 0.65	4.57 ± 0.48	5.06 ± 0.66	3.92 - 6.07
VO_2 max (ml/kg*min)	56.20 ± 1.07	59.32 ± 8.24	60.61 ± 7.02	59.31 ± 6.58	48.40 - 67.79

* Calculated from the data of Kory et al.

Table 22

Anthropometric Characteristics, Repeated Maximal Treadmill Run Data, Suicide Sprint Times, and Knee Flexion/Extension and Bilateral Peak Torque

Variable	Combined group (n=29) Mean ± SD	Guards (n=11) Mean ± SD	Power forwards (n=6) Mean ± SD	Shooting forwards (n=6) Mean ± SD	Centers (n=6) Mean ± SD
Mass (kg)	74.5 ± 7.7	67.3 ± 4.8[b,c,d]	77.1 ± 2.9[a]	78.7 ± 5.7[a]	81.1 ± 7.2[a]
Height (cm)	181.8 ± 6.0	176.5 ± 4.3[b,c,d]	185.1 ± 1.8[a]	181.4 ± 1.7[a,d]	188.5 ± 5.3[a]
Sum of skinfolds (mm)	73.3 ± 17.1	62.2 ± 13.8[c,d]	76.0 ± 9.7	85.0 ± 19.0[a]	79.8 ± 17.5[a]
Chest girth (cm)	94.0 ± 4.9	91.3 ± 5.1	95.3 ± 4.9	95.2 ± 3.3	96.3 ± 4.3
Abdominal girth (cm)	76.6 ± 4.1	73.4 ± 2.4[b,c,d]	78.8 ± 3.3[a]	78.4 ± 4.5[a]	78.4 ± 4.8[a]
Gluteal girth (cm)	102.0 ± 6.2	96.6 ± 5.1[b,c,d]	104.8 ± 2.8[a]	105.5 ± 5.8[a]	105.8 ± 4.5[a]
Right thigh girth (cm)	58.7 ± 3.6	56.5 ± 3.9	59.1 ± 1.4	59.3 ± 4.0	61.6 ± 1.8[a]
	(n=31)	(n=11)	(n=8)	(n=6)	(n=6)
VO_2 max (l/min)	3.77 ± 0.37	3.62 ± 0.32	3.79 ± 0.41	3.68 ± 0.39	4.10 ± 0.37
VO_2 max (ml/kg*min)	51.3 ± 4.9	54.3 ± 4.9[c]	50.7 ± 2.8	47.0 ± 4.3[a]	50.9 ± 4.7

Table 22-Cont

V_E (l/min)	120.9 ± 17.2	122.1 ± 12.3	117.8 ± 19.4	119.0 ± 17.4	124.8 ± 24.6
	(n=30)	(n=10)	(n=8)	(n=6)	(n=6)
Run 1 time (s)	31.8 ± 1.9	31.0 ± 1.6	32.0 ± 2.1	31.4 ± 1.5	32.9 ± 2.3
Run 2 time (s)	33.6 ± 2.1	32.4 ± 1.4	34.3 ± 2.3	33.3 ± 1.4	35.1 ± 2.3
Run 3 time (s)	34.9 ± 2.4	33.6 ± 1.8[d]	35.3 ± 2.3	34.6 ± 1.8	36.8 ± 2.4[a]
	Mean ± SD	Range			
	(n=25)				
Right flexion/extension at 60°/s	0.63	0.41 - 0.89			
Left flexion/extension at 60°/s	0.63	0.44 - 0.91			
Right flexion/extension at 120°/s	0.69	0.51 - 1.07			
Left flexion/extension at 120°/s	0.69	0.49 - 0.97			
Left/right flexion at 60°/s	0.98	0.73 - 1.29			
Left/right extension at 60°/s	0.97	0.77 - 1.32			
Left/right flexion at 120°/s	0.96	0.76 - 1.17			
Left/right extension at 120°/s	1.01	0.87 - 1.25			

[a] Significantly different from guards; [b] from power forwards; [c] from shooting forwards; [d] from centers

Table 23

Flexor:Extensor Ratios of Various Joints at Selected Speeds (n=13)

		Velocity (°/sec)				
		60	120	180	240	300
Knee						
	Left	0.67	0.71	0.74	0.79	0.84
	Right	0.63	0.67	0.72	0.76	0.79
	% difference	6.00	5.60	2.70	3.80	6.00
Shoulder						
	Left	0.81	0.79	0.82	0.81	0.80
	Right	0.77	0.80	0.84	0.81	0.82
	% difference	4.90	1.20	2.40	0.00	2.40
Elbow						
	Left	0.86	0.94	0.92	0.90	0.95
	Right	0.90	1.03	1.04	1.04	1.01
	% difference	4.40	8.70	11.50	13.50	5.90

		Velocity (°/sec)				
		30	60	90	120	150
Elbow						
	Left	0.37	0.30	0.46	0.54	0.59
	Right	0.39	0.44	0.49	0.54	0.60
	% difference	5.10	2.30	6.10	0.00	1.70

Table 24

Correlations between Peak Torque and Relative and Absolute Endurance (n=13)

		Peak Extension Torque		Peak Flexion Torque	
		Left	Right	Left	Right
Ankle					
	Relative	0.021	-0.009	-0.141	0.118
	Absolute	0.302	0.478	-0.303	-0.113
Knee					
	Relative	-0.699*	-0.160	-0.345	0.110
	Absolute	0.716*	0.789◊	0.626*	0.711*
Shoulder					
	Relative	-0.446	-0.475	-0.430	"-0.691∞
	Absolute	0.515	0.514	0.403	0.706∞
Elbow					
	Relative	0.012	0.027	-0.020	-0.083
	Absolute	0.518	0.150	0.406	0.430

* p<0.05

∞ p<0.01

Table 25

The Mean, Standard Deviation, F-Ratio, and Significant Values of the Basketball Players Grouped According to Playing Position

	Centers (n=5) Mean ± SD	Forwards (n=6) Mean ± SD	Guards (n=7) Mean ± SD	F-Ratio
Age (years)	15.7 ± 0.37	15.4 ± 0.41	15.7 ± 0.48	0.8
Weight (kg)	71.2 ± 6.4[a]	63.9 ± 5.0	57.9 ± 6.4	7.4
Height (cm)	180.0 ± 4.1[a c]	172.6 ± 2.7[a]	162.2 ± 4.9	28.6
Sitting height (cm)	90.8 ± 2.6[a]	88.4 ± 3.8[a]	83.2 ± 1.9	11.4
Lower limb length (cm)	89.2 ± 2.4[a]	84.6 ± 2.6	80.5 ± 5.1	7.9
Upper limb length (cm)	68.8 ± 4.4[b]	67.8 ± 7.4[b]	61.4 ± 2.3	4
Shoulder width (cm)	40.8 ± 1.2	38.4 ± 3.6	39.4 ± 1.7	1.4
Hip width (cm)	35.0 ± 1.8[a]	33.5 ± 1.3[b]	30.9 ± 1.8	9.4
Humeral width (cm)	6.6 ± 0.4	6.3 ± 0.3	6.4 ± 0.3	1
Femoral width (cm)	9.6 ± 0.6	9.3 ± 0.4	9.3 ± 0.4	0.6
Extended hand width (cm)	17.9 ± 1.1	18.1 ± 1.9	16.5 ± 1.9	1.5
Chest circumference (cm)	87.2 ± 3.9[a]	84.4 ± 1.8	83.2 ± 1.9	3.7
Abdominal circumference (cm)	79.9 ± 4.1[a]	76.4 ± 3.3	72.3 ± 4.6	5.1
Relaxed arm circumference (cm)	26.3 ± 1.3	25.2 ± 1.4	25.8 ± 1.5	0.8
Flexed arm circumference (cm)	28.5 ± 1.4[c]	26.3 ± 1.4	27.4 ± 1.3	3.9

Table 25-Cont.

Calf circumference				
(cm)	36.7 ± 1.7	35.1 ± 1.7	34.9 ± 1.8	1.8
Sum 6 skinfolds				
(mm)	83.2 ± 13.4	69.1 ± 16.5	70.8 ± 11.3	1.3
Ponderal index	13.2 ± 0.4	13.1 ± 0.4	12.8 ± 0.3	2.4
Trunk width index	86.3 ± 1.9	81.6 ± 10.5	87.1 ± 5.9	1.1
Skelic index	98.4 ± 3.2	95.5 ± 6.6	96.9 ± 7.4	0.3
Endomorphy	4.1 ± 0.5	3.5 ± 1.0	3.4 ± 0.6	1.3
Mesomorphy	3.5 ± 0.6[b]	3.8 ± 1.0[b]	4.9 ± 0.5	6.4
Ectomorphy	3.7 ± 1.0	3.4 ± 1.3	2.6 ± 0.8	1.7
% fat	18.3 ± 2.3	17.9 ± 2.3	17.9 ± 1.1	1.1
Absolute fat (kg)	13.1 ± 2.4	11.5 ± 2.2	10.4 ± 0.6	2.7
Lean body weight				
(kg)	58.1 ± 4.7[a d]	52.4 ± 3.2	47.5 ± 4.9	8.7
Vertical jump (cm)	47.6 ± 5.3	47.2 ± 6.5	47.6 ± 4.9	0.1
Anaerobic power				
(kg*m/sec)	108.5 ± 12.7[b]	97.5 ± 6.6	88.9 ± 12.9	4.5
Right grip (kg)	32.6 ± 5.2	31.2 ± 5.3	30.0 ± 5.2	0.4
Left grip (kg)	29.2 ± 6.7	26.5 ± 5.3	26.7 ± 5.0	0.4
Laterality quotient	61.3 ± 12.1	41.0 ± 18.9	48.2 ± 17.0	2.1

[a] Significantly different from the guards at 1% level of confidence

[b] Significantly different from the guards at 5% level of confidence

[c] Significantly different from the forwards at 1% level of confidence

[d] Significantly different from the forwards at 5% level of confidence

Table 26
Mean (± SD) Physical Characteristics and Performances on Maximal Treadmill Test and 30 Second All-Out Test Functions

		Centers (n=22)	Forwards (n=22)	Guards (n=14)	Pro A (n=33)	Pro B (n=25)	Overall mean (n=58)
Physical characteristics							
	Age (years)	24.5 ± 4.7	24.2 ± 5.5	23.6 ± 4.3	24.2 ± 5	24.2 ± 4.6	24.1 ± 4.8
	Size (cm)	203.9 ± 5.3	195.8 ± 4.8	185.7 ± 6.9	197 ± 8.5	195.7 ± 9.6	196.4 ± 8.9
	Body mass (kg)	103.9 ± 12.4	89.4 ± 7.1	82.0 ± 8.8	93.9 ± 13	92.1 ± 13.6	93.1 ± 13.2
	% fat	14.4 ± 3.7	11.4 ± 2.3	11.4 ± 1.7	12.7 ± 2.7	12.4 ± 3.7	12.6 ± 3.1
Maximal treadmill test							
	VO_2 max (ml/min*kg)	52.9 ± 6.2	55.2 ± 6.5	57.5 ± 9.2	53.7 ± 6.7*	56.5 ± 7.7	54.9 ± 7.2
	VMA (km/h)	15.5 ± 1.2	16.3 ± 1.6	16.8 ± 1.5	16 ± 1.2	16.0 ± 2.1	16.1 ± 1.9
	V_{AT} (km/h)	14.7 ± 1.3	15.1 ± 1.7	15.7 ± 1.6	15.1 ± 2.2	15.0 ± 2.1	15.1 ± 1.8
30 sec. all-out test							
	Pmax (W/kg)	11.1 ± 2.1	12.7 ± 3.5	13.1 ± 1.7	12.5 ± 3	11.9 ± 2.36	12.2 ± 2.7
	Pmin (W/kg)	4.7 ± 1.6	5.2 ± 1.7	4.7 ± 1.9	4.6 ± 2	5.3 ± 1.2	4.9 ± 1.7
	% fatigue	56.3 ± 15.7	58.1 ± 9.3	63.8 ± 14.7	63.3 ± 13.8*	54.1 ± 11.1	58.9 ± 13.6
	V_{max} (rpm)	156.5 ± 18.4	170.3 ± 18.3	168.4 ± 14.8	168.0 ± 15	159.4 ± 20.3	164.5 ± 18

VO_2 max: maximal oxygen uptake; VMA: maximal aerobic velocity; VAT: velocity at the anaerobic threshold ; Pmax: highest value of power measured; Pmin: lowest value of power measured; % fatigue index; Vmax: maximal pedaling frequency. [a]) Significantly different from forwards. [b]) Significantly different from guards. * Significantly different from Pro B

Table 27

Physical, Physiological, and Technical Characteristics of Greek Elite Junior Basketball Players (n=13)

Variables	Mean ± SD
Age (years)	18.5 ± 0.5
Height (cm)	199.5 ± 6.2
Body mass (kg)	95.5 ± 8.8
% fat	11.4 ± 1.9
Fat mass (kg)	11.0 ± 2.5
VO_2 max (ml/min*kg)	51.7 ± 4.8
Maximum heart rate (beats/min)	187.0 ± 9.1
Ventilatory threshold (% VO_2 max)	77.6 ± 7.0
Maximum power output (Watts/kg)	10.7 ± 1.3
Fatigue Index (%)	49.5 ± 20.4
Post-exercise blood lactate concentration (mmol/l)	11.1 ± 1.6
Squat jump height (cm)	39.8 ± 3.7
CMJ height (cm)	40.1 ± 4.0
Control dribble (s)	13.70 ± 0.96
Defensive movement (s)	16.58 ± 1.12
Speed running (s)	4.20 ± 0.23
Speed dribble (s)	4.28 ± 0.21
High intensity shuttle run (s)	27.92 ± 1.04
High intensity shuttle run and dribble (s)	29.53 ± 1.22

CMJ: counter-movement jump

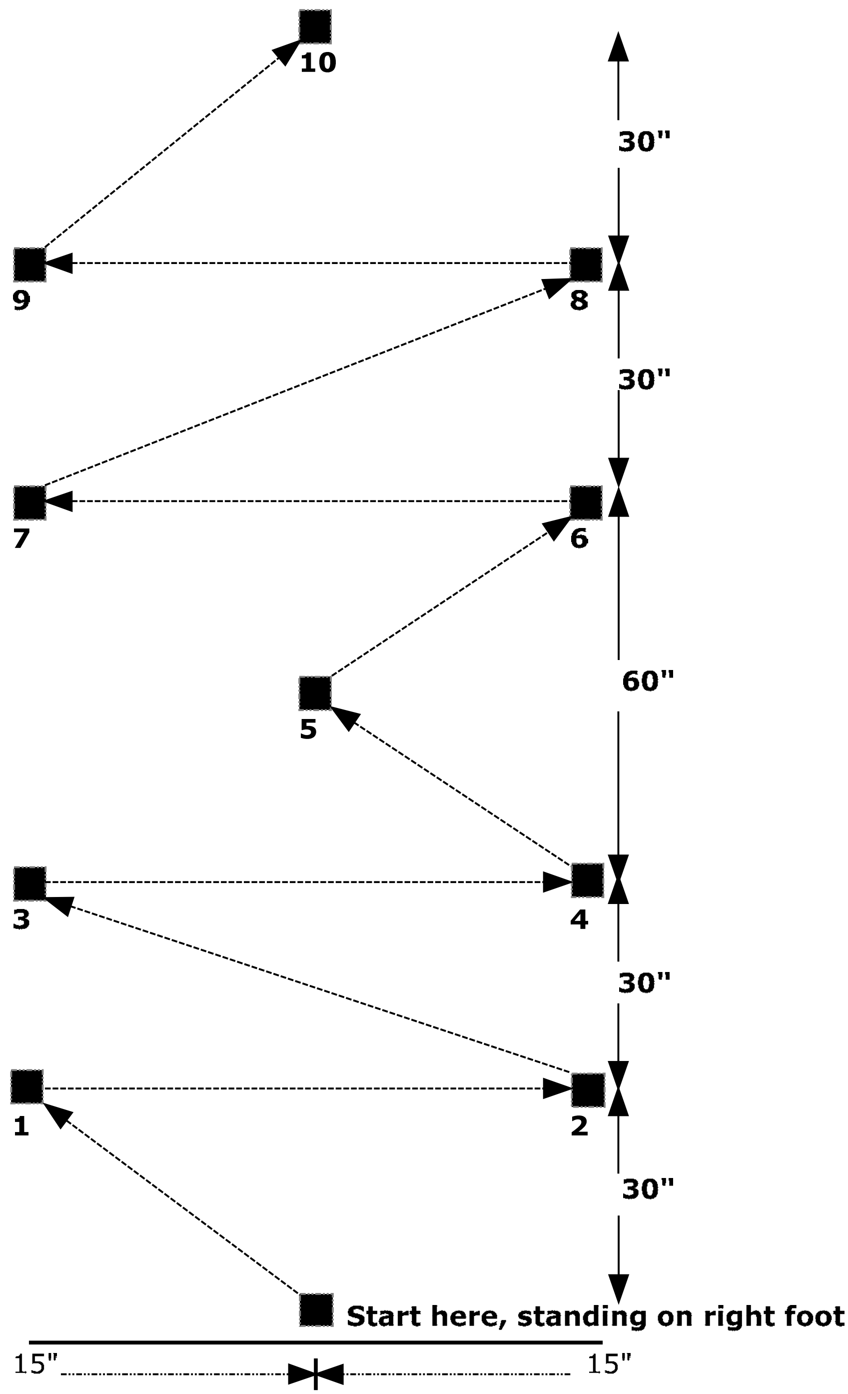

Figure 1. Floor Pattern of Modified Bass Dynamic Balance Test

VITA

Michael Lloyd Hobbs was born in Channelview, Texas, on September 14, 1979, the son of Linda Faye Rix and Chester Lloyd Hobbs. After completing his work at Schulenburg High School, Schulenburg, Texas, in 1997, he entered Blinn Junior College. During the spring of 2001, he attended the Texas A&M University in College Station. He received the degree of Bachelor of Exercise and Sports Science from Texas State in December 2005. During the following years he was employed as graduate assistant with the Health, Physical Education, and Recreation Department at Texas State University-San Marcos. In January 2006, he entered the Graduate College of Texas State University-San Marcos.

Permanent Address: 1602 Mill St. A

San Marcos, Texas 78666

This thesis was typed by Michael L. Hobbs.