European **Rev**iew for **Med**ical and **Pharmacol**ogical **Sci**ences 2022; 26: 6073-6083

Postural profile of female basketball players and differences among playing positions

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Abstract. – OBJECTIVE: Basketball players often display poor balance and increased injury rates when compared to other athletic categories. Therefore, the relationship between postural control and injury risks in basketball athletes requires investigation. The purpose of this study was to: (a) establish a postural profile of elite women basketball players, (b) compare postural control of the different playing positions to detect the vulnerability of postural balance, and (c) attempt to understand the reasons underlying these differences.

PATIENTS AND METHODS: 30 elite female basketball players (aged 21.4±2.3 years) were assigned to three groups according to their playing positions (n=10 guards; n=10 forwards; n=10 centers). A one-way analysis of variance was performed to determine differences between balance test variables under three conditions (static, dynamic antero-posterior and medio-lateral). When a significant main effect was observed, Tukey's post-hoc multiple comparisons tests were used to determine statistical significance. Associations between balance and morphological variables, muscle strength and power were assessed using Pearson's correlation coefficient.

RESULTS: Results reveal that basketball players had better postural control than previously studied handball players and non-athletes, but they are more dependent on vision than other categories. When comparing postural controls of playing position, centers show greater vulnerability [Y mean (OE)] than forwards: $p<0.001$; or guards: $p<0.01$), due to morphological factors (body mass $r=-0.80$, height $r=-0.68$, and lower limb length $r=-0.63$, and specific power $r=-0.40$).

CONCLUSIONS: Therefore, coaches and strength and conditioning specialists should give specific focus to improving lower limb strength and power in centers and taller basketball players to mitigate against injury risks related to postural control.

Key Words:
Postural control, Basketball, Playing position, Specific power.

Introduction

Basketball is known to place considerable overload on the lower limbs, leading to greater injury risk when compared to many other team sports. Specifically, Agel et al[1] reported between 7 and 10 injuries per 1,000 athletic exposures, with most injuries (58-66%) affecting the lower extremity. Furthermore, females reported to have a higher rate (2-4 times) of falls than males[2-4]. Recently, Foschia et al[5] reported that basketball was the leading cause of injury among female athletes. Similarly, injury frequency rates could vary according to the players' position[6]. Such vulnerability could be attributed to poor functional balance or biomechanical factors, such as poorer muscle power and joint motion[7].

Balance control is considered to be an essential functional parameter in sport, and directly affects athletic performance[8]. Nevertheless, previous studies[9,10] have indicated that basketball players have inferior bipedal balance than other athletes and non-athlete categories. However, a lower level of balance originates injuries, among

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Table I. Anthropometric variables and discrepancies between positions.

	Centers (n=10)	Forwards (n=10)	Guards (n=10)
Age (years)	21.5 ± 2.6	21.3 ± 2.5	21.3 ± 2.3
Body mass (kg)	78.2 ± 8.1 **a*******b****	60.2 ± 3.5	64.5 ± 6.9
Height (cm)	180.5 ± 4.2 **a*******b*****	172.4 ± 3.5	168 ± 4.6
Lower limb length (cm)	108.7 ± 6.6 **a*******b*****	98.1 ± 5.4 **b***	91.5 ± 4.3
BMI (kg/m^2)	24.1 ± 2.9 **a***	20.9 ± 1.5	22.8 ± 1.6
Leg muscle volume (L)	11.5 ± 2.9 **a****	8.4 ± 0.9	9.53 ± 1.30
Thigh muscle volume (L)	8.52 ± 2.69 **a****	5.72 ± 0.87	6.89 ± 1.44
Mean thigh CSA (cm^2)	199.2 ± 73.4	153.6 ± 26.2	173 ± 22.5
Maximal thigh CSA (cm^2)	274.7 ± 51 **a***	224.4 ± 32.7	239.3 ± 28

a: significantly different than forwards; b: significantly different than guards; c: significantly different than centres; *: $p<0.05$; **: $p<0.01$; ***: $p<0.001$.

which sprains and muscles, tendons and ligaments strains are most common[11,12]. Therefore, screening for postural abnormalities is of great concern to prevent the occurrence of injuries and falls. Nevertheless, unlike other sports where one condition of balance prevails over the other (i.e., judo)[13], basketball involves static and dynamic conditions of balance depending on the situation and from one position of play to another. Given the actions they perform during the game (running, continuous movement of cuts and penetrating movement towards the basket), the wing positions require control of the body in motion. Conversely, due to their positioning relatively close to the basket, centers do not require a lot of movement and running, but rather the search for preferred positions concerning the opponent and the basket. This requires optimal body control in static conditions. Finally, guards' movements during matches need optimal control of the body in a dynamic state. The alternation between the two aforementioned conditions of equilibrium should be done according to the phases of play, such as dynamic equilibrium during the rise of the ball and some penetrations towards the basket executed by the players evolving in this position of play, whereas during the tactical organization such players are required to call upon static balance conditions.

Anthropometric and physical differences between playing positions are likely to induce differences in postural control[14]. Furthermore, muscle strength and power are essential skill-related, interlinked neuromuscular components of physical fitness and balance[15], and are key to the efficient prevention of falls and injuries[16]. Indeed, players have to react promptly to external constraints by generating muscle force and power to stabilize the center of mass[17]. Several investigations have evaluated the modification and variation of postural control in basketball players following numerous training programs[18-21]. However, there is a lack of descriptive data concerning the postural control of elite female basketball players.

This postural evaluation aimed at establishing a postural profile of elite women basketball players and comparing postural control of the different playing positions and detecting the vulnerability of postural balance while attempting to understand the reasons underlying these differences.

Patients and Methods

Participants

A group of thirty healthy elite female basketball players took part in this study. Players were assigned as centers (CG, n=10), forwards (FG, n=10) or guards (GG, n=10) based on their predominant playing positions. The participants had 10.5±3.07 years of professional practice on average. They must have been participating in competitions for at least five years, not suffering from an injury that could affect their performance. They were required not have been dependent upon a medical procedure on the lower limb for at least a half year. All the participants signed their informed consent following the Declaration of Helsinki. The age and anthropometric characteristics of the groups are presented in Table I.

Intervention

All procedures were conducted following the latest version of the Declaration of Helsinki and were approved by the Institutional Review Committee for the ethical use of human subjects of the University of Manouba (Research Unit (UR-17JS01) «Sport Performance, Health & Society», Higher Institute of Sport and Physical Education of Ksar Saîd, University of "La Manouba", Tunis, Tunisia, according to current national laws, regulations, and procedures.

The study took place mid-season (4 months after the beginning of the playing season), during the winter rest period. The experimental protocol comprised the assessment of the anthropometric variables, the evaluation of balance under the static and dynamic conditions (antero-posterior and medio-lateral axis) and the measurement of the quadriceps and hamstrings' power and peak torque of both legs. A familiarization session was established two weeks before the protocol. Tests were held at the same time of the day and under consistent experimental conditions. Participants maintained regular consumption (food and water) habits during the testing period. However, participants were required to avoid caffeine-containing beverages.

Measurements

Anthropometrics

Body mass and height were assessed using a weight scale and a stadiometer, respectively. Muscle volume estimation was calculated according to the formula of Jones and Pearson[22]. A Harpenden caliper (Baty International, Burgess Hill, Sussex, United Kingdom) was used to measure skinfolds of the front of midthigh, back of midthigh, and the posterior and lateral portion of the calf. Further details of the testing procedure can be found in the study by Jones and Pearson[22].

The mean and maximal cross-sectional area (CSA) of the thigh were calculated from maximal and mid-thigh circumferences and allowance of the overlying skin folds, described by Chelly et al[23].

Postural test conditions

The balance test was carried out using the "WinPosture®" device. The test consisted of standing upright with the arms alongside the body and the feet slightly apart. During the static condition, the subject had to stare at a target (10 cm^2) placed on the wall at a distance of 2.5 m and a height of 1.70 m, for 51.2 sec. The dynamic condition was created by a seesaw that created instability in the antero-posterior and the medio-lateral axis. The participants had to stand as still as possible to keep the seesaw horizontal as much as possible during 25.6 s; a total loss of balance would invalidate the trial. This methodology minimizes the effect of intrinsic physical differences among participants on the reliability of center of pressure (COP) measures[24]. The three aforementioned conditions have been achieved both with open (OE) and closed eyes (CE).

Postural control measures assessed

During the test, different parameters of the COP are recorded, such as:

- *Surface area S*: includes 90% of the sampled positions of the COP, evaluates the subject's postural performance; the smaller the area, the better the performance. For a healthy adult, this area's expected value is an average of 91 mm^2 in OE condition (39 to 210) and 225 mm^2 CE (79 to 638).
- *Romberg's index*: is the quotient of the surface area of COP with CE by the surface area of COP with OE multiplied by 100; the expected value for a healthy adult is 249 (112 to 677). A quotient equal to 100 means that the subject is standing without the need for visual afferences. Conversely, a decreased quotient suggests that visual information is interfering with postural control.
- *Path length (LFS)*: measures the distance travelled by the center of pressure per unit area. It characterizes the energy expenditure necessary to maintain balance while standing. The normal value of LFS is 1 (0.72 to 1.39) EO and 1 (0.7 to 1.44) CE. The increase in the LFS is indicative of the energy expenditure required to maintain balance. Conversely, a decrease in the LFS indicates an inadequate response to instability.
- *X means:* the average position of the COP along the lateral-lateral axis (average X), which evaluates the lateral deviation of the COP. It provides information on the symmetry of postural tone. The mean X's expected value for a healthy adult is 1 OE (-10 to 12) and 0.3 (-10.6 to 11.1) CE.
- *Y means:* the average position of the COP along the antero-posterior axis. This variable allows the detection of antero-posterior or retro-projection disorders of the COP. The mean Y's expected value for a healthy adult is -29 OE (-1 to -57) and -27 (-3 to 51) CE.
- *Velocity of COP*: corresponds to the sum of the accumulated COP displacement divided by the total time. It reflects the efficiency of the postural control system; the smaller the velocity, the better the postural control. This parameter is considered the most sensitive when comparing individuals from different groups[25].

The "normal" values assigned by the "WinPosture®" device (Tracxn, Shangai, China) refer to the standard values according to the standards

Table II. Balance variables in the static condition and discrepancies between position.

	Centers (n=10)	Forwards (n=10)	Guards (n=10)	All players (n=30)
COP surface area (OE) (mm^2)	76.4 ± 32.3	86.2 ± 33.5	66.5 ± 27	76.4 ± 31.1
COP surface area (CE) (mm^2)	166.6 ± 78.8 **b***	127 ± 61.6	89.8 ± 40.4 c	127.8 ± 68
QRBG (%)	219.5 ± 49.7 **b***	154.9 ± 67.5	154.4 ± 95.2	176.3 ±77.2
Path length (OE) (mm)	0.80 ± 0.20	0.76 ± 0.10	0.67 ± 0.10	0.74 ± 0.15
Path length (CE) (mm)	0.96 ± 0.21 **b****	0.80 ± 0.15	0.69 ± 0.14	0.82 ± 0.2
X mean (OE) (mm)	-2.41 ± 11.56	-2.31 ± 5.55	-6.15 ± 11.26	-3.62 ± 9.71
X mean (CE) (mm)	1.24 ± 10.11	-0.42 ± 7.03	-5.09 ± 12.07	-1.43 ± 9.99
Y mean (OE) (mm)	-62.3 ± 6.3 **a*******b****	-38.8 ± 9.2	-44.4 ± 13.4	-48.5 ± 14.1
Y mean (CE) (mm)	-60.1 ± 6.3 **a*******b****	-40.9 ± 5.2	-44.8 ± 12.4	-48.61 ± 11.8
COP velocity mean (OE) (mm.s^{-1})	7.80 ± 1.78 **b***	7.09 ± 0.92	6.32 ± 1.01	7.1 ± 1.39
COP velocity mean (CE) (mm.s^{-1})	11.7 ± 2.84 ^{a}***b****	9.24 ± 1.72	7.99 ± 1.65	9.64 ± 2.59
Velocity variation (OE)	55.5 ± 5.7	34.7 ± 7.9	38.9 ± 13.8	43 ± 13.1
Velocity variation (CE)	52.6 ± 7.2	38.5 ± 4.6	42.3 ± 10.5	44.5 ± 9.6

a: significantly different than forwards; b: significantly different than guards; c: significantly different than centres; *: $p<0.05$; **: $p<0.01$; ***: $p<0.001$.

of the French Posturology standard APE 85 or formerly AFP 85.

Isokinetic testing

Quadriceps and hamstrings' strengths were assessed using an isokinetic dynamometer (Biodex, Medical Systems, Inc., Shirley, NY, USA). Before the start of exploration, participants performed a 20 min warm-up consisting of 10 minutes of treadmill running, 5 minutes of pedaling, and 5 minutes of static stretching lower-extremity muscles. The participants were then placed and immobilized by straps on the dynamometer chair. Starting with the dominant leg, the hip and knee were flexed to 90°, and the center of rotation was aligned with the tested knee, while the bilateral leg was fixed. Participants were verbally encouraged to perform maximal five concentric knee extensions and flexions in succession, at 60°.s^{-1}. A computer program provided the average power and peak torque for the aforementioned muscle groups. Based on the weight of the limb and accessories, gravitational corrections were applied.

Specific power expressed as relative to the thigh's muscle volume (Watts/L) was calculated by dividing the average power at 60°.s^{-1} by the muscle volume, whereas the specific force is the resultant of the equation of the peak torque by the thigh CSA max, expressed in (N/cm^2), as previously described by Chelly et al[23].

Statistical Analysis

Statistical analyses were carried out using the SPSS 20 program for Windows (IBM Corp., Armonk, NY, USA). The normality of data was verified using the Shapiro-Wilk's test, and the homogeneity of variance was checked with Levene's test. A one-way analysis of variance (ANOVA) was carried out to determine the differences between the groups. When a significant main effect was observed, Tukey's post-hoc multiple comparisons tests were used to determine statistical significance, fixed at the 95% confidence level ($p<0.05$). When the normality or the hypothesis of homogeneity were rejected, the non-parametric Kruskall-Wallis' test was run. Associations between balance and morphological variables, muscle strength and power, were assessed using Pearson's product-moment correlation coefficient. Associations were reported by their correlation coefficient (r-value), level of significance (p-value), and the amount of variance explained (r^2-value). Correlations were considered as: 0.1-0.3=small; 0.3-0.5=moderate; 0.5-0.7=large[26].

Results

Table I presents anthropometric variables and discrepancies between the three main playing positions in basketball (centers, forwards and guards). Significant differences were shown between centers and the two other positions when looking at body mass (from forwards: $p<0.001$; from guards: $p<0.01$), height and lower limb length (from forwards: $p<0.001$; from guards: $p<0.001$). Centers differ significantly from forwards regarding BMI ($p<0.05$), leg muscle volume ($p<0.05$), thigh muscle volume ($p<0.01$) and maximal thigh CSA ($p<0.05$).

Table III. Balance variables in the antero-posterior and discrepancies between position.

	Centers (n=10)	Forwards (n=10)	Guards (n=10)	All
COP surface area (OE) (mm^2)	117.7 ± 54.5	176.0 ± 64.5	110.0 ± 44.2 **a***	134.6 ± 61
COP surface area (CE) (mm^2)	1,064.9 ± 553.48	1,734.4 ± 2164	720.1 ± 306.3	1,173.1 ± 1,327.2
QRBG (%)	950.8 ± 333.8	903.3 ± 767.3	688.4 ± 226.8	847.5 ± 496.7
Path length (OE) (mm)	0.85 ± 0.15	0.71 ± 0.11	0.87 ± 0.16	0.83 ± 0.14
Path length (CE) (mm)	0.86 ± 0.35	0.86 ± 0.24	1.06 ± 0.28	0.93 ± 0.30
X mean (OE) (mm)	3.90 ± 12.56	6.32 ± 12.11	1.55 ± 13.36	3.92 ± 12.4
X mean (CE) (mm)	7.66 ± 10.33	3.94 ± 11.08	2.59 ± 15.76	4.57 ± 12.4
Y mean (OE) (mm)	-57.3 ± 15.1 **a******b****	-37.1 ± 6.46	-37.6 ± 12.8	-44.0 ± 15.1
Y mean (CE) (mm)	-53.6 ± 16.2	-41.0 ± 13.5	-41.1 ± 12.9	-45.2 ± 15.0
COP velocity mean (OE) (mm.s^{-1})	16.7 ± 2.8	15.4 ± 2.6	16.5 ± 3.0	16.2 ± 2.7
COP velocity mean (CE) (mm.s^{-1})	38.9 ± 8.5	43 ± 16.1	37.4 ± 9.2	39.8 ± 11.6
Velocity variation (OE)	72.2 ± 17.1 **a*****b***	53.6 ± 8.2	55.7 ± 16.1	60.5 ± 16.3
Velocity variation (CE)	74.6 ± 22.5	64.9 ± 18.9	67.7 ± 25.1	69.1 ± 21.9

a: significantly different than forwards; b: significantly different than guards; c: significantly different than centres; *: $p<0.05$; **: $p<0.01$; ***: $p<0.001$.

Table II presents balance variables in the static condition and discrepancies between positions. Significant differences were found between centers and guards regarding COP surface area in closed eyes condition (CE), COP velocity mean in open eyes condition (OE) and QRBG (all $p<0.05$). Centers differ from the other positions regarding the Y mean (OE), Y mean (CE) (from forwards: $p<0.001$; from guards: $p<0.01$), and COP velocity mean (CE) (from forwards: $p<0.05$; from guards: $p<0.01$).

Tables III and IV show dynamic balance variables of the three positions. In the antero-posterior axis discrepancies between positions concern only Y mean (OE) and Velocity variation (OE), where centers significantly differ from forwards and guards ($p<0.01$ and $p<0.001$). The medio-lateral plane demonstrates significant differences between centers and the two other positions with regards to Y mean (OE) (from forwards: $p<0.001$; from guards: $p<0.01$), Y mean (CE) (from forwards: $p<0.05$; from guards: $p<0.05$), velocity variation in (OE) (from forwards: $p<0.001$; from guards: $p<0.01$) and velocity variation (CE) (from forwards: $p<0.01$; from guards: $p<0.05$).

Table V indicates specific isokinetic power and force at 60°.s^{-1} results. Significant differences between centers and guards are only relevant to the specific power of the quadriceps ($p<0.01$) and the hamstrings of the right and left legs ($p<0.05$).

Tables VI and VII present correlations to explain the underlying factors related to the significant differences between the playing positions marked in postural control variables. Morphological factors, such as body mass, height, lower limb length, and specific power are the main reasons for these differences.

Discussion

This study aimed at: (a) establishing a postural profile of the elite female basketball players; (b) comparing postural control of the different playing positions among them to detect the impact of postural balance of one position in relation to the others, and (c) attempting to understand the reasons underlying these differences. The present study's findings showed major dependence on vision and a high vulnerability of the centers in both dynamic and static stances. Even though there is a lack of studies dealing with this specific topic, based on the similarity of the games' physiognomy, our results will be compared with those of handball players and other categories.

Using this study's results, we can identify associated factors and gain a more reliable understanding of the injury mechanism, thereby determining specific prevention strategies for the powerless players.

Postural Profile of the Elite Women Basketball Players

In static condition, results reveal that contrary to what has been previously reported[9,10], basketball players had better postural control than handball players and non-athletes. However, they were more dependent on vision and activated their feedforward mechanisms to ensure their balance. When comparing the playing positions, results reveal a great vulnerability of the centers in the static condition.

Table IV. Balance variables in the medio-lateral plane and discrepancies between position.

	Centers (n=10)	Forwards (n=10)	Guards (n=10)	All
COP surface area (OE) (mm^2)	154.6 ± 50.3	213.5 ± 113.9	151.9 ± 38.7	173.3 ± 78.2
COP surface area (CE) (mm^2)	1,308.2 ± 546.6	1,481.3 ± 925.8	1,289.0 ± 660.0	1,359.6 ± 708.3
QRBG (%)	980.8 ± 557.4	697.5 ± 260.2	873.8 ± 424.4	850.7 ± 432.9
Path length (OE) (mm)	1.20 ± 0.28	0.99 ± 0.20	0.97 ± 0.23	1.05 ± 0.25
Path length (CE) (mm)	0.76 ± 0.25	0.79 ± 0.29	0.95 ± 0.37	0.83 ± 0.31
X mean (OE) (mm)	-2.87 ± 7.91	-5.26 ± 6.22	-1.57 ± 5.47	-3.23 ± 6.57
X mean (CE) (mm)	0.73 ± 8.26	-6.02 ± 6.65	-2.49 ± 7.01	-2.59 ± 7.61
Y mean (OE) (mm)	-59.3 ± 8.9 a***b**	-40.5 ± 6.2	-44.5 ± 11.4	-48.1 ± 12.0
Y mean (CE) (mm)	-55.0 ± 9.8 a*b*	-41.1 ± 7.31	-41.5 ± 14.6	-45.9 ± 12.5
COP velocity mean (OE) (mm.s^{-1})	22.7 ± 5.2	20.1 ± 5.0	18.8 ± 4.2	20.5 ± 4.9
COP velocity mean (CE) (mm.s^{-1})	45.1 ± 10.4	49.2 ± 15.8	46.2 ± 11.4	47.9 ± 12.5
Velocity variation (OE)	76.7 ± 9.8 a***b**	54.4 ± 7.3	57.9 ± 13.9	63.0 ± 14.3
Velocity variation (CE)	80.6 ± 7.7 a**b*	62.3 ± 10.6	64.4 ± 16.9	69.1 ± 14.5

a: significantly different than forwards; b: significantly different than guards; c: significantly different than centres; *: $p<0.05$; **: $p<0.01$; ***: $p<0.001$.

In open eyes condition, basketball surface areas (76.4±31.1 mm^2) are largely smaller than those of handball players (193±99 mm^2; 12 males+12 females; age=19.5±2.11 years; years of practice: males=7.6 years; females=6.8 years) and non-athletes [216±141 mm^2; male (n=12) and female (n=12); age=22.6±3 years][27], whereas surface area of young female basketball players (age=18.0±6.5 years; height=168±7.5 cm; weight=65.0±8.0 kg; years of practice ≥ five years; competing at the national and state level), tested by Santos et al[28], in static condition with open eyes condition, was almost the same (67.0±60.9 mm^2) as the group tested in this study.

In closed eyes condition, the measure of the surface area, although it expands to 127.8±68 mm^2 (when comparing to OE condition), remains within the standards of the French Posturology Association standard AFP 85 (newly called APE 85) (79 to 638 mm^2). The current results are still lower than those reported for handball players (239±170 mm^2) and non-athletes (299±178 mm^2)[27]. These wide disparities with non-athletes' measures agree with previous results[10,29-31], which support the conclusion that regular physical activity improves postural balance by inducing positive functional adaptations to the postural function[10,29-31].

Even though basketball and handball are both disciplines characterized by intermittent actions, differences in values could be explained by differences in players tested (gender, years of practice, etc.). Furthermore, the increased intensity and load applied to the lower limbs in basketball (total distances covered, number of sprints, changes of direction, jumps etc.)[32], a smaller court size and stricter rules compared to handball, might be responsible for the better stability of the basketball players. Also, basketball players spend a large part of their playing time with their knees bent (shuffling, blocking), lowering their center of gravity and widening their base of support, which may have contributed to improving their postural control.

When considering the Romberg's index, female basketball players have shown a quotient value (176.3±77.2%) within the standard of healthy adult (female and male) subjects, which is 249% (112 to 677)[27]. However, Romberg's value is greater than handball players (130±74%) and non-athletes (160±75%) for both sexes[27]. Furthermore, it is known that postural control is dependent on various sensory integrations; it seems that basketball players, compared to handball players and non-athletes, used more visual information in the sensory integration for their postural control[9]. It was revealed in a previous study that the demand of basketball game situations requires players to focus their gaze on the ball, the rim (height and dimension), the opponents, and team partners, explaining such a visual reliance. These findings, however, contradict the observations that motor experiences (e.g., team sports, combat sports) allow sportspeople to become less dependent on visual information for controlling their posture[33].

The current path length's results in both conditions (OE: 0.74±0.15 mm; CE: 0.82±0.2 mm) are within the standards values (the French Posturology Association standard APE 85 or formerly AFP 85). Indeed, our results are in line with the scores of male and female handball players (OE: 0.64±0.13 mm; CE: 0.66±0.18 mm) but are lower than those of non-athletes (OE: 1.01±0.4 mm; CE:

Table V. Specific isokinetic power and force at 60.s^{-1} and discrepancies between positions.

	Centers (n=10)	Forwards (n=10)	Guards (n=10)
Specific power (Watts/L)			
Quadriceps right	11.9 ± 2.4 **a****	16.1 ± 3.6	13.1 ± 2.5
Quadriceps left	10.9 ± 20.0 **a****	14.8 ± 3.2	12.4 ± 2.4
Hamstrings right	8.87 ± 2.31 **a***	12.6 ± 2.8	10.1 ± 2.3
Hamstrings left	8.67 ± 2.13 **a***	11.9 ± 3.0	10.1 ± 1.3
Specific force (N/cm^2)			
Quadriceps right	0.48 ± 0.08	0.54 ± 0.11	0.51 ± 0.08
Quadriceps left	0.31 ± 0.09	0.35 ± 0.10	0.32 ± 0.03
Hamstrings right	0.30 ± 0.06	0.35 ± 0.07	0.32 ± 0.05
Hamstrings left	0.29 ± 0.06	0.32 ± 0.07	0.32 ± 0.03

a: significantly different than forwards; b: significantly different than guards; c: significantly different than centres; *: $p<0.05$;**: $p<0.01$; ***: $p<0.001$.

1.13±0.58 mm)[27]. Furthermore, the length's values of the female basketball players tested in this study are considerably smaller than those of the female basketball players cited in Santos et al[28], tested under open eyes condition (OE: 137±71.8 mm). These results suggest that physical training could lead to a decrease in the energy expenditure in order to maintain balance. The competition level and the anthropometric differences could be at the origin of these disparities.

X means results are within norms (OE: -3.62±9.71 mm; CE: -1.43±9.99 mm) and reveal that female basketball players have symmetrical postural tone. X means values of both male and female handball players (OE: -0.73±5.64 mm; CE: 0.50±8.15 mm)[27] seemed to be largely lower than those found in the current investigation. Also, the present results indicate a greater deviation to the left side, and this inclination tends to be more pronounced in closed-eye conditions. However, the majority of the participant is right-winged (only one participant is left-winged). This left deviation could be explained by the fact that during layups, which are the most used shooting technique during games and training sessions, the supporting and propulsive leg is the left one in most cases.

Results of Y mean values of our participants (OE: -48.1±12.0 mm; CE: -45.9±12.5 mm) were in line with the French norms (OE: -1 to -57 mm;

Table VI. Correlation between balance variables and specific power and anthropometric variables.

	Body mass	Height	Lower limb length (cm)	BMI	Leg muscle volume (L)	Thigh muscle volume (L)	Mean thigh CSA (cm^2)	Maximal thigh CSA (cm^2)
Static stance								
COP surface area (CE)(mm^2)	0.09	0.24	**0.40***	-0.03	-0.14	-0.09	-0.19	-0.04
QRBG (%)	**0.38***	0.27	0.31	0.33	0.28	**0.36***	0.22	**0.41***
Path length (CE) (mm)	0.14	**0.43***	0.43	-0.12	-0.02	0.02	-0.12	0.04
Y mean (OE) (mm)	**-0.80*****	**-0.68*****	**-0.63*****	**-0.57****	**-0.53****	**-0.44***	-0.29	**-0.51****
Y mean (CE) (mm)	**-0.85*****	**-0.65*****	**-0.60*****	**-0.65*****	**-0.57****	**-0.49****	-0.32	**-0.60*****
COP velocity mean (OE) (mm.s^{-1})	**0.76*****	**0.68*****	**0.63*****	**0.53****	**0.49****	**0.40***	0.25	**0.45***
COP velocity mean (CE) (mm.s^{-1})	**0.72*****	**0.57****	**0.53*****	0.54	**0.45***	**0.40***	0.20	**0.40***
Dynamic stance antero-posterior plane								
Y mean (OE) (mm)	**-0.63*****	**-0.61*****	**-0.57****	**-0.40***	**-0.40***	**-0.39***	-0.22	**-0.43***
velocity variation (OE)	**0.63*****	**0.57****	**0.55****	**0.44***	0.10	0.20	0.06	**0.44***
Dynamic stance medio-lateral plane								
Y mean (OE)(mm)	**-0.75*****	**-0.65*****	**-0.58****	**-0.53****	**-0.51****	**-0.45***	-0.26	**-0.53****
Y mean (CE) (mm)	**-0.77*****	**-0.60*****	**-0.51****	**-0.58****	**-0.48****	**-0.40***	-0.26	**-0.55****
velocity variation (OE)	**0.76*****	**0.66*****	**0.58****	**0.52****	**0.55****	**0.49****	0.30	**0.53****
velocity variation (CE)	**0.67*****	**0.67*****	**0.50****	**0.42***	**0.42***	0.34	0.19	**0.39***

*: $p<0.05$; **: $p<0.01$; ***: $p<0.001$.

Table VII. Correlation between balance variables and power and force at 60°.s^{-1}.

	Specific Power				Specific Force			
	Quadriceps right at 60°.s^{-1}	Quadriceps left at 60°.s^{-1}	Hamstrings right at 60°.s^{-1}	Hamstrings left at 60°.s^{-1}	Quadriceps right at 60°.s^{-1}	Quadriceps left at 60°.s^{-1}	Hamstrings right at 60°.s^{-1}	Hamstrings left at 60°.s^{-1}
Static stance								
COP surface area (CE) (mm^2)	0.11	0.15	0.05	0.11	0.21	0.28	0.17	0.13
QRBG (%)	-0.05	-0.07	-0.19	-0.16	-0.01	0.78	-0.10	-0.12
Path length (CE) (mm)	0.20	0.13	0.08	0.19	0.20	0.14	0.17	0.11
Y mean (OE) (mm)	0.22	$\mathbf{0.37}^{*}$	0.35	$\mathbf{0.40}^{*}$	0.20	0.20	0.24	0.27
Y mean (CE) (mm)	0.31	$\mathbf{0.44}^{*}$	$\mathbf{0.42}^{*}$	$\mathbf{0.44}^{*}$	0.30	0.25	0.34	0.32
COP velocity mean (OE) (mm.s^{-1})	0.18	0.14	0.13	0.22	0.28	0.25	0.27	0.22
COP velocity mean (CE) (mm.s^{-1})	0.16	0.93	0.05	0.15	0.17	0.16	0.15	0.11
Dynamic stance antero-posterior plane								
Y mean (OE) (mm)	0.28	$\mathbf{0.49}^{**}$	$\mathbf{0.40}^{*}$	$\mathbf{0.41}^{*}$	0.21	0.06	0.22	0.28
velocity variation (OE)	-0.05	-0.21	-0.18	-0.27	-0.31	-0.16	-0.31	$\mathbf{-0.38}^{*}$
Dynamic stance medio-lateral plane								
Y mean (OE) (mm)	0.25	$\mathbf{0.40}^{*}$	0.32	$\mathbf{0.39}^{*}$	0.33	0.16	0.24	0.32
Y mean (CE) (mm)	0.16	-0.18	0.28	0.35	0.30	0.22	0.30	0.33
velocity variation (OE)	-0.25	0.32	-0.31	$\mathbf{-0.37}^{*}$	-0.29	-0.23	-0.23	-0.29
velocity variation (CE)	0.19	0.28	-0.27	-0.26	-0.22	-0.09	-0.16	-0.13

*: $p<0.05$; **: $p<0.01$; ***: $p<0.001$.

CE: -3 to -51 mm) investigated using the same Winposture® device. Nevertheless, basketball players tend to back-project themselves more than handball players (OE: -27.9±14.5 mm; CE: -27.1±13.3 mm) and controls (OE: -33.6±14.6 mm; CE: -30.1±12 mm)[27]. These results may be due to female basketball players' morphology having a larger pelvis with shorter hips and decreased hamstrings activation than those in men[18]. They have somewhat developed gluteal muscles, which could have affected their balance in the sagittal plane.

In this study, scores of COP velocity's were (OE: 43±13.1 mm.s^{-1}; CE: 44.5±9.6 mm.s^{-1}), while they were (OE: 18.6±13.8 mm.s^{-1}; CE: 19.4±13.5 mm.s^{-1}) for the handball group and (OE: 21.0 ± 13.2 mm.s^{-1}; CE: 21.3±12.0 mm.s^{-1}) for the non-athlete group[27]. When comparing velocity's COP values of the tested group with those (OE: 12.7 ± 2.4 mm.s^{-1}; CE: 14.4±3.2 mm.s^{-1}) of elite female basketball players with long training experience (age=20.9±2.4 years; height=182.8±7.7; weight=65.9±10.7 kg), results of the present study are much higher[21]. The increased velocity of COP displacement in the tested group (compared to other populations) indicates the greater activation of the feedforward mechanisms for the maintenance of balance[34]. Discrepancies could be due to differences in body mass, center of mass height between the tested populations, platform related variations, testing protocol, years, and practice levels.

Postural Control Comparison Among the Playing Positions and the Reasons Underlying These Differences

In static condition, results reveal that centers differed significantly from guards and forwards ($p<0.05$ and $p<0.001$, respectively) in both open and closed eyes. Indeed, the centers have a higher velocity of movement of the COP than other positions. Also, they have a larger surface area, and greater dependence on visual information (higher QRBG) than guards. Contrarily to hypotheses, our results demonstrated that under the static condition centers showed the weakest postural control. This inconsistency could be explained by the fact that during a real game situation, the static control of the standing position is executed with the centers' feet apart and knees bent, a position that is different from the evaluation position during the test. In an attempt to explain these differences between the playing positions, the relationships between the above variables and the anthropometric variables (Table VI) showed a strong negative correlation, especially with the weight (r=-0.85; p<0.001), height (r=-0.68; p<0.001), lower limb length (r=-0.63; p<0.001) as well as all other anthropometric variables, except mean thigh CSA. These strong relationships could explain the weaknesses of postural control observed in the centers group. However, postural variables seemed to be independent of isokinetic data since there were small and even no correlations with specific power and force (Table VII). At $60°\cdot s^{-1}$ (slow speed), the correlations concerned just the strength of the muscles of the non-dominant leg (quadriceps power and Y mean OE: r=0.37, p<0.05; hamstring power and Y mean CE: r=0.44; p<0.05). In agreement with our results, Katayama et al[35] have reported similar results in young adult females and indicated moderate correlations between balance and knee flexors/extensors muscles.

Postural control assessment in dynamic conditions is more discriminating than in static conditions[36]. The current findings in the two axes (namely AP and ML plane) showed that decreased discrepancies between the playing positions and centers' weakness, although diminished, persists. The nature of basketball could explain this evidence as a sport characterized by the body's dynamics in motion[32]. Furthermore, there is a large increase in the postural variables' values in the closed eyes condition in both AP and ML plane, and forwards appear to be the most dependent on the gaze to maintain balance in the dynamic condition. Female basketball players do not efficiently compensate for visual suppression because they gaze at their surroundings, the ball, opponents, and teammates.

Moreover, closed eyes and moving support in dynamic tests are two new situations unusual in basketball. However, even though in static conditions the contribution of visual cues is essential, in such dynamic conditions, proprioception inputs' contribution is fundamental[37]. It seems that the vestibular capacities of the tested group to decode new somesthetic solicitations have not been too efficient to compensate for the simple loss of visual cues, as previously shown[13].

In the anteroposterior plane, the centers remain those for which postural control is the most vulnerable (Table 3). Centers group shows a significantly higher COP displacement velocity (OE: 72.2±17.1 $mm.s^{-1}$) than forwards (p<0.05) and guards (p<0.05), and they are the ones who back-project themselves the most, which can cause a loss of balance and risk of falls. Guards showed a smaller surface area than forwards (110.0±44.2 mm^2; p<0.05) in OE condition, without significant differences with respect to centers. Also, they were more independent from visual information for maintaining their balance (720.1±306.3 mm^2 *vs.* 1,734.4±2,164 mm^2 for forwards).

In the same sense, guards showed the smallest surface area in both conditions (EO and CE) in the medio-lateral plane. Also, they differ from centers, especially concerning Y mean (OE: p<0.01; CE: p<0.05) and velocity variation (OE: p<0.01; CE: p<0.05). Moreover, the centers differ significantly from forwards in Y mean OE and velocity variation OE (p<0.001).

Results reveal a strong correlation between the tested variables (Y mean and velocity variation) and anthropometric ones in both AP and ML planes, especially concerning body mass and height, affecting the aforementioned values. Indeed, some postural variables were strongly related to some other anthropometric parameters, such as the body mass (Y mean CE in ML: -0.77, p<0.001), height (Y mean OE in ML: -0.65, p<0.001) and lower limb length (Y mean OE in ML: -0.58, p<0.01). Besides, the postural balance on the medio-lateral plane seems more sensitive to the anthropometric parameters than antero-posterior one. It has been previously suggested that postural control in the M/L plane was controlled by the hip muscles[38]. Hence, reduced strength in these muscles accompanied by a large pelvis in women[39] could explain this finding.

In contrast, postural control in the AP and ML planes has moderate or no correlations with the specific power at the speed of $60°.s^{-1}$ (Table VII). Indeed, the highest existing correlation was between the left quadriceps power, and the Y mean OE in the AP plane (r= 0.49, p<0.01). The weakness in the quadriceps and hamstrings power recorded in the centers (Table V) may be the cause of the increase of Y mean (Table III: Y mean = -57.3±15.1) in the AP plane and therefore of a larger back-projection and an altered postural control compared to other groups (significantly different from forwards and from guards; Table III: $p<0.01$).

In terms of the relationship between strength/power and postural control, some studies show that lower-extremity muscle strength/power is a determining factor in postural regulation[17,40]. In comparison, Paillard[37] has stated that an increase in muscle strength does not systematically improve postural performance. Finally, Orr[17] has suggested that the increase in lower-extremity muscle strength generates less postural balance in the bipedal condition.

Although isokinetic measurement is pertinent to assess the dynamic muscle work, it is not specific enough to evaluate functional movements generated during a real game situation, explaining the contrasting correlations between postural variables and isokinetic measures reported in the existing scholarly literature.

To our knowledge, this study is the first one to attempt to highlight the differences in postural control between the different playing positions. Understanding female basketball players' postural profiles could give coaches, trainers, and exercise scientists better working knowledge of each particular playing position.

Limitations

This study's limitations concern the number of players evaluated: a larger number could have led to significant differences between the positions, especially between guards and forwards. Moreover, the balance test was carried out barefoot while the players are used to train with running shoes, which may have influenced their balance. Further, concerning the isokinetic velocity tested, higher velocities closer to the basketball movements' velocities might have been more correlated to the equilibrium parameters.

Conclusions

The results of this investigation and the findings from the existing scholarly literature suggest that sufficient postural control is important in minimizing injury risk and optimizing performance. This study demonstrates that centers had more precarious postural balance compared to other playing positions, which was likely due to morphological factors (body mass, BMI, leg muscle volume) and poor relative quadriceps and hamstrings' power. Therefore, coaches and strength and conditioning specialists should place special focus on lower body muscular power in centers, and generally taller basketball players.

Conflict of Interest

The authors declare no conflict of interest.

Informed Consent

All the participants signed their informed consent following the Declaration of Helsinki.

Ethics Approval

All procedures were conducted following the latest version of the Declaration of Helsinki and were approved by the Institutional Review Committee for the ethical use of human subjects of the University of Manouba (Research Unit (UR17JS01) «Sport Performance, Health & Society», Higher Institute of Sport and Physical Education of Ksar Saîd, University of "La Manouba", Tunis, Tunisia, according to current national laws, regulations, and procedures.

Acknowledgments

The authors thank the "Ministry of Higher Education and Scientific Research, Tunis, Tunisia" for financial support. The authors acknowledge Prof. Hajer Rahali-Khachlouf (Department of Physical and Rehabilitation Medicine, Military Tunis Hospital, Tunisia) for precious experimental help.

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