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Reference Values of Physical Performances in Young Female Basketball Players in Palestine: Effect of Maturity Status

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SUMMARY

Background. Limited research has investigated the relationship between anthropometric profile, biological maturity, and specific physical performances in female basketball players. Therefore, the aim of this study was to assess the influence of chronological age and maturity status on anthropometric variables and physical performances.

Methods. One-hundred-fifty female basketball-players aged between 12-16 years participated in this study. Anthropometric measurement and physical performances such as sprinting performances, jumping performances, 1-kg throw, agility tests and 20-m run test were recorded. Players were aligned by age categories (U-12 to U-16) and 5 maturational groups according to their maturity offset from -1.5 to 2.5 years from Peak-Height-Velocity (PHV). Full model and multiple regression were used to identify which anthropometric parameters significantly contributed to performance variables.

Results. Anthropometric variables demonstrated early development of lower limbs length, which led to significant improvements in jumping performance. Increases in body composition and fat mass significantly influenced the physical performances ($p < 0.05$) such as in endurance performance were observed around-after the PHV. A positive correlation ($p < 0.05$) was observed between anthropometric variables and age, which proved to be the best predictor of all physical performance.

Conclusions. This study provides novel normative data on specific physical performances in female Palestinian basketball players aged 12 to 16 years.

KEY WORDS

Maturity; peak height velocity; basketball; anthropometry; physical performances; prediction.

INTRODUCTION

Performance in basketball relies on a complex combination of high physical fitness (1-5), technical and tactical skills. Game performance and physical fitness levels (6) may vary according to multiple factors including age (7), level of performance, gender, and experience (8). However, the primary need to analyze appropriate anthropometric variables such as body composition, especially body height and body mass is fundamental. Additionally somatotype, body proportions, and conformation are considered as advantages in various aspects of game (9). Prior research and findings have strongly supported the necessity of using chronological age and predicted age at peak height velocity (PHV) to assess physical performances to optimize the identification of players (10). To the best of our knowledge, scientific literature on women's basketball remains limited (11) and there is a paucity of research focusing on characteristics that lead to success in basketball, especially in females (12). While previous studies have explored the anthropometry and fitness levels of basketball players and their relationship with game performance, most research has predominantly focused on males, leaving a gap in understanding relevant predictors for female basketball players. The impact maturity status considered as an optimal parameter for success in sport (10). It is important to known that during the growth process the interaction between physical performance and anthropometric variables is highly complex (12) especially body mass and height, with sport-specific motor abilities and biological age (13) are key components of sporting success. When assessing the adolescent athletes' performance, the impact of maturation must be accounted for, since the development of stature and body mass in youth players follows a characteristic pattern. Young players who mature early often outperform players of the same chronological age who mature later in muscle strength and endurance (14). There is a tendency for international studies to examine the impact of biological maturity on the skill and physical performance of youth basketball players. Consequently, more research is required for a better understanding of maturation effect on each age category. Females tend to reach their PHV at approximately 12 years old, and have shorter growth period, whereas males reach their PHV at 14 years old, with greater velocity curves for peak height and body mass (15). Nevertheless, little is known about the effect of biological maturation on anthropometric characteristics and physical parameters in female Palestinian players which are important for basketball performances. Specifically, relationships between different maturation parameters (biological maturation and physical performances) were identified at the U-14 boys' national level in basketball (16). However, there is a scarcity of studies in the Arab world, particularly in Palestine. The significance of this study lies in its novelty and innovation, as it is the first of its kind in Palestine, focused on examining the development of anthropometric and physical measurements in female basketball players. Moreover, establishing reference values for physical performances according to maturity groups is crucial. These reference values can assist coaches, fitness coaches, and enthusiasts in selecting talented players and developing effective training programs. Understanding the variations in growth within an age group contributes to recognizing differences in the physical development of young female players.

Therefore, the aims of this study were: 1) to analyze the development of anthropometric parameters and physical performances by age in female basketball players in Palestine aged 12 to 16 years; 2) to examine the effect of maturity status on anthropometric parameters and physical performances; and 3) to establish specific reference values for physical performances in female Palestinian basketball players aged 12 to 16 years.

MATERIALS AND METHODS

Study population

One-hundred and fifty female basketball players, aged from 12 to 16 years, volunteered to participate in this study. The players were from different clubs concerned with the basketball game for juniors in different regions of Palestine (north, middle, and south). The experimental procedure took place during July and August. All participants were free from injury, and they were practicing basketball three times a week with an average of 70 minutes per training session. Assessments were conducted over four days for each region.

Experimental design

On the first day, the anthropometric measurement was taken, followed by physical measurements (jumping test, agility, and speed tests) on the second and third day. Finally, the cardiorespiratory endurance test was administered on the fourth day. The participants and their clubs were informed about the nature of the study, and their respective clubs endorsed the young basketball players in the evaluation as part of their strategic plans to utilize the results of the study for player development. Legal signatures were obtained on the consent form of the players and their parents before starting data collection, and approval was obtained from the Palestinian Ministry of Education. The study protocol was approved by the local Ethical Committee of the Faculty of Medicine "Ibn El Jazzar" of Sousse (Tunisia) (N. 213-2023 – date of approval: November 13, 2023).

Anthropometric measurement

All anthropometric measurements were taken by a specialist in the field. Standing height and sitting were measured using a portable stadiometer (Seca 213 portable measuring rod, USA). Arm length, wingspan and length of lower limb were measured by an inextensible plastic tape. Weight, body mass index (BMI), body fat, percentage of fat and fat-free mass were measured (17) with a Human Body Element Analyzer (Detect Elements in the Body MSLCA05). All measurements were taken in accordance with the guidelines, outlined by the international society for the advancement of Kinanthropometry (ISAK) by the same researcher (18).

Maturity status

The determination of maturity status utilized the predictive equation for girls developed by researchers (19). This method was approved for predicting years from PHV, serving as an indicator of maturity offset through anthropometric variables. The predictive equation is a follow: *Maturity Offset = -16.364 + (0.0002309 × Length of lower limbs and Sitting height interaction) + (0.006277 × Age and Sitting height interaction) + (0.179 × Length of lower limbs by Height ratio) + (0.0009428 × Age and Weight interaction)*. The methodology entails forecasting the temporal proximity to peak height velocity (PHV) concerning chronological age through the integration of anthropometric variables (height, sitting height, weight, and lower limb length) into a regression equation, as delineated by the researchers (19). The calculation of chronological age was obtained by deducting the birth date from the testing date, producing an approximate value with an accuracy of 0.1 years. Negative values, signifying time preceding PHV, were added to chronological age, whereas positive values, indicating time following PHV, were subtracted. The maturity status and classification of groups were according to the study of another set of researchers (20). Each player was categorized into 1 of 6 maturity-offset groups (-2.5 YPHV [≤ -2.0], -1.5 YPHV [-1.99 to -1.0], -0.5 YPHV [-0.99 to 0.0], 0.5 YPHV [0.01 to 1.0], 1.5 YPHV [1.01 to 2.0], and 2.5 YPHV [≥ 2.01]).

Physical performances

Maximal sprint speed was evaluated with a five speed tests (5 m; 10 m; 20 m; 20 m with dribbling; 5 ×10 m). The photocell gates (Witty system, photocells witty gate, Microgate, Bolzano, Italy) were positioned at the starting line and at 10, 20 and 30 (m) and were placed 0.7 (m) above the ground. The participants performed the maximum speed test 5 m, 10 m and 20 m (without a ball), then the 20 m test (with dribbling). Participants then performed the (5 × 10 m) shuttle run, and the time was recorded for all tests.

The 10 × 5 m Shuttle test required players to sprint between two marked lines, covering the specified distance by running to the opposite marked line, turning, and returning to the starting line. The test commenced from a stationary position behind the starting line, with one foot raised to the line in a two-point stance. Both feet of the players were required to fully cross the marked lines at each turn. The total time taken to complete the entire distance was measured using a gate of photocell. Each participant was granted two attempts, and the best recorded time was noted (21). Agility was evaluated using Illinois Test following the protocol of Peqini and Kadija (22). The length of the course is 10 meters, and the width (distance between the start and finish points) is 5 meters. Four cones are used to mark the start, finish and the two turning points. Another four cones are placed down the center an equal distance apart. Each cone in the center is spaced 3.3 meters apart.

The Sargent jump (23) is a countermovement jump performed from a static position, incorporating an arm swing to propel the body upward and generate additional thrust (24). The utilization of upper limbs is deemed more natural for basketball players, as it mimics various movements encountered in basketball scenarios (25).

The five-jump test (5JT) involves executing five consecutive strides with feet positioned together at both the beginning and end of the jumps. Starting from the initial joined feet position, participants are prohibited from executing any backward steps with either foot; instead, they are required to leap directly forward with a leg of their choice. After completing the first four strides, involving alternate left and right foot movements for two repetitions, the participant performs the last stride, concluding the test with joined feet once again. In cases where the player falls back upon completing the final stride, the test is repeated. Measurement of 5JT performance is determined using a tape measure, extending from the front edge of the players' feet at the starting position to the rear edge of the feet at the final position. The individual assessing the landing focuses on the last stride of the player to accurately identify the final foot placement, as players may not always maintain an upright position upon landing. The starting position is consistently established at a fixed point (26). 5JT performance was expressed relatively to leg length (5JT-relative) (27).

To assess the muscular strength of the upper limbs, the Medical Ball Throwing Test was performed following the protocol of Hermassi *et al.* (12). The subjects were instructed to carry out a standardized warm-up before the medicine ball throws using a 1-kg rubber ball. After familiarization with the task and a brief description of the optimal technique, seated players held the ball with both hands and then forcefully pushed it from the chest. The distance from the sitting line to the ball's landing spot was recorded as the test score to the nearest 1 cm. Three trials were performed, each separated by 60 seconds of rest, and the best score from each participant was retained for the analysis.

The cardiorespiratory endurance test was the 20-meter shuttle run test (20-m SRT) whose procedure adhered to established protocols as outlined in the study by Ramsbottom *et al.* (28). In brief, test participants engaged in the assessment collectively, and organized in groups of five. Their task involved shuttling between two lines situated 20 meters apart, synchronizing their movement with audio cues emanating from a pre-recorded CD. Starting at a speed of 8.5 km/h[1] in the initial minute, the velocity incremented by 0.5 km/h[1] every subsequent minute. The test was terminated either when the participant voluntarily stopped or failed to maintain the prescribed pace for two consecutive signals, as determined by umpire judgment.

Robust verbal encouragement was provided throughout the test. The recorded data included the last stage reached, with the estimation of VO_{2max}, carried out utilizing the table provided by Ramsbottom *et al.* (28). The Medicine Ball Throwing test (29) was adapted from the Seated Shot-Put Throw (30), utilizing the same procedure but replacing the shot put with a 1-kg medicine ball.

Statistical analysis

We conducted descriptive statistics analysis for anthropometrics and physical performances using SPSS for Windows (version 26.0). The normality of all variables was assessed with Jarque-Bera tests. Arithmetic means and standard deviations (SD) were calculated for each variable and presented. To assess differences between age groups and maturity groups, we employed one-way ANOVA followed by *post-hoc* analysis (Bonferroni). The threshold for statistical significance was set at ($p < 0.05$). Effect size (ES) was calculated using the method proposed by Cohen (2013) considering that the use of the P-value alone provides no information about the size or direction of the effect or the range of feasible values (31). ES lower than 0.35, between 0.35 and 0.8, between 0.8 and 1.5 and equal to or higher than 1.5 were considered trivial, small, moderate, and large, respectively. A multiple linear regression analysis was employed to identify the optimal predictors for both the dependent variables (physical performances) and the independent variable (anthropometric measures).

RESULTS

The data in **table I** highlighted participant anthropometric characteristics (mean ± SD (ES)) of youth female Palestinian basketball players according to age classes. Negative values of YPHV were observed in the U-12 age group, while positive values ($-1 < YPHV < 1$) indicated players in the maturing phase at U-13. Starting from U-14, we identified players with ($YPHV > 1$), indicating late maturation. When considering chronological age, significant differences ($p < 0.05$) were found across U-12 (ES 12-13 = 1.5; Large), U-13 (ES 13-14 = 0.81; Moderate), and U-14 for YPHV. These age groups represent a period of PHV and anthropometric changes for youth Palestinian female basketball players. Changes were generally observed in U-12, U-13, and U-14 age classes, with significant differences ($p < 0.05$), except for BMI, body fat, and percentage of fat. Regarding weight, significant differences ($p < 0.05$) were found between U-12 and the subsequent U-13 and U-14 age groups for Weight, Height, Sitting height, Length of the lower limb, Arm-span, Wingspan, and Fat-free mass. Means (± SD) and effect sizes (ES) of physical performances among youth female Palestinian basketball players in different age groups are presented in **table II**. The data indicate significant differences ($p < 0.05$) among the 12-13-14 age classes. However, the development of physical variables was not irregular between consecutive age groups. Physical performance increases and significant differences ($p < 0.05$) were observed for the T10m and T20m dribbling only, between 13 age classes and category following with ES respectively (-0.83; Moderate, 0.64; Small). No significant differences were observed for T5 and T20m across all categories. An increase in physical performances and significant differences ($p < 0.05$) were observed only for T10m and T20m dribbling between the 13-age class and the subsequent category, with ES respectively (-0.83; Moderate, 0.64; Small). No significant differences were observed for T5m and T20m in all categories. As the horizontal test (5JT), an increase in performances was noted between age groups, with a significant difference ($p < 0.05$) occurring between U-12 and the subsequent age group 12-13, having an ES (-1.91; Large). Improvements in Illinois agility test performance and the 10 × 5 m shuttle run was recorded, although no significant differences were found.

Finally, for the aerobic capacity test (20-m SRT) and upper limb strength tests (1-kg Medicine Ball Throw), significant differences ($p < 0.05$) were observed between the 12-13 age group and the subsequent category, with respective effect sizes of 1 (Moderate), 0.85 (Moderate)

Table I. Anthropometric characteristics of youth female Palestinian basketball players according to the age group.

Variables	U-12 (ES 12-13) (n = 30)	U-13 (ES 13-14) (n = 30)	U-14 (ES 14-15) (n = 30)	U-15 (ES 15-16) (n = 30)	U-16 (n = 30)
YPHV (Years)	-0.71 ± 0.60 (2.25)*	0.70 ± 0.65 (2.83)*	2.15 ± 0.38 (1.32)*	2.84 ± 0.66 (0.90)*	3.40 ± 0.59
Weight (kg)	46.30 ± 9.62 (0.84)*	52.07 ± 4.05 (1.04)*	57.40 ± 6.25 (0.27)	59.03 ± 5.85 (-0.25)	57.43 ± 6.78
Height (cm)	153.50 ± 6.46 (1.58)*	162.07 ± 4.39 (0.81)*	165.43 ± 3.95 (-0.04)	165.27 ± 4.23 (0.24)	166.37 ± 5.07
Sitting height (cm)	67.50 ± 4.76 (1.14)*	73.43 ± 5.62 (1.73)*	81.70 ± 3.91 (0.14)	82.27 ± 4.31 (0.25)	83.27 ± 3.71
LLL (cm)	81.73 ± 3.75 (1.90)*	90.33 ± 5.30 (0.89)*	94.20 ± 3.38 (-0.30)	93.03 ± 4.41 (0.35)	94.43 ± 3.59
Arm span (cm)	62.83 ± 3.38 (1.53)*	67.40 ± 2.59 (0.00)	67.40 ± 2.51 (0.37)	68.57 ± 3.74 (-0.05)	68.40 ± 3.06
Wingspan (cm)	156.87 ± 6.75 (1.72)*	166.70 ± 4.71 (0.38)	168.50 ± 4.77 (0.19)	169.47 ± 5.46 (0.13)	170.20 ± 5.89
BMI (kg/m²)	19.71 ± 4.08 (0.05)	19.85 ± 1.74 (0.61)	20.95 ± 1.86 (0.35)	21.62 ± 1.98 (-0.42)	20.74 ± 2.23
Body fat (kg)	7.63 ± 4.06 (0.42)	8.90 ± 2.09 (0.47)	10.53 ± 4.75 (0.13)	11.16 ± 5.32 (-0.06)	10.88 ± 4.82
Percentage of fat (%)	15.70 ± 4.53 (0.26)	16.61 ± 2.46 (0.45)	18.41 ± 5.53 (0.05)	18.68 ± 5.62 (0.04)	18.92 ± 5.79
Fat free mass (kg)	20.23 ± 3.66 (0.67)*	22.18 ± 2.15 (0.78)*	24.48 ± 3.79 (0.52)*	26.54 ± 4.16 (-0.91)*	23.77 ± 1.89

All variables are expressed as mean ± SD; ES: Effect Size; YPHV: Years from peak height velocity; LLL: Length of lower limbs; BMI: Body mass index. Significant differences ($p < 0.05$) between age category *vs* following age category are denoted as "*".

Table II. Physical performances of youth female Palestinian basketball players from different age group.

Variables	U-12 (ES 12-13) (n = 30)	U-13 (ES 13-14) (n = 30)	U-14 (ES 14-15) (n = 30)	U-15 (ES 15-16) (n = 30)	U-16 (n = 30)
T_{5m} (s)	1.99 ± 0.44 (-0.39)	1.85 ± 0.31 (-0.51)	1.72 ± 0.18 (-0.34)	1.65 ± 0.25 (0.01)	1.65 ± 0.26
T_{10m} (s)	2.98 ± 0.44 (-0.41)	2.82 ± 0.35 (-0.83)*	2.5 ± 0.42 (-0.17)	2.43 ± 0.42 (0.24)	2.53 ± 0.42
T_{20m}(s)	4.61 ± 0.73 (-0.27)	4.45 ± 0.49 (-0.64)	4.17 ± 0.38 (-0.08)	4.14 ± 0.41 (-0.08)	4.11 ± 0.12
T_{20m} dribbling (s)	5.31 ± 0.86 (-0.26)	5.14 ± 0.51 (-0.26)*	4.99 ± 0.63 (-0.51)	4.67 ± 0.63 (-0.49)	4.41 ± 0.43
10 × 5m shuttle run (s)	19.51 ± 1.88 (-0.05)	19.39 ± 1.47 (0.04)	19.46 ± 1.81 (-0.48)	18.62 ± 1.75 (0.00)	18.61 ± 1.55
Illinois test (s)	20.92 ± 1.58 (-0.27)	20.42 ± 1.54 (-0.15)	20.19 ± 1.51 (-0.13)	19.98 ± 1.76 (-0.16)	19.72 ± 1.56
20m SRT (mL× kg·min^{-1})	31.94 ± 3.46 (1.01)*	36.08 ± 4.83 (0.85)*	40.63 ± 5.88 (0.06)	40.95 ± 4.52 (0.14)	41.6 ± 4.84
Sargent test (cm)	35.07 ± 4.89 (0.04)	35.27 ± 6.21 (1.02)*	40.53 ± 4.13 (0.37)	42.07 ± 4.08 (0.09)*	46.73 ± 6.27
5jt (m)	15.32 ± 1.52 (1.91)*	17.77 ± 1.05 (0.35)	18.12 ± 0.97 (0.02)	18.12 ± 0.86 (-0.04)	18.09 ± 0.83
5jt Relative	0.23 ± 0.03 (0.48)*	0.24 ± 0.02 (-1.09)*	0.22 ± 0.01 (-0.08)	0.22 ± 0.01 (-0.27)	0.22 ± 0.01
1-kg throwing (m)	5.41 ± 0.71 (1.01)*	6.22 ± 0.88 (0.84)*	7.03 ± 1.01 (0.69)*	7.67 ± 0.94 (0.61)*	8.17 ± 0.69*

All variables was expressed as mean ± SD; ES: Effect Size; T_{5m}: time 5-m sprint; T_{10m}: time 10-m sprint; T_{20m}: time 20-m sprint; T_{20m} dribbling: Time dribbling with ball; 10 × 5m shuttle run: 10 repetitions of 5m shuttle run; 20m SRT: 20-meter Shuttle run; 5jt: Five jump test; 5jt Relative: five jump test relative 1-kg throwing: throwing 1-kg medicine ball. Significant differences (p <0 .05) between age category *vs* following age category are denoted as "*".

Table III. Correlation coefficients between anthropometric variables and age.

Variables	Age
Body Weight (kg)	0.512*
Body Height (cm)	0.597*
Sitting height (cm)	0.753*
Length of lower limbs (cm)	0.642*
Arm span (cm)	0.467*
Wingspan (cm)	0.571*
BMI (kg/m²)	0.212*
Body fat (kg)	0.276*
Percentage of fat (%)	0.240*
Fat free mass (kg)	0.423*

BMI: Body mass index; *$p < 0.01$.

for 20-m SRT and 1.01 (Moderate) and 0.84 (Moderate) for the 1-kg throwing test. The correlation coefficients between anthropometric characteristics and age ($p < 0.05$) are presented in **table III**. All anthropometric variables show significant and positive correlation with chronological age.

The correlation coefficients between physical parameters and age ($p < 0.05$) are presented in **table IV**. Performances improve with age and significant correlations were found for all physical performances. Anthropometric data (mean ± SD (ES)) of young female Palestinian basketball players according to maturity status are presented in **table V**. Major anthropometric significant changes ($p < 0.05$) were observed from (-0.5 to 1.5 maturity group). Significant differences ($p < 0.05$) were found for YPHV between maturity groups (-1.5, -0.5, 0.5, 1.5 and 2.5) and ES was recorded respectively (3.09; Large, 3.39; Large, 3.07; Large, 2.88; Large). For weight and height, a significant difference ($p < 0.05$) was found only between the 0.5 maturity group and the subsequent group. Regarding sitting height, a significant difference ($p < 0.05$) was recorded between maturity statuses, with the ES recorded as (0.02, Trivial; 1.01, Moderate; 1.31, Large; 0.88, Moderate), respectively. **Table VI** present the Mean ± SD (ES) of physical performances according to the maturity status of young female Palestinian basketball players. Significant differences ($p < 0.05$) were identified in sprinting performances between the 1.5 and 2.5 maturity groups. The relative 5JT test and 5JT demonstrated an early significant difference from -1.5 and -0.5 maturity groups, respectively. Regarding the 20 m SRT, significant differences were observed around and after PHV from 0.5 maturity group. **Table VII** presents the full model of

Table IV. Correlation coefficients between performance variables and age.

Variables	Age
T_{5m} (s)	-0.378*
T_{10m} (s)	-0.343*
T_{20m}(s)	-0.359*
T_{20m} dribbling (s)	-0.457*
10 × 5m shuttle run (s)	-0.331*
Illinois test (s)	-0.253*
20m SRT (mL·kg·min^{-1})	0.572*
Sargent test (cm)	0.628*
5jt (m)	0.551*
5jt Relative	-0.293*

T5m: time 5-m sprint; T_{10m}: time 10-m sprint; T_{20m}: time 20-m sprint; T_{20m} dribbling: Time dribbling with ball; 10 × 5m shuttle run: 10 repetitions of 5m shuttle run; 20m SRT: 20-meter Shuttle run; 5jt: Five jump test; 5jt Relative: five jump test relative 1-kg throwing: throwing 1-kg medicine ball; *p < 0.01.

Table V. Descriptive statistics of anthropometric variables of youth female Palestinian basketball players according to maturity status.

Variables	-1.5 ES (-1.5 *vs* -0.5) (n = 11)	-0.5 ES (-0.5 *vs* 0.5) (n = 21)	0.5 ES (0.5 *vs* 1.5) (n = 15)	1.5 ES (1.5 *vs* 2.5) (n = 25)	2.5 (n = 78)
YPHV (years)	-1.28 ± 0.25 (3.09)*	-0.49 ± 0.26 (3.39)*	0.51 ± 0.33 (3.07)*	1.52 ± 0.32 (2.88)*	2.95 ± 0.68
Body Weight (kg)	50.27 ± 11.88 (-0.13)	45.81 ± 7.49 (0.49)	49.47 ± 5.44 (1.04)*	54.84 ± 5.47 (0.51)	58.19 ± 6.28
Body Height (cm)	155.73 ± 6.37 (0.81)	154.86 ± 6.91 (0.96)	158.27 ± 6.88 (2.28)*	163.84 ± 3.83 (1.38)	165.95 ± 4.43
Sitting height (cm)	64.55 ± 3.88 (0.22)*	67.86 ± 4.44 (1.01)*	71.81 ± 3.76 (1.31)*	78.64 ± 2.23 (0.19)*	82.91 ± 3.94
LLL (cm)	81.82 ± 4.12 (-0.02)	82.67 ± 4.19 (0.76)*	87.33 ± 5.01 (0.62)*	93.28 ± 4.09 (0.14)	94.03 ± 3.88
Arm span (cm)	63.45 ± 3.53 (-0.08)	63.38 ± 3.38 (0.79)*	66 ± 3.53 (0.81)	67.84 ± 2.44 (0.29)	68.24 ± 3.25
Wingspan (cm)	158.64 ± 6.96 (-0.46)	158.05 ± 7.06 (0.57)*	163.62 ± 7.08 (0.98)	168.2 ± 4.27 (0.57)	169.6 ± 5.49
BMI (kg/m²)	20.73 ± 4.65 (-0.41)	19.16 ± 3.27 (-0.23)	19.81 ± 2.38 (0.29)	20.43 ± 1.93 (0.35)	21.12 ± 2.07
Body fat (kg)	9.51 ± 5.83 (-0.52)	7.35 ± 2.51 (0.18)	7.77 ± 2.05 (0.54)	9.17 ± 3.14 (0.48)*	11.13 ± 5.01
Percentage of fat (%)	17.53 ± 6.42 (0.48)	15.35 ± 2.61 (-0.01)	15.37 ± 2.46 (0.52)	17.03 ± 3.97 (0.41)	18.95 ± 5.63
Fat free mass (kg)	21.46 ± 3.66 (0.34)	20.25 ± 3.54 (0.42)	21.53 ± 2.48 (0.55)	23.01 ± 2.91 (0.63)*	25.08 ± 3.65

Data expressed ad mean ± SD; ES: Effect Size; YPHV: Years from peak height velocity; LLL: Length of lower limbs; BMI: Body mass index. Significant differences ($p < 0.05$) between maturity category *vs* following maturity category are denoted as "*".

Table VI. Descriptive statistics of anthropometric variables of youth female Palestinian basketball players according to maturity status.

Variables	-1.5 ES (-1.5 *vs* -0.5) (n = 11)	-0.5 ES (-0.5 *vs* 0.5) (n = 21)	0.5 ES (0.5 *vs* 1.5) (n = 15)	1.5 ES (1.5 *vs* 2.5) (n = 25)	2.5 (n = 78)
T_{5m} (s)	1.93 ± 0.37 (-0.17)	1.97 ± 0.45 (-0.13)	1.92 ± 0.43 (-0.33)	1.81 ± 0.21(-0.67)*	1.66 ± 0.24
T_{10m} (s)	2.92 ± 0.49 (0.02)	2.91 ± 0.35 (0.03)	2.93 ± 0.41 (-0.54)	2.72 ± 0.43 (-0.05)*	2.48 ± 0.43
T_{20m}(s)	4.58 ± 0.53 (-0.23)	4.44 ± 0.67 (0.31)	4.65 ± 0.70 (0.43)	4.38 ± 0.52 (-0.6)*	4.12 ± 0.35
T_{20m} dribbling (s)	5.24 ± 0.70 (-0.03)	5.22 ± 0.86 (0.33)	5.45 ± 0.56 (-0.69)*	5.03 ± 0.64 (-0.69)*	4.62 ± 0.56
10 × 5m shuttle run (s)	19.73 ± 2.35 (-0.09)	19.61 ± 1.48 (0.11)	19.76 ± 1.11 (-0.07)	19.65 ± 1.91 (0.51)*	18.75 ± 1.66
Illinois test (s)	21.11 ± 1.7 (-0.35)	20.55 ± 1.43 (0.19)	20.85 ± 1.63 (-0.35)	20.29 ± 1.52 (0.24)	19.91 ± 1.64
20m SRT ($mL{\cdot}kg{\cdot}min^{-1}$)	32.24 ± 3.95 (0.09)	32.57 ± 3.73 (0.49)	34.71 ± 4.98 (0.71)*	38.4 ± 5.36 (0.55)*	41.24 ± 5.01
Sargent test (cm)	36.27 ± 5.24 (-0.57)	33.19 ± 5.51(0.52)	35.93 ± 5.13 (0.61)*	39.28 ± 5.86 (0.68)*	43.24 ± 5.76
5jt (m)	16.15 ± 1.03 (-0.38)	15.62 ± 1.77 (0.86)*	17.24 ± 2.01 (0.35)	17.78 ± 1.07 (0.36)	18.13 ± 0.88
5jt Relative	0.25 ± 0.03 (-0.67)*	0.23 ± 0.03 (0.30)	0.24 ± 0.03(-0.69)*	0.23 ± 0.01 (-0.58)	0.22 ± 0.01
1-kg throwing (m)	5.17 ± 0.73 (0.76)	5.79 ± 0.92 (0.08)	5.85 ± 0.72 (0.91)*	6.68 ± 1.01 (1.01)*	7.69 ± 0.99

Data are expressed as mean ± SD; ES: Effect Size; YPHV: Years from peak height velocity; LLL: Length of lower limbs; BMI: Body mass index. Significant differences ($p < 0.05$) between maturity category *vs* following maturity category are denoted as "*".

Table VII. Full-model multiple regression predicting physical performance variables.

Variables	Constant	Age	Body Weight (kg)	Stature (cm)	Sitting height (cm)	Length of lower limbs (cm)	Arm span (cm)	Wingspan (cm)	BMI (kg/m^2)	Body fat (kg)	Percentage of fat (%)	Fat free mass (kg)	R-deux	See	P-value
T_{5m} (s)	3.409	-0.333	0.238	0.144	-0.109	0.256	-0.531	-0.090	0.042	-0.291	0.259	0.007	0.176	0.30696	< 0.05
T_{10m} (s)	6.480	-0.343	-0.181	0.147	-0.160	0.116	-0.085	0.258	-0.213	-0.347	0.322	-0.071	0.188	0.42727	< 0.05
T_{20m}(s)	5.468	-0.294	0.051	0.095	-0.020	0.045	-0.118	-0.201	0.285	-0.361	0.296	-0.090	0.159	0.49616	< 0.05
T_{20m} dribbling (s)	-1.003	-0.424	0.791	0.163	-0.030	0.364	-0.608	-1.340	1.016	-0.103	0.099	0.063	0.249	0.62931	< 0.05
10×5m shuttle run (s)	40.343	-0.269	-0.100	0.112	-0.078	0.278	-0.507	0.328	-0.424	-0.124	0.302	0.158	0.016	1.70693	< 0.05
Illinois test (s)	53.119	-0.318	-0.419	0.296	-0.194	0.424	-0.672	1.129	-0.993	-0.013	0.113	0.041	0.117	1.58608	< 0.05
20m SRT ($mL{\cdot}kg{\cdot}min^{-1}$)	43.310	0.357	-0.598	0.098	0.178	-0.126	0.374	0.601	-0.462	0.298	-0.328	0.060	0.382	4.89729	< 0.05
Sargent test (cm)	81.904	0.599	-0.447	0.095	-0.138	0.063	-0.062	0.916	-0.798	0.153	-0.111	0.024	0.409	5.40662	< 0.05
5jt (m)	-56.589	0.187	1.443	-0.127	0.399	-0.105	0.420	-2.585	2.286	0.184	-0.292	-0.016	0.576	1.02939	< 0.05
5jt Relative	-0.546	0.226	1.373	-1.287	0.361	-0.149	0.424	-2.348	2.117	0.187	-0.288	-0.024	0.596	0.01479	< 0.05
1-kg throwing (m)	5.692	0.689	-0.539	0.019	-0.019	-0.184	0.454	0.675	-0.492	0.110	-0.245	0.030	0.607	0.85276	< 0.05

BMI: Body mass index; T_{5m}: time 5-m sprint; T_{10m}: time 10-m sprint; T_{20m}: time 20-m sprint; T_{20m} dribbling: Time dribbling with ball; 10 × 5m shuttle run: 10 receptions of 5m shuttle run; 20m SRT: 20-meter Shuttle run; test 5jt: Five jump test; 1-Kg throwing: throwing 1 kg medicine; See: Standard Error of estimation. Function: Performance = constant + (age coefficient × age) + (weight coefficient × weight) + (height coefficient × height) + (sitting height coefficient × sitting height) + (Length of lower limbs coefficient × Length of lower limbs) + (Arm span coefficient × Arm span) + (Wingspan coefficient × Wingspan) + (BMI coefficient × BMI) + (Body fat mass coefficient × Body fat) + (percentage of fat coefficient × percentage of fat) + (Fat free mass coefficient × fat free mass).

Table VIII. Regression equations predicting physical performances (dependent variables) and anthropometric variables (independent variables).

Variables	Constant	Age (y)	Sitting height (cm)	Length lower limb (cm)	Wingspan (cm)	BMI (kg/m²)	Percentage of fat (%)	R-deux	See	P-value
T_{5m} (s)	3.002	-0.384	-	-	-	-	-	0.147	0.30159	< 0.05
T_{10m} (s)	4.453	-0.399	-	-	-	-	-	0.159	0.41985	< 0.05
T_{20m} (s)	6.145	-0.360	-	-	-	-	-	0.129	0.48742	< 0.05
T_{20m} dribbling (s)	8.080	-0.461	-	-	-	-	-	0.212	0.62217	< 0.05
10 × 5m shuttle run (s)	25.100	-0.330	-	-	-	-	-	0.109	1.69556	< 0.05
Illinois test (s)	24.225	-0.248	-	0.218	-	-	-	0.062	1.57922	< 0.05
20m SRT (mL·kg·min⁻¹)	-6.337	0.433	-	-	-	-	-	0.356	4.84546	< 0.05
Sargent test (cm)	-2.253	0.631	-	-	-	-	-	0.399	5.26801	< 0.05
5jt (m)	-1.781	0.165	-	0.391	0.238	-	-	0.513	1.07263	< 0.05
5jt Relative	0.151	0.252	-1.315	0.396	0.328	0.199	-0.127	0.566	0.01506	< 0.05
1-kg throwing (m)	-2.931	0.761	-	-	-	-	-	0.578	0.85241	< 0.05

T_{5m}: time 5-m sprint; T_{10m}: time 10-m sprint; T_{20m}: time 20-m sprint; T_{20m} dribbling: time dribbling with ball; 10 × 5m shuttle run: 10 receptions of 5m shuttle run; 20m SRT: 20-meter Shuttle run; test 5jt: Five jump test; 1-Kg throwing: throwing 1 kg medicine; See: Standard Error of estimation.Function: Performance = constant + (age coefficient × age) + (sitting height coefficient × sitting height) + (Length of lower limbs coefficient × Length of lower limbs) + (Wingspan coefficient × Wingspan) + (BMI coefficient × BMI) + (Body fat mass coefficient × Body fat) + (percentage of fat coefficient × percentage of fat) + (Fat free mass coefficient × fat free mass).

multiple regression examining the relative contribution of each independent variable to each regression model. The final model of the multiple regression equations predicting physical performances in youth female Palestinian basketball players presented in **table VIII**, indicates that age is the best predictor of sprint performances (T5m, T10m, T20m), T20m dribbling, 10 × 5 m shuttle run, Sargent test, 20-m SRT and 1-kg Medicine Ball Throw. For the Illinois agility test, the predictors were age and lower limb length. Then, the predictors of the 5JT (5-jump test) performances were age, lower limb length, and wingspan. Finally, the best predictors of the relative 5JT were age, sitting height, length of the lower limb, wingspan, BMI, and fat mass.

DISCUSSION

The study aimed to analyze the development of anthropometric and physical performance parameters of female youth basketball players based on chronological age and maturity status and to establish reference values for physical performances among female basketball players aged 12 to 16 years. The main findings revealed that anthropometric measurements, particularly lower limb length showed early development, resulting in notable improvements in vertical jump performance. Developments in body composition, especially fat mass, may influence various physical performances for female basketball players, particularly in agility and sprint tests. Increases in intermittent endurance performance were observed around the time of PHV. This study provides novel normative data on specific physical performances in female Palestinian basketball players aged 12 to 16 years. Anthropometric variables such as weight, height, sitting height, arm span, wingspan, and fat-free mass increased with age and maturity groups. Significant differences and changes were generally observed in the (U12-U13 and U14) age classes and (-0.5 and 1.5) maturity groups. Morphological changes were noted around the PHV between the ages of 13 and 14, which is consistent with the findings of Philippaerts *et al*. (32). The study indicated that the average age associated with PHV is 13.8 ± 0.8 years. Compared to our dataset, female basketball players in Europe participating in the youth championships of the European Division (1st European League, 2nd European League, and 3rd European League) were taller and heavier than Palestinian youth basketball players from the U-15 group (33). Data showed significant differences in lower limb length between successive maturity groups (-1.5, -0.5 and 0.5 YPHV). The increase in fat mass associated with peak weight velocity that occurs in females is observed between consecutive maturity groups 0.5 and 1.5 YPHV. The findings are consistent with normal somatic growth, before PHV for the length lower limb and after 3.5-10.5 months of PHV for the fat mass (34). The development of anthropometric characteristics, with several observed changes between consecutive maturity groups, highlights the importance of regularly assessing maturity (35) status (approximately every 3 months). Morphologic changes primarily result from the processes of growth and maturation (36). The pre-pubertal period is characterized by significant alterations in essential anthropometric elements, including muscle, fat, and bone, as identified in the developmental trajectory (36). The influence of the Growth Hormone (GH) and thyroid hormones (T3 and T4) during the pre-pubertal period was reported by Carabulea *et al*. (37).

The intricate interplay among Growth Hormone, sex steroid hormones such as estrogens and androgens, and the production of insulin-like growth factor I plays an important role in the substantial modifications in body composition and shape throughout pubertal development. According to age groups, the development of physical performances of youth female basketball players was found to be asynchronous and non-linear. Sprinting performance analysis revealed no statistically significant differences in the T5m and T20m between consecutive age groups. This result is contradictory compared to studies conducted in Europe and applied to groups of the same age who found an improvement between age group (10). Higher sprinting performances were recorded of Polish youth basketball players compared to our findings. For example, sprinting performance for T5m U13 (1.24 s-1.84 s). Comparing T20m performance, U-15 Polish basketball players have higher performance (3.53 s-4.14 s) which is like their peers from Division B (2nd European League) teams than to Division A (1st European League).

Regarding maturity groups, less time was recorded in more mature players, indicating faster sprint times with increased maturity. Developmental performances improvements were recorded beginning with the 0.5 maturity group. The increase in lower limb length among these specific groups could account for enhancements in stride length and consequently, improvements in sprint time an occurrence previously observed in male youth athletes (20). An improvement in the T-20m dribbling test performance was recorded across age groups, with the greatest difference noted starting from the 15-year age group. Then, within the maturity groups, the most significant improvement was seen starting from the 0.5 maturity group. This supports the notion that the development of physical qualities is not only influenced by strength development but also by the refinement of proper movement patterns and neuromuscular control (38). Regarding the horizontal jump test (5JT), there was an improvement in performances across different age groups, with a significant difference observed between U-12 and subsequent age groups. In terms of maturity status, the most notable development occurred before the peak height velocity (PHV) for the -0.5 group. This may be associated with hormonal and morphological changes, particularly in muscle mass, that are recognized to occur around the PHV. These observations are in accordance with earlier longitudinal research (39) and cross-sectional studies on strength assessments (40) conducted with non-elite female athletes. Sargent jump test performances showed unclear changes across various maturity groups around the PHV. The results suggest that female basketball players may experience a reduced relative peak force and lower-body power at 0.5 years post-PHV. This decline could be attributed to a potential increase in fat mass associated with peak weight velocity in females occurring 3.5-10.5 months after PHV (41), which may not contribute functionally to athletic performance. This contrasts with other findings indicating that peak strength is greater in more mature girls, which may be related to biological changes associated with advanced maturation, such as increased body mass, and indications that total strength of the lower limbs improves with age (42). While the Sargent jump places demands on enhanced upper-body coordination (43), its significance lies in its applicability to basketball players who excel in coordinating both lower and upper-body movements, a crucial skill in typical jump-and-reach tasks encountered during gameplay. Given the substantial relevance of the Sargent jump in the realm of basketball (44), it proves valuable in talent identification or team selection, where individuals exhibiting superior performance are likely to excel in basketball-specific tasks such as rebounding. Additionally, this test serves as a practical tool for the continual physical assessment of players, specifically focusing on lower-body power generation through a game-specific movement pattern (45). Regarding the 10 × 5 m shuttle run and the Illinois test, there were no significant differences between age groups and maturity groups. Performance recorded higher performance in more mature players. This can be attributed to the fact that mature players have better control over their movements and a greater ability to change direction than younger players (46). These findings are in line with a previous study where no differences were observed among groups of basketball players with varying times from PHV in agility tests (47). Performance in agility is a multifactorial physical ability influenced by strength, speed, balance, and flexibility (48), which aligns with the demands of a short-distance shuttle run. Therefore, enhancements in agility levels and changes in direction account for the improvements in the shuttle run. Throwing ball performance exhibited a significant increase according

age groups and a correlation (r = 0.76) was found between throwing and age. As for maturity groups, significant differences were observed following PHV. This finding contradicts the study conducted by research (49), which reported that early matures achieved the best results only in one variable, medicine ball throwing.
In relation to the 20 m SRT test, our results indicate a consistent increase in endurance between 12 and 16 years. Significant differences were observed among age groups (U-12, U-13, and U-14), with the most significant rate of increase noted between 12 and 13 years. According to maturity status, significant differences were observed after PHV. Philippaerts *et al.* (32) found that the most substantial improvement in cardiorespiratory endurance aligns with the timing of PHV. Earlier studies have indicated that alterations related to growth in both the central and peripheral cardiovascular systems, such as enhancements in stroke volume and cardiac output, as well as modifications in muscular function and metabolic capacity, take place around the PHV (41). The performance levels may be attributed to the observation that young Palestinian female players might not consistently participate in diverse and regular training, which is a crucial factor for strength and speed development. Coaches should take note of the decline in relative peak force after PHV in young female basketball players. This awareness is crucial considering the established connection between strength and athletic performance (50), and the association between low relative strength and an elevated risk of injury in youth player (51). The results emphasize the importance of incorporating structured strength training into the regular training programs of young female soccer players, especially after the PHV period. The influence of social and environmental conditions in Palestinian territories could potentially contribute to this phenomenon. The study provides prediction equations of physical performances based on anthropometric variables and age. A multiple linear regression analysis including physical performances as the dependent variables and all anthropometric variables as the independent variables indicated that age is the best predictor of sprint performances (T5m, T10m, T20m), T20m dribbling, 10 × 5 m shuttle run, Sargent test, 20-m SRT and 1-kg throwing. For the Illinois test, the predictors were age and lower limb length. Then, the predictor of 5JT performances were age, length lower limb and Wingspan. Finally, the best predictors of 5JT relative were, age, sitting height, length lower limb, wingspan, BMI and fat mass. Although this study provides a better understanding of the effect of maturity status on the physical development of youth female basketball players, is not without limits. The use of the predictive equation instead of biological measures of maturation should be used with caution when analyzing these data, as it likely resulting in some degree of error (52, 53). The nature and specificity of the sample calls for caution in the generalization of the data and its application. Various variables that may impact physical performance were not evaluated in the study, such as the training age and experience of the players, training loads, and the effect of the menstrual cycle.

CONCLUSIONS

In conclusion, anthropometric variables demonstrated early development, particularly in the length of the lower limbs, leading to significant improvements in jumping performance. Increases in body composition and fat mass notably influenced various physical performances, especially in agility and sprint tests. Additionally, improvements in endurance performance were observed around and after the period of peak height velocity (PHV). This study enhances coaches' understanding of the impact of maturity status on the anthropometric variables and physical development of young female basketball players and acknowledges the specificity of the development of anthropometric and physical variables compared to other studies.

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

LJ, MT, GR: methodology, investigation, formal analysis, writing – original draft. GR, AF: methodology, investigation, formal analysis, writing – original draft. LR, GMM, JP, YT: writing – original draft. LR, GMM, JP, YT: conceptualization, methodology, supervision, writing – review & editing.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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