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Physical Activity, Gender and Biological Maturation influence on lower-limb explosive anaerobic power measured in sprinting and jumping among youth students: from a biomechanical perspective

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Abstract

The prevalence of sedentary behavior in children evoke the implementation of research in physical fitness performances and their associations to physical activity (PA) level in long with biological maturation. Regarding the lack of knowledge in the subject, the main objective of this study was to assess the general level of physical activity among Moroccan school going youths, and its effect on lower-limbs' explosive anaerobic power and performance in sprinting and jumping by taking in account the gender-based comparison and the maturation status effects. A cross-sectional study design was adopted to address the study objectives, and a sample of 226 children and adolescents (133 boys, 93 girls) aged 12 to 17 years old from a rural middle school, region of Kenitra city of Morocco voluntaries agreed to take part of the study. They were classified according to their maturity offset (MO) as Pre-PHV, Circa-PHV or Post-PHV. However, their physical activity level was assessed by applying a self-reported questionnaire (PAQ-C/A). Whereas, lower-limbs explosive anaerobic power was assessed using field testing methods including: 30m linear sprinting, vertical jumps (SJ, CMJ and DJ) and horizontal jump (5JT). Results showed a low physical activity level for participants (PAQ-score = 2.4±0.72 < 2.5), a moderate to large effects size of gender (η^2 range 0.18 to 0.37 at $p<0.01$) and a small to large effects of maturation status (η^2 range 0.05 to 0.41) were reported on physical performance, respectively. The gender-based comparison reveled better values for boys' vs girls. Whereas, Post-PHV boys performed higher than Circa- and Pre-PHV in most physical fitness tests. The correlation analysis revealed moderate positive relationship between the physical activity level and anaerobic mechanical power (r range 0.32 to 0.50) and small to moderate positive relation of maturity offset to anaerobic power in sprinting, SJ and CMJ at $p<0.05$. This results highlighted the alteration of low PA level to anaerobic power expression and explosive movements performances and the necessity of implementing good lifelong habits regarding PA and minimize sedentary behavior in this crucial age (i.e. childhood and adolescence) in line with World Health Organization recommendations by providing national guidelines regarding physical activity both individually and collectively allowing them to benefit from their morphological and physiological maturation specific developments.

Keywords: Biological Maturation, Physical Activity, Gender-based deference, Explosive Power, Biomechanics

Full length article *Corresponding Author, e-mail: rachid.boujdi@uit.ac.ma

1. Introduction

Physical activity (PA) is a significant factor in children's development and can be a trustworthy predictor of their health and wellbeing. It encompasses all movements of the body caused by skeletal muscle contractions that raise energy consumption [1]. Regarding it benefits such as improved health of bones, muscles, joints, good social and psychological health, and a reduced probability of developing diseases [2] and regarding the risks of Physical inactivity (i.e. insufficient physical activity) such as risk of blood pressure, high blood glucose, Obesity, Heart Disease and Type 2 Diabetes [3] the World Health Organization (WHO) recommend a minimum of one hour per day in moderate to vigorously intense PA for children and adolescents [4]. With concerning, a global statistics of 298 population surveys (1.6 million participants) reported in 2016 showed that 81.0% of students (age range 11 to 17 years old) were physically insufficient active, up to 84.9% in low-income populations [5]. Children and adolescents should engage in a daily physical activity, this can be achieved through games, physical education, leisure or organized exercising [3], [6]. The assessment of physical activity is a crucial component of profiling in schools, whereas subjective techniques such questionnaires to assess physical activity are frequently chosen over the objective ones (accelerometer, pedometer and heart rate monitors) due to the ease of conducting them on children without requiring specific instruments [7].

Biological maturation (BM) is regulated by a number of genetic variables and extrinsic factors (such as socioeconomic status, nutrition, lifestyle) who may affect the BM over this processes and make differences usually, between persons and genders, well it may not constantly correspond to individual's chronological age [8]. Children grow at varying rates, resulting in biological differences between individuals with the same age that can last up to three years. Rapid changes in leg length are seen during the early stages of the developmental period for adolescents, while rapid increases in muscle mass and body mass could not be seen until after peak of height velocity (PHV). This period of growth is considered as non-linear, numerous factors, including gender, maturity, body size, physical activity and motor abilities influences the pattern of this process [9]. Thereby, at this time Physical activity (PA) can be impacted [10] and good lifelong habits regarding PA were established, benefiting from the muscle strength improvement with age.

Males typically have an overall strength level that is 40% higher compared to the average of females in the general population. Wherever, at the same age, they usually have more absolute peak power than females, with increasing differences after puberty [11]. Usually, the term “Anaerobic explosive power” has been utilized to characterize a form of activity that calls for a comparatively intense muscular effort. It is the ability to produce a maximum amount of force with maximal speed and from a mechanical concept is a short rate of work performance, and from a physiological perspective is activities occurring a quick energy generation production assured by the alactic anaerobic metabolism (ATP-CP) [12] which supply muscles with quick energy for brief activities (up to 15 sec) with high intensity like jumping and sprinting for example. Several tests of measurement of the anaerobic explosive power have been proposed such as cycling Wingate [13], sprinting protocols [14], and variety of vertical jumps tests [15] (e.g. squat jump, counter-movement jump…) linking the vertical jump performance to strength and power expression, and variety of horizontal jumps tests such as the five jump test (5JT) offering interesting measures of lower limb horizontal explosive power in field conditions [16]. Notably, among the metrics measuring neuro-motor performance, the muscle anaerobic power in sports practice might be essential for success in a number of sports, such as track and field disciplines, volley ball and football [8]. Information on how biological maturation, gender and physical activity level can affect dynamic muscle anaerobic power for youth students who undergoes the peak of high velocity is still unclear.

Due to the disparate methodological stances taken in the present literature, there is a lack of knowledge about the cross-sectional performance variability in anaerobic explosive movements in school going youth, and the influence of biological maturation status and physical activity level on anaerobic explosive power in sprinting and jumping in this population using field testing methods. The finding of this study will assist physical education teachers and coaches to better deal with youth population in prescribing training session and pedagogical cotenant to address maturation-specific alterations and take advantage of maturation specific developments with consideration of gender influence.

2. Materials and methods

2.1. Study Design and Participants

The main objective of this study was to assess the general level of physical activity among Moroccan school going youths by applying a self-reported questionnaire, and its effect on lower-limbs explosive anaerobic power and performance in sprinting and jumping by taking in account the gender-based comparison and the maturation status effects. A cross-sectional study design was adopted to address the objectives and to determine the influence of the independent variables: Physical Activity level, gender and biological maturation on the dependent variables lower-limbs explosive power performances. Based on these assumptions, the current study postulates that the level of physical activity of youth physical education students may impact the explosive power expressed by the lower limbs during ballistic movements, as well their biological maturation stage and gender may be linked to the muscles anaerobic power.

Two-hundred and twenty-six students (133 boys and 93 girls) from a rural middle school, region of Kenitra city of Morocco, aged between 12 and 17 years old volunteered to take part of this study. Students were classified according to the maturity offset (MO) in long with their gender as pre peak high velocity (Pre-PHV), post (Post-PHV) or Circa (Circa-PHV). Somatic variables and maturity offset for all participants are provided as Means ± standard deviations as shown in Table 1. All students followed weekly, two session of physical education with sixty minutes of duration as scheduled in the Moroccan national curriculum guidelines. No injuries during the study enrollment were reported by participants and none of them were involved in any type of structured training programs.

Anthropometric measurements (body standing height, body sitting height and body mass) were taken for all subjects and BMI was calculated. Also, Physical Fitness testing for explosive power was determined using field measurement tests of jumping performance: squat jump (SJ), counter movement jump (CMJ), drop jump (DJ) and five jumps test (5JT). Mechanical characteristics of maximal sprint performance (MSS, Pmax, F0, V0, RF_{max}, S_{FV} and D_{RF}) for a 30 m sprint test taken place in separate dates. The maturity ratings were determined by a validated regression equations presented by *Mirwald et al.* [17]. Correlation analyses were used in order to clarify the relationships between physical activity level, biological maturity variables and physical fitness performance variables.

Participants wore lightly during anthropometric measurement and it was mandated that they wear identical clothing and footwear for every testing session. A forty height hour were provided between testing sessions. Furthermore, students were instructed to abstain from eating at list one hour prior to field testing. Before the study began a writing informed consent was obtained from participant’s legal garden after informing them about the study aims. The study was conducted in accordance with the declaration of Helsinki.

2.2. Research Procedures

All students were required to complete a Physical Activity Questionnaire, an assessment of biological maturity, jump tests and a maximal sprint test in two consecutive weeks' timeframe as shown in (Figure 1.). All field physical tests were conducted in the same outdoor conditions and occurred during scheduled physical education sessions. The familiarization with tests were scheduled in the first week however performance acquisition was in the second week to avoid learning effect. Before every physical testing session, students performed a standardized 15-min warm-ups (jogging, dynamic stretching, repeated sprint and jumps with active recovery) whereas static passive stretching wasn't allowed [18].

2.3a. Assessment of Maturity

Anthropometric measurements were assessed at the first week wearing light clothes and preferable the same clothes and shoes used habitually in physical education sessions, body mass (kg) was reported nearest 0.05kg using an electronic smart scale (Xiaomi MI scale 2, Anhui Huami Information Technologies Co. Ltd. Hefei. China) whereas, body setting height (cm) and body standing height (cm) were measured to the nearest 1cm using a stadiometer (Kinlee, Hong Kong, China); Lower limb length (cm) was calculated as difference of body standing height and body seated, whereas, the body mass index (BMI) was calculated as body mass in kilogram divided by square of body standing height in meter and reported in ($kg.m^{-2}$). In addition, biological maturity was assessed using a non-invasive method by calculating the maturity offset using a validated gender-specific regression equations (Equation 1 & 2) proposed by Mirwald et al. [17] uses anthropometric measurements (i.e. body mass, standing body height, and sitting body height), chronological age and gender as variables. Subsequently, students were classified according to calculated maturity offset as Pre-PHV (MO ≤ -0.5 years old), Post-PHV (MO ≥0.5 years old) or Circa-PHV (MO between -0.5 years and 0.5 years) from their chronological age.

- Boys' predictive regression equation:

Maturity Offset =-9.236 + 0.0002708xLL and SH interaction +0.001663xA and LL interaction + 0.007216xA and SH interaction + 0.02292xW by H ratio. (**Eq. 1**)

- Girls' predictive regression equation:

Maturity Offset = - 9.376 + 0.0001882·LL and SH interaction + 0.0022xA and LL interaction + 0.005841xA and SH interaction + 0.002658xA and W interaction + 0.07693xW by H ratio **(Eq. 2)**

With: A= Age, LL= Leg Length, SH= Sitting Height, W=Weight, H= Height

2.3b. Assessment of The Physical Activity Level

In order to assess physical activity level, we applied an Arabic version of widely used self-report questionnaire to measure the Physical Activity in school students over the antecedent seven days "The Physical Activity Questionnaire for children and adolescents (PAQ-C/PAQ-A)" [19] which provides cross-cultural adaptation to Moroccan students speaking Arabic as first language with some modifications were imported to the original questionnaire such as reformulation of questions to be more clear and the removal of question Number 10 (about sickness last week) because it doesn't fit with the objective of assessing an usual week physical activity. PAQ responses provide information about any physical activity during the preceding week at and out-school. Participants filled the PAQ-C (children aged 8 to 14 years old) or PAQ-A (adolescents aged 14 to 18 years old) based on their chorological age at the first week of this study timeframe. For each question, a score of 1 indicates low physical activity whereas a score of 5 indicates high physical. At last, final physical activity score of the test is calculated as the mean score of answers to PAQ-C or PAQ-A questions.

2.4a. Physical Fitness testing

2.4.1a. Linear Maximal Sprint Test

Participants performs three trials of maximal over-ground sprint run over a distance of 30m track in a Handball field with at list five minutes of passive recovery to assess linear maximal sprint performance. they were instructed to take a two points ready position (standing start), and after signal student run over 30m linear distance with encouragement of teacher and colleagues to perform at maximal speed. Spatiotemporal data was collected as split times of 5 meters as recommended [14], [20] using a high speed video camera at recording resolution of 1180p and sampling rate of 300 fps. Subsequently, data was biomechanically modeled along with participant' anthropometric data [21] to calculate sprint mechanical outputs (i.e. Theoretical maximal horizontal force HZT-F0, Theoretical maximal running velocity HZT-V0, Maximal mechanical power output HZT-Pmax and maximal Ratio of force RFmax) a full description of experimental sit-up and fitting method is detailed in [14], [22].

2.4.2a. Jump Tests

- **Horizontal Jump Test**

To assess lower limb horizontal explosive power, we introduced the Five Jumps Test (5JT) also known as the five bound test, the test is a valid method to assess muscles explosive power [18], consists of five successive forward jumps, straightforward to perform and doesn't necessitate expensive equipment. In addition, the 5JT is an intriguing way to assess children's segmental coordination skills without resorting to more exacting techniques [16] and a simple and useful test providing information about subject' stride power, considered as an important variable in numerous sport activities.

The test was performed in the same outdoor field, students were instructed to start the test with joined feet behind the starting line, to select which foot to start with, alternate left and right feet and end with joined feet at the fifth stride [16]. Absolute and relative performances were reported for this test. Absolute performance of the 5JT was measured with a tape and reported in (cm) however, relative performance to lower-limb height (5J/LL) and relative to body mass (5J/BM) were obtained by dividing absolute 5JT performance by Lower Limb length and by body mass, respectively. The 5JT relative performance taking in consideration the differences in participant's body size [18].

- ***Vertical Jump Tests***

To assess lower-limb Vertical explosive power. we introduced tree vertical jump tests: Squat Jump (SJ). Countermovement Jump (CMJ) and Drop Jump (DJ). The assessment of all jumps height was provided using My Jump 2 a valid and reliable application mobile [23] for measuring vertical jump in children and adolescent [24] using high speed camera phone (240Hz) to record the jump performance. whereas. the video treatment is done manually frame by frame to select the take-off moment (both feet were off the ground) (Figure 2.B.) and the landing moment (at least one foot was touching the ground) (Figure 2.D.). The time spent between the take-off and landing was estimated as flight time (t) in seconds whereas the application calculates the jump height in meters using equations described by *Bosco et al.* [25] (Equation 3 & 4).

$h = t^2 \times 1.22625$ for (SJT) and (CMJT). **(Eq. 3)**

$h = g.t^2/8$ for (DJT). **(Eq. 4)**

All testing sessions were collected by the same investigator using the same mobile phone IPhone 11 Pro (Apple Inc., USA) mounted on a tree-pod 1m above the ground and 1.5m from the participant executing the jump as recommended [24]. This method enabled the use of field testing and doesn't need expensive equipment (e.g. Opto-Jump, photoelectric cells, force platform) limiting field measurements.

- ***Squat Jump test (SJ)***

Students takes ready position by flexing their knees to ≈ 90° with hands on their hips (Figure 2.A.), they are instructed to hold this squat position for 3sec before jumping as rapid and high possible vertically and avoid countermovement or the displacement in the horizontal direction (Figure 2.B. & C.) [24], if any, the trial was repeated. Each participant executes 2 non-consecutive jumps with three minutes of rest between.

- ***Countermovement Jump test (CMJ)***

Participants were instructed to put their hand on their hips before, during and along the execution of the CMJ. They start from a static position, dip (~ 90◦ knees flexion), and jump immediately (benefiting from the stretch-shortening cycle) as high as possible with minimizing the horizontal displacements, maintaining their legs straight at flight time and no interruption between the downward and upward movements [26]. If any wrong execution was noticed visually, a supplement trial was accorded to the participant.

- **Drop Jump test (DJ)**

Students were demanded to take a standing position with hands on waist above a stair or a box of 30cm of height (Figure 3.A.). When they are ready, they extended one-foot out and move forward to let their body fall vertically with minimizing outwards or upwards pushes (Figure 3.B.). They were instructed to land close to the box with both feet (Figure 3.C. & D.) and jump immediately with reducing contact time as high is possible (Figure 3.E. & F.) [27]. Visual inspection makes it possible to decide wish the trail were properly done or a re-trial was allowed. The best trial of each protocol was analyzed using My Jump 2 application and calculate vertical jump variables:

- ✓ For CMJ and SJ tests: jump height (H), Peak Force (Fpeak), peak Power (Ppeak) and peak Velocity (Figure 2.E.). To allow comparison based on body size, relative jumping force and power were also computed by dividing Fpeak and Ppeak by students' body mass.
- ✓ For DJ test: jump height (H) in cm, flight time (t) in milliseconds, contact time (t_c) in milliseconds, lower limbs vertical stiffness (Kvert) in Kn.m-1 and reactive-strength index (RSI) computed as jump height (H) divided by contact time (t_c) expressed without unit and widely used to quantify Drop Jump performance and to assess explosive strength [28].

2.5. Statistical Analyses

Data were analyzed as a whole sample, as two groups according to gender and also were subdivided into Pre- Circa- and Post- to peak of height velocity sub-groups. Normality of distribution and homogeneity of variance were tested using Shapiro-Wilk and *Levene's* test respectively. A log-transformation was applied to any non-parametric variable to remove bias and standardize data.

Descriptive statistics were competed for all anthropometric variables and physical fitness tests (i.e. sprint, vertical jump and horizontal jump tests) for boys and girls, for the whole sample and also for biological maturity sub-groups (Pre-, Circa- and Post-PHV groups) and presented as (mean ± standard deviation). A t-test for independent samples were used to compare gender groups (boys' vs girls) in physical fitness performance and physical activity level with competing Hedge *g* effect size to highlight groups differences with threshold values established as very large, large, moderate and small effects for > 2.0, > 1.2, > 0.6 and > 0.2 respectively [29]. However, a two-way ANOVA with (Gender X Maturation Offset) interaction to analyze between sub-groups differences and a *Bonferroni* post-hoc test was performed when significant main effect was observed to discriminate between means and control error type I. whereas, eta-squared (η^2) was used to estimate effect size between sub-groups and defined as small (≤0.1) medium (≤0.25) and large (≤0.4) [30]. the relationships between physical fitness performance, physical activity level and biological maturity were inspected using Pearson's correlation coefficients (bivariate and partial) and interpreted according to r values as small (range 0.10 to 0.29), moderate (range 0.30 to 0.49), large (range 0.50 to 0.69) and very large (more than 0.70) [29]. we performed all statistical analyses using SPSS software version 27.0 (IBM, Chicago, USA) with a significance level sited at 5%.

4. Results

The somatic data of students is illustrated in (Table 1.) as mean ± standard deviation, including chronological age, body weight and height (standing and setting) in addition to their calculated BMI and maturity offset for the whole sample and according to gender and biological maturation sub-groups. Scores of the self-report Physical Activity Questionnaire for children and adolescents (PAQ-C/PAQ-A) used to assess physical Activity level are presented in (Table 2.). We recorded that the overall average PAQ-score for the whole sample was themed to be in low physical activity range (PAQ-score = 2.4±0.72 < 2.5).

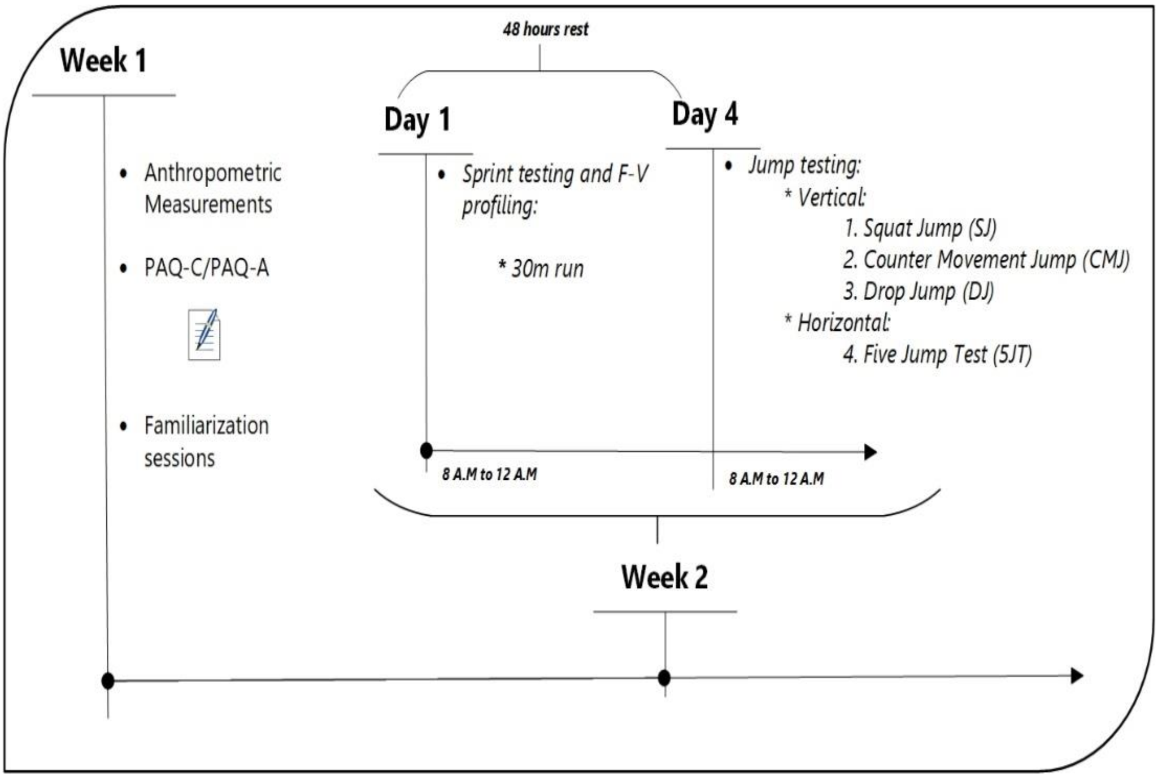

Figure 1: Flowchart of the study design

Table 1. Descriptive somatic data (mean ± SD) for the whole sample and according to gender and biological maturity.

Sample characteristics		Age (years)	Body weight (kg)	Body standing height (cm)	Body setting height (cm)	Maturity offset	BMI (kg.m^2)
Whole sample (N=226)		13.57±1.04	43.48±10.02	154.9±8.2	77.9±5.5	0.16±1.08	17.95±2.89
Boys (n=133)	**All (n=133)**	13.85±1.12	42.66±9.59	155.5±9.6	78.1±5.3	-0.30±1.03	17.45±2.38
	Pre-PHV (n=68)	13.09± 0.64	37.18±5.09	148.9±6.0	69.12±6.03	-1.09±0.42	16.72±1.641
	Circa-PHV (n=35)	13.98± 0.63	44.70±8.15	158.3±6.1	73.62±3.94	-0.16±0.26	17.79±2.84
	Post-PHV (n=30)	15.40± 0.70	52.69±10.07	167.4±5.7	82.51±5.17	1.31±0.46	18.69±2.65
Girls (n=93)	**All (n=93)**	13.16±0.75	44.65±10.50	154.0±6.9	77.7±5.8	0.80±0.79	18.67±3.39
	Pre-PHV (n=24)	11.42±0.61	31.96±2.91	141.5±4.9	66.94±5.88	-0.49±0.33	15.95±1.16
	Circa-PHV (n=23)	12.49± 0.36	40.16±4.70	151.3±4.9	70.45±8.06	0.23±0.18	17.50±1.49
	Post-PHV (n=46)	13.54± 0.63	48.48±10.60	157.1±4.7	79.22±6.35	1.26±0.48	19.56±3.79

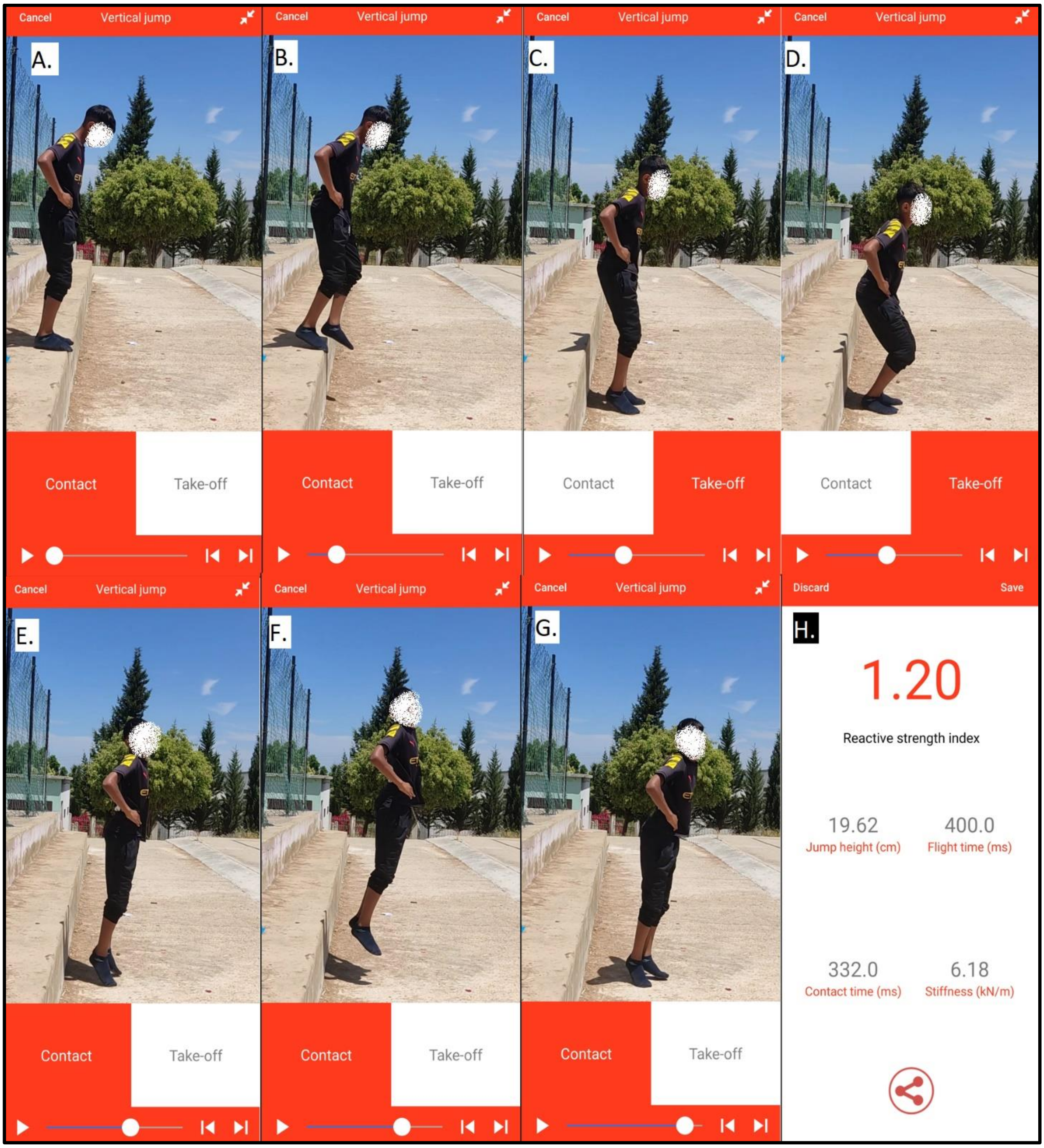

Figure 2. Video analysis of Squat Jump test, key phases using My Jump 2 app

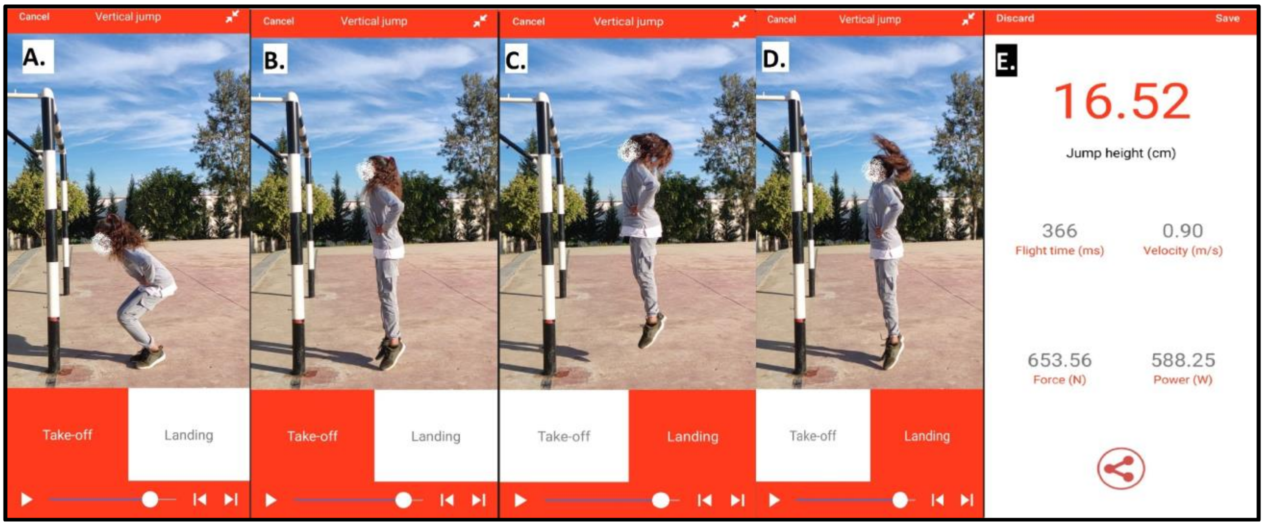

Figure 3: Video analysis of Drop Jump test, key phases using My Jump 2 app

Table 2. The self-reported physical activity level as score (Mean ± SD) of the PAQ-C/A of the whole sample and according to gender and biological maturity.

Sample characteristics		(Q1)	(Q2)	(Q3)	(Q4)	(Q5)	(Q6)	(Q7)	(Q8)	(Q9)	Total PAQs score
Whole sample (N=226)		2.5±1.0	3.0±0.9	1.9±0.8	2.0±0.8	2.2±0.8	2.2±0.8	2.6±0.8	2.1±0.6	2.8±0.7	**2.4±0.72**
Boys (n=133)	**All (n=133)**	3.2±0.8	2.3±0.8	2.4±0.8	2.4±0.8	2.4±0.9	2.9±0.7	2.4±0.4	3.1±0.6	3.1±0.6	**2.7±0.6 A**
	Pre-PHV (n=68)	3.0±0.7	2.1±0.7	2.2±0.7	2.3±0.7	2.1±0.8	2.7±0.6	2.3±0.4	2.8±0.5	2.8±0.5	2.5±0.5 B
	Circa-PHV (n=35)	3.2±0.9	2.5±0.7	2.3±0.8	2.3±0.8	2.6±1.1	2.9±0.7	2.4±0.5	3.2±0.7	3.2±0.7	2.7±0.6 C. f
	Post-PHV (n=30)	3.9±0.8	3.0±0.8	2.9±0.9	3.0±0.8	2.8±0.8	3.4±0.6	2.7±0.4	3.6±0.5	3.6±0.5	3.2±0.6 G. f
Girls (n=93)	**All (n=93)**	2.6±1.0	1.4±0.5	1.6±0.4	1.7±0.7	1.9±0.6	2.1±0.8	1.5±0.4	2.4±0.4	2.4±0.4	**1.9±0.5 A**
	Pre-PHV (n=24)	2.2±1.1	1.4±0.5	1.4±0.4	1.7±0.4	1.9±0.7	1.8±0.6	1.3±0.4	2.2±0.4	2.2±0.4	1.7±0.4 B
	Circa-PHV (n=23)	2.7±0.9	1.5±0.5	1.6±0.4	1.9±0.7	2.1±0.7	2.3±0.7	1.6±0.4	2.5±0.5	2.5±0.5	2.1±0.5 C
	Post-PHV (n=46)	2.6±0.9	1.4±0.6	1.6±0.4	1.7±0.7	1.9±0.6	2.1±0.8	1.6±0.4	2.3±0.4	2.3±0.4	1.9±0.5 D g.

*Spare time activity (Q1), Physical Education activity (Q2), Break time activity (Q3), lunch time activity (Q4), after school activity (Q5), evening activity (Q6), weekend activity (Q7), free time activity (Q8), Activity frequency (Q9); Boys vs. Girls (A); Pre-PHV Boys vs. Pre-PHV Girls (B); Circa PHV Boys vs. Circa -PHV Girls (C); Post -PHV Boys vs. Post -PHV Girls (D); Pre-PHV vs. Circa -PHV (E); Pre-PHV vs. Post -PHV (G); Circa PHV vs. Post -PHV (F) in capital letter = at p < 0.001. in short letter = at p < 0.05.

Table 3. A. Physical fitness performances in linear sprint. horizontal jump. vertical jumps and their main biomechanical variables according biological maturity for boys.

Physical performance variables		Boys			
		All (n=133)	Pre-PHV (n=68)	Circa-PHV (n=35)	Post-PHV (n=30)
Linear Sprint					
	30m (sec)	6.01±0.43	6.06±0.34	6.06±0.49	5.80±0.50
	P_{max} (W.Kg^{-1})	10.22±1.76	9.87±1.46	10.17±1.85	11.05±2.04
	F_0 (N.Kg^{-1})	6.68±1.09	6.54±1.01	6.74±1.10	6.91±1.22
	V_0 (m.sec^{-1})	6.13±0.59	6.05±0.47	6.04±0.63	6.41±0.72
	MSS (m.sec^{-1})	5.92±0.53	5.83±0.41	5.84±0.57	6.18±0.64
	RF_{max} (%)	29.05±14.06	28.03±14.30	27.34±15.18	33.33±11.49
Horizontal Jump					
	5JT (cm)	825.3±92.9	806.7±73.9	819.4±101.6	874.3±106.0
	5JT/LL	10.97±1.93	11.16±1.90	11.06±2.29	10.41±1.42
	5JT/BM (cm.kg^{-1})	20.06±3.91	22.03±3.22	18.77±3.35	17.08±3.50
Vertical Jump					
	SJ Test				
	SJ (cm)	20.8±4.6	20.0±3.92	20.05±5.2	23.4±4.8
	SJ P_{peak} (w)	634.84±194.48	547.41±122.36	614.24±143.55	857. ±209.53
	SJ F_{peak} (N)	626.80±152.33	552.27±96.64	624.47±110.88	798.44±161.63
	SJ V (m.sec^{-1})	1.00±0.11	0.98±0.09	0.98±0.13	1.06±0.11
	CMJ Test				
	CMJ (cm)	32.0±7.3	31.0±6.0	31.3±9.1	35.1±7.36
	CMJ P_{peak} (w)	962.76±280.79	880.36±259.78	933.55±249.71	1183.58±249.93
	CMJ F_{peak} (N)	771.86±201.65	716.53±196.68	765.58±191.07	904.56±165.74
	CMJ V (m.sec^{-1})	1.25±0.14	1.22±0.12	1.22±0.17	1.306±0.13
	DJ Test				
	DJ_{30} (cm)	20.3±4.9	19.89±3.90	19.69±5.25	22.09±6.22
	RSI (m.s-1)	0.77±0.27	0.75±0.26	0.75±0.26	0.81±0.32
	K_{vert} (KN.m)	1.97±0.88	1.73±0.771	2.14±0.86	2.31±1.01

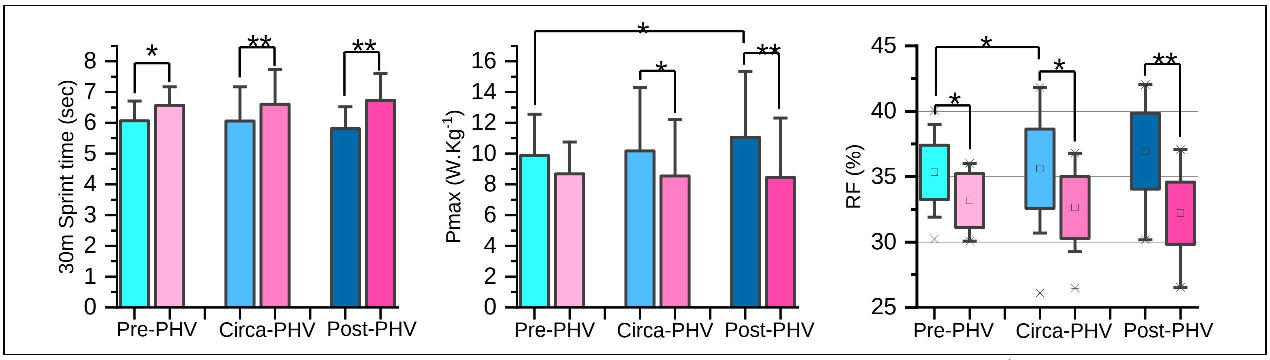

Figure 4. A. Sprint performance (sec). the relative mechanical maximal sprint power (W.kg^{-1}) and the ratio of force application in the anterio-posterior direction as percentage of total ground reaction force (%) respectively in Pre-PHV. Circa-PHV and Post-PHV for boys in bleu and for girls in pink with statistical significance of mean differences reported (*) for p<0.01 and (**) for p<0.05.

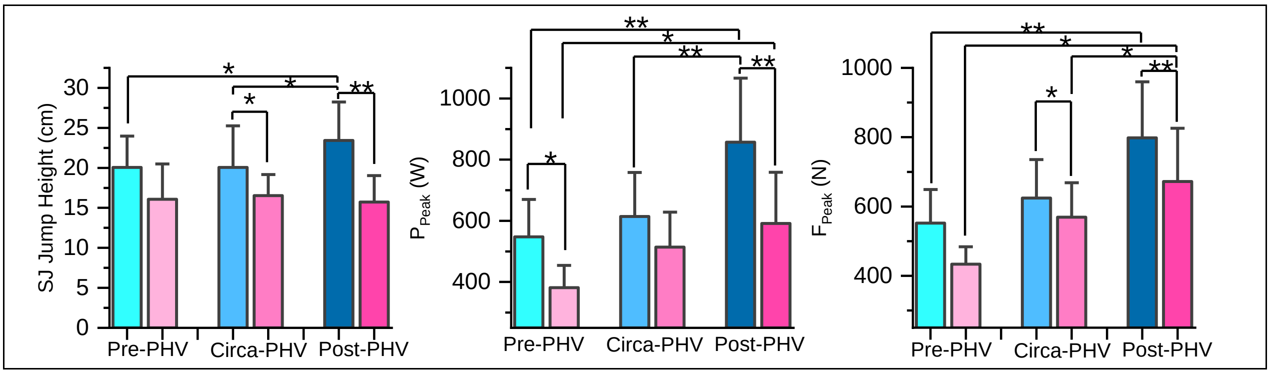

Figure 4. B. Squat Jump (SJ) performance height (cm). the mechanical peak power (W) and the mechanical peak force (N) respectively in Pre-PHV. Circa-PHV and Post-PHV for boys in bleu and for girls in pink with statistical significance of mean differences reported (*) for p<0.01 and (**) for p<0.05.

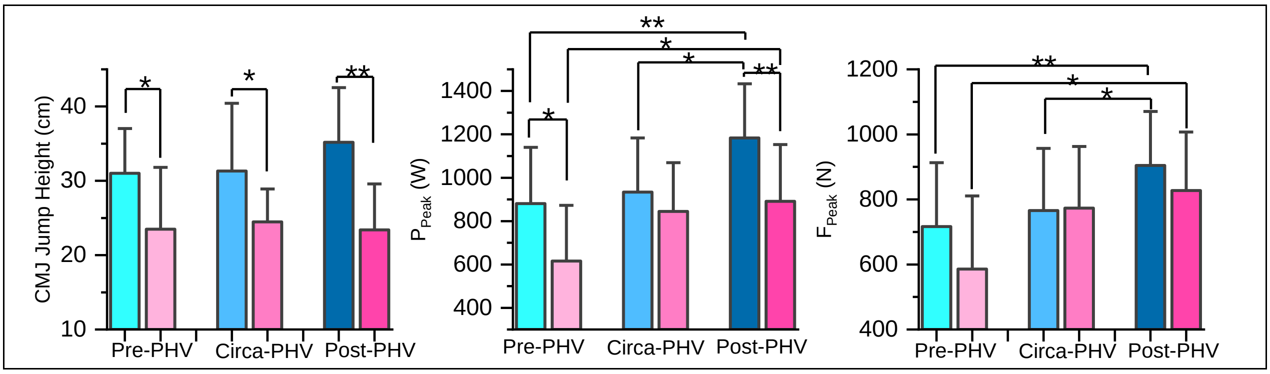

Figure 4. C. Counter Movement Jump (CMJ) performance height (cm). the mechanical peak power (W) and the mechanical peak force (N) respectively in Pre-PHV. Circa-PHV and Post-PHV for boys in bleu and for girls in pink with statistical significance of mean differences reported (*) for p<0.01 and (**) for p<0.05.

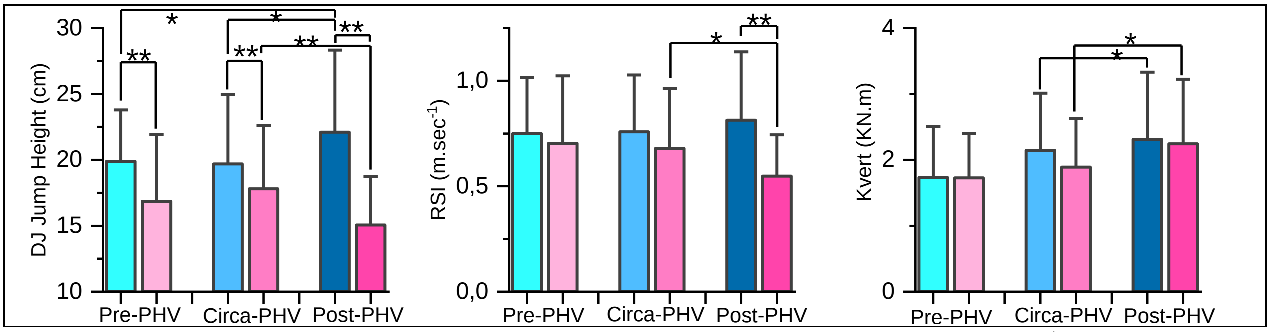

Figure 4. D. Drop Jump (DJ) performance height (cm). the Reactive Strength Indices ($m.sec^{-1}$) and the Vertical stiffness (KN.m) respectively in Pre-PHV. Circa-PHV and Post-PHV for boys in bleu and for girls in pink with statistical significance of mean differences reported (*) for p<0.01 and (**) for p<0.05.

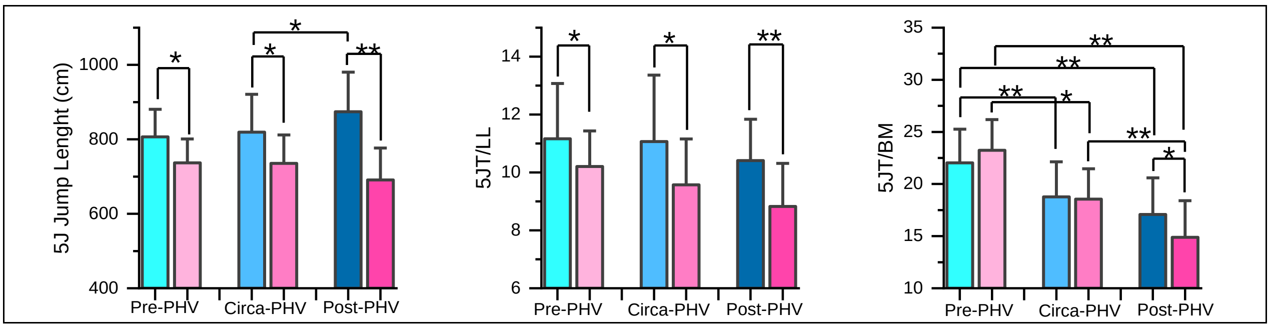

Figure 4. E. Five Jump (5J) performance length (cm). the 5J performance standardized to lower limb length (LL) and the 5J performance standardized to body mass (BM) respectively in Pre-PHV. Circa-PHV and Post-PHV for boys in bleu and for girls in pink with statistical significance of mean differences reported (*) for p<0.01 and (**) for p<0.05.

Table 3. B. Physical fitness performances in linear sprint. horizontal jump. vertical jumps and their main biomechanical variables according biological maturity for girls.

Physical performance variables		Girls All (n=93)	Pre-PHV (n=21)	Circa-PHV (n=23)	Post-PHV (n=48)
Linear Sprint					
	30m (sec)	6.68±0.42	6.56±0.28	6.60±0.44	6.73±0.43
	P_{max} (W.Kg^{-1})	8.50±1.63	8.67±1.49	8.54±1.59	8.44±1.70
	F_0 (N.Kg^{-1})	6.43±1.37	6.42±1.10	6.35±1.36	6.46±1.43
	V_0 (m.sec^{-1})	5.32±0.50	5.41±0.30	5.42±0.50	5.26±0.52
	MSS (m.sec^{-1})	5.17±0.44	5.24±0.26	5.26±0.45	5.12±0.46
	RF_{max} (%)	27.46±11.67	16.47±17.05	25.55±13.78	30.01±8.30
Horizontal Jump					
	5JT (cm)	706.9±83.6	737.1±64.1	735.5±76.3	690.8±85.8
	5JT/LL	9.16±1.55	10.20±1.22	9.57±1.58	8.82±1.49
	5JT/BM (cm.kg^{-1})	16.69±4.29	23.24±2.93	18.54±2.92	14.88±3.51
Vertical Jump					
	SJ Test				
	SJ (cm)	15.9±3.2	16.0±4.4	16.5±2.6	15.7±3.3
	SJ P_{peak} (w)	549.68±161.55	381. ±72.54	514.25±114.09	591.26±167.36
	SJ F_{peak} (N)	621.04±154.77	433.93±50.07	569.33±99.11	672.04±153.91
	SJ V (m.sec^{-1})	0.88±0.093	0.87±0.12	0.89±0.07	0.87±0.09
	CMJ Test				
	CMJ (cm)	23.±6.0	23.4±8.3	24.4±4.4	23.4±6.1
	CMJ P_{peak} (w)	850.08±263.66	615.67±257.37	844.69±224.72	891.20±261.57
	CMJ F_{peak} (N)	787.81±199.58	585.54±225.29	773.35±189.25	827.06±180.09
	CMJ V (m.sec^{-1})	1.07±0.14	1.05±0.20	1.09±0.09	1.06±0.15
	DJ Test				
	DJ_{30} (cm)	15.93±4.27	16.85±5.05	17.80±4.82	15.06±3.68
	RSI (m.s-1)	0.60±0.24	0.70±0.31	0.67±0.28	0.54±0.19
	K_{vert} (KN.m)	2.10±0.91	1.72±0.67	1.88±0.74	2.24±0.97

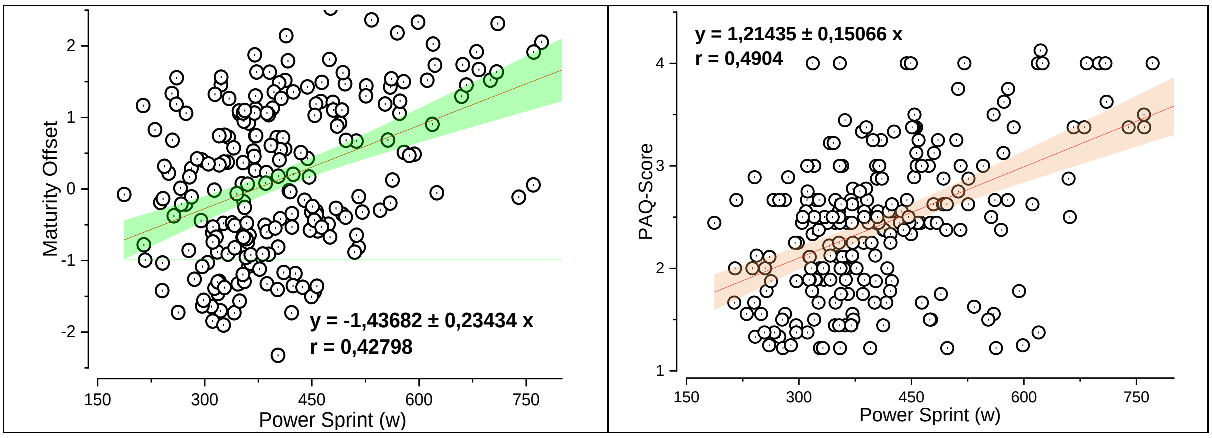

Figure 5 (A). The Correlation of sprint absolute power to biological maturity (left graph) and to physical activity level(right graph).

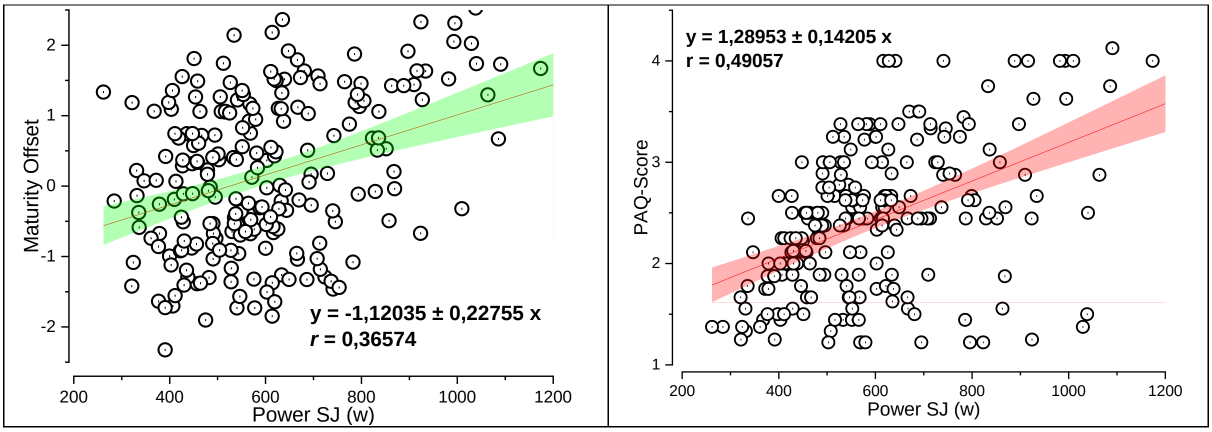

Figure 5 (B). Correlation between Squat Jump (SJ) absolute power to biological maturity (left graph) and to physical activity level (right graph).

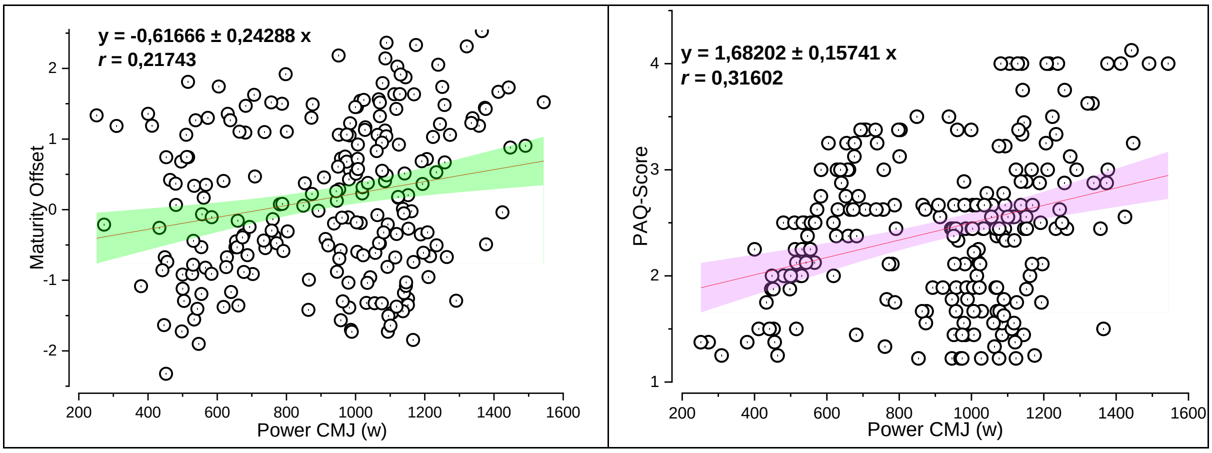

Figure 5 (C). The Correlation of Counter Movement Jump (CMJ) absolute power to biological maturity (left graph) and to physical activity level (right graph).

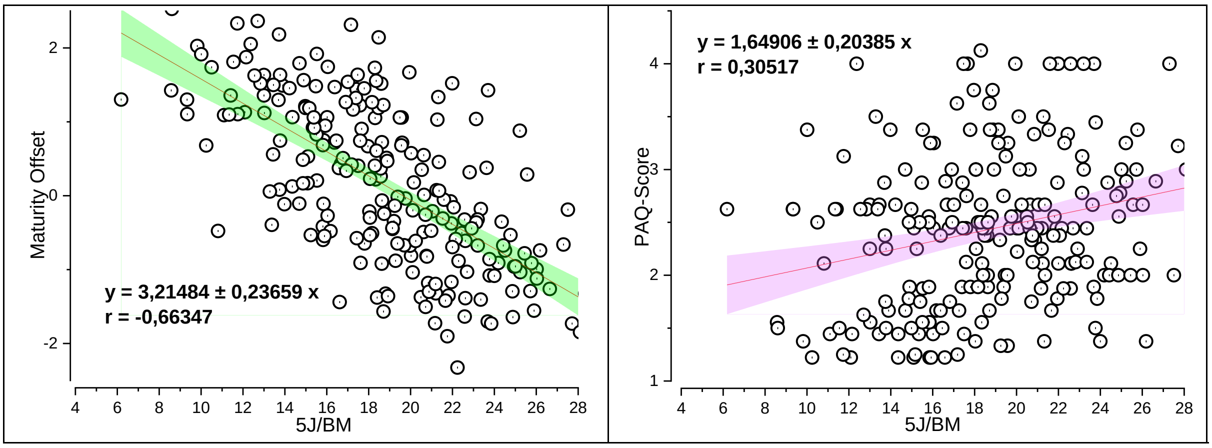

Figure 5 (D). The Correlation of normalized to subject's Body Mass five Jump performance (5J/BM) to biological maturity (left graph) and to physical activity level(right graph).

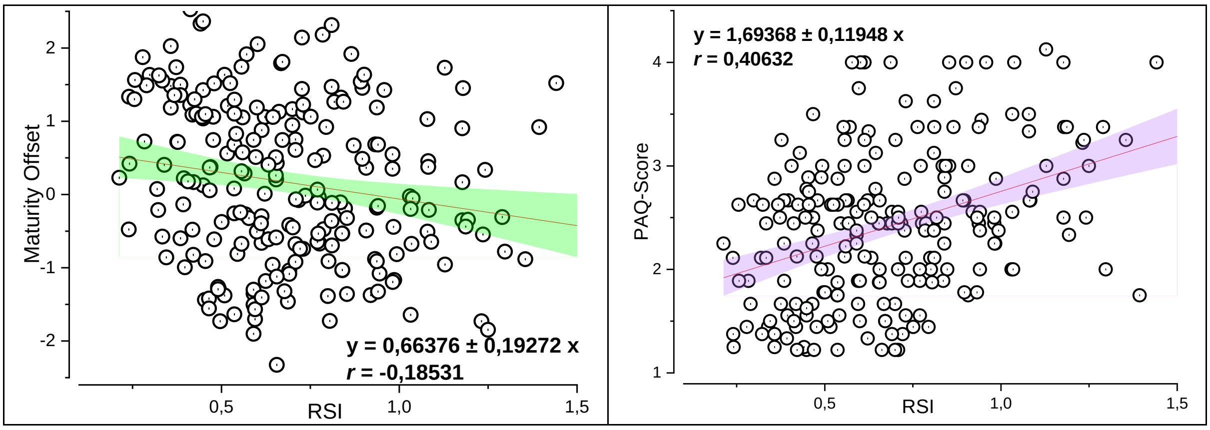

Figure 5 (E). The Correlation of Drop Jump Reactive strength indices (RSI) to biological maturity (left graph) and to physical activity level (right graph).

Table 4. Results of performances analysis of variance, two-way ANOVA and (Gender X Maturation Offset) interaction with eta squared effects sizes estimation and 95% Confidence Interval.

Physical performance variables	**ANOVA Gender Effect**						**ANOVA Maturation Effect**						**Gender X Maturation Offset interaction Effect**		
	df	**F**	***p-value***	**η^2**	**95% CI**		***df***	**F**	***p-value***	**η^2**	**95% CI**		***df***	**F**	***p-value***
					LB	**UB**					**LB**	**UB**			
30m (sec)	1 224	133.9	<0.001	0.37	0.27	0.45	2 223	6.46	0.002	0.05	0.008	0.11	2	42.1	<0.001
Pmax (W/kg)	1 224	55.1	<0.001	0.20	0.11	0.28	2 223	0.91	0.400	0.008	0.001	0.04	2	19.8	<0.001
5J test (cm)	1 224	96.4	<0.001	0.30	0.20	0.38	2 223	4.30	0.015	0.03	0.001	0.09	2	45.8	<0.001
5J/L.L	1 224	56.0	<0.001	0.20	0.11	0.28	2 223	17.9	<0.001	0.13	0.06	0.21	2	30.5	<0.001
5JT/BM ($cm.kg^{-1}$)	1 224	37.3	<0.001	0.14	0.06	0.22	2 223	79.1	<0.001	0.41	0.31	0.49	2	91.0	<0.001
SJ (cm)	1 224	74.4	<0.001	0.25	0.156	0.33	2 223	1.44	0.237	0.013	0.001	0.05	2	26.9	<0.001
SJ P_{peak} (w)	1 224	12.0	<0.01	0.05	0.009	0.11	2 223	17.1	<0.001	0.13	0.05	0.21	2	31.7	<0.001
DJ_{30} (cm)	1 224	48.7	<0.001	0.18	0.09	0.26	2 223	3.82	0.023	0.03	0.00	0.08	2	31.0	<0.001
RSI ($m.s^{-1}$)	1 224	22.3	<0.001	0.09	0.03	0.16	2 223	3.68	0.027	0.03	0.001	0.08	2	15.9	<0.001
K_{vert} (KN.m)	1 224	1.19	0.286	0.005	0	0.03	2 223	7.93	<0.001	0.06	0.01	0.13	2	7.89	<0.001
CMJ (cm)	1 224	81.3	<0.001	0.27	0.17	0.35	2 223	2.47	0.087	0.02	0.001	0.06	2	25.2	<0.001
CMJ P_{peak} (w)	1 224	9.25	0.003	0.04	0.004	0.10	2 223	5.84	0.003	0.05	0.006	0.11	2	13.8	<0.001
CAQ-Score	1 224	8.12	0.005	0.03	0.003	0.09	2 223	0.32	0.726	0.003	0.001	0.02	2	42.1	<0.001

*LB: Lower Band; UB: Upper Band.

Whereas, the gender based comparison reveled a significant difference, girls presented low physical activity range (PAQ-score = 1.9±0.5 < 2.5) in contrast to the boys presented a medium physical activity range (PAQ-Score = 2.7±0.6 > 2.5 and < 3.5). The main differences were in spare time activity (Q1), after school activity (Q5), free time activity (Q8) and activity frequency (Q9) with t-value ranges 6.856 to 12.813 and the effect size was medium to large (g ranges 0.9 to 1.7) [29] in favor of boys at *p*-value < 0.001. The biological maturity based comparison reveled no significant differences between Pre-, Circa- and Post-PHV sub-groups of girls. However, a main difference was signaled by ANOVA test between boys' sub-groups [$F_{(2.130)} = 16.736$; $p<0.001$].

The *Bonferroni* post-hoc test showed higher values score for Post-PHV in comparison to Pre-PHV ($p<0.001$) and in comparison to Circa-PHV group too ($p=0.02$), moreover, the eta-squared effect size was within ($\eta^2=0.249$) indicating medium effects [30]. The physical fitness performance in linear sprint running, horizontal jump, vertical jumps and their main biomechanical variables for the whole sample and according to gender and biological maturity are presented in (Table 3.A. & B.). The ANOVA reported statistically significant main effect of gender [$F_{(1;224)} = 133.99$, $p<0.001$, $\eta^2= 0.37$] in linear sprint performance and [$F_{(1;224)} = 55.19$, $p<0.001$, $\eta^2= 0.20$] for mechanical power outputs. also main effects of gender [$F_{(1;224)} = 96.423$, $p<0.001$, $\eta^2= 0.30$] in 5Jt performance, [$F_{(1;224)} = 74.440$, $p<0.001$, $\eta^2= 0.25$]in SJ performance, [$F_{(1;224)} = 48.733$, $p<0.001$, $\eta^2= 0.18$] in DJ performance and [$F_{(1;224)} = 81.327$, $p<0.001$, $\eta^2= 0.27$] in CMJ performance.

Whereas, results revealed main effect of maturation offset in linear sprint performance, 5JT and DJT at $p<0.05$. In addition, ANOVA showed significant interaction (Gender X Maturation offset) effect in all variables at $p<0.001$ as presented in (Table 4.). The *Bonferroni* post-hoc tests revealed significant statistical differences between maturity sub-groups in many physical fitness performance tests and their main biomechanical outputs as shown in (Figure 4.A. to E.). Generally, boys perform better in physical fitness tests, they were faster than girls with large effect sizes (g =-1.5) and performs greater in horizontal jump (g =1.31; large effect sizes) and vertical jump (g range 0.93 to 1.36; medium to large effect sizes), whereas Post-PHV boys statistically jump higher in SJ and DJ and longer in 5JT when normalized to body mass than Pre- and Circa-PHV boys. However, no statistical differences were reported between girls' maturity sub-groups in sprint variables, Post-PHV girls reported higher Pmax in SJ, DJ and CMJ tests, lower RSI and better vertical stiffness (Kvert) in comparison to Pre- and Circa-PHV. In contrast, Pre-PHV girls jumps higher in SJ, DJ, CMJ and longer than Circa- and Post-PHV girls when the performance was normalized to body mass, all results were at $p< 0.05$.

5. Discussion:

This study aims to assess the influence of biological maturation status and physical activity level on anaerobic explosive power in sprinting and jumping in youth school students using field testing methods. The results highlighted the prevalence of low physical activity in children and adolescents' Moroccan students regardless of their gender, the results in line with the report of *Guthold et al.* [5] presented in 2016 and announced that an average of 84.6% of Moroccan boys and 90.1% of girls were insufficiently physically active.

In general, boys performed better in physical fitness tests irrespectively of their maturation status in agreement with previous research [11], [31], [32] and it may be explained by physical conditions gender-related differences (e.g. leg muscle volume, type of muscle fibers and muscle forces production) [31] and have higher absolute and relative (expressed as a function of body height or weight) maximum power outputs than their counterpart girls [11]. The results showed that students boys Post-PHV display superior sprint mechanical outputs and higher jump performances than their younger counterpart (i.e. Pre-PHV and Circa-PHV), this difference can be attributed to the association of the PHV period to high levels of growth hormone and testosterone [33] associated with the improvement in maximal strength and power due to muscle cross-sectional area development [34]. In contrast, Pre-PHV student performed better than Post-PHV and almost similar to Circa-PHV girls, the imbalances between the quadriceps and hamstrings in late Circa-PHV and earlier Post-PHV period in girls could be a raison of this performance differences [27].

In line with our initial findings, previous research looked into how biological maturation status affects linear sprint performance suggest that improvements in biomechanical sprint variables were noticed as the child undergoes maturation [34]. Untrained male school-age children were found to be able to produce larger antero-posterior ground reaction forces (GRF) throughout shorter ground contacts which can be explained by the use of stretch-shortening cycle (SSC) improves the neuronal and musculo-tendinous capacity to generate maximum force in a short span of time [35] and generate higher propulsive forces by approaching the PHV [34]. The increase in lower limb length during maturation can also be a logical explanation of this improvement, it was observed an increase in stride length and maintain of stride frequency around the PHV [36] whereas, significant differences were reported between Pre-and Post-PHV even when stride length was normalized to lower limb length suggests that other factors, including power, might provide a more compelling explanation for how maturation affects sprinting performance [37].

In our study we highlighted a moderate positive correlation between the maturation status and the mechanical sprint power, especially in boys' $r = 0.60$ at $p<0.01$. Maturity had a significant positive impact on the acceleration and speed of sprinting [38] the positive effect of maturation on over-ground sprinting speed was reported in previous research [39] which can be explained by the development of anaerobic power as the student experiences maturation and positively affect their performance in over-ground sprinting. additionally, our participants presented a low physical activity level (PAQ-score = 2.4±0.72 < 2.5). A positive moderate correlation ($r = 0.49$; $p<0.01$) was found between physical activity level and sprint mechanical power output suggesting a negative effect of lower physical activity on anaerobic power and the overall sprinting performance. Comparison of the anaerobic sprint power of our male participants to well-trained football players with better sprint time performances from a study by Edwards et al. [34] with similar conditions, revealed that our sample present lower mechanical power in all maturation status (14.50 ± 1.77 vs 9.87±1.46 for Pre-PHV; 14.04 ± 2.06 vs 10.17±1.85 for

Circa-PHV; and 13.62 ± 1.59 vs 11.05±2.04 for Post-PHV in w.kg^{-1} of body mass) which goes in line with our findings and confirm the positive effect of physical activity level on sprint outputs and performance.

As previously reported the 5J test was widely introduced as an overview of athletes' capabilities to use horizontal SCC and to estimate the lower limb explosive power [18] the test uses actions similar to sprinting stride. Interestingly, when reporting result as absolute and not relative to subjects' body mass or to lower limb length, Post-PHV boys presented higher performance compared to Pre- and Circa-PHV boys however the relative performances was higher for Per-PHV than Circa- and Post-PHV (Figure 4. E.). In fact, reporting performance in absolute form (as long jump performance values) underestimate the power expressed during the test (Examination of the scaling of human jumping), the lower limb length and subjects' body mass can affect clearly the performance in 5JT. In contrast, younger girls (Pre-PHV) had higher long jumps performance than Circa- and Post-PHV in absolute, relative to lower-limb length and to body mass, but only relative values to body mass presented a statistically significance Pre-PHV vs Circa-PHV at $p<0.05$ and Pre-PHV vs Post-PHV at $p<0.01$ with higher values in favors Pre-PHV girls (Figure 4. E.). Untrained children generally can't benefit strongly from the SSC function in horizontal or vertical direction, even after Post-PHV ages, they have a lower strength to body mass ratio compared to adults [27] especially girls. Gender comparison reveled that boys' skeletons tend to grow progressively longer with increased muscles size, compared to girls [11] in contrast, girls during puberty, their total body fat mass increases, particularly in their lower limbs [40], their muscle volume is much lower, while their percentage of fat mass is higher, in part due to the influence sexual hormones (i.e. estrogen) whereas, female performance cannot match that of their male counterparts [41] thereby, it's possible that they won't be able to generate enough ground reaction force in order to use the kinetic energy during horizontal boundary crossing.

Mid-childhood and adolescence see an increase in muscle strength with age, although the pattern of progress depends on a number of variables, including gender, maturity, body size, and, to a certain degree motor abilities and physical activity [9]. The large negative correlation reported in this study (Figure 5. D.) between horizontal jumping (relative to body mass) performance and maturation offset ($r = 0.66$) in long with the positive moderate correlation to physical activity level ($r = 0.30$) highlight the importance of physical activity to explore the body mass acquisition experiencing maturity in a better way. The anthropometric changes such as body mass and body fat associated with maturation and growth was reported as important factors influencing motor function and strength [32]. Thereby, enhancing the recruitment of muscle fibers and adapt body strength to body size seems to be crucial for children especially in horizontal direction during the maturation process.

Jump height is a useful variable to assess the development of lower limb explosive power undergoes maturation. Similar to results in sprinting, boys in jumping performed higher than girls in vertical tests irrespective of maturity offset, with medium to large effect of gender (g range 0.93 to 1.36) and moderate effect of physical activity level (η^2= 0.22 to 0.38). In drop jump, Post-PHV boys jumped higher than Pre and Circa-PHV, had greater RSI and higher tendon stiffness. This differences in performance still unclear according to literature, lower RSI could be result of the lower tendon stiffness in children [42] affecting the efficacy of the stretch-shortening cycle and increasing contact time [43]. In contrast, Circa -PHV girls jumped higher than Pre and Post-PHV, this difference in jump height may be result of the impairment in balance and coordination around the PHV [44] and the imbalances between the quadriceps and hamstrings in late Circa-PHV and earlier Post-PHV period earlier mentioned for girls [27]. However, a poor negative correlation relation (r = -0.18) were found between RSI and maturity offset supporting previous evidences reporting a development of the SSC capabilities in non-linearly with maturation status in young people [45]. Interestingly, a positive moderate correlation (r = 0.40) were found between the physical activity scores and the RSI index (Figure 5.E) which may highlight the positive effect of the physical activity in the development of the SSC ability by decreasing the contact time and enhancing the jump height, benefiting from the concomitant use in sport performance with actions similar to Drop Jump. Whereas, In SJ no maturity significant effects were reported between Pre- and Circa-PHV in jump height, peak power and peak force in both genders and only in boys for CMJ. Thereby, the Post-PHV boys presented higher performances values (i.e. jump height and peak power) whereas Circa-PHV girls were associated with better performance with no statistical significance at $p<0.05$ in line with *Focke et al.* [31] supposing the increase of jump height with age even in pre-pubertal children. The gender-difference in jump height increased continuously with age, a medium gender effects sizes were reported in SJ (η^2=0.25) and a small one for CMJ (η^2=0.17) jump height. This gender effect could be result of better adaptations in the mechanical properties of muscles and tendons of boys experiencing maturation than girls [28] and gender-related physical and morphological conditions as well as legs length, fat mass, muscles volume, muscles' fibers constitution and their concomitant force and power expression [46]. A positive moderate correlation of the maturity status (r = 0.36) to the peak power in SJ was reported however the correlation was small (r = 0.21) for CMJ, in contrast, a positive moderate correlation was found for SJ and CMJ peak power to physical activity level (r = 0.49; r = 0.31 respectively) see (Figure 5.B & C) some caution in interpretation due to the small effect on CMJ were demanded however the effect was significant whish may be related to the complexity of the counter movement jump in execution, children showed lower skills especially in the preparatory phase with an adequate range of motion (angles of knee, ankle and hip) in comparison to adults [47]. The over-all findings support the benefits of the physical activity behavior to increase the mechanical power expression and jump height enhancement.

6. Conclusions

Overall, the current study has shown a noteworthy occurrence of low physical activity level in Moroccan youth school students with marginal differences between genders. The study also reported moderate to large performance differences in sprinting and jumping test in favor of boys to girls irrespectively of their maturation stages. However, a notable improvement in ballistic performance as children experiences puberty was highlighted. Post-PHV boys performed better in most sprint and jump test as an expression of explosive anaerobic power benefiting from their morphological and physiological maturation specific developments. Whereas Post-PHV girls were slightly slower, proportionally jump higher and express higher power than their counterpart Pre- and Circa-PHV. The ability to develop explosive anaerobic power of fundamental abilities in a variety of sports such as jumping and sprinting across this particular age range is highly sensitive, introduction of ballistic exercises is a good decision making in this age-span. The effect of low level of physical activity was noticed and moderately correlated to the physical fitness performance in both gender. This results highlighted the necessity of implementing good lifelong habits regarding physical activity and minimize sedentary behavior in this crucial age (i.e. childhood and adolescence) in line with World Health Organization recommendations by providing national guidelines regarding physical activity both individually and collectively.

7. Recommendations

illuminated by results of the study, we suggest the subsequent practical recommendations:

✓ We advise parents to encourage their children to practice some recreational physical activities such as walking, cycling, playing outdoors and to engage in organized sport activities.

✓ We incite physical education teachers and coaches to integrate exercises of anaerobic explosive power in this age-span such as sprinting and jumping to take advantage of morphological and physiological maturation specific developments and address maturation-specific alterations.

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