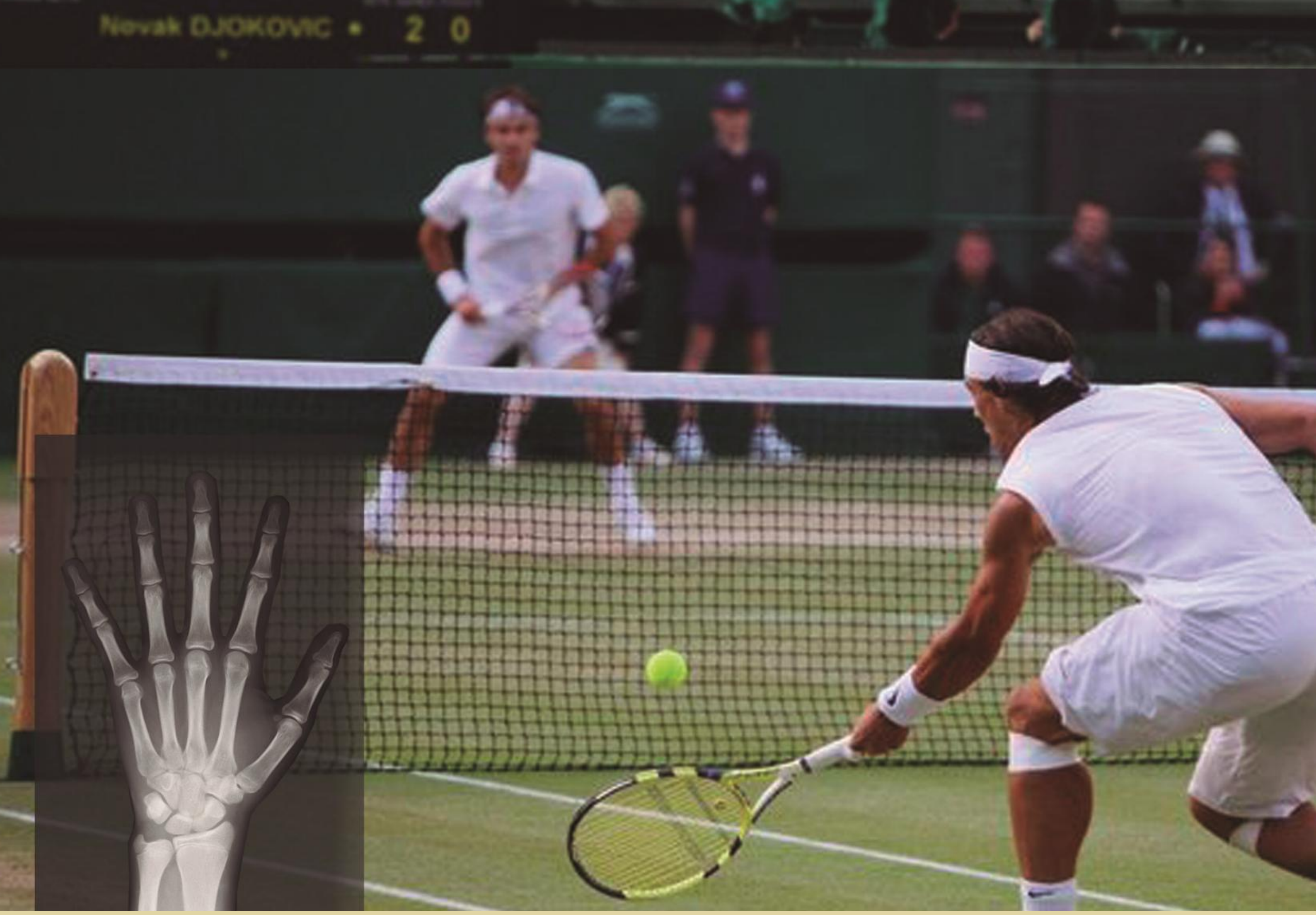

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GROWTH AND MATURATION IN MALE ADOLESCENT TENNIS PLAYERS:
agreement between protocols to estimate skeletal age

Dissertação de Mestrado em Treino Desportivo para Crianças e Jovens,
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GROWTH AND MATURATION IN MALE ADOLESCENT TENNIS PLAYERS: agreement between protocols to estimate skeletal age

Dissertation submitted to the Faculty of Sport Sciences and Physical Education of the University of Coimbra, for the degree of Master in Youth Sports Training.

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ABSTRACT

The aim of this study was to examine the agreement between concurrent protocols for determination of skeletal age (FELS and TW3). The sample consisted of 80 male adolescent tennis players aged 8.69-16.79, they were from Great Britain, Portugal and Colombia. Standard hand wrist radiograph was taken to estimate skeletal age with the protocols to Fels method (Roche et al.,1988) and TW3 method (Tanner et al., 2001). Analysis of variance ANOVA was used to compare Fels and TW3 SAs in players who were not classified as skeletally mature by either method.. The difference between means of Fels and TW3 SAs were significant (F=37,50 , p<0,001). Fels method was a slight more advanced in the classification compared with TW3.

A possible influence by variation in maturity status on body composition, size and physique could determine the performance in adolescents tennis players who needs speed, agility and aerobic capacity for the competition.

Keywords: Growth, Maturation, Skeletal age, Tennis, Adolescent.

RESUMEN

El objetivo de este estudio fue examinar el grado de aceptación que existe entre los protocolos para la determinación de la edad esquelética (FELS y TW3). La muestra consistió en 80 jugadores de tenis adolescentes hombres de 8,69-16,79 años, procedentes de Gran Bretaña, Portugal y Colombia. Se tomaron radiografías estándar de muñeca y mano para estimar la edad esquelética con los protocolos del método de Fels (Roche et al., 1988) y el método TW3 (Tanner et al., 2001). El análisis de varianza ANOVA se utilizó para comparar Fels y TW3 SAs en los jugadores que no fueron clasificados como esqueléticamente maduros por ninguno de los métodos. Las diferencias entre la media de Fels y TW3 SAs fueron significativas ($F = 37,50$, $p < 0,001$). El método Fels fue un poco más avanzado en la clasificación de madurez comparado con la clasificación de TW3.

La posible influencia de la variación en el estado de madurez sobre la composición corporal, el tamaño y el físico podría determinar el desempeño en los jugadores de tenis adolescentes que necesitan de velocidad, agilidad y capacidad aeróbica para la competencia.

Palabras clave: Crecimiento, maduración, edad esquelética, tenis, Adolescente.

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LIST OF ABBREVIATIONS

ATP	-Association of Tennis Professional
CA	-Chronological age
Cm	-Centimeter
GP	-Greulich and Pyle
ITF	-International Tennis Federation
Kg	-Kilogram
K&G	-Kamis and Guo
K&R	-Kamis and Roche
LTAD	-Long Term Athlete Development
RUS	-Radius Ulna and Short bones
SA	-Skeletal Age
TW3	- Tanner and Whitehouse Version 3
USA	-United States of America

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CHAPTER 1:

INTRODUCTION

Tennis is among of the most popular sports. According to *International Tennis Federation* ITF more than 60 million people practice this sport and 200 countries are members of ITF (Pluim et al., 2006) Hence, tennis is a sport extensively studied. Most of the scientific literature focused on physiological (kovacs, 2006; 2007), biomechanical variables (Elliot et al., 2003), physical performance, (Fernandez-Fernandez et al., 2006; 2015; 2016) and prevention and treatment of injuries (Bylak & Hutchinson, 1998).

1.1. Youth tennis

In search of talent identification many authors describe characteristics of the athletes in young ages, in an attempt to asses strengths and weaknesses attributes of given player (Girard, 2009; Sánchez-Muñoz et al., 2007). Prediction of adult stature in young is important (Pearson et al., 2006). Boys advanced in terms of maturity tended to be stronger and to perform better on motor performance items that require strength compared to peers who were on time or late maturing (Baxter-Jones et al., 1995; Malina et al., 2004). Successful youth tennis players are characterized by speed, size, strength, and high skill (Fernandez et al., 2006) . The belief that early identification of talent leads to improved performance has resulted in formal talent identification beginning in late childhood and early adolescence (Balyi & Williams, 2009).

The topic of talent identification, selection and development is central in youth sports (Bompa 1995; Bohme, 2007; Weinek, 2005; Balyi & Williams, 2009) which is a process that implies about 10- 12 years of regular practice and competition (Platonov, 2001). With the aim the continuous improvement of training programs Canada sports implemented the Long Term Athlete Development (LTAD) this is the first program focused on the general framework of athlete development with special reference to growth, maturation, and development, which has like a reference of biological maturation de Peak height velocity (Mirwald et al., 2002). The LTAD is a approach/philosophy that is being implemented in Canada to all sports and is based on empirical study of human development and best sport system practices. LTAD takes into account the development age vs. chronological age of participants there by helping design programs that more accurately reflect the needs of athletes at their current stage of development. Through the systematic identification of LTAD stages is able to maximize the potential of development and increase the enjoyment of participants and athletes. It provides a framework for developing physical literacy, physical fitness and competitive ability, using a stage by stage approach that respects the physical, mental and emotional levels of the participant. LTAD is athlete centered, coach driven and supported by officials, administrators, parents, Sports science, communities and sponsors.

1.2. Growth and maturation

Growth and maturation are two biological processes so important during the period of formation of young athletes, from childhood to adolescence and from adolescence to adulthood occur many transformations. These changes significantly interact with trainability and readiness for sport participation, according to (Malina et al., 2004; 2014; Baxter-Jones et al., 2002). Growth, maturation and development are the major biological processes among the first two decades of life. Growth refers to increase in body size, while maturation refers to progress toward the mature state. Finally, development is mainly behavioral and comprises qualitative changes in the adaptation of the individual to the ecological context. These three processes are simultaneously and investigation in pediatric sports science are emerging and still needed.

Maturation can be assessed by the most commonly used indicators, that is by the appearance of secondary sex characteristics, such as pubic hair or genital development. The somatic growth curve, for example maximum growth in height during adolescent years is a non invasive alternative but demands longitudinal data. Skeletal age obtained from the hand and wrist. (Malina et al., 2004; Baxter-Jones et al., 2002) is a valid measurement and considered the best single criteria to assess biological maturation (Malina et al. 2004).

Children of the same chronological age can vary considerably in biological maturity status. Thus, variation among individuals in maturity status a given point in time and in progress over time influences measure of growth and performance (Malina et al., 2004). Variation in growth and performance associated the maturity status with adolescence on tennis players is described in (Myburgh et al., 2016 a; b.).

1.3. Demands of game and Physical profile

Competitive tennis requires a fine interaction among tactical, technical, psychological and physical attributes (Kovacs, 2007). Physiological demands of competition depend of style and intensity of game, every competitive match can be different duration (approximately 105 min) with a work-to-rest ratio of 1:2 to 1:3. Real play time is about 31% of total play time (Torres-Luque et al., 2011). During this time, a tennis player runs an average of 3 m per shot and a total of 8–12 m in the course of a point, completing 300–500 high intensity efforts during a best of three sets match. (Fernandez et al., 2006).

According to Fernandez et al., (2006) tennis is a intermittent sport of maximal efforts 5-10s by rest time of 10-20s during a time of 1-5h, thus a tennis match involves a combination of low and high intensity periods, and tennis can be considered to be an intermittent anaerobic sport with an aerobic recovery phase. For this reason competitive tennis players needs mixture of anaerobic (speed and agility) combined with a aerobic capacity to competition (Kovacs, 2007).

According to Torres-Luque et al., (2011) the characteristics of competitions in young tennis players is characterized by playing time around 105±20 min (real play time of 32 minutes, and resting time of 74 minutes). The study showed that the temporal structure of individual tennis play in adolescent players playing on a hard surface is similar to that players at higher levels, including the number of strokes per minute. Real play time and resting time in adolescent players was not different between sexes and the adolescent players showed approximately, the same number of strokes per rally but with a greater average duration compared with adult elite athletes, determined by physical conditioning and technique development (Kovacs, 2006).

1.4. The young tennis player

Studies about skeletal maturation in youth tennis players are still limited, and are mainly related to growth status (Malina, 1994; Myburgh, et al., 2016a) or maturity-associated variation in functional characteristics (Myburgh et al., 2016b) To date no studies comparing methods were performed in a sample of young tennis players, regarding the concurrent determination of skeletal age (SA), although this was already done for other sports such as soccer (Malina et al, 2007).

Skeletal age is often considered the best index for the assessment of biological maturation (Malina et al., 2004 ; Baxter-Jones et al., 2002). It is established that skeletal age did not differ between active and inactive boys followed longitudinally from 13 to 18 years (Beunen et al., 1992; Malina, 1994; Beunen & Malina, 2007). The hypothesis about the interrelationship of variation in maturity status related to body size, physique and body composition is often assumed to success in sport career (Malina et al., 2004). Boys who were advanced in maturity tended to be stronger and to perform better on motor skills than the boys of de same chronological age who were on time or later in maturity (Malina et al., 2004; Baxter-Jones et al., 1995). This issue was well documented in soccer (Malina et al., 2000; Hirose, 2009; Figueiredo et al., 2009; Carling et al., 2009; Teixeira et al., 2015).

A previous study (Malina, 2011) summarized the evidences about skeletal age and maturity status in different sports, and it was possible to note a reduction in the proportion of late maturing male athletes as adolescence progressed. The authors hypotesized that this reflected the exclusive nature of sports and selective dropout phenomenon (Pearson et al., 2006; Reilly et al., 2003; Myburgh et al., 2016 a; Myburgh et al., 2016 b). This was of special relevance, since maturation was considered a major confounding variable in talent identification in adolescence and has important implications to long-term developmental models of sport preparation.

1.5. Skeletal age

The assessment of SA is used to estimate the level of skeletal maturity attained by a youngster at the time of observation, (Malina et al., 2004; 2011). FELS and TW3 methods used standard radiographs of the hand wrist skeleton (radius, ulna, carpals, metacarpals and phalanges). They were based on different and specific criteria for each bone, basically shape differentiation, epiphysis union and the attainment of the adult morphology. Therefore both methods were not considered as equivalents and differed in SA results within an individual (Malina, 2011) and this could be also among groups of different populations (Malina et al., 2004).

Skeletal age or also called bone age, in clinical issues is used to assess skeletal development that is believed to be universal to all subjects in terms of stages and sequences of changes. The measurement is taken against a *standard* which consists of data of the skeletal development of *normal and healthy* children. In other words, skeletal age corresponds to the chronological age at which the children on whom the standard was based usually attained that same degree of skeletal development. In clinical, it has been used basically two methods Greulich and Pyle and TW2 (Flores et al., 2005), have been used and compared with ethnic variation (Zhang et al., 2008; Kim et al., 2015), nutrition and endocrine system. (Flores et al., 2005; Flor-Cisneros et al., 2006) and comparison of different methods (Bull et al., 1999; Kim et al., 2015).

On the other hand, sport sciences also also use methods to estimate skeletal age (Malina, 1971). Short-term longitudinal studies in several sports indicated similar gains in skeletal maturation in both athletes and non athletes (Baxter-Jones et al., 2002) variety of books and research describe about the potential influence of variation in maturity status on size, physique and body composition (Beunen et al., 1992; Armstrong, 2013; Malina et al., 2004; 2011; 2014), and definitely on performance in sport.

In sport, it has been used three methods Greulich and Pyle, TW (Version 2 and 3), and Fels Method. Studies commonly examine young athletes contrasting in maturity status within a particular age groups. Difference between skeletal age and chronological age are used to classify participants as early maturing, average or late maturity (Malina, 2011).

Specifically in tennis. maturity-related variation in functional characteristics were recently described (Malina, 1994; Myburgh et al., 2016 b). The authors found that advanced maturity in male players provided advantages in specific motor skills like grip strength, speed, upper and lower body power, agility and aerobic endurance.

The FELS method assigned SAs and was developed based on longitudinal records of 355 boys and 322 girls in the Fels Longitudinal Study between 1932 and 1977. The sample was from middle-class families in south-central Ohio, USA. It used 20 bones, plus the presence or absence of the pisiform and adductor sesamoid, SA and standard error were calculated by a program application (Roche et al., 1988). On the other hand, the TW3 method assigned maturity scores that were converted to SAs. This method had two major revisions. The protocol was based on British Children (~2600) from a home for children and public schools; most were born between 1940 and 1955. The last revision occurred in 2001. The criteria for the stages of maturation of 13 long bones emerged from samples of European (British, Belgian, Italian, Spanish), Argentine, Japanese and well off American youth. (Tanner et al., 2001).

1.6. Research question

Each method had been noted as having advantages and disadvantages. Differences in protocols or their application illustrated variation among methods (Malina et al., 2004; 2011). The current study was aimed to examine the agreement between concurrent protocols for determination of skeletal age (FELS and TW3) in a sample of male tennis players.

CHAPTER 2:

METHODS

2.1. Procedures

Informed consent was obtained from parents. The participation of the players was voluntary and the sports entities were also informed about the whole experimental procedure. Month of birth, height, sitting height body mass were measured, anthropometry involved the use of some references defined for the standardization of measurement procedures, A single anthropometrist measured height, sitting height body mass in each country; Height was measured to the nearest 0.1 cm using a calibrated Harpenden stadiometer fixed to a wall following standardized procedures. Chronological age was calculated as the year between the date of birth and the day of the x-ray examination, the radiograph was taken by an onsite trained and certified technician in each country.

2.2. Participants

The sample is composed of 80 male tennis players aged 8.69-16.79. They were from Great Britain (n=50), Portugal (n=17) and Colombia (n=13).

2.3. Skeletal age

Standard hand wrist radiograph was taken to estimate skeletal age with the protocols to Fels method (Roche et al.,1988) and TW3 method from radio, ulna and shorts bones RUS (Tanner et al., 2001).

2.4. Skeletal maturation

Mature state was obtained considering FELS method and the fact that a skeletal age of 18.0 years corresponds to the mature state. The respective classification for TW3 is 16.5 years (score=1000) for males.

2.5. Skeletal maturity

Players who reached skeletal maturity were labeled mature . Difference between skeletal age and chronological age were used to each subject to classified in average, early and late maturity. (Malina 2011).

Average= skeletal age within ± 1 year chronological age.

Early= Skeletal age older than chronological age by more than 1 year.

Late= skeletal age younger than chronological age by more than 1 year.

2.6. Statistical analysis

Descriptive statistics were calculated for the total sample (mean, standard deviation, standard error and confidence interval 95% CI) to chronological age, stature of the father, stature of the mother and anthropometry, equally descriptive statistics for maturity offset, estimated age at the peak height velocity, predicted mature (according to concurrent protocols) and skeletal aged determined by concurrent protocols.

Analysis of variance ANOVA was used to compare Fels and TW3 SAs in players who were not classified as skeletally mature by either method, the Statistical Program for Social Sciences – SPSS, version 24.0 was used.

Finally, different linear relationships were plotted to CA, stature, body mass and also to concurrent SAs protocols, using the graphpad prism version 5.0.

CHAPTER 3:

RESULTS

Descriptive statistics for the total sample to chronological age, stature of the father, stature of the mother and anthropometry are summarized in table 1.

Mean of chronological age is 12,91 years, stature 159,86cms and body mass 49,70kgs. The sitting height mean is taller than estimated leg length mean. Descriptive statistics for maturity offset, estimated age at the peak height velocity, predicted mature stature (according to different concurrent) and skeletal aged determined by concurrent protocols are summarized in table 2.

Mean of skeletal age determined by TW2 is greater than means of TW3 and Fels methods, and Fels SA mean is greater than TW3 SA. Among players who were not skeletal mature by either method (n= 72) The difference between mean Fels and TW3 SAs are significant ($F=37{,}50$, $p<0{,}001$).

Mean of predicted mature stature K&R is greater than mean of predicted mature stature K&G in the total of the sample (n=80), the difference between mean K&R and K&G is significant ($t=3.682$, $p<0{,}001$).

Table 1. Descriptive statistics for chronological age, stature of the father, stature of the mother and anthropometry (n=80).

Variable	Unit	Mean			Standard deviation
		Value	SE	(95%CI)	
Chronological age	Year	12.91	0.21	(12.49 to 13.33)	1.87
Stature of the father	Cm	178.78	0.91	(176.95 to 180.60)	8.20
Stature of the mother	Cm	165.19	0.69	(163.79 to 166.58)	6.25
Mid parental stature	Cm	171.98	0.61	(170.76 to 173.20)	5.48
Stature	Cm	159.86	1.55	(156.77 to 162.95)	13.88
Sitting height	Cm	82.80	0.80	(81.20 to 84.40)	7.18
Estimated leg length	Cm	77.05	0.81	(75.42 to 78.68)	7.31
Sitting height to stature ratio	%	51.81	0.14	(51.52 to 52.11)	1.32
Body mass	Kg	49.70	1.52	(46.66 to 52.74)	13.66

Table 2. Descriptive statistics for maturity offset, estimated age at the peak height velocity, predicted mature stature (according to different concurrent) and skeletal aged determined by concurrent protocols (n=80).

Variable	Unit	Mean			Standard deviation
		Value	SE	(95%CI)	
Maturity offset	year	-0.64	0.19	(-1.04 to -0.25)	1.78
Age of peak height velocity	year	13.56	0.07	(13.42 to 13.70)	0.64
Predicted mature stature (K&R)	cm	181.77	0.75	(180.28 to 183.27)	6.72
Predicted mature stature (K&G)	cm	180.45	0.82	(178.82 to 182.09)	7.34
Skeletal age (Fels)	year	13.37	0.30	(12.76 to 13.99)	2.76
RUS	#	558.85	26.06	(505.89 to 611.81)	238.00
Skeletal age (TW-Version 2)	year	13.45	0.29	(12.86 to 14.04)	2.51
Skeletal age (TW-Version 3)	year	12.85	0.27	(12.30 to 13.40)	2.48

* K&R (kamis & Roche), K&G (kamis & Guo)

Classification of skeletal maturity status by different protocols and crosstab of absolute frequencies is shown in Table III. The totals to TW version 2 are late (n=7) on time(n=30) early (n=35) mature (n=8), to TW version 3 are late (n=18), on time(n=41) early (n=13) mature (n=8) and Fels are late (n=10) on time(n=35) early (n=33) mature (n=2). The method that most ranked late and on time was TW version 3 (n=18 and n=41)respectively ; early was TW version 2 (n=35) and mature were TW version 2,3(n=8).

Two players are skeletally mature with the Fels method (CA 16,8 and 15.7 years), while eight are skeletally mature with the TW version 2 and 3 (CA 15.0–16.8 years). The two players matures with Fels also are matures with TW method in both versions.

Linear regressions for stature to CA and body mass to CA were plotted in figures 1 and 2. Coefficients of correlation between stature and CA, body mass and CA were r=0.83 and r=0.79 respectively.

Table 3. Skeletal maturity status* by different protocols and crosstab of absolute frequencies (n=80).

		Fels					TW2				
		Late	On time	Early	Mature	Total	Late	On time	Early	Mature	Total
TW2	Late	5	2	0	0	7					
	On time	5	20	5	0	30					
	Early	0	13	22	0	35					
	Mature	0	0	6	2	8					
	Total	10	35	33	2	80					
TW3	Late	8	10	0	0	18	7	11	0	0	18
	On time	2	23	16	0	41	0	19	22	0	41
	Early	0	2	11	0	13	0	0	13	0	13
	Mature	0	0	6	2	8	0	0	0	8	8
	Total	10	35	33	2	80	7	30	35	8	80

*Biological maturation is used for skeletal age and biological maturity status for categories derived from differences between chronological and skeletal ages.

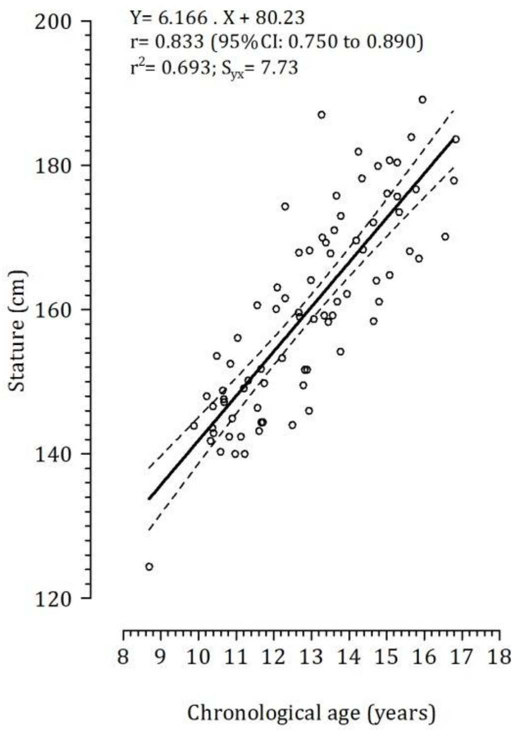

Figure 1. Linear relationship between stature and CA for the total sample (n=80).

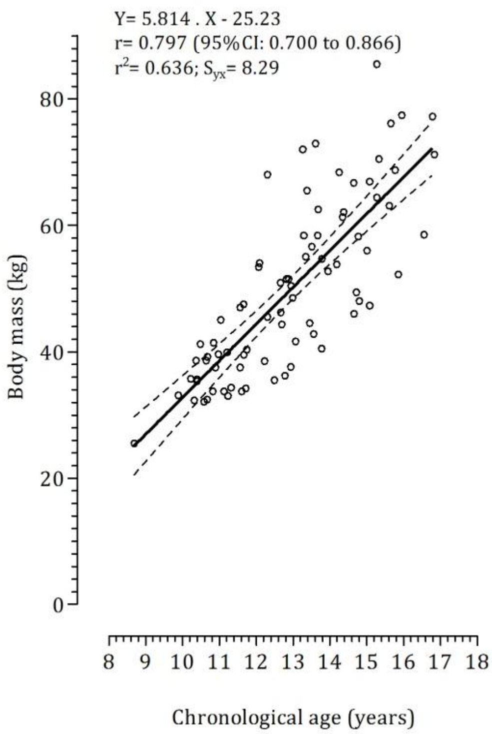

Figure 2. Linear relationship between body Mass and CA for the total sample (n=80).

Lineal regressions for SAs by concurrent protocols and CA were plotted in figures 3, 4 and 5.

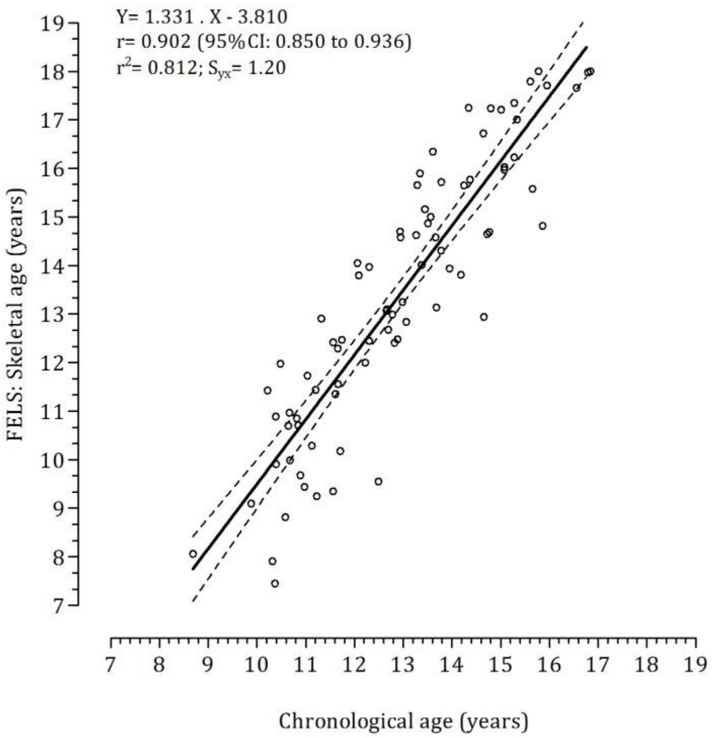

Figure 3. Linear relationship between Fels and CA for the total sample (n=80).

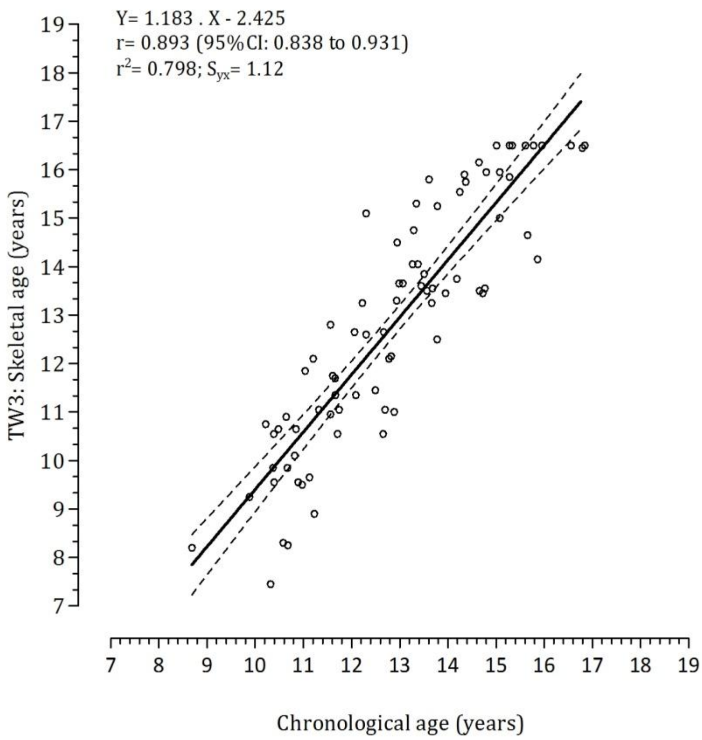

Figure 4. Linear relationship between TW3 and CA for the total sample (n=80).

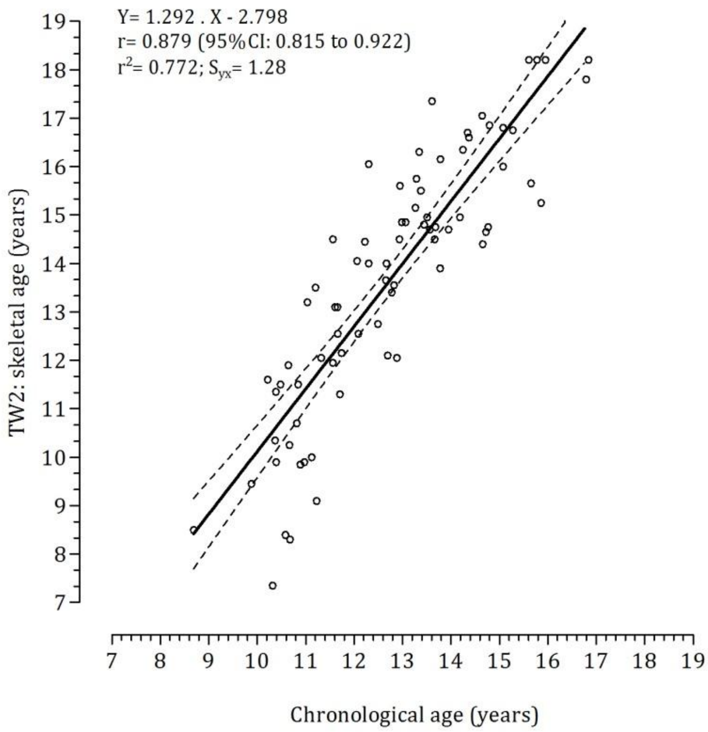

Figure 5. Linear relationship between TW2 and CA for the total sample (n=80).

Coefficients of correlation between Fels and CA were r=0.90, TW3 and CA were r=0.89, TW2 and CA were r=0.87.

Linear regressions between concurrent SAs protocols were plotted in figures 6, 7 and 8. Coefficients of correlation between TW version 3 and Fels were r=0.90, between TW version 2 and Fels were r=0.93, between TW version 2 and TW version 3 were r=0.98

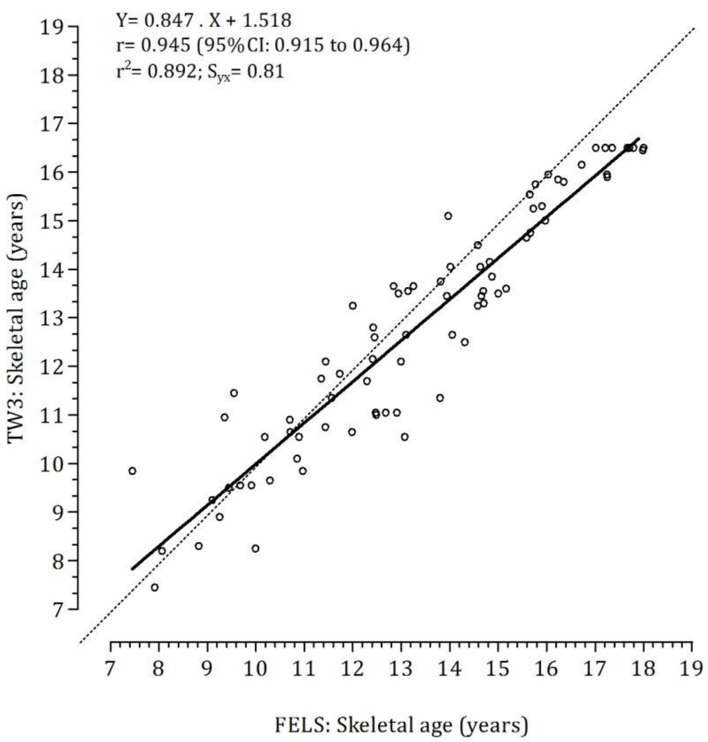

Figure 6. Linear relationship between TW3 and Fels for the total sample (n=80).

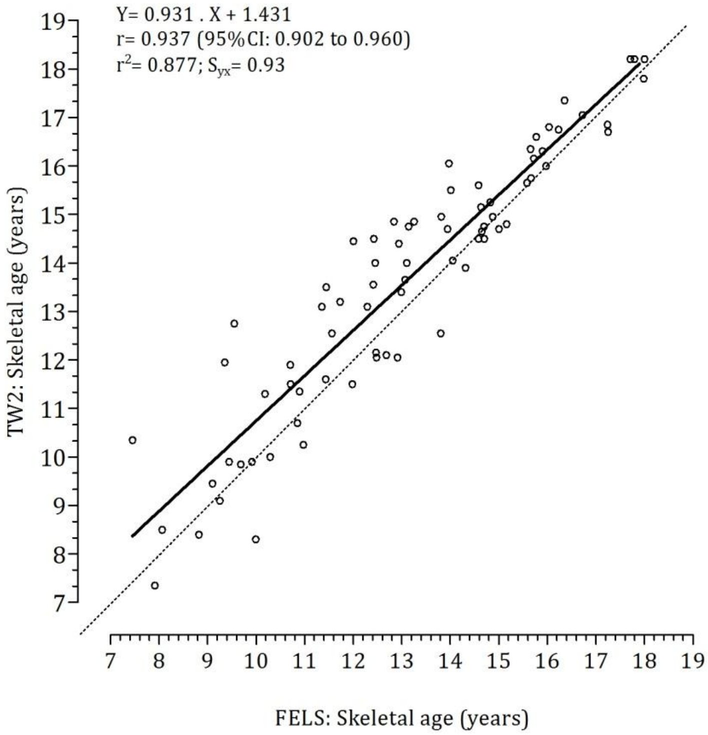

Figure 7. Linear relationship between TW2 and Fels for the total sample (n=80).

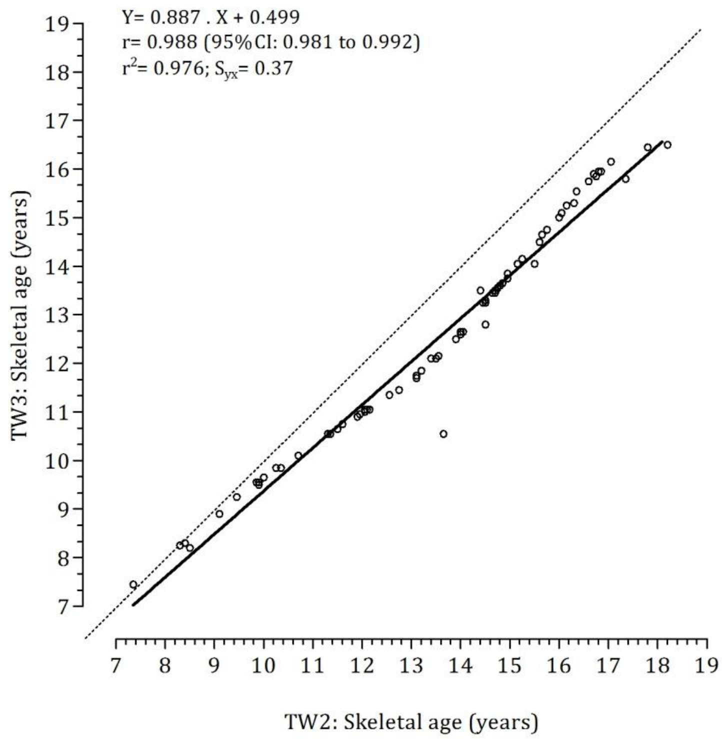

Figure 8. Linear relationship between TW3 and TW2 for the total sample (n=80).

CHAPTER 4:

DISCUSSION

4.1. Main findings

Poor agreement between protocols Fels skeletal ages and TW3 skeletal ages in this sample of male adolescent tennis players could be by different factors ; there are a large inter-individual differences in skeletal maturations among youth (Malina et al., 2004; Malina 2011). British, Portuguese and Colombian are a varied ethnic sample, Therefore some players have been more affinity in a different protocol, mainly in TW3 because the method in this version was based on samples of Europe (British, Belgian, Italian, Spanish), South America(Argentinean) American and Japanese children and adolescents (Malina et al., 2004); in contrast Fels protocol was based in only American sample (Roche et al., 1988; Malina et al., 2004). and does not fit a this sample.

4.2. Greulich and Pyle method

The *Atlas of Skeletal Maturation of the Hand* was published by Todd In 1937. It started at the Western Reserve University School of Medicine in Ohio in 1929. Few years later, Greulich and Pyle published ,in 1950, their atlas partly based on the atlas by Todd. They were able to use all the radiographs obtained in the original study. The Greulich and Pyle method as originally described involves a complex comparison of all bones in the hand and wrist against reference standard radiographs of different ages. A total of thirty bones need to be examined. The sex of the patient is considered. Changes for males and females are described using standard radiographic images of the left hand of children ordered by chronological age.

The first step in the analysis compares the given radiograph with the image in the atlas that corresponds to the chronological age of the patient. Afterwards, one should compare the film with adjacent images representing both younger and older children. When comparing the radiograph against an image in the atlas there are certain features as maturity indicators. These features vary with the age of the child, the presence or absence of certain carpal or epiphyseal, ossification centers, the shape of the epiphyses and the amount of fusion with the metaphysic. (Malina 1971; Malina et al., 2004; 2011; Niemeijer, 2002).

4.3. Tanner and Whitehouse method (TW)

Tanner and Whitehouse contacted with the Greulich and Pyle atlas. They noticed several aspects of the method and improved. The TW method had two important revisions TW1 emerged from a sample of about 3000 healthy British children and the method was matching features of 20 bones of the hand and written criteria for the stages through which each bone passes in its progress from initial appearance to mature state. These bones included the wrist, carpals, the thumb and the third and fifth fingers. A specific point score is assigned to each stage of each bone, and after the total of score are summed to a skeletal maturity score and finally to converter the score to a skeletal age.

The score system changed in the revised TW2. It contains the same bones and it was possible to have a score system from the radio, ulna and short bones (RUS of 13 bones or carpal). The stage corresponding to a reference image is assigned to each bone. When the stage of a certain bone is known the score associated is retained to obtain a final score. After all the required bones have been analyzed, the total score is determined and a certain skeletal age obtained via a conversion table from score into skeletal age.

The most recent version TW3 (Tanner et al., 2001) provide RUS and carpal SAs. It emerged from samples of British, Belgian, Italian, Spanish, Argentine, American and Japanese children and adolescence. The criteria for assessing the maturity status have not been changed, only de scale for converting the skeletal maturity score to an SA (Malina, 1971; Malina et al., 2004; 2011; Niemeijer, 2002).

4.4. Fels method

The FELS method assigns SAs and uses the same 20 bones as the TW2 plus the presence or absence of the pisiform and adductor sesamoid. It was developed from longitudinal records of 355 boys and 322 girls in the Fels Longitudinal Study between 1932 and 1977 and published in 1988. The sample was from middle-class families in south-central Ohio, USA. SA and standard error are calculated by a program system associated with each assessment. This error provides a degree of confidence regarding the predicted values.

Different maturity indicators are involved in assessment at different chronological ages. The values for the measured (epiphysis and metaphysis widths) and assigned grades for specific shape bones are also maturity indicators. (Roche et al., 1988; Malina et al., 2004).

4.5. Agreement among protocols

Although skeleton is a indicator of maturity and both protocols are based in the same principles as they are; standard radiographs on the hand and wrist, shapes and fusions of skeletal progress from cartilage to bone, that means from initial formation towards adult morphology (Malina et al., 2004; Malina 2011); the same radiographs can be two different skeletal ages by Fels and TW3 because they aren't equivalents, as well as in Fels 18.0 years is skeletal mature state and TW3 RUS is score 1000, 16.5 years. Also, between protocols exist some differences in the assessment , TW3 use (radius, Ulna, and short bones) RUS and transform a score to get later a skeletal age (Tanner et al., 2001) whereas Fels use use 20 bones (radius, ulna, metacarpals and falanges of the first, third and fifth digits) presence or absence of the pisiform and adductor sesamoid assigning grades for bones shapes, to get directly a skeletal age. (Roche et al., 1988; Malina et al., 2004). According to Malina et al., (2004) exist disharmony in maturity of bones and this is a genetic, but there is a inclination to reach a mature state first in carpals and in late adolescence radius, ulna, metacarpals and phalanges.

4.6. Growth status

Stature and weight of this sample are below of P 50 like samples of adolescent tennis players presents in different studies of growth state (Malina, 1994; Myburgh et al., 2016a). Although this is a total, result was not separated by chronological age of each country group, it means, the statures and weights of British are not separated of Portuguese and Colombian sub samples, but it is assumed that the Colombians could be a little lower scores in stature and weight.

4.7. Maturity status

Moreover, to this study the mean of Fels skeletal age (13,37 years) is greater to mean of TW3 skeletal age (12,85 years) and mean of chronological age (12,91 years), this indicates that in Fels method there is a slight more advanced classification. On the other hand TW3 has more late, on time and mature ranked players than Fels, but Fels more early ranked players. These results are similar with the results of the study with a sample of 40 elite Spanish soccer players (Malina et al. 2007) where the TW3 ranked more players in mature state than Fels method. In that study Fels skeletal ages are consistently in advance of TW3 Skeletal ages but kappa coefficients indicate moderate agreement between maturity classifications based on the two methods of the assessments, in contrast to this sample who indicate a fair agreement.

4.8. Interrelationship among indicators of biological maturation

Differences between skeletal age with other methods to assess maturation as they are sexual and somatic are explained in (Malina et al., 2004) where exist some differences in the results and in the classifications by maturity status, like the method of maturity offset proposed by (Mirwald et al., 2002) has recently been discussed, mainly by the influence with chronological age and a possible higher agreement with boys who are on time in maturity status than with boys who are late or advanced in maturity status, as well as to be a more effective method during the interval of the growth spurt, 12-15 years in males (Malina & Kozieł 2014). However to date, a few studies comparing methods of concurred protocols to estimate skeletal age in sports, with aim of to explore differences in the youth samples, but also to explore differences between protocols to assess and therefore also in the results of the skeletal ages.

Skeletal age has an important utility in research with youth athletes and impact the selection, development and progression in talent (Pearson et al., 2006; Reilly et al., 2003); The same is exposed in studies with tennis (Myburgh et al., 2016 a; Myburgh et al., 2016 b). The small absence of late maturing as adolescence progresses which are evident in (Malina, 2011), it could be the result of a selective dropout. Competitive youth tennis needs physical conditioning like speed, agility and aerobic capacity to competition (Kovacs, 2007), and morphological conditions like stature and long arms, hence, could be affect by the potential influence of variation in maturity status on size, physique and body composition explained by different authors (Malina et al., 2004; Baxter Jones et al., 1995); Although it continue publishing researches of physical performance and anthropometric characteristics in youth tennis players without taking into account the biological maturation (Fernandez-Fernandez et al,. 2015;2016; Kramer, et al., 2016; Sánchez-Muñoz et al., 2007).

Agreement between protocols Fels skeletal ages and TW3 skeletal ages is a study related with talent identification, selection and development to have a important practice with the long term training and a special reference on the framework to growth and maturation. This study Included for the first time a sample of elite Colombian tennis players.

CHAPTER 5:

CONCLUSIONS

The present study examined the agreement between concurrent protocols for determination of skeletal age (FELS and TW3) in a sample of male tennis players. Mean of skeletal age determined by Fels was greater than TW3 SA. Among players who were not skeletal mature by either method the difference between mean Fels and TW3 SAs was significant. Classification of skeletal maturity status by the two protocols had more frequencies in TW3 "on time" and "late" status than Fels, this indicates that in Fels method there is a slight more advanced classification.

The limitations of this master dissertation were to have a small sample, different number in proportion of the sample from each country, results were not separated by chronological age of each country group, it means, British are not separated of Portuguese and Colombian sub samples, but it is assumed that scores can be different in each sub sample.

CHAPTER 6:

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