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Original article

Ulnar variance related to biological and training characteristics, pain and handgrip strength in Portuguese skeletally immature male gymnasts

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Abstract

Purpose: This study was to investigate the association between ulnar variance (UV) and biological and training characteristics, handgrip, and wrist pain in a group of 23 Portuguese skeletally immature male gymnasts (aged 11.2 ± 2.5 years).

Methods: Left and right UV was obtained using Hafner's procedure and skeletal age was determined by the Tanner–Whitehouse 3-method. A negative mean value for UV measures was observed (−2.4 to −3.6 mm) without significant differences with increasing age-category ($p = 0.09$ to $p = 0.48$). Significant low correlations were observed between some UV parameters and stature, fat percentage, years of training, and left handgrip strength.

Results: Ten gymnasts reported wrist pain with gradual onset and UV values were very similar between painless and painful wrists.

Conclusion: The findings of this study do not directly support the thesis that gymnastics training and biological variables or wrist pain are associated with UV.

Keywords: Gymnasts; Pain; Training; Ulnar variance

1. Introduction

Artistic gymnastics (AG) is a sport characterized by involvement at an early age,[1–3] with a relatively rapid transition to high-volume, high-impact training.[3,4]

AG requires long hours of practice and repetitions of movements,[5] as well as high ability of strength, flexibility and balance to learn complex and high-level skills.[6] It is unique among all athletic endeavors in the demands it places on the upper extremities.[7] AG requires conversion of the upper limb into load-bearing extremities, leading to upper extremity injuries, especially on the wrists.[8–10] In fact, since nearly all gymnasts enter the sport at a young age, the wrist growth plates are potential sites for injuries.[1,11,12] The immature musculoskeletal system, submitted to repetitive biomechanical stress, becomes more vulnerable and may lead to overuse injuries.[6,13,14] Repetitive trauma to the radial physis can lead to a premature partial or complete closure of the growth plate or retarded radial growth.[8,15] It has also been theorized that the increased loading during growth and development of the distal radial physis will result in wrist pain,[11,16] in length discrepancy[1] and an increased incidence of positive ulnar variance (UV),[7,11,17] which are "gymnastics-specific" characteristics.[5,18]

Male gymnasts present more injuries at the upper limbs in contrast to the female,[18–20] probably due to the fact that men's

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gymnastics is comprised by six apparatus, all of which producing load on the wrists.[19]

Little is known about the relationship between some specific UV changes, and arm muscle strength, hand dominance or wrist pain. Wrist pain is common among both elite and non-elite male gymnasts,[8,16] although the specific etiology is often difficult to determine.[15,16] Eventually, there might be a certain predisposition for the occurrence of injuries in a particular side,[5] which may reflect the fact that gymnasts have a preferred side when performing.[17] Some authors state that UV can vary from side to side in an individual, resulting in significant right-left differences.[12,21–23] Studies concerning the impact of gymnastic training on the UV phenomenon are mostly concentrated on female gymnasts. Studies on male gymnasts are rather scarce, and the obtained results are univocal.

The purposes of this study were: (a) to evaluate the relationship between training and biological characteristics and UV in Portuguese skeletally immature male gymnasts; and (b) to observe wrist pain status in relation with UV and handgrip strength in this group of gymnasts.

2. Methods

2.1. Participants

The sample consisted of 23 Portuguese skeletally immature male artistic gymnasts from clubs nearby Porto and Lisbon, varying in chronological age from 7.2 years until 16.0 years, with a mean age of 11.2 ± 2.5 years, competing at national and/or international levels. Gymnasts have begun their practice with a mean age of 6.0 ± 1.9 years.

These subjects were divided into three groups according to their age: "Beginners/Advanced", aged 6−10 years (group A, $n = 9$); "Performers", aged 11−14 years (group B, $n = 12$); and "Elite Juniors and Seniors", aged $\geq$ 15 years (group C, $n = 2$). These competition levels are defined by the Portuguese Federation of Gymnastics (FGP) in accordance to the Age Group Development Program (AGDP) from the International Gymnastics Federation.[24] However, to avoid analyses and comparisons with a very small group of two individuals from the Elite Juniors/Seniors group we included them into group B. This choice leads us to work with only two groups (group A, $n = 9$; group B, $n = 14$) instead of the three beginning groups mentioned.

The Ethical Committee of the Faculty of Sport Sciences from the University of Porto approved this protocol and an informed consent was also obtained from all gymnasts or gymnasts' parents and personal coaches were informed.

2.2. Variables and measuring procedures

2.2.1. Anthropometry and body composition

Stature was measured with a stadiometer Seca 202 (Seca Gmgh & co. kg., Hamburg, Germany) with an accuracy of 1 mm. Body mass was obtained with a scale (Seca) accurate to 0.1 kg. Measurements were taken by the same experienced observer (LA) following the procedures described by Claessens et al.[25] Body mass index (BMI) was calculated as body mass divided by stature (kg/m^2).

Body composition components fat-free mass (FFM, kg) and percentage of body fat mass (Fat, %) were obtained by means of bio-electrical impedance analysis using the Tanita BC 418 MA Segmental Body Composition Analyzer (Tokyo, Japan). This device takes into account chronological age of the subjects and the guidelines suggest categorizing individuals into two activity levels: standard and athlete.[26]

2.2.2. Skeletal maturity

Maturity status refers to the individuals' state of maturation at a given point in time, specifically by the skeletal age (SA) attained at a specific chronological age (CA).[27,28] Skeletal maturity is equivalent to the difference between SA and CA (SA−CA) and it can be advanced or early maturing (above 1.0 year), delayed or late maturing (below 1.0 year) and "on time" or in average maturing (within ±1 year).[27] To estimate SA, the Tanner−Whitehouse 3 (TW3)-method was used, with the radius, ulna, and short (RUS) bone system.[29] Standardized radiographs of the left hand and wrists were taken according to the recommendations given by Tanner et al.[29] SA assessment was made by an orthopedist with experience in the TW3-method. To assess intra-observer reliability 15 wrists were measured twice and the intra-class correlation coefficient was very high ($R = 0.999$, 95% CI = 0.998−1.000).

2.2.3. Ulnar variance determination

UV measuring was done on both right and left radiographs (posteroanterior radiographs of wrists with forearm in neutral rotation, the elbow at 90° flexion and the shoulder at 90° abducted),[30] with Hafner and co-workers'[31] method for immature subjects. The subjects were classified into three UV categories: (a) when the relative length of the distal radius and the relative length of the distal ulna differed by less than 1 mm, UV was considered neutral; (b) when the length of the distal ulna exceeded that of the distal radius by 1 mm or more, UV was considered positive; (c) when the length of the distal ulna was inferior to that of the distal radius by 1 mm or more, UV was classified as negative.[22]

All measurements were taken by the same observer (LA). To assess intra-observer reliability 15 X-rays were marked and measured twice in a blind fashion. There were no significant differences for both variables, and intra-class correlations between readings were high ($R = 0.971$, 95%CI = 0.912 − 0.991 for the distance from the most distal point of the ulnar metaphysis to the distal point of the radial metaphysis (DIDI); $R = 0.987$, 95%CI = 0.962 − 0.996 for the distance from the most proximal point of the ulnar metaphysis to the most proximal point of the radial metaphysis (PRPR)).

2.2.4. Training data and handgrip strength

The senior author collected the training data using individual interviews with gymnasts and confirming the data collected with their coach to reassure that the information was accurate.

Handgrip strength of both left and right hands were measured using a mechanical handgrip dynamometer (Takei Kiki Kogyo

−TK 1201, Niigata, Japan) accurate to 0.5 kg. The dynamometer was adjusted to the gymnasts' hand size to obtain their best performance as prescribed by Schlüssel et al.[32] The highest value in each side (kg) was used to represent handgrip strength.[32,33] All tests were supervised by the same observer.

2.2.5. Pain information

Each gymnast completed an interview-based questionnaire about the detailed history and description of wrist pain experience: presence, limitations and gymnastic apparatus associated with it. Gymnasts were asked if they had pain in their wrists at the moment of data collection. Those who answered "yes" were asked to clarify the nature of the pain onset (sudden or gradual), and those with macro traumatic history (when in a specific moment the tolerance limits of the anatomic structures were exceeded by a compression or avulsion mechanical stress) were excluded from the data analysis. Athletes who have suffered these acute events were forwarded to a clinician by their respective coach.

Gymnasts were divided into categories according to their functional classification based upon both subjective and objective measures:[16,34] grade 1, unrestricted; grade 2, attends all training sessions, but unable to full work; grade 3, misses at least one training session per month; and grade 4, unable to participate.

2.3. Data analysis

Descriptive statistics (mean ± SD) was calculated to study the variables in the total sample used and in the two groups separately.

Moreover, absolute (n) and proportional (%) frequency distributions of both UV variables (PRPR and DIDI) of both wrists within three UV categories (negative, neutral, and positive), for both the total and the two groups, were set-up and the differences were analyzed by means of the Chi-square test. The Mann−Whitney test was used to evaluate the differences of UV values in painful or painless wrists, and to evaluate the difference between groups in all variables. A t test was used to compare the UV values with normative data from the general population. The relationship between the UV measurements, on one hand, and the biological and training characteristics, on the other hand, were analyzed by means of partial correlations, adjusted for CA, SA and the difference between SA and CA. Kruskal−Wallis test was used to compare UV in different maturity status. SPSS version 19.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for statistical analyses and a p value of <0.05 was considered statistically significant.

3. Results

Descriptive statistics of all variables of the total sample and the two groups are given in Table 1.

The results demonstrate significant differences between the mean values of groups A and B for almost all the biological and training characteristics ($p < 0.05$), except the variable SA−CA with no significant difference between the two groups (−0.5 ± 0.8 and −1.1 ± 1.2; $p = 0.17$) and a starting age rather similar in both groups (6.0 ± 2.1 and 6.1 ± 1.9; $p = 0.90$).

Table 1
Descriptive statistics (mean ± SD) and comparison between groups of biological, training, and ulnar variance characteristics from Portuguese skeletally immature male gymnasts.

Variable	Total sample ($n = 23$)	Group A ($n = 9$)	Group B ($n = 14$)	Z	p[a]
Biological characteristics					
Chronological age (year)	11.2 ± 2.5	8.6 ± 1.0	12.8 ± 1.7	−3.97	0.00
Skeletal age (year)	10.3 ± 2.0	8.2 ± 0.9	11.7 ± 1.0	−3.97	0.00
SA−CA (year)	−0.9 ± 1.1	−0.5 ± 0.8	−1.1 ± 1.2	−1.39	0.17
Body mass (kg)	35.8 ± 8.5	28.3 ± 3.7	40.6 ± 7.1	−3.65	0.00
Stature (cm)	141.7 ± 12.0	130.6 ± 5.4	148.8 ± 9.2	−3.94	0.00
BMI (kg/m^2)	17.3 ± 1.5	16.4 ± 1.1	17.9 ± 1.5	−2.35	0.02
Fat (%)	15.4 ± 2.5	17.3 ± 1.8	13.9 ± 1.8	−3.23	0.00
FFM (kg)	29.0 ± 8.3	23.4 ± 2.9	33.2 ± 8.6	−3.13	0.00
Training characteristics					
h/week	17.8 ± 3.9	14.1 ± 2.8	20.1 ± 2.5	−3.81	0.00
Starting age (year)	6.0 ± 1.9	6.0 ± 2.1	6.1 ± 1.9	−0.13	0.90
Years of training	5.4 ± 3.0	2.9 ± 1.7	6.9 ± 2.5	−3.32	0.00
Handgrip-L (kg)	21.4 ± 7.2	14.9 ± 3.5	25.6 ± 5.6	−3.85	0.00
Handgrip-R (kg)	22.2 ± 6.9	16.1 ± 2.7	26.2 ± 5.7	−3.98	0.00
Ulnar variance characteristics					
PRPR-L (mm)	−2.4 ± 1.4	−1.9 ± 1.7	−2.8 ± 1.5	−1.54	0.12
DIDI-L (mm)	−3.1 ± 2.2	−3.1 ± 1.1	−3.1 ± 2.7	−0.71	0.48
PRPR-R (mm)	−2.8 ± 1.5	−2.3 ± 0.9	−3.1 ± 1.8	−1.68	0.09
DIDI-R (mm)	−3.6 ± 1.7	−4.0 ± 1.0	−3.3 ± 2.9	−0.74	0.46

Abbreviations: SA = skeletal age; CA = chronological age; BMI = body mass index; FAT = fat mass; FFM = fat-free mass; PRPR = the distance from the most proximal point of the ulnar metaphysis to the most proximal point of the radial metaphysis; DIDI = the distance from the most distal point of the ulnar metaphysis to the distal point of the radial metaphysis.

[a] Mann−Whitney test, $p < 0.05$ is considered significant difference.

Table 2
Ulnar variance parameters of male gymnasts classified as late, on time, and early in skeletal maturation (mean ± SD) and comparison between these groups of relative skeletal age (SA−CA).

Variable	Late (n = 5)	On time (n = 17)	Early (n = 1)	p[a]
PRPR-L	−1.8 ± 2.2	−2.6 ± 1.2	−3.0	0.53
DIDI-L	−2.6 ± 2.2	−3.3 ± 2.3	−3.0	0.48
PRPR-R	−1.8 ± 1.8	−3.0 ± 1.3	−5.0	0.12
DIDI-R	−3.0 ± 1.7	−3.9 ± 1.4	0.0	0.18

Abbreviations: PRPR = the distance from the most proximal point of the ulnar metaphysis to the most proximal point of the radial metaphysis; DIDI = the distance from the most distal point of the ulnar metaphysis to the distal point of the radial metaphysis; L = left; R = right.
[a] Kruskal−Wallis test, $p < 0.05$ is considered significant difference.

Concerning the UV measures (DIDI and PRPR, left and right), only negative mean values were observed, varying from −3.6 ± 1.7 mm (DIDI-R) to −2.4 ± 1.4 mm (PRPR-L) in the whole sample, with no significant differences between both groups ($p = 0.09$ to $p = 0.48$).

Table 2 shows no significant differences in UV values in our sample of male gymnasts grouped as late, on time, and early maturing as determined by SA−CA.

Absolute and proportional frequency distributions within the UV categories (negative, neutral, and positive) were determined. For the total group of gymnasts, most of the subjects were located within the UV negative category (varying from 73.9% for PRPR-L to 87.0% for both DIDI-L and DIDI-R). The amount of gymnasts in the UV neutral category was much lower (varying from 8.7% for DIDI-L to 26.1% for PRPR-L) and only one subject demonstrated positive UV (4.3%). Although the majority of the gymnasts presented negative UV values in both age groups, the frequency of neutral PRPR in the younger group (A) was slightly higher when compared to group B, whereas no neutral DIDI values were found in group A. When comparing PRPR and DIDI values, no significant differences could be observed between groups.

Table 3 shows the partial correlations between UV, and biological and training characteristics, controlling for CA, SA, and SA−CA. When controlled for CA and SA, an inverse association between UV and fat% ($r = -0.45$ to $r = -0.64$) was observed. More than the correlation with CA, the observed inverse associations with SA reveal a trend to more positive UV with decreasing fat%. Analyzing DIDI-R a significant correlation with handgrip-L ($r = -0.55$) was found by controlling for CA, and significant correlations with stature ($r = 0.46$) and years of training ($r = 0.47$) were demonstrated by controlling for SA. Only one significant correlation was observed between UV values and biological and training characteristics when controlled for SA−CA, and that was between PRPR-L and handgrip strength in the same side ($r = -0.55$).

Concerning wrist pain, 10 out of the 23 gymnasts (43.5%) reported wrist pain of gradual onset and five out of these 10 evidenced bilateral pain. Six subjects (26.1%) showed pain in their right wrists (5 negative UV and 1 neutral) while 17 (73.9%) showed no pain. Nine subjects (39.1%) showed pain in their left wrists (7 negative and 2 neutral PRPR; 7 negative, 1 neutral and 1 positive DIDI) while 14 (60.9%) showed no pain. The negative PRPR values evidenced a discreet higher percentage of painful wrists in contrast to DIDI that showed higher percentage of painless wrists.

Differences in UV data between painful and painless wrists are given in Table 4.

Table 3
Spearman partial correlations between ulna variance, and biological and training characteristics from Portuguese skeletally immature male gymnasts, controlling for CA, SA, and difference between SA and CA (SA−CA).

Variable	PRPR-L			PRPR-R			DIDI-L			DIDI-R		
	CA	SA	SA−CA	CA	SA	SA−CA	CA	SA	SA−CA	CA	SA	SA−CA
Biological characteristics												
Body mass	0.05	−0.09	−0.23	0.17	0.24	−0.15	0.09	0.07	0.14	0.15	0.37	0.02
Stature	0.06	−0.06	−0.24	0.05	0.22	−0.17	0.08	0.06	0.12	0.20	0.46*	0.10
BMI	−0.05	−0.14	−0.18	0.08	0.12	−0.13	0.07	0.75	0.12	0.12	0.25	−0.02
Fat (%)	−0.64*	−0.63*	−0.24	−0.33	−0.45*	−0.13	−0.40	−0.41	−0.36	−0.32	−0.48*	−0.31
FFM	0.24	0.05	−0.08	0.44	0.42	0.05	0.21	0.18	0.22	0.30	0.43	0.11
Training characteristics												
h/week	−0.15	−0.18	−0.31	−0.30	−0.21	−0.31	0.02	0.01	0.01	0.03	0.18	0.12
Starting age	−0.07	−0.05	−0.10	0.00	0.03	−0.05	0.20	0.20	0.26	−0.36	−0.33	−0.30
Years of training	0.09	−0.01	−0.24	0.02	0.09	−0.17	−0.14	−0.11	−0.18	0.37	0.47*	0.29
Handgrip-L	−0.31	−0.32	−0.55*	−0.08	0.10	−0.33	−0.14	−0.08	−0.12	−0.55*	−0.06	−0.12
Handgrip-R	0.18	0.00	−0.40	0.11	0.24	−0.27	−0.05	−0.02	−0.08	−0.01	0.30	0.07
Ulnar variance characteristics												
PRPR-L	–	–	–	–	–	–	–	–	–	–	–	–
PRPR-R	0.74*	0.71*	0.78*	–	–	–	–	–	–	–	–	–
DIDI-L	0.59*	0.58*	0.53*	0.61*	0.63*	0.60*	–	–	–	–	–	–
DIDI-R	0.50*	0.42	0.52*	0.35	0.34	0.28	0.42	0.42	0.46*	–	–	–

*$p < 0.05$.
Abbreviations: CA = chronological age; SA = skeletal age; BMI = body mass index; FAT = fat mass; FFM = fat-free mass; PRPR = the distance from the most proximal point of the ulnar metaphysis to the most proximal point of the radial metaphysis; DIDI = the distance from the most distal point of the ulnar metaphysis to the distal point of the radial metaphysis.

Table 4
Ulnar variance and handgrip strength differences between painful and painless wrists from Portuguese skeletally immature male gymnasts.

Variable	Painful	Painless	p[a]
Right wrist			
n (%)	6 (26.1)	17 (73.9)	
PRPR-R (mm)			
Mean ± SD	−3.2 ± 1.5	−2.7 ± 1.5	
Median	−3.5	−3.0	0.52
Range	−5 to −1	−5−0	
DIDI-R (mm)			
Mean ± SD	−3.3 ± 2.1	−3.7 ± 1.6	
Median	−4.0	−4.0	0.86
Range	−6−0	−6−0	
Handgrip-R (kg)			
Mean ± SD	26.1 ± 5.5	20.9 ± 6.9	
Median	24.3	20.0	0.02
Range	22.0−37.0	12.0−36.5	
Left wrist			
n (%)	9 (39.1)	14 (60.9)	
PRPR-L (mm)			
Mean ± SD	−2.7 ± 1.7	−2.3 ± 1.3	
Median	−3	−3	0.74
Range	−5−0	−4−0	
DIDI-L (mm)			
Mean ± SD	−3.1 ± 3.1	−3.1 ± 1.5	
Median	−4	−3	0.50
Range	−6−4	−6−0	
Handgrip-L (kg)			
Mean ± SD	23.8 ± 8.3	19.9 ± 6.2	
Median	24.0	19.8	0.21
Range	12.0−37.5	9.0−31.5	

Abbreviations: PRPR = the distance from the most proximal point of the ulnar metaphysis to the most proximal point of the radial metaphysis; DIDI = the distance from the most distal point of the ulnar metaphysis to the distal point of the radial metaphysis.

[a] Mann−Whitney test, $p < 0.05$ is considered significant difference.

No significant differences were observed in the UV values between painful and painless wrists, and handgrip strength values were higher in painful when compared to painless wrists. There was a statistical difference in right side handgrip strength when compared painful with painless wrists ($p = 0.02$).

In a 10-gymnasts group, we found 15 wrists presenting pain (5 gymnasts presented both wrists with pain). Nine of these 15 wrists were classified as unrestricted (grade 1) and five wrists were classified as grade 2, when gymnasts could attend all training sessions but were unable to do full workout. Only one wrist was identified as grade 3 implying that this gymnast was forced to miss one training session.

Pommel horse was the apparatus most frequently associated with painful wrists (8 out of 15, 53.3%) referred by gymnasts.

4. Discussion

Concerning the maturity status, most gymnasts were classified on time or average, which is in accordance with previous data on male gymnasts as demonstrated by Baxter−Jones et al.[35] and Malina et al.[27]

UV of immature reference populations is on average negative as demonstrated by the data of Hafner and coworkers.[31] Our sample of Portuguese gymnasts showed also, on average, a negative UV. Despite a more negative UV than the normative values from the immature population[31] significant differences in relation to the general population could only be found for DIDI-R ($p < 0.01$). The normative values presented by Hafner et al.[31] in this age group range from −2.2 to −2.3 mm, whereby the results of PRPR (left and right) and DIDI-L from the 23 Portuguese male gymnasts (7−16 years) did not show significant differences when compared to the general population (ranging from $p = 0.55$ to $p = 0.65$). The reason why we decided to use immature reference values from Hafner et al.[31] such as other authors[5,12,16] has to do with is the fact that there are still no reference values for the Portuguese population.

While Chang et al.[18] did not find significant differences in UV values between their sample and a control group of Chinese musicians, other studies involving gymnasts[5,12,36] showed significantly less negative UV when compared with normative values from Hafner et al.,[31] which can be justified by the different conditions of the referred studies such as the different methods used to measure UV (perpendicular and Hafner's methods), different observers, possible differences in laterality and dominance hands, and ethnographic-related factors.[37] Ethnographic-related factors can, eventually, explain some UV differences[38,39] since more positive UV values were found in Black race when compared to Caucasians.[38] Additionally Koreans also showed significantly higher UV when compared to Japanese or Chinese subjects.[39]

The length of ulna relative to the length of the radius is not constant but varies in the course of life.[40] Change in UV can be attributed simply to CA, SA, SA−CA, and, in the case of gymnasts, may also be eventually due to training characteristics.

In the study of Hafner et al.[31] it was demonstrated that negative UV of immature normative populations became somewhat more negative with age increasing. This trend was observed in PRPR of the Portuguese gymnasts. The group of the older gymnasts (B) showed more percentage of negative PRPR and less neutral PRPR than the younger group (A). On the other hand, the 100% negative DIDI in group A tends to become less negative and therefore more neutral or even positive.

Some studies with gymnasts' populations longitudinally followed during years[9,41] found that a negative UV (DIDI) became more pronounced with age increasing, while in other longitudinal studies[5,11] it was demonstrated that the negative UV (PRPR) observed at baseline became significantly less negative than age-appropriate normative values. Because authors from different studies have used different UV variables (PRPR or DIDI), it is not easy to explain these divergent results and therefore this issue still remains unclear. But, following the concept of Hafner et al.,[31] gymnasts with less CA or SA or late maturing should have less negative UV when compared with the older or early maturing. The UV trend of being more negative with the increasing age may be explained by the different timings of bone fusion of radius compared with ulna's physis.[5] The ulnar physis appears to lose its growth potential earlier than the distal radial physis, when compared with the standards from the Gruelich and Pyle method of bone age measurement.[5,42] Although the majority of late maturing Portuguese's gymnasts had presented UV values less negatives than those at "on time" or early maturing (Table 2), there were no significant differences between them, nor significant correlation was found between UV (PRPR or DIDI) and CA. These observations were in accordance with the results from DiFiori et al.[12] On the contrary, Beunen et al.[42] have verified a significant but rather low correlation ($r = 0.22$) between SA and PRPR, suggesting that gymnasts with more advanced skeletal age tended to show a more positive UV.

With the assumption that wrist load contributes to changes on UV, variables such as the gymnast's biological or training characteristics could be related with UV values.

However, when the UV values were controlled according to the age and the maturational status few variables seem to be associated with UV. Nonetheless, we highlight significant correlations between stature, fat mass percentage, handgrip strength, years of training, and UV parameters but in an isolated non-consistent form.

Based on the literature concerning the relation between UV and biological characteristics studies it is demonstrated that contradictory results were found. In some studies,[17,43,44] a significant relationship between UV and stature and weight could be observed, whereas in other studies[36,41] no significant association could be demonstrated.

These non-coherent results lead us to believe that biological characteristics are not associated with UV, which is contradicting to the idea that bigger, heavier, and stronger immature gymnasts have a higher risk of developing positive UV.[44]

Comparing our sample of Portuguese gymnasts with elite male gymnasts,[45,46] it is demonstrated that our gymnasts training, on average, is much lower than the elite level on the training variable h/week (17.8 *vs*. 27.0 h/week).

Our results indicated that there were no significant associations between training stimulus (h/week or starting age) and UV values.

Several studies suggest that gymnastics training, with sufficient volume and intensity may precipitate abnormal changes of the distal radial growth plate and eventually lead to a premature physeal closure and consequent positive UV.[8,18] Based on these supposed consequences, it is possible to expect a tendency toward a positive UV over the years as a result of gymnastics training. However, it is not clear if training load provokes UV changes. In most studies the authors did not find significant association between UV and training variables.[12,17,36,44]

Because most studies have cross-sectional designs, the association between time of exposure to training and UV changes is unclear. Some longitudinal studies obtained also contradictory results about the possible influence of gymnastics training on UV. Chang et al.[18] and Mandelbaum et al.[47] observed a tendency toward a positive UV with the increase in years of training. DiFiori et al.[12] found a significantly higher positive UV in a group of elite compared to non-elite collegiate gymnasts. In contrast, Claessens et al.[41] have shown that the observed negative UV in female gymnasts at baseline became more pronounced over the years when training level increased, contradicting to the results of positive UV found in the literature. For this reason, some authors consider that AG training does not have a direct negative impact in the relative position of the distal extremities of the ulna compared to the radius, resulting in an ulna's overgrowth.[41]

In our study, the etiology of pain was micro traumatic or gradual onset (43.5%). The pommel horse was the apparatus most frequently related to wrist pain (53.3%), which is in accordance with the results of other research.[12,16,47] Pommel horse demands repetitive, high intensity wrist impacts on a rigid structure, with sustained periods of body weight support on the wrist.[7]

Despite presenting symptomatic wrists, a considerable amount of our gymnasts (60%) were able to train without limitations, which is a similar finding as demonstrated in other studies.[16,34] In fact only a few percentage has been forced to interrupt at least one training session per month, suggesting an underestimation related to the wrist pain, which may create a potential factor of morphologic alterations from distal radius or/and ulnar growth plates, changing the UV.

Based on Webb and Rettig[10] it can be said that UV affects the distribution of forces across the wrist, with the load on the neutral UV wrist being normally shared between radius and ulna in a ratio of approximately 80:20.[48] This ratio changes with increasing or decreasing UV values, e.g., on the positive UV wrist ratio is 69:31 while on the negative UV the ratio is 94:6.[49] However, Rikli et al.[50] demonstrated that the forces transmitted across the ulnar side of the radioulnacarpal joint were much higher than previously stated (the load percentage in neutral wrist position had a relative distribution of 35/55 between radius and ulna). This discrepancy in results may be due to the methodology used and, consequently, to static or dynamic forms of load distribution, but might also be related to age, individual activities, and/or the non differentiation of UV categories.

It is common knowledge that supports of the upper limb in all gymnastics apparatus are performed, mostly, with extended wrists, both with the forearm in neutral or prone or supine position, and/or with wrist deviations (radial or ulnar deviation). According to the results from Rikli et al.[50] the relative distribution of forces was localized more ulnarly, and, hypothetically, may predispose gymnasts to wrist pain due to the load-bearing. Mandelbaum et al.[47] draws our attention to the fact that gymnasts with wrist pain consistently present positive UV. In contrast, other authors state that there is a higher tendency to find wrist pain in gymnasts with negative UV,[4,12] while others do not even consider UV to be a determinant factor in pain onset.[18]

Contrary to the data gathered by DiFiori et al.[12] we did not find significant differences in the UV negative values between gymnasts with and without wrist pain, independently of gymnasts' hand dominance. These contradictory results may be attributed either to intrinsic such as different UV values in the same category, radio and ulna areas, articular surfaces, maturational status, ligament laxity, strength, height, weight, previous injuries, cysts presence, extrinsic factors such as training methodology, intensity, volume and duration of training, equipment and apparatus used.

UV may not be *per se* a determinant factor of wrist pain and/or wrist injuries. Another factor which cannot be excluded is the possible damage to the soft tissues. In fact, wrist pain has long been a problem in terms of diagnosis, partially because of its complex anatomy and the many possible causes of pain in this region.[51]

The negative UV has been associated with Kienböck's disease (avascular necrosis of the lunate),[38,40] however this theory remains controversial.[52] One possible reason to explain the avascular necrosis of the lunate in negative UV wrists may be that during its movements the loads are distributed in the medial part of the distal radius, in the lunate fossa and sigmoid notch.[50,53]

Differently, positive UV may predispose the ulnar column of the wrist to a greater load, which may cause the progression of degenerative changes or perforation of triangular fibrocartilage complex.[39,40] This wrist injury is more common in older gymnast because of the higher frequency of positive UV and increased ulnar side transmission of force from the repetitive weight-bearing over time.[10]

Gymnasts with pain in the right wrist have shown more handgrip strength when compared with asymptomatic ones ($p = 0.02$). Contrary to the expected, the wrist pain and possible muscle-skeletally modifications did not reduce handgrip strength as claimed by some authors.[33] One possible explanation may be related to their biological characteristics or training programs because gymnasts more exposed to heavy training loads may be also more prone to joint overuse risk injuries and higher pain experience.

Although we have categorized objectively the gymnasts in different categories according to the dysfunction caused by wrist pain, we need to consider that the reporting of pain by gymnasts is subjective and thus can be influenced by age, sensitivity threshold, personality, and motivation.

Although our results may contribute to the generalized knowledge about the UV in gymnasts and its association with certain biological and training characteristics, the etiology of UV remains unclear. To evaluate the impact of gymnastics' training in UV and its contributing factors to wrist pain, longitudinal studies using control groups should be performed. Despite the limitation related to the sample size, which restricts the statistical analysis and the generalization of the results, it is still representative of the Portuguese skeletally immature male gymnasts and therefore might be useful for future comparisons in similar studies involving other gymnasts groups.

The importance of studying UV lies in its statistical association with several injuries or pathologies of the wrists.[54] The information about this phenomenon could be essential to prevent and/or reduce the occurrence, recurrence, and severity of injuries in gymnasts' wrists.[37]

5. Conclusion

Portuguese skeletally immature male gymnasts present a discrepancy between chronological and skeletal ages which become more pronounced with increasing age. All average values of UV were negative and did not present significant differences between groups or compared with the reference population's values. Although some significant results obtained in this research, such as the correlations between UV and some variables (stature, fat%, handgrip strength, and years of training), the main results do not directly support the thesis that gymnastics' training or biological characteristics present an evident association with UV. Also the association between UV values and the occurrence of wrist pain could not be demonstrated.

References

1. Caine DJ, DiFiori J, Maffulli N. Physeal injuries in children's and youth sports: reasons for concern? *Br J Sports Med* 2006;**40**:749−60.
2. Claessens AL. Gymnast wrist: the ulnar variance phenomenon. In: Silva MC, Malina RM, editors. *Children and youth in organized sports*. Coimbra: Coimbra University Press; 2004.p.290−8.
3. Daly RM, Bass SL, Finch CF. Balancing the risk of injury to gymnasts: how effective are the counter measures? *Br J Sports Med* 2001;**35**:8−19.
4. Caine DJ, Nassar L. Gymnastics injuries. *Med Sport Sci* 2005;**48**:18−58.
5. Dwek JR, Cardoso F, Chung CB. MR imaging of overuse injuries in the skeletally immature gymnast: spectrum of soft-tissue and osseous lesions in the hand and wrist. *Pediatr Radiol* 2009;**39**:1310−6.
6. Zetaruk MN. The young gymnast. *Clin Sports Med* 2000;**19**:757−80.
7. Markolf KL, Shapiro MS, Mandelbaum BR, Teurlings L. Wrist loading patterns during pommel horse exercises. *J Biomech* 1990;**23**:1001−11.
8. Caine DJ, Roy S, Singer KM, Broekhoff J. Stress changes of the distal radial growth plate. A radiographic survey and review of the literature. *Am J Sports Med* 1992;**20**:290−8.
9. Claessens AL, Lefevre J, Philippaerts R, Thomis M, Beunen G. The ulnar variance phenomenon: a study in young gymnasts. In: Armstrong N, Kirby B, Welsman J, editors. *Children and exercise XIX*. London: E&FN Spon; 1997.p.537−41.
10. Webb BG, Rettig LA. Gymnastic wrist injuries. *Curr Sports Med Rep* 2008;**7**:289−95.
11. DiFiori JP, Caine DJ, Malina RM. Wrist pain, distal radial physeal injury, and ulnar variance in the young gymnast. *Am J Sports Med* 2006;**34**:840−9.
12. DiFiori JP, Puffer JC, Aish B, Dorey F. Wrist pain, distal radial physeal injury, and ulnar variance in young gymnasts: does a relationship exist? *Am J Sports Med* 2002;**30**:879−85.
13. Cornwall R. The painful wrist in the pediatric athlete. *J Pediatr Orthop B* 2010;**30**:S13−6.
14. Kerssemakers SP, Fotiadou AN, de Jonge MC, Karantanas AH, Maas M. Sport injuries in the paediatric and adolescent patient: a growing problem. *Pediatr Radiol* 2009;**39**:471−84.
15. Gerbino P. Wrist disorders in the young athlete. *Operat Tech Sports Med* 1998;**6**:197−205.
16. DiFiori JP, Mandelbaum BR. Wrist pain in a young gymnast: unusual radiographic findings and MRI evidence of growth plate injury. *Med Sci Sports Exerc* 1996;**28**:1453−8.
17. De Smet L, Claessens A, Lefevre J, Beunen G. Gymnast wrist: an epidemiologic survey of ulnar variance and stress changes of the radial physis in elite female gymnasts. *Am J Sports Med* 1994;**22**:846−50.
18. Chang CY, Shih C, Penn IW, Tiu CM, Chang T, Wu JJ. Wrist injuries in adolescent gymnasts of a Chinese opera school: radiographic survey. *Radiology* 1995;**195**:861−4.

19. Dixon M, Fricker P. Injuries to elite gymnasts over 10 yr. *Med Sci Sports Exerc* 1993;**25**:1322−9.
20. Kirialanis P, Malliou P, Beneka A, Gourgoulis V, Giofstidou A, Godolias G. Injuries in artistic gymnastic elite adolescent male and female athletes. *J Back Musculoskelet Rehabil* 2002;**16**:145−51.
21. Claessens AL. Ulnar variance in female gymnasts: an overview. In: Lenoir M, Philippaerts RM, editors. *Science in artistic gymnastics*. Gent: Publicatiefonds voor Lichamelijke Opvoeding; 2001.p.61−71.
22. DiFiori JP. Overuse injury and the young athlete: the case of chronic wrist pain in gymnasts. *Curr Sports Med Rep* 2006;**5**:165−7.
23. Freedman DM, Edwards Jr GS, Willems MJ, Meals RA. Right versus left symmetry of ulnar variance. A radiographic assessment. *Clin Orthop Relat Res* 1998;**354**:153−8.
24. Federation Internationale de Gymnastique. *Age group development program − CD-ROM* 1997. Suisse.
25. Claessens AL, Beunen G, Malina R. Anthropometry, physique, body composition, and maturity. In: Armstrong N, van Mechelen W, editors. *Paediatric exercise science and medicine*. Oxford: Oxford University Press; 2008.p.23−36.
26. Volgyi E, Tylavsky FA, Lyytikainen A, Suominen H, Alen M, Cheng S. Assessing body composition with DXA and bioimpedance: effects of obesity, physical activity, and age. *Obesity (Silver Spring)* 2008;**16**:700−5.
27. Malina RM, Bouchard C, Bar-Or O. *Growth, maturation, and physical activity*. 2nd ed. Champaign, IL: Human Kinetics; 2004.p.277−305.
28. Malina RM, Claessens AL, van Aken K, Thomis M, Lefevre J, Philippaerts R, et al. Maturity offset in gymnasts: application of a prediction equation. *Med Sci Sports Exerc* 2006;**38**:1342−7.
29. Tanner JM, Healy MJR, Goldstein H, Cameron N. *Assessment of skeletal maturity and prediction of adult height (TW3 method)*. 3rd ed. London: WB Saunders; 2001.
30. Palmer AK, Glisson RR, Werner FW. Ulnar variance determination. *J Hand Surg Am* 1982;**7**:376−9.
31. Hafner R, Poznanski AK, Donovan JM. Ulnar variance in children-standard measurements for evaluation of ulnar shortening in juvenile rheumatoid arthritis, hereditary multiple exostosis and other bone or joint disorders in childhood. *Skeletal Radiol* 1989;**18**:513−6.
32. Schlüssel MM, dos Anjos LA, de Vasconcellos MT, Kac G. Reference values of handgrip dynamometry of healthy adults: a population-based study. *Clin Nutr* 2008;**27**:601−7.
33. Balogun JA, Adenlola SA, Akinloye AA. Grip strength normative data for the harpenden dynamometer. *J Orthop Sports Phys Ther* 1991;**14**:155−60.
34. DiFiori JP, Puffer JC, Aish B, Dorey F. Wrist pain in young gymnasts: frequency and effects upon training over 1 year. *Clin J Sport Med* 2002;**12**:348−53.
35. Baxter-Jones A, Maffulli N, Mirwald R. Does elite competition inhibit growth and delay maturation in some gymnasts? Probably not. *Ped Exerc Sci* 2003;**15**:373−82.
36. DiFiori JP, Puffer JC, Mandelbaum BR, Dorey F. Distal radial growth plate injury and positive ulnar variance in nonelite gymnasts. *Am J Sports Med* 1997;**25**:763−8.
37. Amaral L, Claessens AL, Ferreirinha J, Santos P. Ulnar variance and its related factors in gymnasts: a review. *Sci Gymnastics J* 2011;**3**:59−89.
38. Chung KC, Spilson MS, Kim MH. Is negative ulnar variance a risk factor for Kienbock's disease? A meta-analysis. *Ann Plast Surg* 2001;**47**:494−9.
39. Jung JM, Baek GH, Kim JH, Lee YH, Chung MS. Changes in ulnar variance in relation to forearm rotation and grip. *J Bone Joint Surg Br* 2001;**83**:1029−33.
40. De Smet L. Ulnar variance: facts and fiction review article. *Acta Orthop Belg* 1994;**60**:1−9.
41. Claessens AL, Leen VL, Inge B, Levevre J, Renaat P, Martine T. Relationship between ulnar variance and morphological characteristics in female gymnasts. A longitudinal study. *PJSS* 2003;**3**:51−69.
42. Beunen G, Malina RM, Claessens AL, Lefevre J, Thomis M. Ulnar variance and skeletal maturity of radius and ulna in female gymnasts. *Med Sci Sports Exerc* 1999;**31**:653−7.
43. Amaral L, Claessens AL, Ferreirinha JE, Santos PJ. Ulnar variance related to biological and training characteristics and handgrip strength in Portuguese skeletally immature female gymnasts. *J Sports Med Phys Fitness* 2012;**52**:393−404.
44. Claessens AL, Lefevre J, Beunen G, De Smet L, Veer AM. Physique as a risk factor for ulnar variance in elite female gymnasts. *Med Sci Sports Exerc* 1996;**28**:560−9.
45. Georgopoulos NA, Theodoropoulou A, Leglise M, Vagenakis AG, Markou KB. Growth and skeletal maturation in male and female artistic gymnasts. *J Clin Endocrinol Metab* 2004;**89**:4377−82.
46. Markou KB, Mylonas P, Theodoropoulou A, Kontogiannis A, Leglise M, Vagenakis AG, et al. The influence of intensive physical exercise on bone acquisition in adolescent elite female and male artistic gymnasts. *J Clin Endocrinol Metab* 2004;**89**:4383−7.
47. Mandelbaum BR, Bartolozzi AR, Davis CA, Teurlings L, Bragonier B. Wrist pain syndrome in the gymnast. Pathogenetic, diagnostic, and therapeutic considerations. *Am J Sports Med* 1989;**17**:305−17.
48. Anderson J, Read J, Steinweg J. *Atlas of imaging in sports medicine*. Australia: McGraw-Hill; 1998.
49. Bu J, Patterson RM, Morris R, Yang J, Viegas SF. The effect of radial shortening on wrist joint mechanics in cadaver specimens with inherent differences in ulnar variance. *J Hand Surg Am* 2006;**31**:1594−600.
50. Rikli DA, Honigmann P, Babst R, Cristalli A, Morlock MM, Mittlmeier T. Intra-articular pressure measurement in the radioulnocarpal joint using a novel sensor: *in vitro* and *in vivo* results. *J Hand Surg Am* 2007;**32**:67−75.
51. Coggins CA. Imaging of ulnar-sided wrist pain. *Clin Sports Med* 2006;**25**:505−26.
52. Yoshioka H, Tanaka T, Ueno T, Carrino JA, Winalski CS, Aliabadi P, et al. Study of ulnar variance with high-resolution MRI: correlation with triangular fibrocartilage complex and cartilage of ulnar side of wrist. *J Magn Reson Imaging* 2007;**26**:714−9.
53. Yoshida T, Tada K, Yamamoto K, Shibata T, Shimada K, Kawai H. Aged-onset Kienböck's disease. *Arch Orthop Trauma Surg* 1990;**109**:241−6.
54. Mann FA, Wilson AJ, Gilula LA. Radiographic evaluation of the wrist: what does the hand surgeon want to know? *Radiology* 1992;**184**:15−24.