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Characterization of the knee joint phenotype in the Portuguese population

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ABSTRACT

Background: Neutral constitutional alignment and neutral joint line obliquity has been the standard alignment strategy for total knee arthroplasty. This one-for-all measure may negatively impact gait pattern and knee biomechanics. Novel alignment strategies surged, considering the variability in phenotypes found across the literature, as different populations may present different phenotype distributions. The Portuguese population has a distinct genetic origin, with no phenotype distribution data. Our objective was to characterise the population's knee morphology, searching and analysing adjacent joint osteoarthrosis, and calculating the pre-disease coronal alignment.
Methods: A retrospective cohort study was conducted. Full-length X-rays performed between 2016-2023 were analysed. Five alignment parameters were measured (LDFA, MPTA, JLCA, TJLA, HKA), and two parameters were calculated (aHKA, JLO). Knees were classified according to the CPAK classification.
Results: For the arthritic cohort, CPAK-I (23%) II (20%) were most common, aHKA increases as KL increases ($r=0.8352$; $p<0.001$). For the healthy, Type-II (42%) and Type-I (15%) were most common. For paediatric, Type-II (43%) and Type-V (21%) were most common. CPAK Types-VII/VIII/IX were rare. Differences between genders for healthy and arthritic cohorts were statistically significant. The arthritic had higher prevalence of adjacent joint osteoarthritis.
Conclusions: The Portuguese population presents a similar knee phenotype comparing with other populations, some differences have been found regarding the Asian continent. The most common phenotype was a neutral alignment if either healthy or paediatric, or a varus alignment if knee OA. Coronal alignment may not have a major impact in the prevalence of ankle and hip osteoarthritis; however, higher prevalence is observed in patients with knee OA.

Keywords: CPAK, Knee phenotype, Portuguese population, Pre-disease coronal alignment, Osteoarthritis

INTRODUCTION

The mechanical lower limb alignment with neutral constitutional alignment and neutral joint line obliquity (JLO) goals has been the standard alignment strategy for total knee arthroplasty. Although outcomes are usually good with acceptable implant survival and improvement in pain and function; the inherent variability of the patient specific anatomy are not taken into account.[1] This one for all measure may have an impact in gait and knee biomechanics; possibly accounting for the 20% of patients who report bad outcomes following total knee arthroplasty (TKA), approximately 20%.[1-3] To address this percentage of dissatisfied patients, some novel alignment strategies have been described. With the main goal of restoring the original pre-disease anatomy, soft tissue balance and knee movement. The concepts of anatomical knee alignment restoration and kinematic alignment (KA) have gained recent interest.[4-6] As knowledge of knee biomechanics and alignment grows, recent classifications, such as the Coronal Plane Alignment of the Knee (CPAK), provide a more complete description of the knee phenotype in comparison to the traditional varus/valgus classification. Additionally, CPAK can identify patients who are candidate for KA. This can be helpful in reducing costs, considering that KA is more dispendious than simple plain radiographs, and doesn't show advantages for all patient groups that would justify its universal usage. Not all patients with knee osteoarthrosis (OA) had neutrally aligned knees when in their healthy years, therefore various methods of estimating the original knee alignment have been described. Because contralateral limb alignment is unreliable since there is no proven exact left-right symmetry, and previous x-rays from when the patient had healthy knees are difficult to find, a novel mathematical method was described in the literature.[1,7] Considering the variability in knee phenotypes found across the literature, it would seem rational to think that different populations would present a different phenotype distribution. This hypothesis may be important, especially when acknowledging that TKA is performed almost worldwide, and almost entirely with the same alignment method described in the early 80's for a specific population.[8]

The Portuguese population has a relatively distinct genetic origin according to HLA data, as they have a high frequency of the HLA-A25-B18-DR15 and A26-B38-DR13 genes (a unique Portuguese marker), sharing some genetical features with the Basques and Spaniards.[9-11] Also, racial differences and genetic variability have shown in prior studies to influence alignment.[12-14] Therefore, it would be logical to hypothesize the existence of a variability in knee phenotype distribution when comparing the Portuguese population with others. Up to this date, there is no data on patient knee phenotype distribution according to the CPAK classification for the Portuguese population. Our objective was to characterize the knee morphology of the Portuguese population (paediatric, healthy, and individuals with knee OA), by application of the CPAK classification using long leg radiographs. Opportunistically, search for adjacent joint osteoarthrosis and investigation of its relationship with CPAK and other factors, was conducted. Additionally, obtaining the pre-disease coronal knee alignment by the means of a mathematical method and observing if the contralateral knee was in accordance with the obtained alignment was also investigated.

METHODS

A retrospective cohort study was conducted. Full length X-rays performed between January 2016 and May 2023 from various hospital centres; Hospital Particular do Algarve (HPA) Algarve, HPA Alentejo, and HPA Madeira, were retrospectively identified and reviewed. Healthy patients and patients with idiopathic osteoarthritis were included. Radiological measurements were performed.

Exclusion criteria

Out of a total of 792 knees (in 392 patients) gathered in the initial phase, 168 knees were excluded. A total of 320 individuals, 624 knees, where included. Patients with ipsilateral arthroplasty (N=25), ipsilateral long bone fractures (N=12), lower-limb dissymmetry (N=9), intra articular deformities not attributed to OA (N=6), osteomyelitis sequalae (N=2), neurological disease (N=1) and a major vascular event (N=1) history were excluded.

Study population

The study group was composed of three cohorts: a cohort of arthritic patients; a cohort of healthy adults (HA) and a cohort of paediatric patients. All patients had been observed at a hospital group, in 3 major areas of the country, between January 2016 and May 2023. The population from these areas have a high percentage of individuals from the whole country.

The arthritic patient cohort consisted of 64 patients, 120 knees. Inclusion criteria were knees with preoperative grade 1, 2, 3 or 4 Kellgren–Lawrence (KL) tibiofemoral osteoarthritis, with symptoms allocated to the specific analysed knee. The patient's mean age was 60 years (SD=14.3), with 35 (54%) females. The healthy adults cohort was composed of 152 patients, 296 knees. Only asymptomatic patients were included (specific to each knee). The patient's mean age was 41 years (SD=17.2), with 77 (51%) males. The paediatric patient cohort consisted of 104 patients (208 knees) aged between 9 and 18 years. Only asymptomatic were included. The patient's mean age was 14 years (SD=1.9), with 58 (56%) males.

Radiological analysis and measurements

All participants had undergone standing full leg radiographs, with all radiographs evaluated for image quality and correct rotation. An appropriate positioning was defined by the patella facing forward; an equal shape of the lesser trochanters; and an equal overlap of the proximal tibiofibular joints. Patients were required to have an aHKA angle of between -15° and 15, as values above or below this are less reliable and could incur in false measurements.[15] The final radiographic measurements were made by one observer, using the Carestream VueMotion PACS© Carestream Health, Inc. 2023. In total, five alignment parameters were measured, and two parameters were calculated: The lateral distal femoral angle (LDFA): defined as the lateral angle formed between the mechanical femoral axis and the knee joint line of the distal femur. The medial proximal tibial angle (MPTA): defined as the angle formed between the mechanical tibial axis and the knee joint line of the proximal tibia. The joint line convergence angle (JLCA): defined as the angle between the knee joint lines of the distal femur and the proximal tibia. The tibial joint line angle (TJLA): defined as the angle formed between the proximal tibial joint line and a line parallel to the floor. The hip knee ankle angle (HKA): defined as the angle formed by the mechanical femoral axis and the mechanical tibial axis. The arithmetic HKA (aHKA), calculated by applying the formula: aHKA=MPTA-LDFA. The joint line obliquity, calculated by applying the formula: JLO=MPTA+LDFA. Inter-observer reliability was determined by Pearson's r for the angle measurements performed by a second observer and the first observer, both independent and blinded. The interobserver r had an acceptable value (p<0.001). The degree of osteoarthritis was determined based on the Kellgren Lawrence scale.[16] Observation of osteoarthritis in the adjacent joints (hip and ankle) was also investigated.

CPAK classification

The coronal plane alignment of the knee classification comprehends the values of aHKA (varus, neutral, and valgus subgroups) and JLO (apex distal, neutral, and apex proximal subgroups). The CPAK type is obtained when the aHKA is set against the JLO to create nine knee phenotypes (Figure 1).

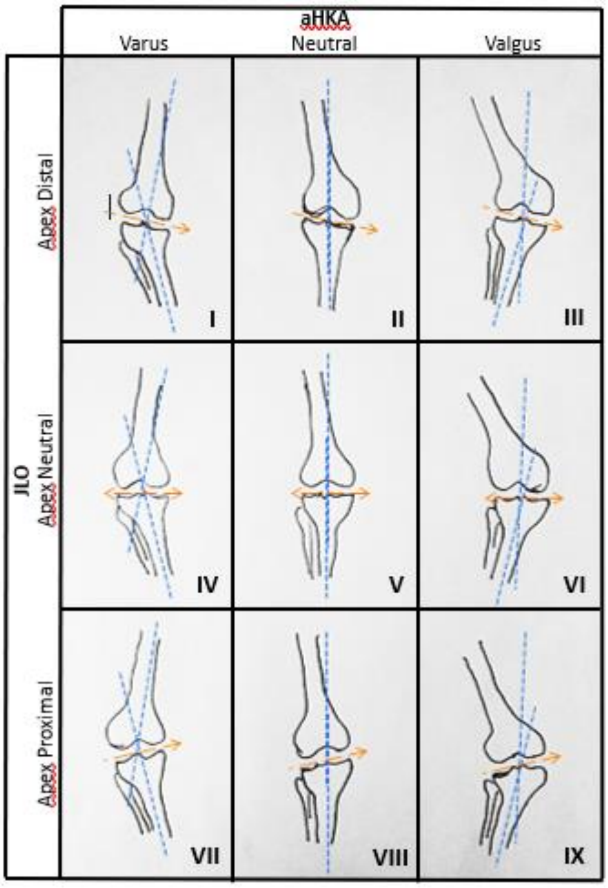

Figure 1: Coronal plane alignment of the knee classification with nine phenotypes.

These are: type I knee varus and JLO apex distal; type II knee neutral and JLO apex distal; type III knee valgus and JLO apex distal; type IV knee varus and JLO apex neutral; type V knee neutral and JLO apex neutral; type VI knee valgus and JLO apex neutral; type VII knee varus and JLO apex proximal; type VIII knee neutral and JLO apex proximal; type IX knee valgus and JLO apex proximal. CPAK boundaries for neutral aHKA are between -2º and 2º inclusive, below -2º for varus aHKA and above 2º valgus aHKA. Boundaries for a neutral JLO are between 177º and 183º inclusive, below 177º for apex distal JLO, and above 183º for apex proximal JLO.[6]

Pre-diseased coronal alignment

For OA knees in the CPAK type I and II phenotypes, a mathematical formula was used to predict the pre-diseased coronal alignment. This formula described by Willian Colyn et al. utilises the HKA angle, LDFA, MPTA, JLCA and the TJLA, considering the correction factors for each KL and CPAK type.[7] Comparison of the results with the contralateral knee alignment was performed.

Statistical analysis

Scatterplots for each population were created to demonstrate alignment distributions for arthritic, healthy and paediatric cohorts as well as comparing the pre-disease coronal alignment and the respective OA knee alignment for CPAK I and CPAK II arthritic subgroups. Boxplot charts were used for exhibiting data when comparing the calculated pre-disease coronal alignment with the healthy cohort.

Normality of data distribution was assessed for continuous variables using Shapiro-Wilk test and Q-Q plots. An independent-samples t-test and one way ANOVA were used to compare differences in means for normally distributed data and Mann-Whitney U test for non-parametric data. The chi-squared test and Fisher's exact test were used for categorical data analysis. Pearson correlation coefficient (r) was used for measuring linear correlation. Statistical significance was set at a p≤0.05. Statistical analyses were performed using SPSS Statistics Package v.25 (IBM, Armonk, New York, USA).

RESULTS

The mean MPTAs of the arthritic, HA and paediatric cohorts were 87.0º (SD=4.6º), 88.1º (SD=2.3º) and 88.2º (SD=2.8º) respectively. The mean LDFAs of the arthritic, HA and paediatric cohorts were 88.7º (SD=3.4º), 88.0º (SD=2.0º) and 87.8º (SD=2.2º) respectively these differences were not statistically significantly different (p=0,14) The mean aHKA of the arthritic, HA and paediatric cohorts were 1.7º (SD=6º), 0.2º (SD=2.9º) and 0.4º (SD=2.7º) respectively, these differences were statistically significantly different (p<0.001). The most common alignment was varus for the arthritic population (38%) and neutral for the HA and paediatric populations (57% and 65% respectively) these differences were statistically significantly different (p<0.001).

CPAK classification

The frequencies of individuals representing the most frequent CPAK types were different when comparing between cohorts (p<0,001). A scatter plot was obtained for each cohort; arthritic, HA and paediatric (Figure 2-4).

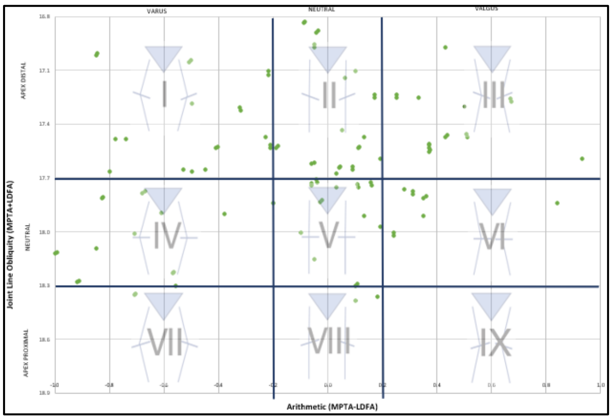

Figure 2: CPAK distribution in the arthritic population.

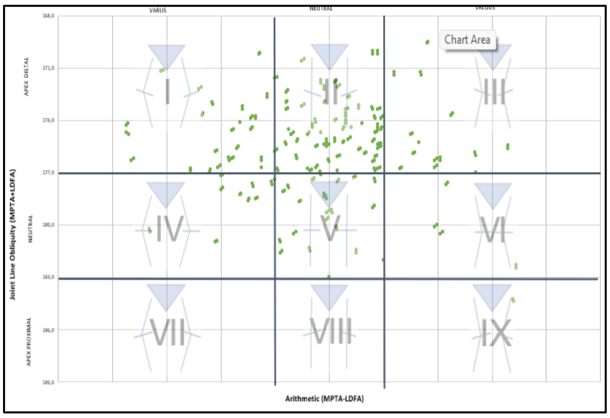

Figure 3: CPAK distribution in the healthy population.

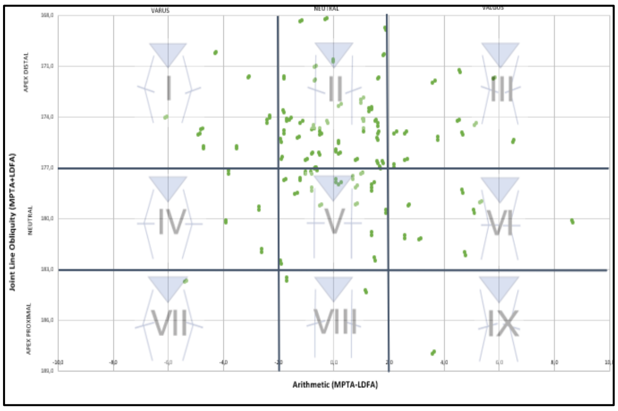

Figure 4: CPAK distribution in the paediatric population.

For the arthritic cohort, the most common CPAK types in order were Type I (N=38; 23%), Type II (N=24; 20%), Type III (N=19; 16%), Type V (N=18; 15%), Type IV (N=16; 13%), and Type VI (N=9; 8%). Regarding the differences between the CPAK subgroups and the KL classification, no statistically significant differences were observed (p=0.78). However, the aHKA angle correlates with the KL grade, in a bidirectional manner: the varus or valgus aHKA increases as the KL grade increases (r=0.8352; p<0.001). A KL grade of "0" had a mean of 2.3º varus and a 2.2º valgus in comparison with a KL grade "4" which had a mean of 9.7º varus and 8.8º valgus. When comparing KL grade and JLO variation, no statistically significant differences were observed (p=0.13). For the HA cohort, the most common CPAK types in order were Type II (N=124; 42%), Type I (N=45; 15%), Type V (N=42; 14%), Type VI (N=32; 11%), Type III (N=27; 9%) and Type IV (N=19; 6%). In the paediatric cohort, the most common CPAK types in order were Type II (N=89; 43%), Type V (N=43; 21%), Type III (N=25; 12%), Type I (N=18; 9%), Type VI (N=17; 8%). CPAK Types VII, VIII, and IX were rare in all populations (Table 1).

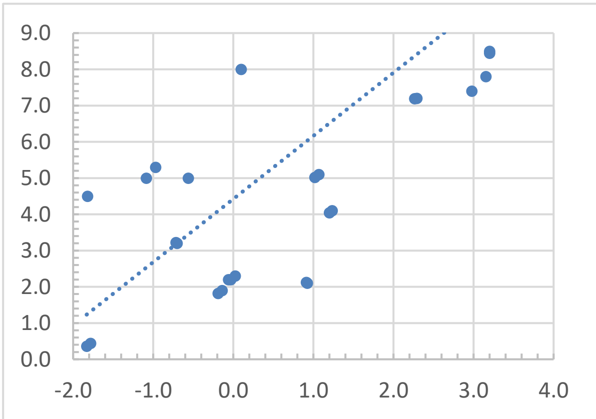

Figure 5: Scatterplot illustrating the difference between the arthritic measured HKA and the HKA obtained by determining the pre-disease coronal alignment.

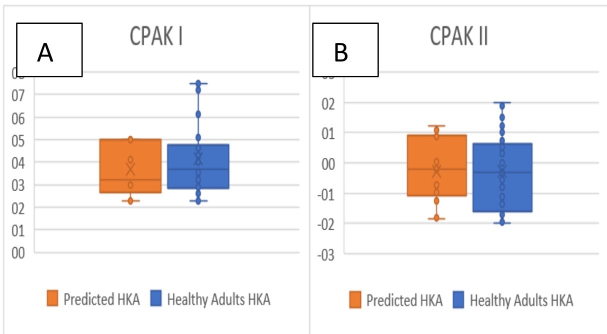

Figure 6: Boxplot comparing the obtained pre-disease coronal alignment values and the values for the healthy cohort in A) CPAK I phenotype, and B) in CPAK II phenotype.

Gender

The mean aHKA for females was 0.7º (SD 3.0º) and -0.7º for males (SD 2.7º) in the HA cohort, while -0.8º (SD 3.3º) and -2.8º for males (SD 5.6º). For the arthritic cohort, the most common CPAK types for females were Type II (n=16; 25%); Type V (N=11; 17%); Type VI (N=9; 14%); and Type I (N=8; 13%). With a residual number of individuals presenting other CPAK types. While for males the most common CPAK types were Type I (N=20; 36%); Type III (N=12; 21%); Type IV (N=9; 16%); Type II (N=8; 14%); Type V (N=7; 13%). With no individuals presenting other CPAK type. The differences regarding gender for the arthritic cohort were statistically different (p=0.008) (Table 2).

Table 1: Distribution by CPAK phenotype (p<0.001).

CPAK	Arthritic (N=120) Frequency (%)	Healthy (N=296) Frequency (%)	Paediatric (N=208) Frequency (%)
I	28 (23)	45 (15)	18 (9)
II	24 (20)	124 (42)	89 (43)
III	19 (16)	27 (9)	25 (12)
IV	16 (13)	19 (6)	8 (4)
V	18 (15)	42 (14)	43 (21)
VI	9 (7)	32 (11)	17 (8)
VII	2 (2)	2 (1)	3 (1)
VIII	2 (2)	3 (1)	3 (1)
IX	2 (2)	2 (1)	2 (1)

Table 2: CPAK distribution by gender in the arthritic population (p=0.008), healthy population (p=0.006), and paediatric population (p=0.073).

CPAK	Arthritic (N=120) Frequency (%)		Healthy (N=296) Frequency (%)		Paediatric (N=208) Frequency (%)	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
I	20 (36)	8 (13)	32 (22)	13 (9)	14 (12)	4 (4)
II	8 (14)	16 (25)	70 (48)	54 (36)	56 (48)	33 (36)
III	12 (21)	7 (11)	9 (6)	18 (12)	13 (11)	12 (13)
IV	9 (16)	7 (11)	10 (7)	9 (6)	2 (2)	6 (7)
V	7 (13)	11 (17)	16 (11)	26 (17)	22 (19)	21 (23)
VI	0 (0)	9 (14)	9 (6)	23 (15)	7 (6)	10 (11)
VII	0 (0)	2 (3)	0 (0)	2 (1)	1 (1)	2 (2)
VIII	0 (0)	2 (3)	0 (0)	3 (2)	1 (1)	2 (2)
IX	0 (0)	2 (3)	0 (0)	2 (1)	0 (0)	2 (2)

In the HA cohort the most common CPAK types for females were Type II (N=54; 36%); Type V (N=26; 17%); Type VI (N=23; 15%); and Type III (N=18; 12%). With a residual number of individuals CPAK types VII, VIII and IX. While for males the most common CPAK types were Type II (N=70; 48%); Type I (N=32; 22%); Type V (N=16; 11%); Type IV (N=10; 7%), Type III and VI (N=9; 6%). With no individuals presenting other CPAK types. The differences between genders in the HA cohort were statistically different (p=0.006) (Table 3). For the paediatric cohort the most common CPAK types for females were Type II (N=33; 36%); Type V (N=21; 23%); Type III (N=12; 13%) and Type VI (N=10; 11%). For males the most common CPAK types were Type II (N=56; 48%); Type V (N=22; 19%); Type I (N=14; 12%); Type III (N=13; 11%) and Type VI (N=7; 6%). With a residual number of individuals CPAK types IV, VII, VIII and IX for both genders. There was no statistical difference between genders (p=0.073) (Table 4).

Adjacent degenerative changes

Concerning the presence or absence of osteoarthritis in the adjacent joints (tibio-talar and hip joints), a statistically significant difference (p<0.001) in prevalence was observed when comparing the arthritic and HA cohorts. The arthritic cohort had higher prevalence of adjacent joint osteoarthritis in comparison. No statistically significant differences were observed in prevalence of adjacent arthritis when comparing between the various grades of the KL classification (p=0.17). The same goes for the different CPAK types (p=0.15). Patients within the subgroup of tibio-talar joint osteoarthritis had a mean MPTA of 86.4º (SD 3.1º), LDFA of 88.2º (SD 4.3º), aHKA of -1.8º (SD=6.1º) and JLO of 174.7º (SD 4.3º). While patients with hip osteoarthritis had a mean MPTA of 87.2º (SD=4.3º), LDFA of 89.1º (SD=4.3º), aHKA of -1.9º (SD=5.4º) and JLO of 177.3º (SD=5.3º). When comparing these two subgroups no statistically significant differences were found (p=0.15), as well as when comparing with the mean values of the general population.

Table 3: Adjacent joint OA distribution comparison between the healthy and arthritic cohorts (p<0.001).

AJDC	Arthritic (N=120) Frequency (%)	Healthy (N=296) Frequency (%)
Present	16 (13)	9 (3)
Absent	104 (87)	287 (97)

AJDC-adjacent joint degenerative changes

Pre-diseased coronal alignment-CPAK I & II

In the arthritic cohort, following calculation of the pre-diseased coronal alignment, a scatter plot comparing the pre-diseased HKA and the arthritic HKA was obtained (Figure 5). In CPAK I subgroup, the degree of correction, calculated by the subtraction (difference) of the mean predicted HKA to the mean HKA of the arthritic cohort for KL I grade was 1.5 (SD=0.8), for KL II grade was 3.1 (SD=1.2), KL III grade was 4.8 (SD=1.5) and for KL IV was 8.0 (SD=2.8). While in the subgroup of patients classifying as CPAK II, the difference for KL I grade was 0.6 (SD=0.3); for KL II grade was 2.0 (SD=0.6) and for KL III grade was 1.8 (SD=0.02), there were no patients with KL IV in this subgroup. Noteworthy, in the CPAK I subgroup, 16 (64%) changed from a varus to a neutral alignment after obtaining the pre-diseased coronal alignment. Of these, only 3 out of 10 patients (30%) had a contralateral knee alignment in correspondence with the obtained pre-disease alignment. In CPAK II subgroup all patients maintained their coronal plane alignment (neutral) after application of the formula. The distribution of the predicted knee alignment was similar to the alignment of the HA cohort (Figure 6).

Table 4: Mean difference between initial aHKA and predicted aHKA after obtaining the pre-disease coronal alignment, in the arthritic cohort.

KL	CPAK I HKA difference±SD	CPAK II HKA difference±SD
1	1.5±1.5	0.6±0.6
2	3.1±1.2	2.0±1.8
3	4.8±1.5	1.8±0.0
4	8.0±2.8	--

DISCUSSION

Noteworthy variability in knee phenotype exists in the Portuguese population. The choice of using the CPAK classification, was made because it is a simple but complete system for describing knee alignment. As the aHKA is not influenced by bone loss as is mHKA, aHKA can be used safely for either the OA or healthy knee. This in turn shows an advantage of the CPAK over other recent classification systems, which use mHKA and are more complex.[6] Another benefit of using the CPAK classification is that can help determine which patients are most likely to benefit from kinematic alignment, which include but are not restricted to CPAK Types I, III, IV, VI. Posing as a preoperative method to determine which alignment strategy can be best suited for each patient, preserving the original native soft tissue envelope.[6,17] The Portuguese population is composed mainly of neutral knees in the healthy adults and paediatric individuals (57% and 68% respectively), and varus knees for individuals with knee OA (38%), with apex distal JLO predominance, as seen on (Table 1). As for the CPAK phenotype distribution, the most common CPAK types in order were Type I for the arthritic cohort (23%) and Type II for the HA and paediatric cohorts (42% and 43% respectively), followed by Type II in the arthritic cohort (20%) and Type I for the HA cohort (15%) and Type V for the paediatric cohort (21%). Thirdly, Type III for the arthritic cohort (16%), Type V in the HA cohort (14%) and Type III (12%) for the paediatric cohort. With rarity for all populations in term of CPAK Types VII, VIII, and IX prevalence.

When comparing the phenotype distribution for the arthritic cohort in our series with the work of McDessi et al our results differ from the latter. This can be explained by limitations of the before mentioned author's study. Considering that in their study population, individuals were from different continents, with no analysis on racial background carried out. This fact could have had an impact on alignment results.[13,14] Also in the same study there was no equal gender distribution, with a female predominance in the population with knee OA.[6,14] In contrast, our study was comprised of a population with equal gender distribution. In fact, for the arthritic cohort the most common CPAK Type for females was Type II (25%); Type V (17%); Type VI (14%); and Type I (13%), while for males the most common CPAK types were Type I (36%;); Type III (21%). The evidence shows a tendency towards neutral/valgus knees phenotypes in females when compared to male individuals in the arthritic cohort. Possibly explaining McDessi et al results in a cohort with a large majority of females. Nevertheless, our results are in accordance with the work of Huber S. et al, who concluded that a varus alignment was more common in males while neutral and valgus alignments were more common in females. Also, concluding that the most common CPAK phenotypes were CPAK Type I followed by Type II for the population with knee OA in Austria.[18] The same goes for other studies, for example in India, which show similar results as our series.[19] In contrast, the mean coronal alignment for the healthy adult Korean female population, shows a slightly higher tendency towards varus when compared to the HA Portuguese female population (-1.35º HKA vs. 0.7º HKA, and 20% varus vs. 16% varus respectively).[14] For our series, regarding the HA cohort there were differences between genders, with a tendency towards a valgus alignment in females in contrast to a varus alignment in males was observed. The KL classification does not correlate with CPAK classification; however, it is known, and our results show that the KL grade does correlates with the aHKA, as they both increase with each other.[7] Possibly, the KL grade may not have a strong and proportional influence on JLO, which can in turn explain why we didn't observe an influence in CPAK phenotype. Regarding the paediatric cohort, a neutral knee with an apex distal JLO was the most common phenotype as above mentioned, the mean MPTA, LDFA and aHKA were within the reference values in literature.[20] There were no statistically significant differences between genders, with the most common CPAK types for females and males being Type II (36% and 48% respectively), with slight variation in the third most common CPAK (I for male and III for female), possibly showing a weak but present tendency in paediatric females towards valgism and the opposite in the paediatric male population. The distributions by CPAK type (Table 1) show that 22% of HA and 38% of arthritic patients have constitutional varus and 66% of HA and 59% of arthritic patients have an apex distal JLO. After applying the pre-disease coronal alignment prediction method described by Colyn et al we noted that not all patients switched from a varus knee to a neutral knee alignment. This again raises the question that if aligning the knee into a neutral mechanical alignment with neutral JLO is always the best arthroplasty alignment goal, as this combination only represents a percentage of the population. Noteworthy, 3 out of 10 patients that switched CPAK phenotypes had a contralateral knee alignment in correspondence with the obtained pre-disease alignment. Having these observations in mind, one can hypothesize that the most appropriate goal for alignment is the obtaining the pre-disease constitutional alignment, accomplished by prediction of the original native healthy aHKA. Further questioning the idea that the contralateral limb could be used to predict the constitutional alignment.[21,22] However, obtaining the pre-disease knee anatomy remains incomplete as there is currently no validated method for calculation of the healthy joint line obliquity. Regarding degenerative changes in adjacent joints, one can conclude that the knee phenotype has no direct impact in prevalence. According to the literature, the prevalence of OA in the ankle is low, with most cases having a posttraumatic origin (above 70% according to some series).[23-25] Of these, some patients had altered MPTAs, especially in end stage knee OA. However, our series showed that MPTA has no statistically significant impact in ankle OA prevalence. A recent study by Kai et al concludes that tibial varus (decreased MPTA) is associated with progression of ankle OA but remains unclear whether it causes ankle OA.[26] While hip OA aethiology is idiopathic in most cases, genetic, sex, obesity and repetitive stress and biomechanical overload, especially in the setting of a preexisting hip joint anatomical abnormality, are other likely causes of hip OA.[27-30] However, the increase in prevalence in the arthritic cohort when comparing to HA may be explained by age being a risk factor for radiographic OA. The arthritic patient cohort had a superior mean age when compared to the HA cohort (60 versus 41 years respectively). Although, joint tissue "ageing" and OA development are distinct processes, age related chondrocalcinosis may contribute to OA by stimulating production of proinflammatory mediators.[27,31]

Limitations

Our study had the following limitations: radiological measurement errors related to rotational deformities of the distal femur.[32] Also, CPAK does not consider axial or sagittal alignment, which also contribute to knee balance. Further studies that address understanding of 3D alignment and balance may be necessary.[33] However routinely submitting all patients to high doses of radiation may unfold medical, economic, ethical, and practical issues.[15,32]

CONCLUSION

In summary, the study unveils a predominant knee coronal alignment pattern in the Portuguese population, showcasing apex distal joint line obliquity with neutral constitutional alignment in health or paediatric cases, and varus alignment in knee OA. Gender disparities reveal varus prevalence in males and neutral/valgus in females. While Portuguese knee phenotypes align globally, distinctions emerge in Asian cohorts, emphasizing nuanced population-specific variations. This underscores the rejection of one-size-fits-all approaches. Incorporating pre-disease coronal alignment and CPAK classification in clinical practice offers crucial insights for optimizing outcomes, especially in the era of rising robotic surgery utilization. While knee phenotype and constitutional alignment may not independently impact ankle or hip osteoarthritis prevalence, higher prevalence can be observed in patients presenting with knee OA, highlighting the possible influence of age and other factors specific to OA of the joints in question. The findings improve the understanding of knee OA by delineating population-specific considerations, paving the way for tailored interventions to enhance patient care and outcomes, in a field where robotic surgery's popularity is increasing.

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