The Bone & Joint Journal
Over 70 years of orthopaedic excellence

MacDessi SJ, Griffiths-Jones W, Harris IA, Bellemans J, Chen DB. Coronal Plane Alignment of the Knee (CPAK) classification: a new system for describing knee phenotypes. *Bone Joint J*. 2021;103-B(2):329-337.

https://doi.org/10.1302/0301-620X.103B2.BJJ-2020-1050.R1

2 July 2021

Authors' reply:

Sir,

We are very appreciative of the deep consideration Drs Huang and Hsu have given to our paper.[1] The suggestions they have offered provide us with an opportunity to delve into why and how the classification and its algorithms were constructed, something we were unable to outline in the recent manuscript due to the limitations of space.

As they have affirmed, the Coronal Plane Alignment of the Knee (CPAK) classification has significant merits compared with previous classifications for coronal plane alignment of the knee.[2,3] First, its simplicity is key to optimizing its widespread adoption as research in the field of individualized alignment evolves. The CPAK classification describes nine possible knee phenotypes, of which only six are common. This straightforward system is essential in the analysis of which patients benefit most when their unique constitutional alignment and joint line obliquity (JLO) are actually restored, rather than significantly altered.[1]

At their core, CPAK algorithms uniquely define each patient's constitutional lower limb alignment (arithmetic hip-knee-ankle angle (aHKA)) and JLO, regardless of whether the individual has arthritis or not. The two algorithms have been intentionally derived to keep simplicity, consistency, and reproducibility at the fore. Both use the coronal mechanical joint line angles of the distal femur (lateral distal femoral angle (LDFA)) and proximal tibia (medial proximal tibial angle (MPTA)).
The constitutional lower limb alignment is determined by the algorithm ***aHKA = MPTA - LDFA*** (Figure 1).[1,4,5]

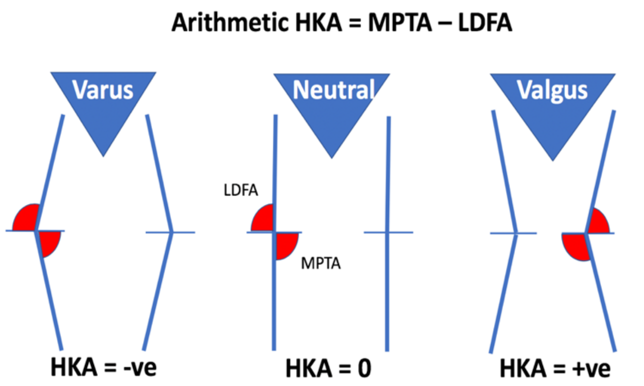

Figure 1. Arithmetic hip-knee-ankle angle (aHKA) algorithm

Joint line obliquity is defined by the algorithm ***JLO = MPTA + LDFA*** (Figure 2).[1]

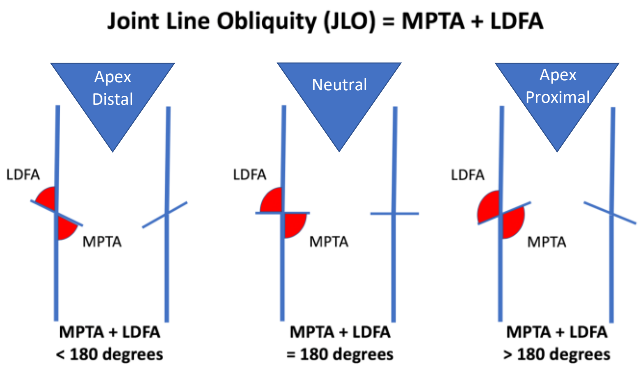

Figure 2. Joint line obliquity (JLO) algorithm

The α and β angles Huang and Hsu propose are the complements of LDFA and MPTA. Adding more variables for surgeons and researchers to remember inevitably adds a further layer of complexity and confusion to these fundamental concepts. Further, neither α nor β is a commonly used anatomical descriptor, unlike MPTA and LDFA. In order to disseminate this important concept effectively, we chose to use terminology that is already widely employed in our field.

We did consider their proposition that JLO should be the mean of the two joint line angles. However, once again, in the pursuit of developing the first straightforward method to determine JLO, we opted for minimalism over complexity. The concept of JLO is to illustrate the *direction* of the joint line of the knee, regardless of the stage of arthritis and associated joint space changes. It is not a numerical value of the angular deviation relative to the ground, which is the mean of the MPTA and LDFA (or α and β angles). Finally, having JLO centred on 180° creates a point of differentiation from the aHKA, which is centred on 0°. It is not by chance that these two angular relations are relatively perpendicular to one another and also the inverse of each other.

When categorizing phenotypic traits for coronal plane alignment of the knee, it is critical to respect population-based statistical boundaries of variance. The CPAK boundaries for aHKA and JLO are hence based on population SDs of 1,000 normal and arthritic knees, rounded to the nearest whole number. The boundaries for neutral aHKA are +/-2°, inclusive (SD 1.8°), and for neutral JLO are +/-3°, inclusive (SD 2.9°) (Figure 3).

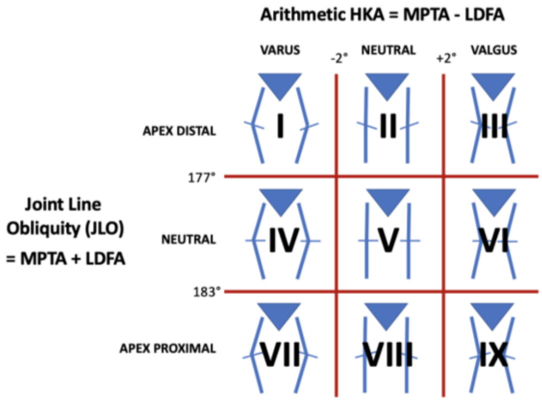

Figure 3. The Coronal Plane Alignment of the Knee (CPAK) classification

On their last point, the alignment boundaries of 0°+/-3° have recently been brought into question. Despite having been espoused as important for achieving a satisfactory outcome for more than three decades, there is now convincing evidence that systematically restoring each knee to this mechanical alignment target may result in significant soft-tissue imbalance,[6-8] disturbance of normal gait pattern,[9] and potentially inferior patient outcomes.[10-15] Further, when recent high-quality studies using long leg imaging[16-19] were compared with earlier studies that only used short knee imaging,[20,21] knees that were aligned outside 0°+/-3° had no impact on long-term survivorship of the prosthesis. Registry data have supported these findings, with kinematically aligned implants showing excellent survivorship at seven years.[22] The use of data sets from normal and arthritic populations to define what is truly normal is fundamental in our quest to understand the complex relationship between alignment of the knee, restoration of kinematic function and, most importantly, better outcomes for our patients.

S. J. MacDessi, MBBS (Hons), FRACS, PhD,
W. Griffiths-Jones, MBChB, FRCS, Tr & Orth,
I. Harris, MBBS, FRACS, MMed (Clin Epi), PhD,
J. Bellemans, MD, PhD,
D. Chen, MBBS (Hons), FRACS,
Sydney Knee Specialists,
Sydney, Australia.

1. **MacDessi SJ, Griffiths-Jones W, Harris IA, Bellemans J, Chen DB.** Coronal Plane Alignment of the Knee (CPAK) classification: a new system for describing knee phenotypes. *Bone Joint J*. 2021;103-B(2):329-337.
2. **Hirschmann MT, Moser LB, Amsler F, Behrend H, Leclerq V, Hess S.** Functional knee phenotypes: a novel classification for phenotyping the coronal lower limb alignment based on the native alignment in young non-osteoarthritic patients. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(5):1394-1402.
3. **Lin YH, Chang FS, Chen KH, Huang KC, Su KC.** Mismatch between femur and tibia coronal alignment in the knee joint: classification of five lower limb types according to femoral and tibial mechanical alignment. *BMC Musculoskelet Disord*. 2018;19(1):411.
4. **Griffiths-Jones W, Chen DB, Harris IA, Bellemans J, MacDessi SJ.** Arithmetic hip-knee-ankle angle (aHKA): an algorithm for estimating constitutional lower limb alignment in the arthritic patient population. *Bone Jt Open*. 2021;2(5):351-358.
5. **MacDessi SJ, Griffiths-Jones W, Harris IA, Bellemans J, Chen DB.** The arithmetic HKA (aHKA) predicts the constitutional alignment of the arthritic knee compared to the normal contralateral knee: a matched-pairs radiographic study. *Bone Jt Open*. 2020;1(7):339-345.

6. **MacDessi SJ, Griffiths-Jones W, Chen DB, et al.** Restoring the constitutional alignment with a restrictive kinematic protocol improves quantitative soft-tissue balance in total knee arthroplasty: a randomized controlled trial. *Bone Joint J*. 2020;102-B(1):117-124.
7. **An VVG, Twiggs J, Leie M, Fritsch BA.** Kinematic alignment is bone and soft tissue preserving compared to mechanical alignment in total knee arthroplasty. *Knee*. 2019;26(2):466-476.
8. **Blakeney W, Beaulieu Y, Kiss MO, Rivière C, Vendittoli PA.** Less gap imbalance with restricted kinematic alignment than with mechanically aligned total knee arthroplasty: simulations on 3-D bone models created from CT-scans. *Acta Orthop*. 2019;90(6):602-609.
9. **Blakeney W, Clement J, Desmeules F, Hagemeister N, Riviere C, Vendittoli PA.** Kinematic alignment in total knee arthroplasty better reproduces normal gait than mechanical alignment. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(5):1410-1417.
10. **Young SW, Sullivan NPT, Walker ML, Holland S, Bayan A, Farrington B.** No Difference in 5-year Clinical or Radiographic Outcomes Between Kinematic and Mechanical Alignment in TKA: A Randomized Controlled Trial. *Clin Orthop Relat Res*. 2020;478(6):1271-1279.
11. **Winnock de Grave P, Luyckx T, Claeys K, et al.** Higher satisfaction after total knee arthroplasty using restricted inverse kinematic alignment compared to adjusted mechanical alignment. *Knee Surg Sports Traumatol Arthrosc*. 2020 Jul 31. Online ahead of print.
12. **Calliess T, Bauer K, Stukenborg-Colsman C, Windhagen H, Budde S, Ettinger M.** PSI kinematic versus non-PSI mechanical alignment in total knee arthroplasty: a prospective, randomized study. *Knee Surg Sports Traumatol Arthrosc*. 2017;25(6):1743-1748.
13. **Waterson HB, Clement ND, Eyres KS, Mandalia VI, Toms AD.** The early outcome of kinematic versus mechanical alignment in total knee arthroplasty: a prospective randomised control trial. *Bone Joint J*. 2016;98-B(10):1360-1368.
14. **Dossett HG, Estrada NA, Swartz GJ, LeFevre GW, Kwasman BG.** A randomised controlled trial of kinematically and mechanically aligned total knee replacements: two-year clinical results. *Bone Joint J*. 2014;96-B(7):907-913.
15. **McEwen P, Dlaska C, Jovanovic I, Doma K, Brandon B.** Computer-Assisted Kinematic And Mechanical Axis Total Knee Arthroplasty: A Prospective Randomized Controlled Trial of Bilateral Simultaneous Surgery. *J Arthroplasty*. 2020;35(2):443-450.
16. **Abdel MP, Ollivier M, Parratte S, Trousdale RT, Berry DJ, Pagnano MW.** Effect of Postoperative Mechanical Axis Alignment on Survival and Functional Outcomes of Modern Total Knee Arthroplasties with Cement: A Concise Follow-up at 20 Years. *J Bone Joint Surg Am*. 2018;100-A(6):472-478.
17. **Hadi M, Barlow T, Ahmed I, Dunbar M, McCulloch P, Griffin D.** Does malalignment affect revision rate in total knee replacements: a systematic review of the literature. Springerplus. 2015;4(1):835.
18. **Bonner TJ, Eardley WGP, Patterson P, Gregg PJ.** The effect of post-operative mechanical axis alignment on the survival of primary total knee replacements after a follow-up of 15 years. *J Bone Joint Surg Br*. 2011;93-B(9):1217-1222.
19. **Parratte S, Pagnano MW, Trousdale RT, Berry DJ.** Effect of postoperative mechanical axis alignment on the fifteen-year survival of modern, cemented total knee replacements. *J Bone Joint Surg Am*. 2010;92-A(12):2143-2149.
20. **Fang DM, Ritter MA, Davis KE.** Coronal alignment in total knee arthroplasty: just how important is it? *J Arthroplasty*. 2009;24(6 Suppl):39-43.
21. **Ritter MA, Faris PM, Keating EM, Meding JB.** Postoperative alignment of total knee replacement. Its effect on survival. *Clin Orthop Relat Res*. 1994;(299):153-156.
22. **Klasan A, de Steiger R, Holland S, Hatton A, Vertullo CJ, Young SW.** Similar Risk of Revision After Kinematically Aligned, Patient-Specific Instrumented Total Knee Arthroplasty, and All Other Total Knee Arthroplasty: Combined Results From the Australian and New Zealand Joint Replacement Registries. *J Arthroplasty*. 2020;35(10):2872-2877.