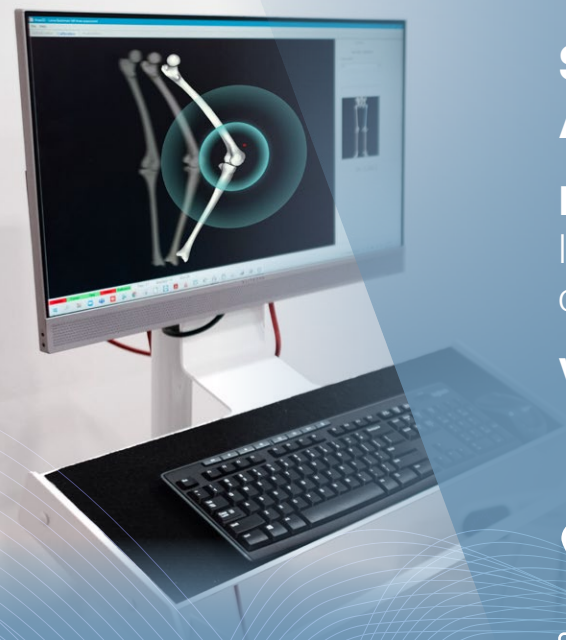

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KNEE KINESIOGRAPHY EXAM:
literature review of an innovative dynamic assessment of knee dysfunctions - towards functional imaging

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Session 10: Bone and Skeletal Imaging, Segmentation, Registration, Decision-Making

February 22nd 2022

2:40 PM - 3:00 PM

KNEE KINESIOGRAPHY EXAM: literature review of an innovative dynamic assessment of knee dysfunctions - towards functional imaging

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ABSTRACT

Knee osteoarthritis (OA) is typically well diagnosed with a clinical evaluation and confirmed by conventional radiographic imaging. While this disease is associated with pain and functional impairments, there is a well-documented discordance between radiographic severity and symptoms in knee OA patients.

In order to update a technical literature review from 2012 on the Knee Kinesiography, a comprehensive review was carried out to identify materials published since which used this technology to improve the understanding of the relationships between biomechanical dysfunctions and OA severity and progression (clinically and radiographically). This innovative exam, which can be performed with a KneeKG™ system, quickly assesses and quantifies knee joint function in the sagittal (flexion-extension), frontal (varus-valgus), and transverse (internal-external rotation) planes while the patient is walking on a commercial treadmill.

This review showed that biomechanical dysfunctions assessed through a Knee Kinesiography exam were most strongly associated with pain and function than OA radiographic severity. Furthermore, the added value of this assessment tool was highlighted in the primary care and total knee arthroplasty (TKA) populations. Objective data from this exam showed to be clinically relevant in conservative treatment care, as an input measure to identify patients deemed appropriate for surgery, and helped assessing how function is restored post-TKA while acquiring new insights on the choice of implant and surgical techniques.

This study suggests that the Knee Kinesiography can act as an add-on to conventional imaging to gather relevant and objective functional data to help clinicians better understand knee OA, its progression and impact of TKA.

Keywords: Knee Kinesiography, biomechanical dysfunctions, TKA, radiographic imaging, functional imaging, functional data, knee OA, 3D kinematics

1. INTRODUCTION

Knee disorders can lead to chronic conditions associated with pain and functional impairments. Although some knee disorders are preceded by a traumatic event, the majority are directly related to biomechanical dysfunction. This is often the case for knee osteoarthritis (OA), which is the leading cause of disability among older adults[1]. This disease is typically diagnosed with a clinical evaluation and confirmed by conventional radiographic imaging. However, there is a well-documented discordance between radiographic severity and symptoms in patients with knee OA; patients with severe symptoms may have mild radiographic evidence of disease, and vice-versa[2]. Static radiographs are typically used to assess knee OA structural degeneration; however, disease progression and functional limitations are intensified during dynamic activities. To date, there have been limited integration of dynamic assessments with medical imaging and clinical exams to develop effective conservative treatment plans and aid in the decision for surgical management with total knee arthroplasty (TKA).

2. PURPOSE AND METHODS

Biomechanical evaluation during gait is recommended as a complement to radiographic imaging to assess dysfunctions and risk factors related to disease progression and symptoms in patients with knee OA[3]. However, this assessment is often skipped due to a lack of validated tools, space in clinic, and difficulty in the visual identification of small misalignments during gait. The knee kinesiography examination is an evaluative procedure that quickly assesses and quantifies knee joint motion and function in the sagittal (flexion-extension), frontal (varus-valgus), and transverse (internal-external rotation) planes while the patient is walking on a commercial treadmill. Although traditional motion capture systems can assess knee kinematics, the movement artifact of soft tissues upon which reflective markers are attached often leads to inaccurate measurements. Knee kinesiography, which can be performed with the KneeKG™ system, addresses these limitations. More specifically, the validated exoskeleton is fixed on the bony landmarks of the patient's knee and quantifies motions with an accuracy of 0.4° for adduction/abduction (varus/valgus), 2.3° for axial rotation (tibial internal/external rotation), and 2.4 mm for anterior/posterior translation when compared to fluoroscopy images4. Intra- and inter-rater reproducibility meet or exceed 0.8 ICC values, and differences in intra- and inter-rater reliability for joint angles are less than 1°.

Figure 1. A Knee Kinesiography exam in a clinical setting. The KneeKG™ system's exoskeleton is fixed on the lower limb and motion is displayed on the monitor through imaging reconstruction.

A 2012 review[4] gathered studies related to the development, validation and use of this exam, and suggested that this reliable tool could improve the understanding of the relationships between biomechanical dysfunctions and degenerative changes of the knee. The present paper aims at updating this work with original materials published since. A comprehensive review was carried out to identify studies related to the Knee Kinesiography exam (and the KneeKG™ system) reporting functional data on the knee OA population and healthy controls. Studies from the past 10 years were considered and relevant articles were searched using MEDLINE and RESEARCHGATE databases.

3. RESULTS

3.1 Relation between biomechanical and radiographic imaging

The work of Blouin et al. (2014) reported the correlations between 3D kinematics measured by Knee Kinesiography and OA radiographic severity using OAISYS grading system[5,6]. Frontal plane kinematics were most strongly associated with radiographic severity grade of patients with patellofemoral ($|r|>0.78$) and tibiofemoral OA ($|r|>0.64$, all $p<0.005$). This correlation was also confirmed on a larger sample of 294 patients[7] even if radiographic severity was measured using Kellgren-Lawrence (KL) grades. 3D mechanical dysfunctions measured by Knee Kinesiography were accentuated in the three planes (especially in the frontal one) as OA severity worsened, confirming the association between radiographic evolution and dynamic functional limitations measured by the Knee Kinesiography exam. More recently, Ben Salma et al. (2021) proposed a more direct comparison between radiographic severity, biomechanical parameters, and clinical assessment data[8]. Results suggested that biomechanical markers measured by Knee Kinesiography were better associated with the Knee Injury and Osteoarthritis Outcome Score (KOOS) patient reported outcome measure[9] than radiographic KL severity grades. This was especially the case on the pain ($|Corr|=0.36$ vs 0.12 respectively) and function during daily living activities ($|Corr|=0.42$ vs 0.08 respectively; both $p<0.05$) subscales of the KOOS. These results support previously published papers on the discordance or low correlation between radiographic severity and knee OA symptoms, while biomechanical dysfunctions appeared to be associated with pain and functional limitations[2,10]. This suggests that such assessment may be useful to help clinicians assess the functional impact of knee OA. The value of complementing static imaging assessment with a dynamic functional evaluation

was also reinforced by a study from Clément et al. (2019)[11]. These authors concluded that lower limb radiographic measures of coronal alignment (Hip-Knee-Ankle; HKA) were limited predictors of dynamic alignments behavior during gait ($0.27<r<0.56$). Out of 90 healthy subjects, 22% of the knees changed the frontal alignment (varus to valgus and vice-versa) of their HKA between static radiographs and dynamic measures by Knee Kinesiography. The proportion of "changers" was 15% of the varus knees and 39% of the valgus knees ($p<0.001$). This could have significant repercussion when planning corrective therapeutic options (i.e., bracing, or orthotic) and planning arthroplasty procedure aiming at restoring a mechanical alignment.

3.2 Applications for the conservative treatment of the knee OA population

Beyond the quantification of knee kinematics, evaluation and interpretation of these objective data is a crucial issue, especially to support decision-making of clinicians during the design of conservative treatment strategies. Using artificial intelligence (AI), biomechanical markers associated to knee OA can be extracted from Knee Kinesiography measures and instantly displayed in a succinct report including comparison with data from the literature and suggestions of specific corrective options. Patients from a recent randomized controlled trial (RCT) whose primary care physicians had access to this functional assessment report demonstrated significant improvements in symptoms, pain, and function (KOOS), as well as satisfaction at 6-month follow-up compared to a control group who followed usual care[12]. Furthermore, those who benefited from complementary education had higher adherence (88%; $p<0.001$) to their physician recommendations and better performance on objective functional tests (both $p\leq0.01$), suggesting that this exam may help guide a personalized treatment plan. Secondary analyses of patients from this RCT who followed treatment suggestions (including tailored exercises) based on Knee Kinesiography measures also showed that it is possible to correct specific biomechanical dysfunctions (i.e., varus thrust, dynamic flexion contracture), reinforcing the added value of this exam in this population to address risk factors linked to knee OA progression[13,14].

3.3 Applications for functional parameters of the TKA population

Opting for a TKA surgery is a meaningful decision for a knee OA patient and his/her clinician. It is often the last solution when the symptoms are no longer tolerable. In this context, a clinician could benefit from the help of objective functional data to help make the best decision while considering multiple factors such as the radiography severity, age, and clinical condition of his/her patient. Using AI and functional Knee Kinesiography measures as input, Mezghani et al. (2016) developed a classification model to help identify patients deemed appropriate for a knee arthroplasty consultation[15]. The model reached an accuracy of 85% (80% for sensitivity, and 90% for specificity) to classify 153 OA patients between those who should be operated versus those who should not when compared to the decision of their orthopaedic surgeon. Assessing how function is restored post-TKA surgery is another concern for orthopaedic surgeons. It is currently limited to subjective patient reported outcome measures using questionnaires. It is crucial to collect functional objective data which could help understand why up to 20% of TKA patients remain dissatisfied two years after surgery[16]. Standard imaging brings great information when causes are link to implant loosening or migration, but a high portion of patients with residual pain come back with no radiological finding. In this context, Planckaert et al. (2018) compared Knee Kinesiography functional measures of 3 groups: painful TKA, asymptomatic TKA, and a healthy control group[17]. Differences were reported between the painful TKA group and both other groups on the KOOS questionnaire, but also in kinematics patterns where painful TKA exhibited a stiffer knee gait in the sagittal plane and a valgus alignment during stance (-1.5°).

Surgical techniques and implant choice can significantly impact joint function post-surgery. As the kinematic alignment technique recently gained popularity among surgeons performing TKAs, the usefulness of a functional evaluation was highlighted by two studies in 2019. First, the work of Larose et al. showed that while the mechanical alignment of the knee was corrected with the surgery on 19 patients, pre-operative stiff knee gait adaptation was maintained 12 months after TKA, reinforcing the need for a dynamic functional assessment to guide rehabilitation after TKA[18]. Blakeney et al. used the Knee Kinesiography as a more direct functional comparison tool between conventional mechanical and the kinematic alignment techniques[19]. Post-operative functional scores (KOOS) were lower in patients operated with the mechanical alignment technique versus the kinematic one, and their kinematics were significantly more different compared to a healthy control group in the three movement planes (all $p<0.05$).

4. CONCLUSION

Knee kinesiography has been used for 10 years to provide additional insight on knee biomechanical dysfunction and its relationships with clinical parameters. The objectiveness and accuracy of this innovative exam in a dynamic and functional context contribute to its value in the evaluation and interpretation of biomechanical imaging data. This study suggests that Knee Kinesiography can act as an add-on to conventional imaging to gather relevant and objective functional data to help clinicians better understand knee OA, its progression, and the functional impact of TKA.

This work is not being, or has not been, submitted for publication or presentation elsewhere.

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REFERENCES

1. Neogi, T., "The epidemiology and impact of pain in osteoarthritis," Osteoarthritis and Cartilage 21(9), 1145-1153 (2013)
2. Bedson, J., Croft, P. R., "The discordance between clinical and radiographic knee osteoarthritis: a systematic search and summary of the literature," BMC Musculoskelet Disord. 9, 116 (2008)
3. Farrokhi, S., Voycheck, C. A., Tashman, S., Fitzgerald, G.K., "A biomechanical perspective on physical therapy management of knee osteoarthritis," J Orthop Sports Phys Ther. 43(9), 600-619 (2013)
4. Lustig, S., Magnussen, R. A., Cheze, L., Neyret, P., "The KneeKG system: a review of the literature," Knee Surg Sports Traumatol Arthrosc. 20(4), 633-638 (2012)
5. Blouin, J., Mezghani, N., Cooke, T. D., Brean, M., Fuentes, A., "Correlation between 3D knee kinematics and tibio femoral radiographic osteoarthritis grading system," Osteoarthritis and Cartilage 22, S96-97 (2014)
6. Blouin, J., Mezghani, N., Cooke, T. D., Brean, M., Fuentes, A., "Correlation between 3D kinematic parameters during gait and patellofemoral osteoarthritis radiographic grading scale," Osteoarthritis and Cartilage 22, S97-98 (2014)
7. Cagnin, A., Choinière, M., Bureau, N. J., Durand, M., Fuentes, A., De Polo, L., Hagemeister, N., "Knee 3D kinematics differ in a larger cohort of knee osteoarthritis patients based on their radiographic severity," Osteoarthritis and Cartilage 26(S1), S365-366 (2018)
8. Bensalma, F., Hagemeister, N., Cagnin, A., Ouakrim, Y., Fuentes, A., Choinière, M., Bureau, N. J., Durand, M., Gaudreault, N., Mezghani, N., "Musculoskeletal and biomechanical characteristics are better associated with knee clinical condition than radiographic severity in osteoarthritis patients," Osteoarthritis and Cartilage 29(S1), S265-267 (2021)
9. Roos, E. M., Toksvig-Larsen, S., "Knee injury and Osteoarthritis Outcome Score (KOOS) - validation and comparison to the WOMAC in total knee replacement," Health and quality of life outcomes 1(17), (2003)
10. Omori, G., Narumi, K., Nishino, K., Nawata, A., Watanabe, H., Tanaka, M., Endoh, K., Koga, Y., "Association of mechanical factors with medial knee osteoarthritis: A cross-sectional study from Matsudai Knee Osteoarthritis Survey," J Orthop Sci. 21(4), 463-468 (2016)
11. Clément, J., Blakeney, W., Hagemeister, N., Desmeules, F., Mezghani, N., Lowry, V., Venditolli, P. A., "Hip-Knee-Ankle (HKA) angle modification during gait in healthy subjects," Gait Posture 72, 62-68 (2019)
12. Cagnin, A., Choinière, M., Bureau, N. J., Durand, M., Mezghani, N., Gaudreault, N., Hagemeister, N., "A multi-arm cluster randomized clinical trial of the use of Knee Kinesiography in the management of osteoarthritis patients in a primary care setting," Postgrad Med. 132(1), 91-101 (2020)
13. Cagnin, A., Choinière, M., Bureau, N. J., Durand, M., Mezghani, N., Gaudreault, N., Hagemeister, N., "Impact of a personalized home exercise program for knee osteoarthritis patients on 3d kinematics: A cluster randomized controlled trial," Osteoarthritis and Cartilage 27(S1), S34-35 (2019)
14. Cagnin, A., Choinière, M., Bureau, N. J., Durand, M., Mezghani, N., Gaudreault, N., Hagemeister, N., "Impact of a personalized care approach on 3D gait impairments in knee osteoarthritis patients (a cluster randomized controlled trial)," Osteoarthritis and Cartilage 28(S1), S25 (2020)
15. Mezghani, N., Dunbar, M., Ouakrim, Y., Fuentes, A., Mitiche, A., Whynot, S., Richardson, G., "Biomechanical signal classification of surgical and non-surgical candidates for knee arthroplasty," International Symposium on Signal, Image, Video and Communications (ISIVC), 287-290 (2016)
16. Baker, P. N., Rushton, S., Jameson, S. S., Reed, M., Gregg, P., Deehan, D. J., "Patient satisfaction with total knee replacement cannot be predicted from pre-operative variables alone: A cohort study from the National Joint Registry for England and Wales,". Bone Joint J. 95-B(10), 1359-65 (2013)
17. Planckaert, C., Larose, G., Ranger, P., Lacelle, M., Fuentes, A., Hagemeister, N., "Total knee arthroplasty with unexplained pain: new insights from kinematics," Arch Orthop Trauma Surg. 138(4), 553-561 (2018)
18. Larose, G., Fuentes, A., Lavoie, F., Aissaoui, R., de Guise, J., Hagemeister, N., "Can total knee arthroplasty restore the correlation between radiographic mechanical axis angle and dynamic coronal plane alignment during gait?" Knee. 26(3), 586-594 (2019)
19. Blakeney, W., Clément, J., Desmeules, F., Hagemeister, N., Rivière, C., Vendittoli, P. A., "Kinematic alignment in total knee arthroplasty better reproduces normal gait than mechanical alignment," Knee Surg Sports Traumatol Arthrosc. 27(5), 1410-1417 (2019)