PEER-REVIEWED PUBLICATIONS KNEE KINEMATIC GRAPHIC

TABLE OF CONTENTS

1 – VALIDATION

OBJECTIVITY
RELIABILITY
REPRODUCIBILITY
ACCURACY

KneeKG - Summary of peer reviewed papers attached:

The KneeKG™ system computes the three angles of the knee joint in motion, i.e. flexion/extension, internal/external rotation and abduction/adduction. Acquiring the movement accurately at knee level is not simple: skin movement over the underlying bones varies significantly over both the medial and lateral femoral condyles and is, therefore, the greatest obstacle by far in obtaining accurate movement data non-invasively. The KneeKG™ attachment system and KneeKG™ axis definition procedure were developed with the objective of providing high reliability movement analysis.

Sati, M., de Guise, J.A., Drouin, G., ***«Improving In Vivo Knee Kinematic Measurements: Application to Prosthetic Ligament Analysis »,*** **The Knee, Vol. 3, No. 4, pp. 179-190, 1996** Tab 1

Objectives: To propose a mechanical fixation system to improve three-dimensional (3D) in vivo knee measurement. The system attaches sensors onto the underlying bone non-invasively. To demonstrate a clinical application of the system, its use to predict prosthetic ligament bending and torsion deformations in vivo is reported.

Conclusions: The semi-flexible design of the attachment system allows subject comfort while providing precise in vivo measurements. This paper has shown that the attachment system accuracy is more than sufficient to predict ligament torsion and bending in vivo.

Sati, M., de Guise, J.A., Drouin, G., «*Quantitative Assessment of Skin Movement at the Knee*», The Knee, Vol. 3, No. 3, pp. 121-138, 1996 Tab 2

Objectives: To accurately quantify the relative movement between skin and the underlying bone of the knee, via X-ray fluoroscopy.

Conclusions: It was found that skin-bone movement varies significantly over both the medial and lateral femoral condyles (from 2 to 17 mm rms) and is, therefore, the greatest obstacle by far to obtaining accurate movement data non-intrusively.

Sati, M., de Guise, J.A., Drouin, G., *«Computer Assisted Knee Surgery: Diagnostics and Planning of Knee Surgery»*, Computer Aided Surgery , vol. 2, pp. 108-123, 1997. Tab 3

Objectives: To present a computerized system which has been developed to provide the surgeon with a virtual interface allowing accurate visualization of three-dimensional (3D) bone structure and movement normally hidden beneath layers of soft tissue.

Conclusions: Through comparison with cadaver studies and a perturbation analysis, the system (KneeKG™) is shown to be sufficiently accurate to predict certain in vivo ligament bending and torsion deformations.

Hagemeister, N., Yahia, L'H., Duval, N., de Guise, J.A., *«In Vivo Reproducibility of a New Non Invasive Diagnostic Tool for the Evaluation of the Injured and Operated Knee»*, The KNEE, 6(3), pp. 175-181, 1999. Tab 4

Objectives: To present a reproducibility study for a new 3D knee analyser developed for pre- and post-operative evaluation of the ligament injured knee. The experimental protocol for the evaluation of three-dimensional (3D) knee kinematics assesses the intra-patient reproducibility on 16 healthy subjects.

Conclusions: For most subjects, abduction/adduction and internal/external tibial rotation movement during 10 knee flexions was very reproducible. Intra-patient reproducibility of abduction/adduction movements is generally excellent with ICC mean values of 0.9292 and 0.9698 for the movement from extension to flexion and the movement from flexion to extension, respectively. Mean values for the reproducibility of internal-external tibial rotation are 0.9083 and 0.8635 for flexion and extension movement, respectively.

Shafagh Ganjikia, Nicolas Duval, L'Hocine Yahia, Jacques de Guise. *«Three-Dimensional Knee Analyzer Validation by Simple Fluoroscopic Study »* The Knee, 7, 2000 pp221-231. Tab 5

Objectives: To demonstrate that the improved exoskeleton attachment system of the KneeKG™ effectively reduces skin movement with respect to underlying bone.

Conclusions: This system (KneeKG™) has shown a great potential to be used in experimental settings.

Turcot K, Aissaoui R, Pelletier M, Hagemeister N, Parent G, de Guise JA. *«Évaluation de la marche par une méthode accélérométrique tridimensionnelle. »* 72e congrès de l'ACFAS, 10 au 14 mai 2004. Tab 10

Objectifs : Le but de cette étude est de décrire les accélérations fémorales et tibiales tridimensionnelles (3D) durant la marche. La cinématique 3D du tibia et du fémur de 15 sujets sains est évaluée.

Conclusion : Les accélérations tibiales et fémorales ont été estimées et moyennées sur 15 participants. Les accélérations tibiales maximales obtenues sont de 1.0 +/- 0.11g selon l'axe antéro-postérieur, de 0.86 +/- 0.08g selon l'axe proximo-distal et de 0.25 +/- 0.08g selon l'axe médio-latéral. Les accélérations fémorales maximales sont de 1.16 +/- 0.14g selon l'axe antéro-postérieur, de 0.32 +/- 0.06g selon l'axe proximo-distal et de 0.26 +/- 0.07g selon l'axe médio-latéral. La mesure accélérométrique représente aujourd'hui un réel intérêt pour caractériser la biomécanique articulaire durant la marche et pourrait éventuellement servir au suivi de l'évolution articulaire chez des populations arthrosiques soumises à divers traitements.

Hagemeister N, Parent G, Van de Putte M, St-Onge N, Duval N, de Guise J.A. (2005) "*A Reproducible Method for Studying Three-Dimensional Knee Kinematics.*" Journal of Biomechanics, 38(9): 1926-1931. Tab 11

Objectives: The first aim was to present a functional and postural method to define a bone-embedded anatomical frame on the femur and tibia, and, subsequently, a knee joint coordinate system. The repeatability of the proposed method was also assessed. Four kinematic parameters (flexion/extension, abduction/adduction, tibial internal/external rotation, and antero-posterior translation) were computed for 15 healthy subjects.

Conclusions: The method yielded very interesting data for small rotation angles at the knee. The mean repeatability value ranged between 0.41° and 0.81° for rotation angles and between 0.8 and 2.2mm for translation. This type of method shows great potential when considering patient's evolution after a treatment.

Boivin K, Turcot K, Hagemeister N, Parent G, de Guise JA. (2005) *"Feasibility and Reliability of a New Biomechanical Approach for the Functional Assessment of the Knee Osteoarthritis: Preliminary Results on an Asymptomatic Elderly Population."* SIBA 2005, Montreal, p. 117 Tab 12

Objectives: A new biomechanical method for assessing patients with knee OA is proposed. The objective is to verify the feasibility of the new method on an asymptomatic elderly population and to determine the test-retest reliability of the measures.

Conclusions: The preliminary results show that the first 10 participants were able to perform motor tasks with low knee pain due to the harness. These results suggest that the proposed method is feasible.

Charbonneau et al, *"Towards the Use of 3D Motion Capture in Clinical Setting,* From the Lab to Clinics", 3rd International Symposium on Advanced Biomaterial/Biomechanics, April 3-6, 2005 Tab 14

Objectives: To verify the feasibility of recording 3D Knee kinematics during the execution of various movements in clinical settings with the KneeKG. The study was performed on 303 subjects: 113 healthy and 190 suffering from a knee pathology.

Conclusions: The KneeKG is appropriate for people of different body sizes and shapes. The exoskeleton was well tolerated by the subjects, with low discomfort. The average pain caused by wearing the exoskeleton was low 1,7 ± 1,3 out of 10. It is possible to use portable motion capture equipment in a clinical setting. Objective, quantitative, 3D precise and reliable information is now possible with the KneeKG system.

Boivin K, Hagemeister N, Turcot K, Aissaoui R, Prince F, de Guise JA. (2006) *"Influence of a 3D Knee Movement Analyzer on Gait Patterns of Knee Osteoarthritis Patients.'* First Joint ESMAC & GCAS Meeting, p. 046, Amsterdam, Pays-Bas, 25-30 sept. Tab 16

Objectives: To determine if the exoskeleton alters gait patterns in a knee OA population.

Conclusions: The exoskeleton allows an accurate quantification on the knee's 3D kinematics while having very small impact on the gait.

Südhoff I, Van Driessche S, Laporte S, de Guise JA, Skalli W. (2007) *"Comparing Three Attachment Systems Used to Determine Knee Kinematics During Gait."* Gait & Posture, 25 (4): 533-543. Tab 19

Objectives: To compare three attachment systems designed to minimise soft tissue artefacts in gait analysis measurements, using a low dose X-ray system, on 18 healthy subjects.

Conclusions: The system with a more invasive fixation was found to have the most stable attachment. The study highlighted that displacement in the transverse plane is hard to limit with all attachment systems.

Nicola Hagemeister, Gerald Parent, Sabine Husse, Jacques A. de Guise (2008). "A Simple and Rapid Method for Electromagnetic Field Distortion Correction When Using Two Fastrak Sensors for Biomechanical Studies". Journal of biomechanics Volume 41, Issue 8, Pages 1813-1817 Tab 22

Objectives: This article presents a simple and rapid method for the correction of electromagnetic distortions when using electromagnetic Fastrak sensors.

Conclusions: The authors showed that the developed method, qualified as a dynamic assessment of the measurement volume, was more effective than static methods using

calibration tables. It can be considered useful in the present form to correct orientation distortions and to measure accurately relative rotation of the leg with respect to the tight during gait with electromagnetic sensors.

Labbé DR, Hagemeister N, Tremblay M, de Guise JA. *"Reliability of a Method for Analyzing Three-Dimensional Knee Kinematics During Gait."*, Gait & Posture 2008, vol 28, 170-174 Tab 26

Objectives: To evaluate the reliability of the exoskeleton attachment system for recording 3D knee kinematics during gait, in both intra- and inter-observer settings, on 15 healthy subjects.

Conclusions: In the intra-observer setting, ICC values were 0.92, 0.94 and 0.88 for knee flexion/extension, abduction/adduction, and internal/external tibial rotation, respectively. In the inter-observer setting, the corresponding values were 0.94, 0.92 and 0.89. These results indicate very high reliability of the exoskeleton for recording 3D knee kinematics despite reinstallation. Moreover, its reliability is independent of the observer who performs the installation. Therefore, evaluations may be carried out by several different clinicians without impacting reliability.

Turcot K, Aissaoui R, Boivin K, Pelletier M, Hagemeister N, de Guise JA. (2008) *"Test-Retest Reliability and Minimal Clinical Change Determination for Three-Dimensional Tibial and Femoral Accelerations during Treadmill Walking in Knee Osteoarthritis Patients."* Arch Phys Med Rehabil. 89(4):732-37. Tab 14

Objectives: To determine the test-retest reliability and the minimal clinical change determination for accelerometric parameters, estimated by a new accelerometric-based method that estimates 3-dimensional (3D) linear accelerations of the tibia and femur during comfortable and fast walking speeds.

Conclusions: The results show reliable tibial and femoral accelerations in ML, AP, and proximal-distal directions across the 2 performed sessions, with ICCs greater than or equal to .75 for 96% and 88% of all point parameters and RMS values at comfortable and fast speed, respectively. No influence in walking speed was found. The proposed method is the first to have determined the reliability and the minimal detectable change for tibial and femoral acceleration parameters in knee OA patients during a treadmill walking evaluation.

2 – FOR KNEE OSTEOARTHRITIS

Summary of Peer Reviewed papers attached:

The KneeKG™ system is the first clinical tool enabling a visual accurate and objective assessment of the tri-planar function of the knee joint. The measured biomechanical parameters are sensitive to changes in gait due to knee osteoarthritis (OA) and ACL deficiency, which eventually allows for gait pattern classification. Test-retest reliability and minimal clinical change determination for accelerometric parameters have been assessed. The identified accelerometric parameters have a great potential to be used as follow-up parameters for patients having knee OA in a rehabilitation context, as well as to detect abnormalities at early stages of OA.

Turcot K, Aissaoui R, Pelletier M, Hagemeister N, Parent G, Van de Putte M, de Guise JA. *"Accelerometric Gait Analysis for Use in the Assessment of Knee Osteoarthritis: A Preliminary Study*." **Gait and Posture. Vol.18. 2003, S2, S113-S114.**

Tab 6

Objectives: To compare 3D accelerations of the knee joint with data from literature during walking gait cycle. Secondly, to understand impulsive gait pattern associated with OA population.

Conclusions: An original and accurate method for the assessment of acceleration at knee joint during gait has been developed. In general, maximal ranges obtained from the method presented are comparable with the literature data which are based on acceleration measurements. During gait, maximal acceleration was detected for thigh segment in the antero-posterior direction (1.25g).

Turcot K, Aissaoui R, Pelletier M, Hagemeister N, Parent G, de Guise JA. (2004) ***"Estimation of Tibial and Femoral 3D Linear Accelerations During Gait"*** **26th Annual International Conference IEEE Engineering in Medicine and Biology Society [EMBS], San Francisco, É.-U., vol. 7, pp. 4700-4703**

Tab 9

Objectives: To propose a method to estimate three-dimensional (3D) tibial and femoral linear accelerations during treadmill walking.

Conclusions: An accurate description of 3D knee accelerations could describe several phenomena affecting gait pattern such as knee joint loading and transient occurring during locomotion activities.

Boivin K, Turcot K, Hagemeister N, Parent G, de Guise JA. (2005) ***"Feasibility and Reliability of a New Biomechanical Approach for the Functional Assessment of the Knee Osteoarthritis: Preliminary Results on an Asymptomatic Elderly Population."*** **SIBA 2005, Montreal, p. 117**

Tab 12

Objectives: A new biomechanical method for assessing patients with knee OA is proposed. The objective is to verify the feasibility of the new method on an asymptomatic elderly population and to determine the test-retest reliability of the measures.

Conclusions: The preliminary results show that the first 10 participants were able to perform motor tasks with low knee pain due to the harness. These results suggest that the proposed method is feasible.

K. Turcot, MSc.A, R. Aissaoui, PhD, M. Pelletier, MD, N. Hagemeister, PhD, G. Parent, MSc.A and J.A. de Guise, PhD. ***"Measurement of Knee Joint Impact Using Gait With Three-Dimensional Linear Accelerations: Reproducibility of a Medical Knee Osteoarthritis Population",*** **10rh world congress on osteoarthritis, 2005**

Tab 13

Objectives: Many studies have shown the potential of accelerometric sensors to estimate the transmission of shock loading through the skeleton during functional activities. Knowing that knee osteoarthritis is an important degenerative pathology affecting joint absorption, a method that estimates knee joint impact using three dimensional (3D) linear accelerations was developed.

Conclusions: Linear accelerations found in this study showed consistent results between session evaluations. Hence, femoral and tibial linear accelerations will be useful to assess knee joint impact in a follow-up osteoarthritis population. Preliminary results from patients that have sustained a rehabilitation treatment in physiotherapy show a decrease in linear acceleration magnitude. These findings could indicate the capacity of patients to reduce their impact loading during walking gait during rehabilitation treatment.

Li Y, Aissaoui R, Boivin K, Turcot K, Duval N, Roy A, Pontbriand R, Hagemeister N, de Guise JA. ***"3D Kinematic Pattern Classification of Healthy Knee Joints and Comparison with Osteoarthritis Joints."*** **Annual Meeting of the Canadian Orthopaedic Association, Toronto, Canada, June 2-4 2006.**

Tab 15

Objectives: To detect abnormalities at early stages of osteoarthritis (OA) using three-dimensional (3D) gait data. To determine if those individuals with OA displayed a gait pattern other than the typical one, and to identify which parameters best describe the gait patterns.

Conclusions: Biomechanical parameters can be used to classify the gait patterns of healthy subjects using cluster analysis. Three different gait patterns were identified.

Fuentes A, Hagemeister N, Ranger P, Heron T, de Guise J.A. ***"ACL Rupture Increases Knee Adduction Moment During Gait."*** **6th Combined Meeting of the Orthopaedic Research Societies. October 21-24, 2007, Honolulu, Hawaii. Paper 36** Tab 17

Objectives: It is widely accepted that an ACL rupture increases the risk of secondary knee injuries such as meniscal and osteochondral lesions. Higher knee adduction moment is highly correlated with the development or progression of knee OA. Therefore, the objective of this project was to characterize and compare knee adduction moments during gait for an ACL-deficient (ACLD) and healthy population.

Conclusions: Preliminary results show that ACLD patients showed a significant increase in their adduction moment, which gives new insights on OA development for the ACLD population.

Mezghani N, Husse S, Boivin K, Turcot K, Aissaoui R, Hagemeister N, de Guise JA. (2008) ***"Automatic Classification of Asymptomatic and Osteoarthritis Knee Gait Patterns Using Kinematic Data Features and the Nearest Neighbor Classifier."*** **IEEE Trans Biomed Eng, 5(3):1230-32.** Tab 23

Objectives: To develop an automatic computer method to distinguish between asymptomatic (AS) and osteoarthritis (OA) knee gait patterns using 3-D ground reaction force (GRF) measurements.

Conclusions: The best discrimination rate (91%) was achieved with the wavelet decomposition using the anteroposterior and the medial lateral components. These results demonstrate the validity of the representation and of the classifier for automatic classification of AS and OA knee gait patterns. They also highlight the relevance of the anteroposterior and mediallateral force components in gait pattern classification.

Boivin K, Hagemeister N, Turcot K, Pelletier M, Aissaoui R, Prince F, de Guise JA. (2008) ***« Détermination de paramètres biomécaniques sensible à la gonarthrose ou à son niveau de sévérité à partir d'un analyse de la cinématique dans le plan frontal à la marche. »*** **28e Journée de la recherche / Programme d'Orthopédie Édouard-Samson, Centre de recherche du CHUM, Montréal, mai 2008, p. 58.** Tab 24

Objectifs: Déterminer des paramètres biomécaniques sensibles à la gonarthrose ou à son niveau de sévérité à partir de l'analyse du patron de cinématique au genou dans le plan frontal.

Conclusions: Seize sujets asymptomatiques et 33 patients gonarthrosiques (16 avec une atteinte légère au niveau du compartiment fémoro-tibial interne et 17 avec une atteinte modérée à sévère) ont participé à l'étude. Le changement d'angle dans le plan frontal entre le contact talon et la phase de simple support à la marche est un paramètre discriminant entre gonarthrosiques et asymptomatiques. De nouveaux

paramètres biomécaniques pouvant être pertinents pour le suivi de patients gonarthrosiques ont été trouvés.

Turcot K, Aissaoui R, Boivin K, Pelletier M, Hagemeister N, de Guise JA. (2008) ***"New Accelerometric Method to Discriminate Between Asymptomatic Subjects and Patients With Medial Knee Osteoarthritis During 3-D Gait".*** **IEEE Trans Biomed Eng, 55(4):1415-22.** Tab 25

Objectives: The study presents a new method to estimate 3-D linear accelerations at tibial and femoral functional coordinate systems. The purpose of the study is to determine if the method can discriminate between medial osteoarthritic and asymptomatic knees during gait.

Conclusions: Results show good discriminative capacity of the new method. Eight of the eighteen parameters evaluated were significantly different between both groups. The proposed method has the potential to provide new parameters that could be used in the comprehension of the knee instability (medial/lateral and anterior/posterior accelerations) and transmission of shock (proximal/distal acceleration) between tibia and femur during gait in knee OA. The accelerometric parameters identified here have a great potential to be used as follow-up parameters for patients having knee OA in a rehabilitation context.

Turcot K, Aissaoui R, Boivin K, Pelletier M, Hagemeister N, de Guise JA. (2008) ***"Test-Retest Reliability and Minimal Clinical Change Determination for Three-Dimensional Tibial and Femoral Accelerations during Treadmill Walking in Knee Osteoarthritis Patients."*** **Arch Phys Med Rehabil. 89(4):732-37.** Tab 27

Objectives: To determine the test-retest reliability and the minimal clinical change determination for accelerometric parameters, estimated by a new accelerometric-based method that estimates 3-dimensional (3D) linear accelerations of the tibia and femur during comfortable and fast walking speeds.

Conclusions: The results show reliable tibial and femoral accelerations in ML, AP, and proximal-distal directions across the 2 performed sessions, with ICCs greater than or equal to .75 for 96% and 88% of all point parameters and RMS values at comfortable and fast speed, respectively. No influence in walking speed was found. The proposed method is the first to have determined the reliability and the minimal detectable change for tibial and femoral acceleration parameters in knee OA patients during a treadmill walking evaluation.

Boivin K, Hagemeister N, Turcot K, Pelletier M, Aissaoui R, Prince F, de Guise JA. (2008) ***"The Relationship of Frontal Plane Knee Kinematics with Knee Alignment and Adduction Moment."*** **Journal of Biomechanics, 41(S1): S206.**

Tab 28

Objectives: To determine the relationship of previously identified frontal plane kinematic parameters of the knee (Boivin, 2007) with a functional varus/valgus alignment and a knee adduction moment.

Conclusions: High and significant correlations were obtained from the frontal angle at heel contact (HC) and the mean frontal angle during the simple support phase of gait. These parameters inform about the dynamic alignment during gait and are easier to evaluate in clinical setting than the adduction moment. They could be interesting for the follow up of knee OA patients.

Turcot K, Aissaoui R, Boivin K, Pelletier M, Hagemeister N, de Guise JA. (2009). ***"The Responsiveness of Three-Dimensional Knee Accelerations Used as an Estimation of Knee Instability and Loading Transmission during Gait in Osteoarthritis Patient's Follow-Up."*** **Osteoarthritis Cartilage, 17(2):213-219.**

Tab 31

Objectives: To determine the responsiveness of a new three-dimensional (3D) acceleration method used as an estimation of knee instability and joint loading transmission during gait in OA subjects after a rehabilitation treatment.

Conclusions: A significant reduction of the anterior posterior (AP) knee acceleration peak ($P = 0.02$) has been detected after the rehabilitation treatment in the OA subjects. No difference for both distal and lateral knee accelerations peak was found. A significant increase in quadriceps ($P < 0.001$) and hamstring ($P = 0.006$) strength was seen after treatment. The WOMAC of pain had shown significant reduction after the treatment ($P < 0.001$). The study demonstrates that the estimation of knee acceleration parameters is sensitive to changes in knee OA gait after a rehabilitation treatment. This study also indicates that a treatment of 3 months which combines therapeutic and exercises programs could have benefits on knee OA by increasing AP knee stability and by stabilizing joint loading transmission during gait.

Gaudreault N., de Guise JA, Hagemeister N. ***"Towards the Integration of 3D Biomechanical Measures in the Development of a New Clinical Guideline for Knee Osteoarthritis Patients."*** **5th Guideline International Network conference, Helsinki, Finland, octobre 1-3 2008. (poster)**

Tab 29

Objectives: To present the rationale for integrating new evidence-based biomechanical measures in the evaluation and treatment of knee OA, as a prelude to developing a new clinical guideline. The hypothesis is that efficacy of exercise programs would increase if such programs were developed according to measures obtained from a three-dimensional (3D) dynamic biomechanical assessment of the knee.

Conclusions: Based on the results, a clinical guideline will be elaborated considering all domains of the Appraisal of Guidelines Research and Evaluation (AGREE) instrument. This tool may improve the quality of care of knee OA patients.

Tab 33

Gaudreault N., Villalobos E., Hagemeister N., de Guise JA ***" Can we identify workers at risk of developing knee OA using gait kinematic " International*** **conference on Prevention of Work-Related Musculoskeletal Disorders (PREMUS), Angers, France, August 2010**

Objectives: Altered kinematics during gait can relocate joint contact force to areas of the knee cartilage not adapted to receive this load, resulting in degenerative changes. Therefore, measuring knee kinematics can be a useful tool in identifying persons possibly at risk of developing knee OA. Kinematic data were collected during the gait (using the KneeKG^{TM} system) of 24 participants exposed to occupational knee loading.

Conclusions : Workers exposed to loading had greater knee flexion and adduction angles at initial contact than did sedentary workers (flexion angle: 13.4° ± 7.9 vs. 7° ± 4.4, p=0.03; adduction angle: 6.5° ± 3.3 vs. 2.6 ° ± 5.9, p=0.02). The workers of the present study demonstrated knee kinematics that may predispose them todevelopment of knee OA.

Tab 35

Turcot K., Hagemeister N., de Guise JA., Aissaoui (2011) ***"Evaluation of unipodal stance in knee osteoarthritis patients using knee accelerations and center of pressure "***
Osteoarthritis and cartilage ; 19. P281-286

Objectives: This study aims to compare knee joint instability and postural impairments during the performance of a unipodal stance task between patients having knee OA and healthy elderly subjects using knee accelerations and center of pressure (COP) measurements of 24 participants exposed to occupational knee loading.

Conclusions : an accelerometric-based method (using the KneeKGTM system), this study highlighted the higher knee joint instability in the frontal and sagittal planes in knee OA patients compared with able-bodied subjects during a unipodal standing task.

Additional References Suggested:

Tab 30

Hunter, David J. (2009) ***"Focusing Osteoarthritis Management on Modifiable Risk Factors and Future Therapeutic Prospects".*** **Therapeutic Advances in Musculoskeletal Disease, 2009; 1; 35. Onligne. <http://tab.sagepub.com/cgi/content/abstract/1/1/35>.**

"This narrative review focuses on the influence of biomechanics and obesity on the etiology of OA and its symptomatic presentation. We need to revisit the way we currently manage the disease and focus on the modifiable, primarily through nonpharmacologic intervention."

3 – FOR KNEE INJURIES

Summary of Peer Reviewed papers attached:

The KneeKG™ evaluation can provide additional 3D, biomechanical information for specific injuries or problems. This has been done in the following situations:

- To evaluate the effect of ski binding parameters on knee biomechanics;
- To develop a computerized system for accurate visualization of three-dimensional (3D) bone structure and movement for surgery;
- To predict certain in vivo ligament bending and torsion deformations;
- To evaluate if the knee is biomechanically ready to resume contact sports when orthopedic surgeons release the patient from ACL reconstruction treatment;
- To illustrate the importance of 3D biomechanical evaluation in ACL injuries.

Sati, M., De Guise, J.A., Drouin, G., *"Computer Assisted Knee Surgery: Diagnostics and Planning of Knee Surgery".* Computer aided Surgery, vol. 2, pp. 108-123, 1997 Tab 3

Objectives: To present a computerized system which has been developed to provide the surgeon with a virtual interface allowing accurate visualization of three-dimensional (3D) bone structure and movement normally hidden beneath layers of soft tissue.

Conclusions: Through comparison with cadaver studies and perturbation analysis, the system (KneeKG ™) is shown to be sufficiently accurate to predict certain in vivo ligament bending and torsion deformations.

Nancy St-Onge, Yan Chevalier, Nicola Hagemeister, Maxime Van de Putte and Jacques De Guise (2004) *« Effect of Ski Binding Parameters on Knee Biomechanics: A Three-Dimensional Computational Study ».* Med Sci Sports Exerc. Jul;36(7):1218-25. Tab 8

Objectives: To evaluate the effect of the position of the binding pivot point and binding release characteristics on ACL strain during a phantom-foot fall during skiing.

Conclusions: A binding with two pivot points might be a solution to reduce the occurrence of ACL injuries.

Fuentes A, Hagemeister N, Ranger P, Heron T, de Guise J.A. *"ACL Rupture Increases Knee Adduction Moment During Gait."* 6th Combined Meeting of the Orthopaedic Research Societies. October 21-24, 2007, Honolulu, Hawaii. Paper 36 Tab 17

Objectives : It is widely accepted that an ACL rupture increases the risk of secondary knee injuries such as meniscal and osteochondral lesions. Higher knee adduction moment is highly correlated with the development or progression of knee OA. Therefore, the

objective of this project was to characterize and compare knee adduction moments during gait for an ACL-deficient (ACLD) and healthy population.

Conclusions : Preliminary results show that ACLD patients showed a significant increase in their adduction moment, which gives new insights on OA development for the ACLD population.

Fuentes, Alexandre; Hagemeister, Nicola; Sudhoff, Ingrid; Requiao, Luis; Fernandes, Julio; Ranger, Pierre; de Guise, Jacques A. ***"Effets d'une rupture du ligament croisé antérieur sur la biomécanique 3D du genou: résultats préliminaires.*** **27e Journée de la recherche / Programme d'Orthopédie Édouard-Samson, Centre de recherche du CHUM, Montréal, avril 2007, p. 50.**

Tab 20

Objectifs : Étant donné le rôle prépondérant du LCA dans le contrôle de la stabilité articulaire selon les six degrés de liberté du genou, il y est primordial d'évaluer la biomécanique du genou en 3D. La mesure quantifiée des mouvements en 3D lors de blessures au LCA représente un atout important pour compléter de façon objective les résultats cliniques de laxité ligamentaire.

Conclusion : Des altérations aux patrons biomécaniques 3D du genou ont été identifiées, principalement durant la phase de chargement du cycle de marche. La rotation tibiale, l'abduction-adduction du genou ainsi que les moments articulaires dans les plans transverse et frontal sont affectés par une lésion au LCA lors de la marche. La capacité fonctionnnelle du patient est elle aussi réduite. Les résultats démontrent l'importance d'évaluer la biomécanique du genou en 3D suite à une lésion du LCA.

Fuentes A. Hagemeister H, Südhoff I, Fernandes J, Ranger P, de Guise JA. (2007), ***« New 3D Biomechanical and Imaging Technologies to Evaluate the Effect of Anerior Cruciate ligament Reconstructions: Preliminary Results »*** **Clin J Sport Med, Volume 17, Number 2, March**

Tab 21

Objectives: To evaluate if the knee is biomechanically ready to resume contact sports when orthopedic surgeons release the patient from ACL reconstruction surgery.

Conclusions: Preliminary results show the pertinence of 3D knee biomechanical analysis in assessing the effects of an ACL rupture and ACL reconstruction. Alteration to the 3D knee biomechanics six months after an ACL reconstruction is susceptible to explain why most patients do not return to their pre-injury level of activity.

Fuentes A. Hagemeister H, Ranger P, de Guise JA. (2011), ***«Gait adaptation in chronic anterior cruciate ligament-deficient patients: Pivot-shift avoidance gait »*** **Clinical Biomechanics. 26, 181-187**

Tab 32

Objectives: To evaluate, using the KneeKG™, if ACL-deficient patients would make distinctive gait changes to prevent anterolateral rotatory knee instability. We hypothesized that during the terminal stance phase of the gait cycle, ACL-deficient

patients would reduce the internal rotation knee joint moment and exhibit a higher knee flexion angle. We call this altered gait a pivot-shift avoidance gait.

Conclusions: ACL-deficient patients adopted the proposed pivot-shift avoidance gait, possibly to prevent anterolateral rotatory knee instability. The patients were not able to adapt their knee biomechanics as effectively during fast-paced walking. This study reinforces the pertinence of gait analysis in ACL-deficient knees to acquire more information about the function of the knee joint.

Grimard G. Fuentes A., de Guise JA. (2011), *«Knee Injury- Soccer»* Clinical case slides at American college of sports medicine (ACSM) annual meeting. Medicine & Science in Sports & Exercise. Vol43 No.5 Supplement. S120

Tab 36

History: 12-y/o high school soccer player sustained a left knee injury during a soccer game
Clinical exam : positive Lachman, grade II pivot shift and grade I varus stress test at 30°. Posterolateral drawer and Dial tests were negative.
Test results: X-ray show no fractures and open growth plates. MRI shows complete ACL tear and posteromedial horn meniscal tear. Functional assessment (KneeKG exam) shows important transverse internal tibial rotation excursion and knee flexum to stabilize de joint
Treatment: ACL reconstruction with 2 strand hamstrings tendon graft
Post op clinical assessment show no thigh atrophy, no effusion, full ROM (0-140°), Lachman negative, and grade I pivot-shift test. Functional assessment still show after 6 months biomechanical adaptation to stabilise the knee (flexum). Transverse plane ROM was reduecd. Sagittal plane mechanics was restored close to normal after 26 months.

4 – TO HELP OR ASSESS TREATMENTS

Summary of Peer Reviewed papers attached:

The KneeKG™ system is sensitive to changes in gait due to knee OA and ACL deficiency. The identified accelerometric parameters have a great potential to be used as follow-up parameters for patients having knee OA in a rehabilitation context, as well as to detect abnormalities at early stages of OA. As an example, the use of the KneeKG™ system has allowed to suggest that a treatment of 3 months which combines therapeutic and exercises programs could have benefits on knee OA by increasing AP knee stability and by stabilizing joint loading transmission during gait.

Sati, M., de Guise, J.A., Drouin, G., ***«Improving In Vivo Knee Kinematic Measurements: Application to Prosthetic Ligament Analysis »,*** **The Knee, Vol. 3, No. 4, pp. 179-190, 1996** Tab 1

Objectives: To propose a mechanical fixation system to improve three-dimensional (3D) in vivo knee measurement. The system attaches sensors onto the underlying bone non-invasively. To demonstrate a clinical application of the system, its use to predict prosthetic ligament bending and torsion deformations in vivo is reported.

Conclusions: The semi-flexible design of the attachment system allows subject comfort while providing precise in vivo measurements. This paper has shown that the attachment system accuracy is more than sufficient to predict ligament torsion and bending in vivo.

Sati, M., de Guise, J.A., Drouin, G., ***«Computer Assisted Knee Surgery: Diagnostics and Planning of Knee Surgery».*** **Computer Aided Surgery , vol. 2, pp. 108-123, 1997.** Tab 3

Objectives: To present a computerized system which has been developed to provide the surgeon with a virtual interface allowing accurate visualization of three-dimensional (3D) bone structure and movement normally hidden beneath layers of soft tissue.

Conclusions: Through comparison with cadaver studies and a perturbation analysis, the system (KneeKG™) is shown to be sufficiently accurate to predict certain in vivo ligament bending and torsion deformations.

Tremblay M., Hagemeister N., Parent G., Pelletier M., de Guise J. A. (2003). ***"Immediate Effect of Two Types of Orthoses on 3D Lower Limbs Kinematics and Kinetics."*** **Gait and Posture. 18, S2 : S93.** Tab 7

Objectives: To assess quantitatively the immediate effect of plantar orthopaedic treatment on 3D lower limb kinematics and kinetics.

Conclusions: Preliminary results show that the method could be useful to quantify the effects of the orthosis on kinematics and kinetics and could allow a quantitative functional assessment of lower limbs.

Turcot K, Aissaoui R, Boivin K, Pelletier M, Hagemeister N, de Guise JA. (2008) ***"Test-Retest Reliability and Minimal Clinical Change Determination for Three-Dimensional Tibial and Femoral Accelerations during Treadmill Walking in Knee Osteoarthritis Patients."*** **Arch Phys Med Rehabil. 89(4):732-37.** Tab 27

Objectives: To determine the test-retest reliability and the minimal clinical change determination for accelerometric parameters, estimated by a new accelerometric-based method that estimates 3-dimensional (3D) linear accelerations of the tibia and femur during comfortable and fast walking speeds.

Conclusions: The results show reliable tibial and femoral accelerations in ML, AP, and proximal-distal directions across the 2 performed sessions, with ICCs greater than or equal to .75 for 96% and 88% of all point parameters and RMS values at comfortable and fast speed, respectively. No influence in walking speed was found. The proposed method is the first to have determined the reliability and the minimal detectable change for tibial and femoral acceleration parameters in knee OA patients during a treadmill walking evaluation.

Gaudreault N., de Guise JA, Hagemeister N. ***"Towards the Integration of 3D Biomechanical Measures in the Development of a New Clinical Guideline for Knee Osteoarthritis Patients."*** **5th Guideline International Network conference, Helsinki, Finland, octobre 1-3 2008. (poster)** Tab 29

Objectives: To present the rationale for integrating new evidence-based biomechanical measures in the evaluation and treatment of knee OA, as a prelude to developing a new clinical guideline. The hypothesis is that efficacy of exercise programs would increase if such programs were developed according to measures obtained from a three-dimensional (3D) dynamic biomechanical assessment of the knee.

Conclusions: Based on the results, a clinical guideline will be elaborated considering all domains of the Appraisal of Guidelines Research and Evaluation (AGREE) instrument. This tool may improve the quality of care of knee OA patients.

Turcot K, Aissaoui R, Boivin K, Pelletier M, Hagemeister N, de Guise JA. (2009). ***"The Responsiveness of Three-Dimensional Knee Accelerations Used as an Estimation of Knee Instability and Loading Transmission during Gait in Osteoarthritis Patient's Follow-Up."*** **Osteoarthritis Cartilage, 17(2):213-219.** Tab 31

Objectives: To determine the responsiveness of a new three-dimensional (3D) acceleration method used as an estimation of knee instability and joint loading transmission during gait in OA subjects after a rehabilitation treatment.

Conclusions: A significant reduction of the anterior posterior (AP) knee acceleration peak ($P = 0.02$) has been detected after the rehabilitation treatment in the OA subjects. No difference for both distal and lateral knee accelerations peak was found. A significant increase in quadriceps ($P < 0.001$) and hamstring ($P = 0.006$) strength was seen after treatment. The WOMAC of pain had shown significant reduction after the treatment ($P < 0.001$). The study demonstrates that the estimation of knee acceleration parameters is sensitive to changes in knee OA gait after a rehabilitation treatment. This study also indicates that a treatment of 3 months which combines therapeutic and exercises programs could have benefits on knee OA by increasing AP knee stability and by stabilizing joint loading transmission during gait.

Tab 34

Gaudreault N., Villalobos E., Hagemeister N., de Guise JA (2011) ***" Effects of physiotherapy treatment on knee osteoarthritis gait data using principal component analysis"*** **Clinical Biomechanics, 26, p284-291**

Objectives: The objective of this study was to investigate the impact of using principal component analysis for grouping knee osteoarthritis (OA) patients' gait data in more homogeneous groups when studying the effect of a physiotherapy treatment.
Using the KneeKG™ and an instrumented treadmill, 3D knee kinematic and kinetic data were recorded during the gait of 29participants diagnosed with knee OA before and after they received 12 weeks of physiotherapy treatment.

Conclusions : Except for the knee flexion/extension angle, two different groups (G1 and G2) were extracted from the angle and moment data. When pre- and post-treatment analyses were performed considering the groups, participants exhibiting a G2 knee moment pattern demonstrated a greater first peak flexion moment, lower adduction moment impulse and smaller rotation angle range post-treatment ($P<0.05$).