Title of the Internship:

Evaluation of abdominal muscle forces in daily activities for biomechanical evaluation of stresses on repaired abdominal wall.

Laboratory (name, n°, website):

Laboratoire de Biomécanique des Chocs – LBMC UMR_T9406 – https://lbmc.univ-gustave-eiffel.fr/

Research team (name, website): LBMC is a single-team laboratory.

Supervisor to contact (name, email address): Aline Bel-Brunon, aline.bel-brunon@univ-eiffel.fr and Raphaël Dumas, raphael.dumas@univ-eiffel.fr

Project description including a short introduction, aim/objectives and methods/approach to be used

Ventral incisional hernia (VIH) occurs when abdominal contents protrude through a weakened abdominal wall, with approximately 300,000 and 500,000 repair procedures performed annually in Europe and the US, respectively [1]. Despite the use of textile meshes, recurrence rates remain high at a 25% plateau after three years [2]. Both the meshes and the abdominal wall exhibit complex, non-linear, and anisotropic mechanical properties which are still poorly characterized. Specifically, the forces exerted by the muscles on the abdominal wall tissues in active conditions and the resulting intra-abdominal pressure, remain poorly evaluated. Besides, in-vivo estimation of patient passive and active properties prior to surgery would most provide valuable information to the surgeons to choose the appropriate mesh and surgical strategy. Numerical modeling, based on continuum mechanics and musculoskeletal modeling, are promising to estimate these properties [3], [4].

The project aims to evaluate the potential of musculoskeletal models to estimate muscular forces in the abdominal wall and intra-abdominal pressure during daily activities, including those at risk of VIH recurrence, such as lifting heavy loads or coughing. The goal is to use these models to inform continuous, deformable models of the abdominal wall with biofidelic contraction and pressure patterns. The project aims to couple the expertise of the team on Finite Element Simulation for soft tissues and on musculoskeletal modeling.

The tasks are the following:

- Literature review on existing musculoskeletal models and Finite Element Models of the abdominal wall, in passive and active condition.
- Familiarization with musculoskeletal modeling software; extraction of abdominal muscle force and intra-abdominal pressure for certain daily activities and confrontation to literature data.
- Integrating these data into a simplified Finite Element model of the abdominal wall and calibration of the mechanical behavior of the muscles.

Skills required:

The candidate should have a background in mechanics, including dynamics and continuum mechanics, both theoretical and numerical.

[1] S. Sauerland, M. Walgenbach, B. Habermalz, C. M. Seiler, et M. Miserez, « Laparoscopic versus open surgical techniques for ventral or incisional hernia repair », *Cochrane Database of Systematic Reviews*, n° 3, 2011, doi: 10.1002/14651858.CD007781.pub2.

[2] P. Bhardwaj, M. T. Huayllani, M. A. Olson, et J. E. Janis, « Year-Over-Year Ventral Hernia Recurrence Rates and Risk Factors », *JAMA Surg*, vol. 159, n° 6, p. 651-658, juin 2024, doi: 10.1001/jamasurg.2024.0233.

[3] S. Todros, N. de Cesare, G. Concheri, A. N. Natali, et P. G. Pavan, « Numerical modelling of abdominal wall mechanics: The role of muscular contraction and intra-abdominal pressure », *Journal of the Mechanical Behavior of Biomedical Materials*, vol. 103, p. 103578, mars 2020, doi: 10.1016/j.jmbbm.2019.103578.

[4] R. Remus, S. Selkmann, A. Lipphaus, M. Neumann, et B. Bender, « Muscle-driven forward dynamic active hybrid model of the lumbosacral spine:

combined FEM and multibody simulation », *Front. Bioeng. Biotechnol.*, vol. 11, sept. 2023, doi: 10.3389/fbioe.2023.1223007.