# Prediction of low back load during gymnastics landings for the prevention and follow-up of athlete injuries

## Context

The ENS Rennes (Ecole Normale Supérieure de Rennes) and the M2S (Mouvement Sport Santé) lab are hiring a PhD student for a project initiated and funded by the European Research University (EUR) of DIGISPORT (Digital Sport Sciences) in Rennes (France). This project aims at promoting a unique graduate school of international excellence in interdisciplinary training and research in digital sport sciences. It covers sport, computer, electronic, human and social sciences. Building on the strong multidisciplinary research and graduate training skills of the site, the school will federate and improve synergies between the partner universities and Grandes Ecoles in close collaboration with national research institutes.

**The challenge of the current thesis proposal is to better evaluate the risk of low back injuries in elite gymnastics.** To date, the relationship between back injury risk, level of practice, medical and functional assessments, and injury history has not been well established and are still being discussed in the litterature. In addition, the transfer between new scientific evidence/knowledge in this aera and the sport/clinical field is not efficient despite the introduction of new innovative measurement methodologies. Injury rates in sports tend to decrease with the level of expertise. However, the rates for severe or overuse injuries tend to increase, sometimes ending the most promising or successful careers.

Main factors of overuse musculoskeletal injuries include mechanical constraints exceeding physiological capacities of the athlete's body (Edwards, 2018). Therefore, not only the empirical number of repetitions shall be counted, mechanical load related to physiological capacities have to be integrated and in relation to the athlete's history of injury and rehabilitation. Hence, monitoring all these mechanical loads has become one of the most salient interests for athletes and staff. It is also one of the biggest challenges for data sciences related to elite sports because it requires the development of numerical tools compatible with training and competition. Better communication tools addressed to the staff could improve the prevention and follow-up of injuries. Therefore, the French Gymnastics Federation (FFGym) wished to promote, as a high priority, the development of new research projects at the crossroad between health and performance. One of these projects is entitled: the "LombalGym®" program.

In gymnastics, lower back injuries are very common, around 62% of gymnasts (Sweeney et al., 2019) and considered as "normal" among elite gymnasts (Fawcett et al., 2020). Previous authors have identified the functional tasks related to high mechanical loads in the lower back; large lifted loads and lumbar flexion but also repetitive impacts during jump and acrobatic landings (Sweeney et al., 2019). Those significant solicitations could produce low back muscle fatigue (Sung, 2013) associated with delayed or disorganized muscle response (Tsao et al. 2010), and to a joint instability (Borghuis et al., 2008). In both cases, some previous evidence has suggested that strengthening and endurance training of lower back muscles tend to reduce low back pain (Shin et al., 2018; Raghav et al. 2017; Ripamonti 2010).

Despite abundant literature, the evaluation of the risk of nonspecific low back pain remains complex as it lacks evidence-based recommendations on reliable functional assessments (Cholewicki et al., 2019; Lehman, 2004; Retailleau & Colloud, 2020a). Several functional movement tools are suggested to evaluate this risk in assessing mobility and joint stability (Bennett et al., 2017; Cook et al., 2014; O'Connor et al., 2020) but it does not specifically investigate the range of motion of the lumbo-pelvic

complex and the methodology is not still in line with new evidence on the biomechanics of low back in sports such as gymnastics.

Lower back injuries diagnostics methods based only on classical medical imaging are not reliable (Suri et al., 2014). Additionally, traditional medical/manual tests often focus on the function of a specific joint, the overall behavioural manifestation (i.e. global movement) reveals the intricate relationship of a whole chain of interlinked subcomponents. Exploring new ways in developing new objective outcome measures appears an actual challenge to make spinal assessments more reliable to inform individual diagnosis and guide the management of the athlete (Chenaut et al., 2019). The use of active self-induced motions (functional assessment) if combined with a set of objective measures may provide a set of objective data and are a promising alternative (Retailleau & Colloud, 2020b).

## Objective

**The objective of this project is to develop new methodological approaches and reliable clinical assessments tools to evaluate low back function and fatigue in elite gymnastics.**

## Main activities

### (1) Kinematics-based impact prediction

In this development, the main lock is to discard existing methods based on external forces measurements that are not available in the gym. In order to analyse load back loading in motion, the measurement of external contacts forces is required. These measurements require specific and expensive equipment that cannot be moved easily. This equipment is inadequate in the context of gymnastics training. Similar difficulties for ergonomics have prompted the development of an optimization-based method to predict external forces from kinematical data (Müller et al. 2019b). Data acquisition will require the use of motion capture cameras or inertial measurement units (IMU), and the parametrization of a kinematical model allowing large amplitude movements of the lower part of the back (Raabe and Chaudhari, 2016; Poulet, et al., 2020). A further complexity in the gymnastics environment arises from the specific viscoelastic behaviour of the landing mats and the diversity of them. Modelling those behaviours together with the prediction of impact loading will be the first challenge of this thesis.

### (2) Kinematics-based fatigue prediction

The main lock is to get rid of the existing fatigue measurement methods based on cumbersome instrumentation or tedious protocols. Nowadays, muscle endurance and muscle fatigue can be estimated through many mechanical, physiological, and neurophysiological measurements. In the case of muscle endurance, the fatigue is expected to arise mostly at neuromuscular level. Therefore, the most suited tool would be electromyographic (EMG) signals or isokinetic measurements. However, EMG measurements are embarrassing, not autonomous and their calibration is time and force consuming (EMGs). Being able to estimate fatigue solely through kinematical measurement should be a real improvement for sports monitoring. In order to identify the relationship between kinematical parameters and fatigue a multivariate statistical approach has to be developed either based on data analysis or machine learning.

### (3) Functional prediction into the gym

Previous developments are designed to be transferred into the gym. For that purpose an interface for the coaches and staff will be developed in collaboration with the french federation. At this point, the implementation into the training environment must be validated. A recent approach has been

developed to differentiate lower back functional behaviour in a large population of athletes (Ménard et al., 2019). This approach using kinematical data and class correlation tests will be used to identify dominant behaviour in the elite gymnast in relation to fatigue. It will be used to evaluate the reliability of the kinematics-bas tools used during training. This thesis will face challenges regarding both numerical and experimental developments.

Two experimental campaigns will be held. The 1st year of the thesis, an experiment should take place in the M2S lab with competitive gymnasts in order to develop and validate the two kinematics-based developments doubled by direct measurements of external forces and fatigue. At the end of the 2nd year, another experiment should take place with gymnasts in real configuration to test the developed tools in regards to clinically relevant indicators in collaboration with INSEP and the gymnastics french federation.

## Environment

The M2S laboratory (http://m2slab.com) is interested in the effects of sports and physical activity on performance and health. The M2S lab pursues this goal using multidisciplinary approaches, specifically coupling movement analysis and synthesis based on both experimental data and digital human models. To do so, the laboratory can rely on an exceptional ImmerMove technical platform that includes a virtual reality room (12x4x4 m) and a sports hall (30x20x10 m) dedicated exclusively to the analysis of the movement. This platform includes various motion analysis equipments such as optical and inertial motion capture systems, external force evaluation and electromyographic systems for measurements in terrestrial and aquatic environments

The PhD candidate will also join the Inria MimeTIC team (https://team.inria.fr/mimetic/), internationally recognized for its multidisciplinary approach to analyse, model and synthesize motion.

This research topic will be carried out in **Rennes**, the capital of Brittany and the tenth largest city in France, with a metropolitan area of about 720,000 inhabitants. Moreover, with more than 66,000 students, Rennes is also the eighth-largest university campus of France and it has the 2nd highest concentration of digital and ICT firms in France after Paris. Rennes is also known to be one of the most festive and lively cities of France, home of several music and culture festivals. In 2018, the newspaper “L'Express” named Rennes as "the most liveable city in France".

## Profile

We are looking for a candidate to prepare a doctoral thesis in the fall of 2021. The candidate must have a master's degree in biomechanics and demonstrate skills in numerical methods. Experience using experimental tools (motion capture, IMU, EMG, force platforms) will be a real plus. A good level in international English will also be needed. A scientific curiosity and an experience in elite sport or in sport sciences are also appreciated.

### Supervision & Contact


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## References


Bennett, S., Macfarlane, C., & Vaughan, B. (2017). The Use of Osteopathic Manual Therapy and Rehabilitation for Subacromial Impingement Syndrome : A Case Report. *EXPLORE: The Journal of Science and Healing*, *13*(5), 339‑343. https://doi.org/10.1016/j.explore.2017.01.002

Chenaut, P., Ménard, M., Vaucher, P., Lancelot, L., Bideau, B., & Bourgin, M. (2019). Biomechanical analysis of the lumbar-pelvic-femoral complex during the one- sided tilt test : A pilot study in triathletes. *Computer Methods in Biomechanics and Biomedical Engineering*, *22*, S1‑S393. https://doi.org/10.1080/10255842.2020.1714921

Cholewicki, J., Breen, A., Popovich, J. M., Reeves, N. P., Sahrmann, S. A., van Dillen, L. R., Vleeming, A., & Hodges, P. W. (2019). Can Biomechanics Research Lead to More Effective Treatment of Low Back Pain? A Point-Counterpoint Debate. *Journal of Orthopaedic & Sports Physical Therapy*, *49*(6), 425‑436. https://doi.org/10.2519/jospt.2019.8825

Cook, G., Burton, L., Hoogenboom, B. J., & Voight, M. (2014). Functional movement screening : The use of fundamental movements as an assessment of function - part 1. *International Journal of Sports Physical Therapy*, *9*(3), 396‑409.

Edwards, W. B. (2018). Modeling overuse injuries in sport as a mechanical fatigue phenomenon. Exercise and sport sciences reviews, 46(4), 224-231.

Fawcett, L., Heneghan, N. R., James, S., & Rushton, A. (2020). Perceptions of low back pain in elite gymnastics: A multi-disciplinary qualitative focus group study. Physical Therapy in Sport.

Lehman, G. J. (2004). Biomechanical assessments of lumbar spinal function. How low back pain sufferers differ from normals. Implications for outcome measures research. Part I : Kinematic assessments of lumbar function. *Journal of Manipulative and Physiological Therapeutics*, *27*(1), 57‑62. https://doi.org/10.1016/j.jmpt.2003.11.007

Ménard, M; Vaucher, P., Chenaut, P., Lancelot, L., Launay, F., Bourgin, M., Bideau, B.2019, Analyse biomécanique du complexe lombo-pelvi-fémoral lors du test d'inclinaison unilatérale du bassin : étude pilote sur des triathletes, Osteopathic Care and Applied Biomechanics, 26 (3)

Muller, A., Pontonnier, C., & Dumont, G. (2019b). Motion-based prediction of hands and feet contact efforts during asymmetric handling tasks. IEEE Transactions on Biomedical Engineering, 67(2), 344-352.

O'Connor, S., McCaffrey, N., Whyte, E. F., & Moran, K. A. (2020). Can a Standardized Visual Assessment of Squatting Technique and Core Stability Predict Injury? *The Journal of Strength & Conditioning Research*, *34*(1), 26‑36. https://doi.org/Hamill

Poulet, Y., C. Eyssartier, T. Marsan, L. Valdes-Tamayo, M. Robert, P Billard, P. Rouch, P. Thoreux, and C. Sauret, (2020).Lumbar lordosis obtained with and without intervertebral thoracic spine motions during rhythmic gymnastics movements: a preliminary study. 4ème Congrès de la Société de Biomécanique, Metz.

Raab, M. E., Chaudhari, A. M. W. (2016). An investigation of jogging biomechanics using the full-body lumbar spine model: Model development and validation. *Journal of Biomechanics*, 49(7), 1238-1243. https://doi.org/10.1016/j.jbiomech.2016.02.046.

Raghav, S., & Anshika, S. (2017). Role of Swiss ball exercises in reducing pain, diability and improving muscle endurance in patients with mechanical low back ache. IJPR, 5(2), 1966-70.

Retailleau, M., & Colloud, F. (2020). New insights into lumbar flexion tests based on inverse and direct kinematic musculoskeletal modeling. *Journal of Biomechanics*, 109782. https://doi.org/10.1016/j.jbiomech.2020.109782

Ripamonti, M. (2010). Détermination des relations moment-vitesse et puissance-vitesse des muscles du tronc: application à l'évaluation isocinétique de patients lombalgiques chroniques (Doctoral dissertation, Le Mans).

Shin, M. K., Yang, H. S., Yang, H. E., Kim, D. H., Ahn, B. R., Kwon, H., ... & Ahn, D. Y. (2018). Effects of Lumbar Strengthening Exercise in Lower-Limb Amputees With Chronic Low Back Pain. Annals of rehabilitation medicine, 42(1), 59.

Suri P, Boyko E, Goldberg J, Forsberg C, Jarvik J: Longitudinal association between incident lumbar spine MRI findings and chronic low back pain or radicular symptoms: retrospective analysis of data from the longitudinal assessment of imaging and disability of the back (LAIDBACK). BMC Musculoskeletal Disorders.2014;15: 152. doi: 10.1186/1471-2474-15-152.

Sweeney, E. A., Potter, M. N., MacDonald, J. P., & Howell, D. R. (2019). Low back pain in female adolescent gymnasts and functional pain scales. Physical Therapy in Sport, 38, 66-70.

Tsao, H., Druitt, T. R., Schollum, T. M., & Hodges, P. W. (2010). Motor training of the lumbar paraspinal muscles induces immediate changes in motor coordination in patients with recurrent low back pain. The journal of pain, 11(11), 1120-1128.