PhD Thesis Proposal Form
China Scholarship Council (CSC)/ENS Rennes
Call for projects 2019
FIELD open

Thesis subject title: Propulsive forces and neuromuscular capabilities directed to efficient external power production: relationships with high level swimming performance

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- Thesis proposal (max 1500 words):

  The M2S laboratory (Movement, Sport, Health - University of Rennes 2 / ENS Rennes) is interested in the optimization of sports performance and the effects of physical activity and sports on health. In this context, the M2S lab develops devices and methods for evaluating the athlete from physiological and biomechanical viewpoints. One of the main M2S research program focuses on the analysis of motion in a complex environment, such as the aquatic environment. More specifically, understanding of biomechanical factors in swimming is crucial because of their critical value to performance. In order to improve performance, a swimmer can either increase his propulsive forces with a proper training or reduce his/her hydrodynamic resistance by improving his swimming technique and his hydrodynamic body position in water, or both. Since the beginning of the 2000s, several works have led to the development of dynamical approaches aiming at estimating drag that limits the swimmer's progress, or the external mechanical power supplied during its displacement. Thus, the locally developed ADES device (Active Drag Evaluation System) made it possible to estimate the drag encountered by the swimmer from the Velocity Perturbation Method -VPM- (Bideau et al., 2003; Kolmogorov et al., 1992). Indeed, the VPM manipulates the maximum swimming velocity by using an additional hydrodynamic body with known resistance. In the VPM, the swimmer needs to carry out two swimming trials at maximum speed, with and without a hydrodynamic body. Considering that in both swims, the power output to overcome drag is considered maximal and constant, it is possible to estimate the active drag encountered by the swimmer during his sprint performance. From this method, it was revealed that swimming technique is a more important component in determining active drag as compared to body composition (Toussaint et al., 2002). To assess the swimming technique, kinematical analyses have commonly been used based on 2D or 3D videographic recording but in a restricted motion capture environment with limits the possibility to evaluate the kinematics all along the race. Such an evaluation is of crucial interest an attempt to address the alterations of swimming technique due to fatigue or exercise intensity, for instance. To overcome these limitations, recent advances in the development of microelectromechanical systems (MEMS) through wearable measurement systems such as inertial measurement units (IMU) seem to be a consistent/convenient solution for in-field swimming analysis as it allows a continuous data
acquisition throughout the complete exercise. In this context, M2S lab currently develops IMU-based motion capture methodology to quantify joint kinematics in swimming but also in cycling (Cordillet et al., 2017; Cordillet et al., 2019 -submitted). However, such analyses did not consider the strength capabilities of the swimmers when evaluating both kinematics and dynamics in water. In particular, recent studies have brought new insights into the evaluation of power-force-velocity profiles in sprint running or jumping movements (Morin and Samozino, 2015). This relationship is proven to be a major physical component of performance in many sports that led to specific methods of assessment that have been developed and validated for in field conditions. However, this topic is less investigated as regards to swimming performance. It can be questioned to what extent measurements performed in terrestrial environment are relevant as regards to in-situ capabilities considering a propulsion in an aquatic environment.

The main aims of this PhD thesis are to link the strength and neuromuscular capabilities of the swimmers to hydrodynamic and kinematic skills of swimmers during sprint exercises. To do so, this PhD thesis will follow the following steps:

- **Evaluation of strength and power profiles in laboratory conditions.** The aim is here to evaluate the athletic resources of the swimmers using conventional and validated devices and methods:
  
  o Isokinetic strength assessment using CON-TREX dynamometer to predict maximal joint torques and joint power profiles of selected muscle groups involved in swimming motion. Measurement of muscle strength is an important factor in the evaluation and prediction of muscular condition in addition to functional capacity. A lot of research supports this concept applied to various sports. The same way, Isokinetic power-velocity profiles have been identified as important criteria to assess the abilities in sprint exercises. Indeed, maximal power output is the product of force and velocity and is defined and limited by the force –velocity relationship (Fenn & Marsh, 1935; Hill, 1938). On this basis, maximal power output may improve by increasing the ability to develop high levels of force at a given velocity (i.e. force capability or strength) and/or higher velocity at a given force (i.e. velocity capability) (Cormie, McGuigan, & Newton, 2011).
  
  o Force-velocity profiles identification using conventional methods based on force plates during vertical jumps such as Counter Movement Jump or Drop Jump (Samozino et al., 2008). Vertical jump are commonly used movements to assess leg power because of their simplicity and explosiveness for in field evaluation (Cormie et al., 2011). This specific stage of the project may be of interest as regards to push phases (starts and turns) on the wall during swimming.
  
  o Wingate Anaerobic Test for the evaluation of short term and high intensity exercise to predict muscle power. The Wingate anaerobic test (WAnT) is a classic laboratory tool and the most commonly used for the evaluation of anaerobic performance. The test determines values of peak and mean power with high reliability (Bar-Or, 1987). The typical protocol for implementing the WAnT includes maximal effort on a mechanically or electrically braked cycle ergometer for 30s. Correlation of upper body power values as measured by the WAnT and swimming performance, is presented in several studies. Specifically, performance during various distances (25 to 400 m) of
front-crawl swimming, revealed a relationship with peak power and mean power values. Studies examining the correlation of lower body power production with swimming performance have not drawn the same attention which may be of interest in the present PhD project.

- **Evaluation of strength and power profiles in aquatic conditions.** To this end, some specific and validated devices developed in M2S (Nicolas et al., 2007, 2010) will be used:
  - Using tethered and assisted swimming, subject specific hydrodynamic parameters (e.g. active drag, drag coefficient) will be evaluated as well as the external power developed to overcome drag during sprint exercises. Active drag will be computed with the ADES (Active Drag Evaluation System) (Bideau et al., 2003; Nicolas et al., 2007, 2009, 2010), based on Velocity Perturbation Method (VPM) (Kolmogorov and Duplisheva, 1992). In the VPM, the swimmer needs to carry out two swimming trials at maximum speed, with and without a hydrodynamic body (HB). In both swims, the power output to overcome drag is considered maximal and constant. Nevertheless, the use of VPM with a hydrodynamic body generates some uncertainties (Bideau et al., 2003). To overcome this limitation, an approach in which the load is controlled outside of the water is preferable, which can be achieved with ADES. In this approach, the swimmer is linked via a non-elastic wire to the device on the side of the pool. The VPM method associated to ADES system thus gives the opportunity to estimate active drag in a precise way but also to estimate the external power to overcome drag. Moreover, the swimmer wears a belt placed around the hip joint, which also gives the opportunity of recording the pelvic girdle’s speed.
  - Based on previous parameters, building an in-situ force-velocity curve. As previously mentioned, one of the main physical performance determinants in sprint swimming is the ability to produce high mechanical power output. This power output depends on the ability of athletes’ neuromuscular and osteoarticular systems to generate high levels of force and to apply it with effectiveness onto the aquatic environment, especially at high contraction velocity. As out of water measurements of power production may be associated with variability in its application during swimming movements, there is a need of identification of an in-situ force-velocity curve. We will pay particular attention to this specific point in the project.

- **Evaluation of swimming technique in relation to power profile.** A very important point is to evaluate to what extent the swimming technique affects the power production during swimming sprint exercises. To this end, the following process will be applied using water proof devices:
  - Joint kinematics will be assessed using conventional video and IMU. To do so, M2S lab currently develops specific methodology concerning IMU based motion capture in water environment in order assess human joint kinematics in swimming. One of the major issues of the joint kinematic assessment using IMU devices lies in the misalignment of sensors axes with anatomical body segment axes which is not straightforward. This topic is crucial when attempting to provide a functionally meaningful 3D joint kinematics based on inertial sensors. In this project, this problem will be solved by performing calibration procedures for the calculation of relative orientation between IMU frames and body segment frames. Another PhD student from the M2S research team is already involved on this particular topic and will be have to work in pairs with the present PhD candidate.
Neuromuscular coordination will be evaluated through surface electromyography during swimming. In this aim, the research team benefits of a 16 channel waterproof and wireless EMG system that can be combined to IMU sensors for a synchronized data recording of kinematic and neuromuscular measures. All experiments will be conducted on high level swimmers whose recruitment will facilitated by the numerous collaborations of the M2S lab with federal partners and local high level swimming staffs.

- Publication of the laboratory in the field (max 5):

- Joint Phd (cotutelle) : YES
- Co-directed PhD : NO

In case of a co-directed or a joint PhD, please detail:

Partner university name: East China Normal University (ECNU) of Shanghai and particularly the «School of Physical Education and Health» (SPEH) with its Key Laboratory of Adolescent Health Assessment and Exercise Intervention (KL-AHAEI).

- Laboratory name and web site: http://www.ahaei.ecnu.edu.cn/main.htm

- PhD co-director (contact person):
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- Provisional duration and timetable of the PhD student’s stay at ENS Rennes:
  - 2020-2024
  - 48 months
- If previous collaborations with the Chinese co-director/university, please detail:

- Interest of the Joint PhD for the French co-director, for his/her laboratory, for ENS Rennes:
The M2S laboratory entails two main research areas, which result in the following distinct axes: Sport/Performance and Sport/Health axis. The present PhD project is part of the Sport/Performance axis. It is at the crossroads of several areas of expertise or research areas of the laboratory in swimming from both physiological and biomechanical points of view. To date, these approaches have so far not been analyzed in a common way and leave the opportunity to mutualize means of investigation to support the analysis of the factors involved in swimming performance.
Part of this project is a continuation of work carried out for years now on the use of IMU sensors as applied to the analysis of motion outside of the lab. Two PhD theses were developed on this topic with a first one as applied to cycling and another one as applied to swimming. Other projects of the M2S lab deals with the use of isokinetic measurements in order to improve mathematical models with better knowledge related to physiological parameters that underneath these models. Thus, models associated to swimming activity may be a new and innovative application and can be a great opportunity to test the model under extreme conditions in the aquatic environment.
The research team has a strong expertise in the field of biomechanical analysis in swimming, but also many other applications sports sciences which is confirmed by an international recognition, especially through the Shanghai Ranking’s Global Ranking of Sport Science Schools and Departments for several years. The present collaboration between ENS Rennes and ECNU would prove to be a major opportunity to stimulate a strongest research from a joined work that emanate from two recognized entities. By its applications in the field of sports sciences, this project is totally in line with the innovative scientific contributions in the the perspective of the 2024 Olympic Games in Paris.

Date: 29.01.20

Signature of the PhD director

N. Bideau G. Nicolas

Name and signature of the Laboratory director

B. Bideau