THE INTERFACE BETWEEN CLINICAL AND PERFORMANCE RELATED BIOMECHANICS – AN EMERGING RESEARCHER'S JOURNEY

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INTRODUCTION: The presentation will describe the journey my career has taken so far, using three main themes, which have been selected to reflect my experience to date. The examples demonstrate how sports biomechanics can contribute towards developing new knowledge in a multidisciplinary setting with specific reference to the interface between clinical practice and performance related biomechanics.
The three main themes will include: *Clinical Biomechanics (*ACL injury*), Adapted Performance (*Amputee Sprinting*), and Environmental Interaction (*Artificial Turf*).* The initial theme *Clinical Biomechanics*, emerges from my work at the University of Salzburg, exploring ACL-injury and a conservative treatment (RegentK), where acute effects of ACL-injury on gait and lower limb impacts will be discussed. The second theme will examine the contemporary aspect of *Adapted Performance*, specifically the use of blades in amputee sprinting during the sprint start; this example draws on a successful collaboration with the German Sports University Cologne, Germany and the Cardiff School of Sport, Cardiff Met, UK. The final theme, *Environmental Interaction,* investigates the use of artificial turf in soccer and rugby*.* I will discuss my work as a Research Officer on the FIFA, IRB, and Cardiff School of Sport project. This research employed an interdisciplinary approach to address the question of perception (psychology) and performance (biomechanics) on the introduction of artificial turf. Finally, I will draw some global conclusions regarding my research experience to date and will present perspectives for the future.

CLINICAL BIOMECHANICS: The rupture of the ACL is one of the most common knee injuries and incurs a functional loss in stability, proprioception (e.g. Zatterstrom, Friden, Lindstrand, & Moritz, 1994) and gait mechanics (Ferber, Osternig, Woollacott, Wasielewski, & Lee, 2002; Risberg, Moksnes, Storevold, Holm, & Snyder-Mackler, 2009; Torry, Decker, Ellis, Shelburne, Sterett, & Steadman, 2004). Currently, there is still a lack of knowledge regarding the acute responses of ACL rupture on gait mechanics, functional tests and range of motion (Hurd & Snyder-Mackler, 2007). Under the light of the patient's need to decide whether a surgical or conservative treatment of the ruptured structure is the best treatment, little evidence based information to guide this decision process is available. Especially as the current trend shows a demand for clinical sports medicine to develop and to improve conservative therapies with possible lower risks compared to surgical treatment is increasing. Therefore, the aim of the presented research was to investigate with an interdisciplinary approach a) acute effects of the ACL rupture on gait and cycling performance and b) investigate the effect of the manual therapy RegentK, which has already shown promising results in terms of ACL healing mechanisms (Ofner, Kastner, Wallenboeck, Pehn, Schneider, Groell et al., 2014). Nine male patients with acute (< 3 weeks of injury) MRI-approved unilateral ACL-rupture underwent an orthopaedic exam and gait analysis immediately before and after the one hour RegentK treatment. On the same day participants significantly increased gait velocity by 0.17 m/s (18%) by increasing step frequency and step lengths for both limbs. The faster gait velocity involved an increase of the maximal anterior-posterior and vertical ground reaction forces (Michael Ofner, Strutzenberger, Alexander, Kastner, & Schwameder, submitted). The impaired gait could be identified through a pattern classification using principal component analysis and linear support vector machine methodology of the kinematic data, which provided an interesting holistic approach (Christian, Alexander, & Schwameder, 2014). After the treatment six of seven patients significantly improved their gait quality score, three of them passed the separation criterion to the normal gait pattern group (Christian et al. in preparation). Additionally, after intervention participants were able to cycle with an increase of the maximal tangential force in all

analysed intensities (60 W to 300 W in 40 W steps). The performance enhancement is characterised by effect sizes between 1.18-1.66. Additional to the biomechanical data a medical research team of five different disciplines analysed pain, blood, HRV, orthopaedic and thermal parameters (Litscher, Ofner, & Litscher, 2013) and put the research question into a complex picture. This pilot study was repeated after a year, showing similar improvement in gait pattern and providing further evidence of the ACL's ability to heal after being completely ruptured.

ADAPTED PERFORMANCE: Integrating physical activity into the daily life of an amputee has a major social, physical, and psychological impact on the individual's health (Bragaru, Dekker, Geertzen, & Dijkstra, 2011). Understanding gained from running and sprinting research can be of impact for both elite athletes and recreationally active individuals, as the ability to run and sprint is a key component for most sports, but also increases the mobility and independency of each amputee. Yet, very little is known about the effect of the prosthetics on the actual movement and force generation in various sprint stages (Alt, Heinrich, Funken, & Potthast, in press; Bezodis, Salo, Kerwin, Churchill, & Trewartha, 2010; Brueggemann, Arampatzis, Emrich, & Potthast, 2008; Taboga, Grabowski, di Prampero, & Kram, 2014; Weyand & Bundle, 2010). Therefore, the purpose of this study was to investigate temporo-spatial parameters and the vertical and horizontal ground reaction forces as well as the resulting impulse of the early acceleration phase of the sprint start (10m). Seven amputees with different amputation levels (unilateral transfemoral: 2; unilateral transtibial: 4 and bilateral transtibial: 1) were individually analysed. The temporal-spatial parameters revealed that the affected leg needed more time to swing through to be positioned for the next step compared to the unaffected one. By this, high asymmetries in temporo-spatial parameters as well as in kinematic parameters in the early acceleration phase are induced. These asymmetries showed a tendency to increase from the bilateral transtibial to the unilateral transtibial sprinters and were highest in the unilateral transfemoral sprinters. The ground reaction forces revealed almost no braking force on the affected leg for the first steps. The unilateral sprinters displayed higher maximal horizontal force values on the intact leg, but the horizontal impulse data were generally higher on the affected leg. The vertical impulse data, however, were higher on the intact leg. This suggested that adaptation mechanisms (such as longer step length) occurred to allow the generation of a horizontal impulse also on the affected leg, while the vertical ground reaction impulse was mainly realised via the intact leg. Additionally, it became apparent that transfemoral athletes have to display different strategies to generate acceleration than transtibial amputees (Strutzenberger, von Lieres, Davies, Funken, Willwacher, Müller et al., 2014). How these adaptations are realised by the musculoskeletal system, which loads occur at the remaining joints and how the prosthetic device contributes to the movement are highly interesting questions, which are hoped to be addressed with further research.

ENVIRONMENTAL INTERACTION: The third study was conducted at Cardiff Sports Biomechanics Research Group, Cardiff Met University, UK and investigated the player perception of artificial turf (AT) across football and rugby code of sport. More particularly, this study aimed to determine whether the mainly negative perception (Andersson, Ekblom, & Krustrup, 2008; Zanetti, 2009) of AT is driven by a pre-existing bias due to inference, memory, and knowledge representation towards AT or by actual performance changing aspects induced through the artificial surfaces. To identify these underpinning aspects, it seemed critical to combine sports psychology and sports biomechanics. 15 elite football players (Cardiff City Football Club) and 15 elite rugby players (Wales 7 Squad) were asked to perform a football specific manoeuvre (Figure 1) with both degraded and normal perception on natural turf (NT) and AT.

In the degraded perception trial participants wore blindfold goggles, a nose clip and ear plugs to remain unaware of the surface type. Prior to the testing participants were accustomed in a habituation phase to perform the movement task with the degraded perception. Temporo-spatial parameters of the manoeuvre were collected using High Speed Cameras (Basler AG, Ahrensburg, Germany, 100 Hz). Immediately after each condition, participants filled out a

psychological questionnaire and were interviewed. As expected, degrading perception led to performance chances across a number of biomechanical measures, no significant interaction effect occurred between perception and surface type. The main surface effect revealed for AT shorter contact times across conditions for rugby players, while for all players significantly longer flight times on NT compared to AT were shown.
The findings of the psychological tests identified a pre-existing negative bias against AT that was only apparent during the normal perception trials. This suggests that opinion is not driven by the surface characteristics, but by a bias players already brought with them to the pitch. Future studies are now examining the surface interaction with a more detailed focus on biomechanical aspects.

SUMMARY:

The presentation provided three main themes with specific examples of research for which the key take home message included:

- Clinical biomechanics: The manual therapy RegentK can facilitate the recovery from ACL injury and gait mechanics in a significantly reduced time scale.
- Adapted performance: The sprint starts mechanics differ between amputation levels, the more proximal the amputation the greater the asymmetry.
- Environmental interaction: An inherent negative towards AT turf is not supported by biomechanical performance data.

During this presentation it has been demonstrated how sport biomechanical methodology provides an interface for varying research questions involving multiple teams of scientists with different expert domain knowledge. This research approach highlights the need to continually strive for research with high levels of ecological validity. It became apparent, that we need to utilize teams of experts to produce interdisciplinary research, where theoretical constructs combine to examine the whole picture. Our long-term aim should be to address our research from a question specific rather than domain specific perspective, highlighting the need for collaboration and communication between the scientific areas. Finally, the studies reflected represent original/pilot research, out of which further and more in depth research questions emerged, which are currently worked on by various research teams.

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