INTEGRATING RESEARCH AND PRACTICE WITH A VIEW TO ENHANCING SPORTS PERFORMANCE: EXAMPLES FROM SPRINT ACCELERATION

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One of the three primary purposes of ISBS is to bridge the gap between researchers and practitioners. This paper aims to identify important concepts for incorporating coaching viewpoints into biomechanical analyses in an attempt to enhance sports performance. A continuum of possible sources of evidence was identified and, through a series of sprint acceleration-based examples, four key concepts were proposed. These were 1) the need for a clear and appropriate common goal to be defined, 2) the requirement for asking relevant questions, 3) the need to provide meaningful answers, and 4) the ability to demonstrate that a difference can be made. These concepts provide a framework to stimulate discussion amongst researchers and practitioners for how this integration of information, and ultimately levels of sporting performance, can continue to be improved.

KEY WORDS: biomechanics, coaching, research-practice continuum, sprinting.

INTRODUCTION: Sports biomechanists typically possess a vast array of skills which allow the quantification of numerous aspects of an athlete's technique. These skills are often used to try and relate certain aspects of technique to the consequent levels of performance attained. How these skills are used in respect to applied practice closely relates to one of the primary purposes of ISBS: bridging the gap between researchers and practitioners. Bridging any gap is a two-way process – the coach and the sports biomechanist both have specific expertise that must be used. Knowledge from coaching practice must be used to guide research just as knowledge from research must be used to guide coaching practice. However, these are not two discrete processes, rather they are distinct ends of a research-practice continuum. This paper aims to present examples of the use of evidence from across this continuum to combine the expertise of coaches and sports biomechanists towards the identification of ways in which sports performance could be enhanced.

KEY CONCEPTS: Consideration of my research and applied work led to the identification of four key concepts which are proposed to be fundamental for the successful integration of research and practice. These concepts reflect my experiences to date and are designed to provide a framework for discussion amongst the sports biomechanics community about how we can best learn from, support and enhance applied practice. It should therefore be treated as a work-in-progress rather than a definitive list on which all future work should be based. Each concept will be sequentially discussed in the context of the sprint start and early acceleration using evidence from across the research-practice continuum. Finally, lessons that have been learnt and the general applicability of these concepts will briefly be reflected on by considering their application towards future work in a new area, rugby place kicking.

1) Defining a clear and appropriate common goal. An objective goal must be agreed from the outset in order for biomechanical support to be fully effective. Whilst overall performance in a sprint over any given distance is clearly and objectively quantifiable using a simple time-based measure, objectively quantifying performance in a smaller part of an entire sprint provided an early, unexpected challenge: *what is good sprint start performance?* Informal discussions with several elite coaches revealed little agreement in the responses to this question. A subsequent review of peer-reviewed literature revealed that this lack of a consensus existed across the research-practice continuum. Perhaps of most concern, it seemed possible that contrasting technical recommendations could be made based solely on the choice of performance measure. A study was conducted which demonstrated that the use of different performance measures could affect a coach's interpretation of the relative success of different athletes (Bezodis et al., 2010). Based on coaching practice and theoretical considerations, an agreed, appropriate performance goal during the sprint start and early acceleration was to produce maximum levels of horizontal external power. Importantly, it was demonstrated that this could be quantified accurately from video data in an ecologically-valid applied setting (Bezodis et al., 2010; 2012a).

Clearly some sports or skills have a single, easily identifiable and measureable, objective performance outcome. However, there is often some discrepancy, particularly when a part or phase of a larger skill or activity is being considered, when there are multiple performance demands (e.g. speed and accuracy, as is often the case in ball striking skills), or when tactics must be an additional consideration for a coach. In such instances, evidence from across the research-practice continuum must be critiqued to determine an objective performance measure that is accepted by both the coach and sports biomechanist.

2) Asking relevant questions. Any research findings are influenced by the assumptions and limitations inherent to the methods used to obtain them. Due to the complexity of human movement, sports biomechanics analyses all typically include assumptions. However, any assumptions must be considered in the context of the entire research-practice continuum: *how well can elite sprint coaching practice be appraised?* With an objective performance measure determined, the next step was to help the coach understand the techniques specific to the performances of his three elite sprinters. Having convinced the coach of the benefits of moving a training session to a location where it was possible to collect data for an inverse dynamics analysis (IDA), it was paramount that the questions asked were relevant to the coach's practice.

Two issues became evident when appraising sprint biomechanics IDAs in the context of additional evidence from across the research-practice continuum. Firstly, sprinting analyses have typically considered the leg to comprise three joints; the ankle, knee and hip. It was proposed that this may not sufficiently reflect early acceleration technique based on the coach's practice. A resultant plantar flexor moment was identified at the metatarsal-phalangeal (MTP) joint during the first stance phase which was comparable in magnitude to the resultant extensor moment at the knee joint and thus demonstrated the importance of considering MTP kinetics (Bezodis et al., 2012b). Secondly, it was determined that the use of mismatched cut-off frequencies to filter the kinetic and kinematic data in an IDA of early accelerative sprinting led to artefacts in the resultant knee joint moment soon after touchdown (Bezodis et al., 2013). A previous lack of clarity regarding the role of the knee joint in early acceleration was therefore suggested to be largely due to the data processing approaches adopted.

Whilst some assumptions must always be made in any biomechanical analysis, it is important that we do not ask misdirected questions which overlook important aspects of coaching practice or potential limitations in previous research. When using lower limb kinetic data to help the coach understand technique and performance during early acceleration, it was demonstrated that the MTP joint should be included and that appropriate data filtering is required. Ensuring that relevant questions are asked is the initiator for the process of providing the coach with meaningful answers.

3) Providing meaningful answers. As well as asking the right questions, it must also be considered whether the way in which these questions are asked will allow the provision of meaningful answers to a coach. These two concepts must clearly be considered largely concurrently to ensure that biomechanical research is of applied benefit: *is the information provided meaningful to an elite sprint coach?* An applied study was therefore designed which incorporated three in-depth case studies of the coach's elite sprinters (Bezodis et al., 2014). This used the relevant IDA methods alongside information from across the research-practice continuum to provide meaningful answers about the common aspects of early acceleration technique amongst elite sprinters as well as identifying potentially important between-elite sprinter differences.

The resultant MTP plantar flexor moment was firstly discussed in the context of relevant experimental research which recently demonstrated possibilities for specific training or acute (i.e. footwear) interventions to enhance running and horizontal jumping performance by affecting MTP joint kinetics in student athletes (Goldmann et al., 2013; Willwacher et al., 2013). Secondly, the MTP joint was demonstrated as important for early acceleration performance by explaining its potential effects on the ankle joint mechanics (Mann & Hagy, 1979; Roy & Stefanyshyn, 2006). The importance of the ankle joint during early acceleration was then discussed in the context of an entire 100 m sprint. Whilst the ankle goes through phases of dorsi flexion followed by plantar flexion in all stance phases of a sprint, during early acceleration it was shown to generate up to four times more energy than it absorbed (compared to maximum velocity where it acts as a net energy absorber; Bezodis et al., 2008a). The most powerful sprinter clearly generated the greatest energy at the ankle joint and combined with the MTP kinetics and additional ankle joint kinetics evidence (Charalambous et al., 2012), a 'stiff' foot and ankle was explained as a key feature of early acceleration in these elite sprinters. The knee joint extended from the onset of stance. Using the new filtering methods, the most powerful sprinter was shown to demonstrate a resultant knee extensor moment from early stance. Due to a larger and earlier rise in this resultant knee moment, he generated at least twice the energy at the knee joint compared to the other two sprinters. Considered alongside additional evidence describing knee motion in early acceleration (Debaere et al., 2013), knee extensor work appeared to be another important feature of elite early acceleration technique.
Having developed appropriate methods to ask relevant questions, meaningful answers were provided to the coach regarding both the common, and potentially discriminating, technique factors between the early acceleration techniques of his three elite sprinters. In order to provide additional technical implications for the coach, selected linear kinematic data from this study and across the research-practice continuum (Bezodis et al., 2008b) were considered alongside the resultant joint moments. In addition to the importance of the 'stiff' foot and ankle, it was also suggested that linear foot kinematics at touchdown may play an important role in the knee joint mechanics and ultimately performance.

4) Demonstrating that a difference can be made. As highlighted earlier, sports biomechanists often work towards the goal of enhancing performance. Whilst the above research has identified potential aspects of technique which could be manipulated in an attempt to enhance performance, one of the biggest challenges facing any sports biomechanist is demonstrating that these suggestions can actually benefit performance: *how can performance be improved for a given elite sprinter?* Prospective intervention studies offer an appealing approach through which such suggestions can be assessed. However, examples of prospective intervention studies in an applied sporting environment are scarce as elite coaches and athletes are typically unwilling for experimental manipulation of their training to take place.
An alternative approach is computer simulation modelling (Yeadon, 2008). Such models allow specific questions to be answered by manipulating input variables and observing the effect on the outputs. As computer simulations relate directly to the motion of a model, it is paramount that the model used provides an appropriate, carefully evaluated representation of the intended system of interest; in this case an elite human sprinter. In order to maintain the applied focus of this work, an angle-driven model of one of the coach's elite sprinters was developed with increasing complexity until a sufficiently close match with specific empirical kinematic and kinetic data was achieved (Bezodis et al., 2009). Simulations could then be run using this evaluated model to assess the key applied points from the previous empirical study which were proposed as important for elite early acceleration performance. Two specific questions relating to touchdown kinematics and ankle motion, respectively, were formed from a combination of the previous empirical findings and evidence from across the research-practice continuum.
Simulations revealed a curvilinear relationship between touchdown distance and early acceleration performance. This elite sprinter was already very near his optimum touchdown

distance and therefore touchdown distance did not appear to be a beneficial aspect of technique for the coach and athlete to focus their efforts on during training. However, these results helped to identify a specific aspect of technique which could further explain research regarding the importance of the direction of force application above the magnitude of the force vector *per se* during accelerative sprint running (Kugler & Janshen, 2010; Morin et al., 2011). A second set of simulations revealed that a slight reduction in ankle dorsi flexion during early stance could lead to performance improvements for this sprinter. This was demonstrated to be within physically achievable limits, thus identifying an aspect of an elite sprinter's technique that could potentially be addressed to enhance his performance. Furthermore, this provided additional support for empirical research regarding the importance of the ankle during early acceleration (Bezodis et al., 2014; Charalambous et al., 2012).
Careful development and appropriate evaluation of a computer simulation model can provide a method through which specific questions related to elite sports performance can be addressed. This model appraised two aspects of early acceleration technique that were specifically identified using information from across the research-practice continuum. Specific interventions were identified which could benefit the performance of an elite sprinter and further the broader biomechanical understanding of early acceleration.

FUTURE APPLICATIONS BASED ON LESSONS LEARNT: Whilst considerable evidence from towards the practice end of the continuum was used to inform the sprinting research discussed throughout this paper, it is regrettable that this was never more formally recorded. Moving institutions has led to a return to my previous rugby place kicking research (Bezodis et al., 2007) and new applied work. Formalising experiential coaching knowledge through semi-structured interviews (Smith, 1996) and using deterministic models (Chow & Knudson, 2011) to help combine all of the available information from across the research-practice continuum has recently proven to be beneficial for developing a framework for biomechanical consideration of rugby place kicking (Bezodis & Winter, 2014). This should provide greater clarity and objectivity to help assess the definition of a clear and appropriate common goal as well as ensuring that relevant questions are asked and meaningful answers are provided to the coaches.
Greater difficulty perhaps lies in demonstrating that a difference can be made. Although a computer simulation model was demonstrated to offer a useful means of systematically addressing applied sprinting questions, the time and resources required to carefully develop and evaluate such models seemingly conflicts with the practice-based desire for near-instant results. For largely uncontrollable reasons, the implications resulting from the above simulations were never applied in practice. An important challenge for sports biomechanists appears to be to try and achieve greater buy-in from coaches, and perhaps the governing sporting organisations, to undertake applied prospective experimental studies. Attendance at ISBS conferences and learning from established experts in the field continues to be an invaluable resource for my work and specific discussions for how we, as a community, could best try to achieve this should be welcomed.

CONCLUSION: This paper provides personal reflections on my work to date. Four key concepts were identified as fundamental to my attempts to integrate research and practice. A series of examples were discussed to demonstrate these concepts in sprinting. By always being mindful of the need to seek and appraise evidence from across a research-practice continuum, relevant scientific methods were designed to yield a meaningful understanding of specific aspects of early acceleration for both researchers and coaches with a view to ultimately enhancing the performance of elite sprinters.

ACKNOWLEDGEMENTS: I would like to express my gratitude to Dr Aki Salo and Dr Grant Trewartha for their continued support and to Dr John Mercer for inspiring my initial passion in sports biomechanics. I would like to thank Dr Liz Bradshaw, Prof. Bruce Elliott and Dr Aki Salo for offering their advice on various drafts of this paper.

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