Research Informing Practice: Current Issues in Gymnastics Research
"*Injury, skill development, elite performer and fundamental movements"*

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Introduction

The aim of this applied session is to explore four key themes relating to current research in gymnastics. The themes include Injury occurrence (Professor Patria Hume), Skill development (Professor Gareth Irwin), Working with the Elite Gymnast (Professor William Sands) and Fundamental movements in gymnastics (Dr Toshiyuki Fujihara). Each speaker will explore their area, as experts in this applied science, drawing on a body of research evidence and gymnastics practice to report findings that impact understanding and hence have the potential inform coaching. Research has previously demonstrated that a conceptual understanding of how a skill works biomechanically can provide a coach and clinician with knowledge of effective, efficient and safe technique development (Irwin et al., 2005). Bridging the gap between the fundamental axioms of science and real world practice is a key aim of the Society's approach to sports biomechanics. To achieve this bio-fidelity the approach must be one that is rich in ecological validly. Professor **Hume** will explore injury rates and current issues associated with biological failure due to technique and maturation. Professor **Irwin** will draw on research to outline the impact of technique selection on injury potential and skill development. Professor **Sands** will draw on his wealth of experience as a biomechanist and applied scientist working with Olympic gymnasts to highlight issues associated with this fundamental scientific role. Dr **Fujihara** will complete the session by examining "fundamental skills". His talk will focus on rotational mechanics and include practical considerations for circles on pommel horse including the influence of a suspension aid in the development of skill.

Professor Patria Hume (New Zealand): Injury occurrence

Injuries still occur in gymnastics despite our injury prevention efforts. Internal and external risk factors when combined with the mechanism (inciting events) of injury may make a gymnast more prone to injury. We will examine the risk factors and mechanisms for injury causation in gymnastics.

Higher amounts of mechanical energy for more difficult gymnastics skills are related to higher energy when landing from the skill and increased biomechanical requirements for the biological structures involved. The key factor for minimizing the risk of long-term overuse is the appropriate loading of the biological structures guaranteeing tissue strength adaptation and strengthening. Loading frequency and total loading time appear in combination with the loading amplitude as key determinants of the mechanical stimulus in gymnastics. Increasing mechanical loading impacts primarily on the most distal joints of the kinematic chain, i.e. the hands/elbows/shoulders, the lower extremities (feet, ankle, and knee joints) and the spinal structures.

Large impact forces, in combination with poor lower limb geometry during landings, in gymnastics are resulting in injuries predominantly to the lower limbs. Using functional movement screening, biomechanically instrumented equipment (e.g., beat board, rings, and bars), or instrumentation on the gymnast (e.g., accelerometers) to monitor gymnasts' motion, and equipment and techniques to help reduce biomechanical loading should be useful. Given the high magnitude of impact load, both acute and accumulative, coaches should monitor impact loads in training, considering quality and quantity such as control of rotation and heights from which landings are executed. Evidence-based injury prevention interventions should be developed for gymnastics focused on reducing biomechanical loading during landings.

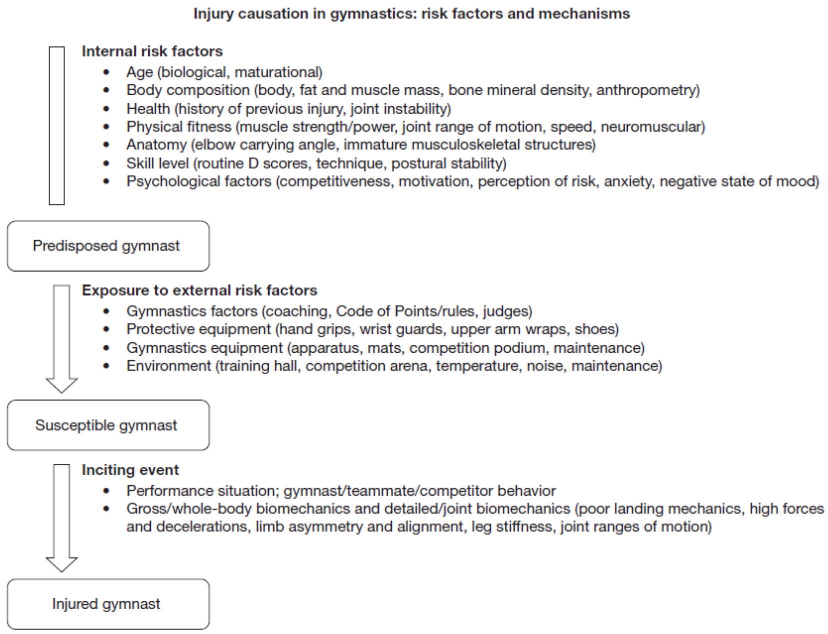

Figure from Hume PA, Bradshaw E, Bruggeman GP. Biomechanical approaches to injury mechanisms and risk factors. In: Caine DJ, Russell K, Lim L, editors. Handbook of Sports Medicine and Science, Gymnastics. Wiley-Blackwell; 2013.

Professor Gareth Irwin (UK): Skill development

A principal desire for gymnastic coaches, applied scientists and sports clinicians is to prepare, nurture and develop performance in a safe and effective manor. This presentation will outline two aspects of skill development to prepare robust and adaptive performers. The first part of the presentation will examine *technique selection*, this aspect of skill development is important to the experienced and novice gymnasts, with impact on injury risk and skill progression. Research groups from Ostrava and Cardiff have examined injury risk and technique selection associated with the choice of hand placement in round off skills (Farana et al., 2013). These authors showed increased elbow joint abduction torques and lower levels of biological variability (Farana et al., 2014) in parallel technique round off skills. This important finding has implications for technique selection of young gymnasts, where elbow lesions are the primary career ending injury. From a performance perspective the Cardiff group have examined the concept of technique selection on bars with the focus on the longswing and Tkachev skills. Building on a body of evidence these researchers demonstrated that there are “functional phases” of the longswing preceding release. In the longswing this occurs when the gymnast performs shoulder maximum flexion to extension and hip extension to flexion through the bottom of the swing which accounts for 70% of the gymnasts energy input. Manning et al. (2010) observed how longswing selection (arch, pike or straddle) preceding the outward Tkachev (passing the low bar on the descending phase) influences the functional phases and release characteristics. More recently the joint kinetic and bio-energetics contributions to these techniques have been explained and will be further discussed in the presentation. Kerwin and Irwin (2010) built on this research and showed how the outward and inward (passing the low bar on the ascending phase) Tkachev can influence the key variables for success. They highlighted that these skills are kinematically similar but place different biophysical demands on the performer, a finding that has direct implications for physical preparation of the gymnast. The first decade of the 21st Century saw the increased popularity of the Toe On Tkachev, and coaches suggested that this technique might provide the opportunity to perform the straight Tkachev. Kerwin and Irwin (2011) and Irwin *et al.,* (2011) showed the enhanced angular momentum, time in the air and musculoskeletal demand that these 'newer skills produced'.

The second part of the talk will focus on fundamental skill development to examine how performers learn gymnastics skills. This section is based on collaborative research between Cardiff and the Penn State University Group lead by Professor Karl Newell. Biomechanics and motor control are combined to examine questions relating to how we develop complex skills and how the kinematics, kinetics and bio-energetics change during this process. Examining these questions from the theoretical framework of self-organization theory and the constraints lead approach provides useful insights into the mechanisms by which gymnastics skills are developed. Williams *et al.*'s (2013; in press) work will feature strongly in this part of the presentation and include links to variability and coordination within an ecologically valid environment.

Professor William Sands (USA): Making a Difference in Elite Gymnastics

Sport science has a great deal to offer elite gymnastics. Sport scientists often desire to work with elite gymnasts because of the perceived special needs of these athletes. 'Elite' has been an abused term, ranging from 'trained' to Olympic and World medalists. The U.S. Olympic Committee has defined 'elite' as top eight in the world, or more recently top 20 in the world. By this definition, it is clear that few studies actually address elite gymnasts. Experience has shown that there are at least two paths for involvement with elite gymnastics.

The first path targets coach, athlete, and administrator relationships. Former and current athletes, former and current coaches, and former and current scientists generally have an easier time achieving acceptance. Coaches are reluctant to embrace the ideas of someone they do not know. Coaches are reticent to accept scientific information that is of limited use and may contradict the coach's views.

Sport scientists have to establish a presence in the gymnastics world. Scientists should consider the following: 1) attend competitions, 2) attend coach education events, 3) offer services for education first and research second, 4) stay completely in the background, 5) write for coaching publications, 6) write a lot, 7) keep things simple, 8) find and solve coaching problems. A helpful tactic is to ask the coach, athlete, administrator what single problem they find most troublesome. Once a significant problem is identified, design and implement a project to solve that problem. Maintain your motives within a service model. Once you are involved, you are only as good as the last problem you solved. You should work doubly hard to ensure that your contributions continue unabated.

The second path is simpler - get a job working for the national governing body or related institution and have them assign you. Top-down management commonly accompanies administration unfamiliar with gymnastics culture. Unfortunately, administrative dictates seldom result in optimal interactions, deep research projects that matter, or longevity. Scientist and coach relationships are fragile. Research should rise from the coach and athlete, not descend from uninformed administration. Keep in mind that you may work for years without achieving enough quality data to produce a peer reviewed publication. Samples will be too small, attrition will be high, data collection will be limited, and reviewers will not understand the limitations inherent in working with elite athletes.

Finally, be really good. In spite of limited funding, access, and cooperation, the scientist must produce the highest quality work. Produce reports on findings that can be read by athletes, coaches, and parents. Quality is not measured by impact factor. Quality sport science is measured by the people who receive the service.

Dr Toshiyuki Fujihara (Japan): Fundamental movements in gymnastics

Introduction: Biomechanics is helpful for our understanding of the mechanism and technique of many gymnastic skills. To review a cluster of many biomechanical works in gymnastics, there are two important papers available. First, Brüggemann (1994) classified dynamic skills of gymnastics into categories based on the movement patterns. Second, Prassas, Kwon, and Sands (2006) reviewed available literature on each apparatus in addition to the discussion on biomechanical performance variables and future research directions. Both papers shared the idea that there was a clear gap between practical needs and available scientific data for pommel horse. Recently, several studies on pommel horse have been documented. Most of these recent studies dealt with a skill called “circles,” the most fundamental skill that involves a horizontal rotation. Re-examining these papers and understanding the basic mechanism of horizontal rotation should be valuable to practitioners as well as interested researchers. The purpose of this presentation is to review recent works related to the mechanics and practical considerations of the fundamental skill on pommel horse in men’s artistic gymnastics.

Rotational mechanics of circles on pommel horse: The horizontal rotation of legs during circles is a combination of two kinds of rotations (Fujihara, Fuchimoto, and Gervais, 2009). One is the rotation of a whole body about its mass centre, and the other is the rotating movement of the mass centre itself like an orbit. The former rotation is not a complete rotation about an axis through the mass centre as would be the case with a somersault. Instead, the mass centre is the fulcrum for the conical pendulum swing of the legs. Available kinematic data confirms that a gymnast rotates his legs by moving the upper body and the lower extremities in the opposite directions to each other, maintaining a dynamic balance. We also observed a horizontal rotation of the whole-body mass centre, the latter of two kinds of rotations mentioned above. Actually, the horizontal path of the whole-body mass centre is not circular but rather elliptical. This phenomenon is explained in the presentation using Fujihara (2010)’s model with some supportive data. *Practical considerations for circles on pommel horse:* To perform circles on a pommel horse, there are a couple of important factors to be considered. The first consideration is a physical constraint related to the area available to a gymnast to place their hands for support. A gymnast’s hand placement is constrained to a specific location on the pommel horse for the skill unlike performing circles on a floor. It is also important to avoid collision with the pommel horse. Depending on the orientation of circles, the relative position of a pommel horse to be passed over changes. One of the most essential factors to evaluate the quality of circles is the amplitude. The hip angle is often used to evaluate the amplitude of circles. Baudry et al. (2009) additionally determined three other variables: the horizontal diameter of the ankle excursion, the horizontal diameter of the shoulder excursion, and the shoulder extension angles during a rear support phase. *Influence of using a suspended aid:* A suspended aid is sometimes used for young gymnasts to learn circles and for more advanced gymnasts to polish their technique. Fujihara and Gervais conducted a series of studies to investigate how a suspended aid influences biomechanical characteristics of circles. To summarize these results, a suspended aid could be used as “spotting,” which could help a gymnast experience a more sought-after motion for circles. However, it is critically important to understand the fact that the joint kinetic profiles are altered. Following studies further revealed that gymnasts became less dependent on the suspended aid as their skill levels improve (Fujihara and Gervais, 2012d), and that the location of suspension had influence on both kinematics and kinetics of circles (Fujihara and Gervais, 2012e). Although a suspended aid has been used at least over 30 years with a lot of anecdotal support and criticism, these studies provided biomechanical evidence and suggested a variety of potential uses and the limitations.