Dynamics and Biomechanics of Sports

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Improving athlete performance and reducing the risk of injury are the main goals of sports biomechanics researchers and sports engineers. In order to accomplish these goals, researchers use a variety of approaches including experimental measurements, and computer modeling, simulation, and/or optimization. While these approaches have enabled a scientific understanding of sports performances, the primary means by which this information is translated back to athletes and coaches is though rule changes, and innovations in sports equipment and footwear. Instead, if key movement features are identified that indicate performance success or risk of injury for each athlete, fast and easy to use tools could be developed to provide real-time quantitative information during athlete training. These tools would enable coaches to transition from having to rely solely on previous experience gained by trial-and-error, to incorporating quantitative measurements in order to help an athlete optimize their performance and reduce their injury risk. During this talk I will describe two studies that use very different approaches to gain insights into key factors influencing sports performance, and discuss the benefits and challenges associated with each.

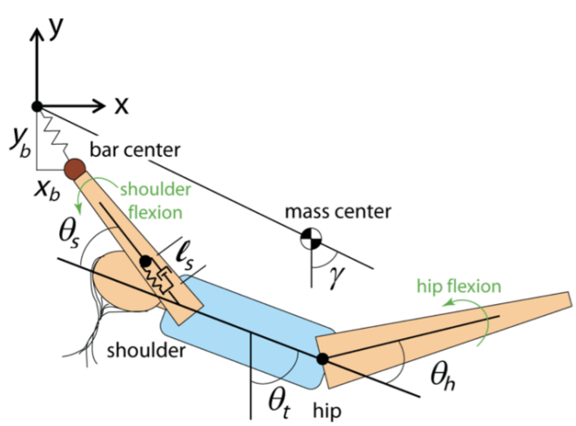

Figure 1: Gymnast model used to optimize swing and maximize dismount performance

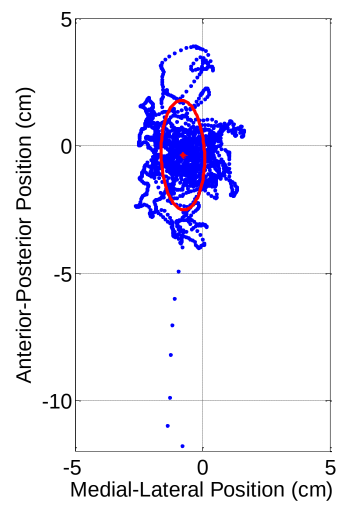

Figure 2: Center of pressure trajectory (blue) during 20s single leg balance and ellipse (red) calculated using PCA

The first study aimed to improve a gymnast's performance during a dismount from the uneven parallel bars by using optimization to identify her anatomical and/or physiological limitations. During this study a subject-specific gymnast model (Figure 1), and forward dynamics simulation of a swing on the uneven bars were developed and validated (Sheets and Hubbard, 2008). The model had 7 degrees of freedom and was composed of two legs, a combined arm, and a torso/head segment. Segment mass, center of mass location and moments of inertia were estimated using geometric approximations and a constant density assumption (Yeadon, 1990). The gymnast's strength capabilities were defined by measuring her shoulder and hip joint torques as a function of joint angle and angular velocity. These shoulder and hip joint torques as a function of time were optimized during the swing simulation, using the downhill simplex method, to maximize the number of revolutions that a gymnast could perform during a dismount (Sheets and Hubbard, 2009). Multiple optimizations were performed to identify the sensitivity of the calculated performance to the model parameters. It was found that the gymnast's ability to hold onto the bar during the swing was the largest performance limitation; therefore, this is the biggest opportunity to positively affect the gymnast performance.

The goal of the second study was to understand the relationship between prior ankle injury and training on balance using a fast and simple to administer experimental protocol. Forty-two highly competitive football and soccer players performed three trials each of static and dynamic balancing tasks. During the static trials, subjects stood on one foot with their hands placed on their hips with their eyes shut, and attempted to remain as still as possible for 20s (Ross, et al. 2011). During the dynamic balance test, the athletes to jumped from a distance of 70cm, landed on one leg, then shut their eyes and attempted to regain balance as quickly as possible in the static balance posture described above. The three-dimensional reaction forces between the foot and ground, position where the force was applied (center of pressure, Figure 2), and moment about the vertical axis were measured throughout each trial. The gross quality of movement was rated using a point system. Balance was quantified using parameters derived from the position of the center of pressure during the trial, and it was hypothesized that athletes with better balance were less likely to have suffered an ankle injury. The need for a fast protocol was driven by the limited time available for testing in a high level athlete's schedule. Additionally, simple experimental procedures increase athlete participation by allowing accurate measurements to be made in convenient settings, such as at the athlete's training facility.

Key insights into athlete performance can be gained using computational and experimental approaches. By working with coaches and trainers, results from studies such as these could be used to improve athlete performance, and to develop training tools and strategies to reduce an athlete's risk of injury.

References

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