

ATHLETE – EQUIPMENT INTERACTION

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The purpose of this research is to understand how to match an athlete to a piece of athletic equipment. Individual athlete characteristics require specific equipment parameters to optimize performance. Similarly individual movement patterns can be matched to equipment characteristics to help prevent injury. The athlete and equipment form a biomechanical system influenced by biomechanical principles such as the force-length and force-velocity relationship of skeletal muscle. By understanding the athlete-equipment interaction, sport equipment can be tuned to individual athletes to maximize performance and minimize injury.

KEY WORDS: performance, injury, sport equipment, tuning

INTRODUCTION: Sports require athletes to utilize athletic equipment to perform their sport. From complex equipment such as bobsleds and sailboats to the most basic of equipment including footwear or apparel, practically all athletes rely on their equipment to keep them safe and aid in performance. The key in developing sport equipment is to realize that the athlete and equipment form a biomechanical system where the athlete applies loads to the equipment, which influence how the equipment reacts. Therefore, biomechanical principles like the force-length and force-velocity relationship of skeletal muscle become important equipment design parameters.

ATHLETE-EQUIPMENT INTERACTION: Golf research provides a good illustration of the importance of matching a piece of athletic equipment to an individual athlete. Mechanical properties of club mass, inertia, stiffness, etc. are often matched to individual golf swing characteristics (e.g. Winfield & Tan, 1996; Suzuki & Inooka 1998; Iwatsubo et al. 2000; etc.).

Highlighting an example related to club mass, Haufle et al. (2012) found that individual athletes reacted very differently to mass added to the golf club shaft. A mechanical model predicted that clubhead speed would decrease with increasing mass in the shaft. However, when golfers were tested with experimental clubs with increased mass, most athletes either had increased clubhead speed or their clubhead speed remained unchanged. The biomechanical testing obviously led to very different results than the

purely mechanical predictions. How the athlete loaded the club dictated the club performance. These equipment-athlete relationships are difficult to estimate from mechanical models.

As well as understanding the athlete-equipment interaction, the musculoskeletal force-length and the force velocity relationships should be considered when developing sport equipment.

FORCE-LENGTH RELATIONSHIP: Since muscle force is dependent on muscle length (Gordon et al., 1966) modifying a piece of athletic equipment to place a muscle at a length where it can maximize force production should improve athletic performance. An easily understandable example is through adjusting bicycle seat height. Historical studies have shown that cycling performance, as measured through oxygen consumption and work performed, can be largely influenced by seat height (Hamley & Thomas, 1967; Nordeen-Snyder 1977). If seat height was too high or too low, performance variables decreased but for an optimal seat height, the cycling activity was maximized due to positioning the leg muscles at an optimum length for force production.

FORCE-VELOCITY RELATIONSHIP: The force-velocity relationship (Hill, 1938) also plays a role when designing athletic equipment. To maximize power output, which is required in numerous sports, muscle contraction should occur at approximately 31% of the maximum speed a muscle can contract (Herzog, 2007). Cycling again provides an excellent example to better understand the influence of equipment selection on muscle contraction velocity for maximizing performance as pedaling rate has a direct influence on power output. Intermediate pedaling rates maximize power output while slow and fast pedaling rates result in decreases in power output (Yoshihuku & Herzog, 1990). Choosing the appropriate gear allows an athlete to pedal at the desired frequency to best maximize power output.

SUMMARY: To properly develop athletic equipment, the athlete-equipment interaction must be taken into consideration. The loads that an athlete applies to the equipment and how these loads change with equipment modification are important factors in identifying appropriate equipment parameters. Equipment design can shift where an athlete functions on the force-length and force-velocity relationships to maximize force or power production. Since these properties are individually specific, small changes to a piece of equipment can help optimize individual athletes according to their explicit biomechanical characteristics.

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