REVERSE ENGINEERING THE SKATE

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Success in sport and the facilitation of active, health lifestyles through exercise is in large part influenced by technical advances in equipment including ergonomic designs, the incorporation of new synthetic polymer materials or metal alloys, and / or the utilization of novel manufacturing and construction processes 1,12,22. Any or all of these changes to the product may have a profound effect on performance and safety. A recent example is seen in the technical revolution of the speed "klap" skate that has led to new world and Olympic records 9,11,35. Typical of most sports, ice hockey equipment has evolved more by trial-and-error field-testing rather than from planned scientific or engineering analysis 7,23,29. However, the planned study of the ergonomic factors improving (and impairing) performance can accelerate new product development by providing feedback to engineers regarding perceptions and quantitative measures of performance to specific components of the product. Controlled studies provide a framework for systematic evaluation of products as well as to provide validation (or rejection) of mechanical theories regarding function.

Despite past and current research efforts, much remains unknown about the physics of tasks involved in ice hockey 3,7,13,24,29 let alone the fundamental behavior of gliding on ice 2,5 and the effect of equipment design and construction on task performance. In general, research regarding the mechanics of ice hockey has been limited 29. For instance, some rudimentary aspects of the forward stride 4,6,8,10,15-21,27,30-34, and starts and stops 14,25,26 have been described. Overall, research addressing the effect of design and construction on ice hockey performance has been sporadic and of indirect application to manufacturers, coaches and athletes. Hence, continued efforts are needed to dissect the mechanical function of the ice hockey skate i.e. some reverse engineering.

If we think of the skate as a mechanical device, considerable force must be applied over a sufficient area in the skate boot wall and insole to stabilize the foot/ ankle during key phases of glide and push-off. To achieve this, two techniques of force transmission are employed: (1) maximize total contact between foot-ankle and lower leg i.e. even pressure distribution; and, (2) molding of boot to localize the pressure in certain prescribed areas of the skate boot. For optimal function, several interacting factors must be considered, such as: the need for (1) kinesthetic sense of joint position and limb orientation; (2) avoid pinching of sensitive soft tissue areas overlying muscles and neurovascular structures; (3) accommodation for geometric anthropometrics and orientation of bony structures such as width, height, circumference, radius of curvature (both simple and compound) and dynamic changes in foot/ankle alignment; (4) provision for effective anterior-posterior and medial-lateral alignment stability and range of motion (i.e. defined plantar-dorsi and pronation-supination stiffnesses and endpoints); (5) provision for effective forefoot and rear foot leverage for controlled blade movement; (6) accommodation for the restriction of joint movements and coupled foot-ankle-knee-hip chain coordination; as well as, consideration for variables of weight, shape, color, material texture, aesthetics and so forth.

To speak to the interdependent issues of fit, comfort, protection and performance of the ice hockey skate, general considerations of the pertinent kinematics and kinetics must be known. The issue of greatest interest is optimizing the fit of a skate design for comfort, effective force transmission and skate control. Within this presentation, various biomechanical evaluation techniques will be demonstrated including a) lower limb joint kinematics (ankle inversion-eversion, plantar-dorsi flexion; knee flexion-extension; hip flexion-extension, abduction-adduction) utilizing electrogoniometers (Penny & Giles, XM-110) and portable data logger 4, b) plantar foot pressures and forces 32-34; and c) muscular activity (i.e. electromyography or

EMG) of the major lower limb muscle groups using surface bipolar electrodes with preamplification connected to a portable amplifier and data logger 6.

REFERENCES:

Armenti A (1992) The Physics of Sports, Springer Publishing, New York.
Bluhm H, Inoue T, Saleron M (2000) Physical Rev B 61: 7760.
Bowbiggin B (2001). The Stick. Macfarlane Walter and Ross, Toronto.
Chang R et al. (2002). IV World Cong of Biomechanics, Calgary, Alberta, Canada.
Colbeck SC (1995). Amer J Physics 63: 888.
Goudreault R et al. (2002). IV World Cong of Biomechanics, Calgary, Alberta, Canada.
Haché A (2002). The Physics of Hockey. John Hopkins University Press, Baltimore.
Hoshizaki TB et al. (1989). ASTM STP 1050, ASTM, Philadelphia, 141-149.
Houdjik H et al. (2000). Med Sci Sports Ex 32:635.
Humble RN & Gastwirth BW (1988). Clinics in Podiatric Med & Surg 5(2): 363-376.
Koning de et al. (1991). J Biomech, 24(2), 137.
Kreighbaum EF et al. (1996). Human Kinetics: Champaign, IL.
Lafontaine D et al. (1998). Int Soc Biomech Sports Procs. 1:481-483.
Lamontagne M et al. (1983). Can J Appl Sport Sci. 8(3):169-179.
Marino GW (1977). Res Q Exer Sport, 48(1):93-97.
Marino GW (1979). Res Q Exer Sport, 50(1):55-59.
Marino GW (1983). Res Q Exer Sport, 54(3):234-238.
Marino GW (1984). J Can Assoc Health Phys Ed Recreation, 4-8.
Marino GW (1998). Proc 1st Int Soc Biomech Sport., Konstanz, Germany, 184-187.
Marino GW et al. (1978). Proc Int Cong Physical Act Sci, Symposia Specialist,193-201.
Marino GW et al. (1979). Sci in Skiing, Skating and Hockey Del Mar: Academic Pub, 65-74.
May M (2000). Scientific Amer 74-79.
Minkoff J et al. (1994). Baltimore: Williams & Wilkins, 397-444.
Montgomery DL (1999). Exercise & Sport Science, Ed. WE Garrett Jr, DT Kirkendall, Williams & Wilkins., Ch 42.
Naud et al. (1979). Can J Appl Sport Sci, 4(1): 8.
Naud et al. (1980). Can J Appl Sport Sci, 5(2): 94.
Nobes K et al., (2003). Can J Exer Physio 28:1-12.
Pearsall DJ et al. (1999). 4th Symp Footwear Biomechanics. Alberta, Aug 5-7
Pearsall DJ et al. (2000). Exercise & Sport Science, Vol 1. Ed. WE Garrett Jr, DT Kirkendall, Williams & Wilkins. Ch 43.
Pearsall DJ et al. (2001). XIX ISBS, San Francisco, 78-81.
Purvis et al., (2002). 4th Int Symp on Safety in Ice Hockey, Pittsburgh, PA, USA.
Turcotte R et al. (2001). XIX ISBS, San Francisco, June 20-26, 82-85.
Turcotte R, Pearsall DJ, Montgomery DL. (2001). Sports Engineering 4:43-48.
Turcotte R et al. (2004). Safety in Ice Hockey. Fourth Volume, ASTM STP 1446, D.J.Pearsall and A.B. Ashare, Editors., ASTM, 265-271.
Van Ingen Schenau et al. (1996). Med Sci Sports Exe, 28(4): 531.