ASPECTS AND CHALLENGES OF APPLIED SPORT BIOMECHANICS RESEARCH

Hermann Schwameder

**BioMotion Center, Institute of Sport and Sport Science,
University of Karlsruhe, Germany**

Biomechanics in general and sports biomechanics in particular, are well established scientific disciplines. Due to the wide scope of application, sport biomechanics represents a very strong area within the of biomechanical research field. The specific goals of sports biomechanics research primarily cover issues of performance enhancement, comfort, injury prevention and safety regarding elite, leisure and rehabilitation sport. Due to its specificity, the research of applied sports biomechanics is confronted with significant challenges. The specific circumstances of sport disciplines have to be considered and necessitate the development of the appropriate methodology of data collection and data analysis. A large number of sophisticated and useful solutions have already been reported for many sport disciplines. These methods have to cover the scientific demands of validity, reliability and accuracy along with the more practical issues like range of usage, complexity, costs and the amount of interference with the athletes. One important challenge in sports biomechanics is to overcome the discrepancy between reliability and validity of the collected data sets. This conflict often corresponds to the issue of collecting data in a lab or field situation. Usually, data collected in the lab are more accurate and reliable, but the validity can be substantially restricted. Data collected in the field typically provide the opposite situation: high validity, but restricted accuracy and reliability. In elite sport, the highest level of validity can only be guaranteed when data are collected during competitions; however, the regulations often hamper the usage of biomechanical methodology. To overcome these problems data should be collected in semi-competitive situations. This can be performed in field studies, but also by mimicking competitions using simulation and/or imitation conditions. Furthermore, sport biomechanists should perform detailed error estimation in each specific situation of data collection for providing detailed information on data accuracy. In the literature sophisticated solutions regarding the aspects, issues and challenges on applied sports biomechanics research have already been reported. Further examples with a specific focus on walking, mountaineering and winter sports using both lab and field studies are presented with respect to usability, validity, reliability, accuracy and error estimation.

KEY WORDS: applied biomechanics, accuracy, validity, reliability

ASPECTS OF APPLIED SPORT BIOMECHANICS RESEARCH:

Biomechanics can be defined as ‘the science that examines forces acting upon and within a biological structure and effects produced by such forces’ (Nigg, 2007). The ‘biological structure’ in this context can be wide spread and covers systems of different levels: cells, tissue, joints, segments, the entire body or even a complex system consisting of several bodies or the human body in combination with the surroundings (water, air, equipment, floor etc.). The main focus of applied sport biomechanics research is primarily directed to the entire human body in the complex sport discipline or sport specific situation.
Among others, biomechanical research primarily deals with the following issues (Bartlett, 2007; Brüggemann & Klapsing, 2003; Nigg & Herzog, 2007):

- gaining a better understanding of human posture, locomotion and movement
- increasing the understanding of the mechanics, structure and function of biological structures
- establishing biomechanical principles
- studying the biological response of mechanical loading.

The main goals of biomechanical research are

- to provide preventive measures and recommendations regarding safety aspects in order to avoid pain and injury,
- to improve medical treatment (e.g. surgery, preventive and rehabilitative interventions),
- to enhance performance in movement and locomotion,
- to improve subject specific comfort in movement and locomotion.

Biomechanical research is characterised by its interdisciplinary approach with other related fields such as medicine, neuroscience, physics and engineering (Enoka, 2004; Nigg & Herzog, 2007). The content of biomechanics can be separated in three main areas with substantial overlapping: medicine, engineering as well as movement and sport science.
The area of movement and sport science covers important interactions with motor control, training science, exercise physiology and orthopaedics. Due to the wide scope of application, sport biomechanics represents one of the main subcategories of biomechanics. The specific goals of sports biomechanics research primarily cover issues of

- performance enhancement
- comfort
- injury prevention and
- safety

regarding all kinds of sports: high performance, elite and competition; leisure and recreation; prevention and rehabilitation.
As in other scientific disciplines, sports biomechanics can be separated into basic and applied fields. Basic research deals with aspects to better understand the mechanics and control mechanisms of human sport movement and to investigate the response of loading in sport movements on biological structures. The applied field in sports biomechanics is very wide due to the manifold of characteristics of movement and locomotion in sports. The most important issues of the applied research are (Bartlett, 2007; Nigg & Herzog, 2007; Robertson et al., 2004):

- the application of biomechanical knowledge provided from basic research to sports in general,
- the biomechanical description and analysis of sport movements,
- the development of specific measurement and analysis methodology,
- the development and design of sport equipment,
- the effect of mechanical intervention (e.g. material, surface, equipment) on movement and motor control.

CHALLENGES OF APPLIED SPORT BIOMECHANICS RESEARCH:
Due to its specificity, the research of applied sports biomechanics is confronted with significant and substantial challenges. The specific and partly very complex circumstances of sport and sport disciplines (e.g. competition area, surface, material, equipment, partners and/or opponents, etc.) have to be considered and necessitate the development of appropriate biomechanical measurement and research methodologies. In close cooperation between biomechanical research groups and appropriate companies a large number of measurement devices and software packages have already been developed and are available on the market. For many very specific research questions and applications, however, these standard packages often are not adequate and not sufficient. In these cases innovative and appropriate hardware and software solutions have to be developed. A large number of sophisticated and useful solutions to these challenges have already been reported for many sport disciplines. Several examples can specifically be found in the journal ‘Sports Biomechanics’ (e.g. Schwameder et al., 2005; Stöggl et al., 2006; Ong et al., 2006, Elliott &

Alderson, 2007; Schwameder et al., 2008). Worth to mention is that these innovatively developed methods as a matter of course also have to cover the scientific demands of validity, reliability and accuracy. Furthermore, the more practical issues like range of usage, transfer, complexity, range of motion to be analysed, expenditure of time for data collection and data analysis, handling of the equipment, costs and the amount of interference of the measuring devices with the athletes have to be considered if the methodology should be used as a standard tool for training support and competition preparation.

One of the most important challenges in applied sports biomechanics is to overcome the discrepancy between reliability and validity of the collected data sets. In general, reliability (accuracy of determining or measuring the parameter value) and validity (degree to which a test or system measures what it was designed to measure) are independent from each other. In applied research fields like sports biomechanics, however, an interaction between reliability and validity might occur. This conflict often corresponds to the issue of collecting data in a lab or field situation. Usually, data collected in the lab are more accurate and reliable, but the validity can be substantially restricted. This should be explained by an illustrative example. Simulated take-offs in ski jumping performed on force plates provide very accurate and reliable data regarding the kinematics and dynamics of the take-off movement (Schwameder, 2007; Schwameder, 2008). It has to be considered, however, that in the lab situation the mechanical conditions are substantially different from hill jumps due to the differing friction and aerodynamic force situation. In simulated take-offs the friction between the boots and the surface is high and no aerodynamic forces act on the jumper. In hill jumps the conditions are vice versa (low friction between skis and track, high aerodynamic forces). Thus, the validity of the collected data might be substantially restricted. This has to be considered when the data are interpreted with respect to performance and coordination abilities.

Data collected in the field typically provide the opposite situation: high validity, but the accuracy and reliability might be restricted due to the lack of appropriate measurement devices. Up to now no measuring system is available, for example, to determine the ground reaction forces in hill jumps in three dimensions.

In competitive sport, the highest level of validity can only be guaranteed when data are collected during competitions; however, the regulations hamper the usage of biomechanical methodology in competitive conditions substantially. To overcome these problems data can be collected in semi-competitive situations. This can be performed in field studies providing conditions as close as possible to competitive situations, but also by mimicking competitions using simulation and/or imitation conditions.

The ‘golden standard’ is to establish measurement methods and conditions providing a combination of high validity, reliability and accuracy. Consequently, sport biomechanists should perform detailed error estimation in each specific situation of data collection for providing detailed information on data accuracy. Hence, specifically in complex situations, differentiated error estimation is challenging due to overlapping of errors from different sources. It can be distinguished between systematic errors (e.g. image distortion, calibration errors, placement of markers and electrodes, level of model abstraction) and random errors (e.g. errors due to signal resolution and sampling frequency, digitizing errors, cross talk etc.). In general, systematic errors are harmless when data sets are compared relatively. Although random errors can be severe, substantial reduction can be achieved by using appropriate filter and/or frequency analysis routines. Careful attention should be given to the issue of biovariance. As it is well known that repeated movements never can be performed identically, repeated movements have to be interpreted within a meaningful range of deviation. Hence, these deviations must not be assessed as errors. Nevertheless, the range of deviation has to be discussed along with the optional errors in data acquisition and data analysis.

Surprisingly, the report of accuracy, reliability, error estimation and validity is rather humble in papers dealing with applied biomechanics topics. These aspects, however, are very important to prevent researcher, coaches and athletes from misleading or misinterpretation of collected data.

In the literature sophisticated solutions regarding the aspects, issues and challenges on applied sports biomechanics research have already been reported. Further examples with a specific focus on mountaineering and winter sports using both lab and field studies will be presented with respect to usability, validity, reliability, accuracy and error estimation.

REFERENCES:

Bartlett, R. (2007). Introduction to Sports Biomechanics. London & Now York: Routledge.
Brüggemann, P. & Morey-Klapsing, G. (eds.) (2003). Biologische Systeme: Mechanische Eigenschaften und ihre Adaptation bei körperlicher Belastung. 7. Symposium der dvs-Sektion Biomechanik vom 13. - 15. März 2003 in Köln. Hamburg: Czwalina.
Elliott, B. & Alderson, J. (2007). Laboratry versus field testing in cricket bowling: A review of current and past practice in modelling techniques. Sports Biomechanics, 7 (1), 99-108.
Enoka R (2003). Neuromechanics of Human Movement. Human Kinetics, Champaign.
Nigg, B.M. & Herzog, W. (Eds.) (2007). Biomechanics of the musculo-skeletal system, 3rd ed., Chichester: Wiley & Sons Ltd.
Ong, K., Elliott, B., Ackland, T. and Lyttle, A. (2006). Performance tolerance and boat set-up in elite sprint kayaking. Sports Biomechanics, 5(1), 77-94.
Robertson, G. et al. (Eds.) (2004). Research Methods in Biomechanics. Champaign, Human Kinetics.
Schwameder, H., Lindenhofer, E., & Müller, E. (2005). Effect of walking speed on lower extremity joint loading in graded ramp walking. Sports Biomechanics, 4 (2), 227-243.
Schwameder, H. (2007). Current and future aspects of ski-jumping biomechanics. In V. Linnamo, P. Komi & E. Müller (eds.), Science and nordic skiing. (pp. 225-236). Oxford: Meyer & Meyer Sport.
Schwameder, H. (2008). Biomechanics research in ski jumping – 1991-2006. Sports Biomechanics, 7, 114-136.
Schwameder, H., Müller, E., Stöggl, T. & Lindinger, S. (2008). Methodology in alpine and nordic skiing biomechanics. In Y. Hong & R. Bartlett (eds.), Handbook of Biomechanics and Human Movement Science, (pp. 182-196). London: Routledge.
Stöggl, T., Lindinger, S.´& Müller, E. (2006). Biomechanical validation of a specific upper body training and testing drill in cross-country skiing. Sports Biomechanics, 5(1), 23-46.
Winter, D. (2004). Biomechanics and motor control of human movement. Chichester: Wiley & Sons.