Resource Guide in Sport & Exercise Biomechanics

INTRODUCTION

Whilst biomechanics is a wide ranging subject that can include all living things, sport and exercise biomechanics may be defined as the study of forces and their effects on humans in sport and exercise (McGinnis, 2005, p.3) This definition should also be expanded to include equipment such as running shoes, cricket balls, boxing gloves etc. Learning and teaching in biomechanics is often considered to be more difficult than other disciplines in sport and exercise science because it inherently requires a greater use of mathematics. Students, particularly those with a weakness in mathematics, are often more motivated to study this area if they are aware of the applications and benefits that it can have in sport and exercise. McGinnis (2005) recognises the goals of sport and exercise biomechanics to include the following, and includes some good examples of each:

- Performance Improvement, through:
    - Technique improvement.
    - Equipment improvement.
    - Training improvement.

- Injury Prevention and Rehabilitation, through:
    - Technique modification to reduce injury.
    - Equipment designs to reduce injury.

In both physiology and particularly psychology, the distinction between sport and exercise has become more apparent in recent years. However, the same transparency does not seem to exist in biomechanics; particularly in resources from the United States. Performance improvement, through whichever biomechanical means, applies primarily to sports biomechanics. Whereas, prevention of and rehabilitation from injury is important for both sports people and those involved in exercise, particularly after a time away from activity. Other areas of biomechanics that relate more to exercise than competitive sport include the design of exercise programmes to improve bone health, particularly in individuals who are susceptible to osteoporosis, or to improve balance and reduce the risk of falling in the elderly.

This guide aims to provide as complete a list of resources as possible for lecturers in sport and exercise biomechanics, in FE and HE. It includes texts on introductory biomechanics that are typically used to support teaching at Levels 1 and 2 of undergraduate study, and more advanced texts more suited to Level 3 or postgraduate study. Biomechanics is often a key element of modules that have been

developed in sports injury. In addition to chapters relating to this area in some introductory texts, whole books have been available in this area since the late 1990s; these are included in a separate section. Texts on topics of special interest (e.g. running shoes, data analysis methods) have also been written and these complete the list of books.

Journals have also been included, particularly those that would be most useful to teachers and students of sport and exercise biomechanics. Biomechanics societies are also present, some of these (e.g. International Society of Biomechanics in Sports) provide an excellent resource for teachers. Whilst it is recognised that websites may be transitory or stagnant some particularly useful ones that have remained stable for some time have been included.

ANNOTATED BIBLIOGRAPHY

This section contains an annotated guide to key sport & exercise biomechanics texts. They have been categorised to aid finding a suitable text, but some titles could be placed in more than one section. For example; Nigg and Herzog (1999) is included under Biomechanics of Injury although arguably could be categorised under Advanced Biomechanics. Many of the introductory texts draw practical examples from specific sports (e.g. Hay, 1993), so a separate section for sports performance has not been included. Other sections also include texts that focus on performance enhancement (e.g. Bartlett, 1999 and Zatsiorsky, 2000; both in the Biomechanics of Injury section)

Introductory Biomechanics Texts (in alphabetical order)

Adrian M.J. and Cooper J.M. (1995) *Biomechanics of Human Movement* (2nd edition), Madison, WIS: WCB Brown & Benchmark

In comparison to the majority of other texts, this text first deals with the measurement of the centre of gravity, then functional anatomy and then biomechanical principles, rather than grouping information into the more recognisable chapters on kinematics and kinetics. The second section on measurement tools contains some useful information, but is now largely outdated. Where this book differs from most is in its later and substantive section on the biomechanics of various movements. This begins with sections on exercise, rehabilitation and occupational biomechanics, and continues with activities that are covered elsewhere, such as running, jumping and kicking. Less common amongst introductory texts are sections on combative sports and those that take place on snow, ice and water. Both the age and unorthodox way in which this text is organised may prevent it from being a key resource on undergraduate biomechanics modules. However, it could serve as a useful resource for tutors and students seeking an overview of the biomechanics of activities other than mainstream sports.

Bartlett R. (1997) *Introduction to Sports Biomechanics*, London: E & FN Spon

Like most other introductory texts in this area, this one begins with a detailed account of bone, joint and muscle structure and function; although it doesn't contain the detailed functional anatomy that can be found in (e.g.) Hall's or Hamilton and Luttgen's texts. The following two chapters are devoted to a discussion of (linear and angular) kinematics and kinetics that goes beyond the level of detail offered by Hall/ Hamil and Knutzen. This trend is continued with a chapter on fluid mechanics and energetics that is far more detailed and complex than similar chapters that are found in other books within this section. Each chapter is also concluded by a series of exercises that are generally far more taxing that those presented in similar texts. The book's main strength is its second part that includes chapters which are devoted to

all the major methods of recording and analysing biomechanical data. Whilst the clear benefit of Bartlett's introductory text is that it provides more detail than others within this section, a limitation is the lack of quality and user friendliness of some of its figures. Regardless of this, it is still an extremely valuable text for undergraduates, although probably best suited for those at Level 2 and 3.

Carr G. (1997) *Mechanics of Sport: A Practitioner's Guide*, Champaign, IL: Human Kinetics
The omission of virtually all mathematical formulae from the coverage of linear and angular kinematics and kinetics make it largely unsuitable for undergraduates on sport and exercise science related courses. However, for those on coaching related courses who only need a basic understanding of biomechanical principles this would be a suitable text.

Dyson G.H.G. (revised by Woods B.D. and Travers P.R.) (1986) *Dyson's Mechanics of Athletics* (8th edition) London: Hodder and Stoughton
The revised edition of this classic text contains drawings from earlier editions and thus retains the feel of a book written more than twenty years ago. For this reason its chapters on biomechanical principles are relatively superficial, and it is unlikely to feature on reading lists for students studying introductory biomechanics on sport and exercise science related courses. That said it contains some useful information, none more so than the appendix showing a series of angular motion experiments using a turntable, weights and a bicycle wheel that have been used by many tutors.

Enoka R.M. (2002) *Neuromechanics of Human Movement* (3rd edition) Champaign, IL: Human Kinetics
The third edition of this book has a basic biomechanics section that has been expanded to over 200 pages from earlier versions, both of which went under the title of Neuromechanical Basis of Kinesiology. It includes basic concepts of linear and angular motion, but presents these very concisely and uses them as a stepping stone to more advanced concepts; including calculations of resultant muscles forces in both static and dynamic situations. Biomechanical measurement techniques (e.g. electro- and acoustomyography) are also included, as is an excellent section on curve fitting and smoothing. The biomechanics section concludes with a chapter dedicated to the biomechanics of running, jumping and throwing that is based on the findings of relevant and contemporary literature. More strengths of Enoka's text include its informative appendices on equations, SI units and conversion factors, as well as the extensive glossary and list of references. Despite covering basic topics, due to the style in which it is written and organised, this book should only be used to introduce biomechanics to students with a strong science background. Otherwise it should be used for selected topics from Level 2 of undergraduate study right up to postgraduate level. An accompanying graphics package can also be purchased that includes a CD-ROM containing over 260 Microsoft PowerPoint slides.

Hall S.J. (2003) *Basic Biomechanics* (4th edition) Boston, MA: McGraw-Hill
Arranged very much in the style of Hay's The Biomechanics of Sports Techniques, this text's later chapters are devoted to kinematic and kinetic concepts of linear and angular motion, as well as fluid mechanics. The book begins by defining many of the variables that are used in later chapters and includes a useful, although limited, introduction to biomechanical measurement techniques. An advantage of this book over some others within this section is its broad coverage of bone, joint and muscle structure and function as well as detailed chapters devoted to the functional anatomy of each of the major joints. Most chapters also contain related tutorial problems, suggested laboratory experiences and websites. As with many modern texts, both tutors and students can also benefit from McGraw-Hill's Online Learning Centre

(http://www.mcgraw-hill.com.au/highered/elearn/OLC.jsp) that provides simulations and animations, Microsoft PowerPoint presentations and a bank of test questions. Due to its coverage of a wide range of resources, this text is strongly recommended for use in the teaching of fundamental biomechanics at undergraduate level.

Hamill K.M. and Knutzen K.M. (2003) *Biomechanical Basis of Human Movement* (2nd edition) Philadelphia, PA: Lippincott, Williams & Wilkins
This text contains very much the same information as found in Hall's book and is structured in the same way. The first introductory section includes chapters on skeletal, muscular and neurological considerations, the middle section is devoted to functional anatomy of major joints. As an alternative to Hall's text, these chapters are centred more on the biomechanics of these joints during sports, exercise and daily living, whilst providing more anatomical information in appendices. The later mechanics chapters again logically separate content into linear and angular kinematics and kinetics. Review questions are contained at the end of each chapter and there is a companion website (http://connection.lww.com/productarea.asp?area=47) that contains an interactive quiz and resource centre for tutors, containing an image bank, Microsoft PowerPoint slides etc. The content of this text is at a slightly higher level than Hall's book, and it is also an excellent choice for basic biomechanics courses at undergraduate level.

Hamilton N. and Luttgens K. (2002) *Kinesiology: Scientific Basis of Kinesiology* (10th edition) Boston, MA: McGraw-Hill
Similar to both Hall's and Hamill and Knutzen's texts this begins by introducing skeletal, muscular and neuromuscular concepts before providing detailed chapters on the functional anatomy of major joints. This section has traditionally been and is still the strongest aspect of this book. The following section on basic biomechanics considers both kinematic and kinetic concepts together in separate chapters on linear and angular motion, but does not provide the same level of detail or range of examples as can be found in Hall or Hamill and Knutzen. This and the many now dated images that have been retained from previous editions may prevent this from being a recommended text on introductory biomechanics courses. It should, however, be included on reading lists of modules that include a focus on the kinesiological analysis of motion in sport and exercise. Being from McGraw-Hill, most chapters follow the same format as those in Hall's book, including website links and suggested laboratory experiences. Students and tutors can also benefit from the related resources available from McGraw-Hill's Online Learning Centre.

Hay J.G. (1993) *The Biomechanics of Sports Techniques* (4th edition) Englewood Cliffs, NJ: Prentice Hall
Despite being out of print, this text by the late James Hay should still be available in every university library that runs sports related courses and be included on module reading lists. The first edition in 1973 was the forerunner of what has now developed into a long list of texts dealing with sport & exercise related biomechanics. Many of these have copied the structure of Hay's book, which separates kinematic and kinetic concepts into both linear and angular sections. It also contains a basic section on fluid mechanics, but is most celebrated for the later chapters that are devoted to the biomechanics of specific American sports. The majority of these are analysed through Hay and Reid's (1988) hierarchical, deterministic models that show the relationships between the biomechanical variables that determine success in that particular sport. Examples of such models should be introduced to all undergraduates who are studying sports biomechanics.

Hay J.G. and Reid J.G. (1988) *Anatomy, Mechanics, and Human Motion* (2nd edition) Englewood Cliffs, NJ: Prentice Hall
This text includes fundamental linear and angular kinematics and kinetics presented in much the same was as in Hay's (1993) other introductory text. However, here the content is preceded by comprehensive sections on the skeletal system, muscular system and functional anatomy of the major joints of the body. Despite this material being reworked in subsequent contemporary texts (e.g. Hall, 2003 and Hamill and Knutzen 2003) it is still worth introducing to students studying sports biomechanics for its detailed section on qualitative analysis. This describes the creation of a model or block diagram that shows the relationship between a particular result and the factors that produce that result. The final sections develop this model, now more commonly referred to as a hierarchical, deterministic model for a number of sports including running, diving and serving in tennis.

Knudson D.V. and Morrison C.S. (2002) *Qualitative Analysis of Human Movement C*hampaign, IL: Human Kinetics
The majority of this text approaches qualitative analysis from a motor control perspective and is therefore of limited value in teaching sport and exercise biomechanics. However, an early chapter devoted to the role of models (including Hay and Reid's hierarchical models) in such analyses and a later one on the use of video are valuable resources. The book also comes with a CD-ROM that contains video clips of various sports, some at various developmental stages that are designed to be used with the interactive software, but could simply be used as a separate resource.

Kreighbaum E. and Barthels K.M. (1996) *Biomechanics: A Qualitative Approach for Studying Human Movement (*4th edition) Boston, MA: Allyn and Bacon
This book begins by covering the skeletal system, neuromuscular system and mechanical principals, although it provides more of an overview of the latter than maybe required on sport and exercise science courses. The middle section of the book includes comprehensive coverage of biomechanical relationships in the upper and lower extremities, trunk etc. Aerodynamics and hydrodynamics are then included in detail appropriate to undergraduate level before biomechanical principals are applied to specific sports. Unlike other texts these are grouped into those that involve throwing/pushing, balancing and rotating both free of support and whilst supported. Similar to Adrian and Cooper's text, both the age and unorthodox way in which it is organised may prevent it from being a key resource on undergraduate biomechanics modules.

McGinnis P.M. (2005) *Biomechanics of Sport and Exercise* (2nd edition) Champaign, IL: Human Kinetics
This book begins with a very useful chapter on the importance of studying biomechanics that should be brought to the attention of students about to take a module in this area. Following this, the chapters on forces, kinematics and kinetics, and work, energy and power vary very little from the content offered by other introductory texts (e.g. Hall) Skeletal, muscular and neural concepts are adequately covered, although in the middle of the book rather than at the start, as is the case in most others. Much of the final section is devoted to qualitative analysis of sports, including the use of hierarchical models and kinesiological analysis. The simple and user friendly way in which this text is presented, together with simple self-experiments and questions throughout make it a valuable resource, although mainly at Level 1.

Biomechanics of Injury Texts

Bartlett R. (1999) *Sports Biomechanics: Reducing Injury and Improving Performance* London: E & FN Spon
Building on his earlier introductory text, Bartlett divides this one equally into the two major areas of sports biomechanics. Beginning with sports injury, the book follows a traditional structure by dealing with the terminology relating to loading and material testing that most undergraduates would be unfamiliar with. Material properties of bone, cartilage, muscle, ligament and tendon are described as well as injuries to specific areas of the body. A useful chapter on the effects of equipment and technique on injury is included and the section is concluded by calculations of joint reaction forces and moments. The second section provides a comprehensive introduction to both simple and complex models that are used to simulate and optimise sports performance. Included are statistical modelling that further explores the hierarchical approach described by Hay and Reid (1988), mathematical modelling and simulation of various sports, as well as more complex models of muscle and the sports performer. The author's experience in athletics provides the majority of the examples in these sections, which also include an often ignored section on how biomechanical information should best be fed back to and used by coaches. As with Bartlett's first introductory text, this one suffers from relatively crude figures and a general non-user friendliness, particularly in the area of calculating joint forces and moments, which may persuade students to search for similar material elsewhere. Despite this, it is a useful text for undergraduates at Levels 2 and 3, and postgraduates.

Nigg B.M. and Herzog W. (Eds.) (1999) *Biomechanics of the Musculo-Skeletal System* (2nd edition) Chichester: John Wiley & Sons
This is a superbly organised book that begins with an enlightening historical view of biomechanics, which is a theme that continues throughout. The text and figures are presented in a clear and standardised fashion that match the level of readership to which it is intended; which is the upper end of undergraduate but more likely postgraduate level. It covers an extensive range of topics that continues with detailed chapters on the physical and biomechanical properties of bone, cartilage, ligament, tendon and muscle; before discussing how these properties are affected by exercise, disease and age. The middle section is devoted to often detailed descriptions of virtually all of the measuring techniques that are used in biomechanics, as well as applications of these that are geared mainly towards human motion. The final section on modelling is intended for those with a strong mathematical background and is a must for any student embarking on a higher degree in this area. Extensive glossaries and reference lists at the start and end of each section add to the book's value.

Nordin M. and Frankel V.H. (2001) *Basic Biomechanics of the Musculoskeletal* System (3rd edition) Philadelphia, PA: Lippincott, Williams & Wilkins
Whilst written for a more clinical audience than for students of sport and exercise biomechanics, this text is a worthwhile inclusion on the reading list of modules including injury biomechanics. It provides excellent detail on the mechanics of biological materials and on injury related biomechanical factors of specific joints. As a further attraction to tutors and students with more of an interest in exercise biomechanics, this third edition also includes new informative chapters on standing, sitting, lying and gait.

Watkins J. (1999) *Structure and Function of the Musculoskeletal System* Champaign, IL: Human Kinetics
Following a summary of elementary mechanics the remainder of this text is largely devoted to the structure and function of the musculoskeletal system, as its title would

suggest. The later chapters (from nine onwards) warrant its inclusion among injury related texts, as these deal with the calculation of muscle moments and joint reaction forces, including a comparison between lifting techniques, as well as loading and its effect on the properties of biological tissues. The material is well organised, with clear diagrams and provides sufficient detail for the study of this area at undergraduate level.

Whiting W.C. and Zernicke R.F. (1998) *Biomechanics of Musculoskeletal Injury* Champaign, IL: Human Kinetics
This text is an ideal companion for any module that includes the biomechanics of sports injury. The early chapters set the scheme by recapping on both the structure and function of biological tissues and on mechanical concepts relating to materials. A summary of how tissues adapt to factors such as ageing and exercise follows before the bulk of the book is given over to mechanisms of injury and the biomechanics of injuries to specific areas. Clear figures, an easy to read style and text boxes assigned to the discussion of key areas make this book particularly useful and student friendly.

Advanced Biomechanics Texts

Allard P. Stokes I.A.F. Blanchi J.P. (Eds.) (1995) *Three-Dimensional Analysis of Human Movement* Champaign, IL: Human Kinetics
The first part of this text includes chapters on the use of video and other optoelectronic systems in obtaining 3D co-ordinates. The second section describes various 3D models of the musculoskeletal system, commonly used to estimate muscle and joint forces, and the final section illustrates how 3D analysis has been applied, including a chapter relating to sports. Chapters are written by recognised experts and, despite being ten years old now, the book is still a valuable resource for postgraduate students and tutors.

Allard P. Cappozzo A., Lundberg A. Vaughan C.L. (Eds.) (1997) *Three-dimensional Analysis of Human Locomotion* Chichester: John Wiley & Sons
This is essentially a text that concentrates on gait analysis, with kinematic and kinetic data for a range of populations presented in the final chapters. However, it should also be of interest for biomechanists working in other fields due to the inclusion of more general chapters on real-time motion analysis systems and the measurement of force, acceleration and power. Chapters on the use of 3D co-ordinates of external markers to predict joint centres of rotation and the measurement of joint kinematics are also very useful summaries of research in these areas.

Dainty D.A. and Norman R.W. (Eds.) (1987) *Standardizing Biomechanical Testing in Sport* Champaign, IL: Human Kinetics
Most of the information in this text relating to the equipment used in biomechanics is now very dated and consequently of little use. Sections on the relevance of using particular measurement techniques and some of the information on measurement procedures are still informative and of use for Level 3 undergraduates and postgraduates.

Robertson D.G.E. Caldwell G.E. Hamill J. Kamen G. Whittlesey S.N. (2004) *Research Methods in Biomechanics* Champaign, IL: Human Kinetics
This text succeeds in describing how modern measurement techniques are used to collect and analyse biomechanical data. The first two parts are dedicated to kinematics and kinetics, with both two and three-dimensional techniques being expertly explained. Other techniques including electromyography, muscle modelling, computer simulation and signal processing complete those available for biomechanical analysis. This book is recommended as a primary resource for any

module that has biomechanical measurement techniques as its focus. It is well illustrated and is written in a user friendly style that Level 3 undergraduates and postgraduates with a reasonably good mathematical background will understand. Some very useful appendices, a decent glossary and a current reference list complete an excellent text.

Winter D.A. (2004) *Biomechanics and Motor Control of Human Movement* (3rd edition) New York: John Wiley & Sons
This, and the earlier editions before it, has long been one of the key texts on Level 3 undergraduate and postgraduate modules in biomechanics. In addition to the chapters on kinematics, including a particularly useful section on the processing of raw data, a new chapter is included that is devoted to understanding both 2D and 3D measurement. The structure of the remainder of the book is largely unchanged with chapters devoted to anthropometry, work energy and power, muscle mechanics and electromyography.

Zatsiorsky V.M. (1998) *Kinematics of Human Motion* Champaign, IL: Human Kinetics
This is an excellent text that provides details on the measurement of linear and angular kinematics during human motion. A summary of key journal articles serve to bring the text to life, as do examples. Some of these are from sport and exercise, including the tennis serve as an example of a kinematic chain. The second part of the book provides detailed representations of the kinematics of the vast majority of the joints of the body. The text is clearly aimed at postgraduate students and tutors that already have a sound knowledge of biomechanics and mathematics, although it does include a number of refresher pages. Parts of the book at least should be essential reading for all students studying biomechanics at postgraduate level.

Zatsiorsky V.M. (2002) *Kinetics of Human Motion* Champaign, IL: Human Kinetics
Another excellent text that follows on from the same author's *Kinematics of Human Motion* and is written in the same style. The first section on external contact forces contains many examples from sport and exercise, and summarises many seminal papers. All topics that would expect to be found in this book are covered in a comprehensive fashion including the calculation of joint torques and forces, and mechanical work and energy. There is also a chapter on inertial properties of the human body with a comprehensive appendix including relevant data. The text is again aimed at postgraduate students and tutors, who should find most, if not all of the book a valuable resource.

Texts on Special Topics in Biomechanics

Cavanagh P.R. (Ed.) (1990) *Biomechanics of Distance Running* Champaign, IL: Human Kinetics
A collection of chapters that summarise the position of running related biomechanics research at the end of the 1980s. This book covers the measurement of rear foot motion and ground reaction forces in a more organised and understandable format than Nigg's earlier text. Key summaries on muscle activity, acceleration, injury and economy in running are also included, these would make excellent starting points for students or tutors interested in researching or teaching these areas.

Epstein M. and Herzog W. (1998) *Theoretical Models of Skeletal Muscle* Chichester: John Wiley & Sons
The first part of this text provides a basic introduction to skeletal muscle and an overview of models that have been used to represent its structure and function. Thus, it is an ideal starting point for Level 3 undergraduate and postgraduate students as well as tutors who are starting to work in this area. Applications of these models are covered in the second part of the book, which is more suitable for postgraduates and tutors with some experience of muscle models.

Frederick E.C. (Ed.) (1984) *Sport Shoes and Playing Surfaces: Their Biomechanical Properties* Champaign, IL: Human Kinetics
This out of print book includes eleven edited chapters that summarise much of the biomechanical research into sports shoes and surfaces, which became popular in the 1970s and 1980s. It is presented in a form similar to Biomechanics of Running Shoes and is again a useful resource for students and tutors with an interest in these areas.

Grabiner M.D. (Ed.) (1993) *Current Issues in Biomechanics* Champaign, IL: Human Kinetics
A text that includes very informative chapters on issues that were current at the start of the 1990s and, in many cases, are still relevant today. Written by experts in their field, each chapter provides an excellent starting point for both students and tutors beginning teaching or research in these areas.

Hong Y. (Ed.) (2002) *International Research in Sports Biomechanics* London: Routledge
This is a collection of short papers that were considered by the editors to be the best from the XVIIIth Symposium of the International Society of Biomechanics in Sports (ISBS), Hong Kong 2000.

Latash M.L. and Zatsiorsky V.M. (Eds.) (2001) *Classics in Movement Science* Champaign, IL: Human Kinetics
This text devotes a chapter to the pioneering work of each of twelve movement scientists from the late nineteenth and twentieth centuries. Each chapter is written by a contemporary scientist who gives an introduction to the pioneer before providing a commentary of their seminal work. Whilst most of the chapters relate to biomechanics, some lean more heavily towards discoveries made in muscle physiology or motor control. Nevertheless, it is an interesting text that will allow postgraduate students and tutors to discover or rediscover research that shaped developments in movement science.

Nigg B.M. (Ed.) (1986) *Biomechanics of Running Shoes* Champaign, IL: Human Kinetics
Despite being nearly twenty years old this text, which is now out of print, is still a useful library resource for aspects of biomechanics modules that deal with this popular subject. The early chapters summarise methods used to measure rear foot motion and forces acting on the musculoskeletal system during running that were popularised in the early 1980s. Some of the later chapters summarise findings from the plethora of research that was carried out in this area during the same period.

Nigg B.M. MacIntosh B.R. and Mester J. (Eds.) (2000) *Biomechanics and Biology of Movement* Champaign, IL: Human Kinetics
This edited text is divided up into sections on work and energy, balance and control, load during physical activity, and fatigue and exercise. The first chapter in each section provides a valuable introduction to the area, while the remaining chapters concentrate on specific current areas of interest. In the early section, students with

an interest in sport and exercise biomechanics will find the chapters on musculo-tendinous unit length changes during sports by Hay, and the influence of athletic equipment on work and energy by Stefanyshun and Nigg to be most interesting. The second section contains a chapter by Yeadon on stability and control in aerial sports, while the majority of the third section on loading will be of interest to students studying biomechanics relating to sport and exercise. The book is presented in a similar style to Nigg and Herzog (1999) and, as such, is generally very readable for undergraduates in their last year, or postgraduates.

Stergiou N. (Ed.) (2004) *Innovative Analyses of Human Movement: Analytical Tools for Human Movement Research* Champaign, IL: Human Kinetics
This text deals with more complex processing and statistical analyses used in biomechanics and motor control that are generally not covered in other texts. The first two sections of the book on variability of movement, and co-ordination and stability may only be of use to postgraduate students and tutors working in these areas; but the final section on data analysis, including cross-correlation, power spectrum analysis and filtering will be of interest to most.

Zatsiorsky V. M. (Ed.) (2000) *Biomechanics in Sport: Performance Enhancement and Injury Prevention* Oxford: Blackwell Science
Despite its title, this text concentrates far more on the biomechanics of performance in specific sports than on injury mechanisms. Chapters written by an array of renowned experts are categorised under locomotion, jumping and aerial movement, throwing and hitting, and special Olympic sports. In addition to chapters on injury prevention and rehabilitation, the text begins with some excellent chapters on the biomechanics of muscle. Whilst relevant chapters of the text could be useful for Level 2 undergraduates, it is probably more suitable for Level 3 or postgraduate students; particularly those beginning project work in any of the many areas of sports biomechanics that are included. This book should be available in the library of any university that offers sports biomechanics modules at undergraduate and postgraduate level.

ANNOTATED GUIDE TO JOURNALS

This section contains an annotated guide to the main journals that sport and exercise biomechanists publish in.

BioMechanics - The Magazine of Body Movement and Medicine
www.biomech.com/index.jhtml
This monthly publication contains contemporary articles on the biomechanics of medical related issues. Some of the articles are summarised from research papers previously published in related journals or conference proceedings.

Clinical Biomechanics
www.intl.elsevierhealth.com/journals/clbi/
This journal contains research articles as well as review papers and correspondence on all aspects of biomechanical research relating to the causes and management of musculoskeletal injury.

Gait and Posture
www.intl.elsevierhealth.com/journals/gapo/
This is the official journal of the Gait and Clinical Movement Analysis Society (GCMAS) and includes research articles relating clinical aspects of balance and locomotion.

Human Movement Science
www.elsevier.com/wps/find/journaldescription.cws_home/505584/description#description
This is primarily a journal for research output in the fields of psychology and neurophysiology, although most issues contain at least one article with a clinical or sports biomechanics based theme.

Isokinetics and Exercise Science
www.iospress.nl/html/09593020.php
This journal concentrates on research into the theoretical and applied aspects of human muscle performance. As the title suggests it takes a particular interest in exploring the considerable potential of isokinetic dynamometry, particularly with respect to the issues of reproducibility and validity of testing.

Journal of Applied Biomechanics
www.humankinetics.com/JAB/journalAbout.cfm
Formerly the *International Journal of Sports Biomechanics*, this journal now has a wider remit to publish research articles on human biomechanics relating to sport, exercise and rehabilitation. A special issue of this journal in 1997 (13[4]) was dedicated to the mechanics and energetics of the stretch-shortening cycle.

Journal of Biomechanics
www.jbiomech.com/
This journal is widely considered to be the most prestigious by biomechanists and is the official journal of the International Society of Biomechanics (ISB), among other societies. It includes research articles, letters to the editor and book reviews on all aspects of biomechanics, which often include those relating to sport and exercise.

Journal of Electromyography and Kinesiology
www.intl.elsevierhealth.com/journals/joek/
This is the official journal of the International Society of Electrophysiology and Kinesiology (ISEK) and includes research articles on the use of electromyography in the understanding of muscle contraction.

Journal of Sports Science
www.tandf.co.uk/journals/titles/02640414.asp
This is the official journal of the British Association of Sport and Exercise Sciences (BASES), which publishes biomechanics articles along with those from other related disciplines. An edition of the journal is also devoted to abstracts from the BASES Annual Conference.

Medicine & Science in Sports & Exercise
www.ms-se.com/pt/re/msse/home.htm;jsessionid=CAIs1xabbNxX0E31nCHNchYBBw5uL1nh4kS1hCSxiy8QxJapKDFL!-1738921856!-949856031!9001!-1
This is the official journal of the American College of Sports Medicine. It covers a wide range of topics in sport and exercise science and usually has more than one article relating to sport, exercise or clinical biomechanics in the Applied Sciences section.

Sports Biomechanics
www.uni-stuttgart.de/External/isbs/Journal/journal.htm
This relatively new publication is the official journal of the International Society of Biomechanics in Sports (ISBS). In addition to publishing original research articles

and reviews, the journal also accepts articles related to the teaching of sports biomechanics.

ANNOTATED GUIDE TO SOCIETIES

This section contains an annotated guide to societies that biomechanists belong to. Most of them also contain or have links to resources for teachers.

British Association of Sport and Exercise Sciences (BASES)
www.bases.org.uk/newsite/home.asp
The education link of the BASES website provides links to other useful learning and teaching related sites. BASES also co-ordinates a series of workshops on measurement techniques used in biomechanics that are useful for tutors or researchers wishing to know more about current developments in these areas.

Gait and Clinical Movement Analysis Society (GCMAS)
www.guardian.curtin.edu.au/cga/
This is a site with a wealth of information that should be useful to biomechanists even if their areas of interest lie outside of the clinical environment. There is a 'teach-in' section containing over twenty laboratory exercises, many of which would be suitable for sport and exercise science undergraduates or postgraduates. Links are also provided to sites containing biomechanical data, software and videos, as well as suppliers of biomechanics equipment.

International Society of Biomechanics (ISB)
www.isbweb.org/
More geared towards researchers than teachers, this informative site contains an Information Services link to other related societies, standards for reporting global and joint co-ordinate systems, as well as data and software resources.

International Society of Electrophysiology and Kinesiology (ISEK)
http://www.isek-online.org/
A site that contains some useful links to other electromyography related sites, as well as ISEK's 'Standards for Reporting EMG Data'.

International Society of Biomechanics in Sports (ISBS)
www.uni-stuttgart.de/External/isbs/
This site contains links to both the ISBS Coaches' and the Teachers' information services (see Annotated Guide to Internet Resources below) In addition, it also contains a limited number of links to other teaching aids and a Student's Corner area designed for them to submit questions to the site.

International Sports Engineering Association (ISEA)
www.sportsengineering.co.uk/
This site contains a limited number of links to technological developments in specific sports.

ANNOTATED GUIDE TO INTERNET RESOURCES

This section contains an annotated guide to sport & exercise related biomechanics resources on the internet that can be integrated into lectures, tutorials etc.

Biomechanics Classes on the Web

darkwing.uoregon.edu/~karduna/biomechanics/

Dr. Andrew Karduna has collated biomechanics resources relating to different branches of biomechanics from dozens of universities. Those searching for resources in sport and exercise biomechanics should follow the Kinesiology link. Unfortunately, no facility exists to search for chosen topics so the user has to invest time in trawling through the links to over thirty biomechanics courses. While many are limited to providing only a syllabus and reading list, or require a password for entry, others provide free access to lecture notes, PowerPoint slides, laboratory activities and test questions. Some of these links provide excellent resources such as those to courses running in the School of Human Kinetics at the University of Ottawa, Canada.

BioLab - Biomechanics Teaching & Learning Tool Box

http://www.biolab.org.uk/

The BioLab project aims to develop a teachers' resource to improve accessibility and enhance the quality of sport and exercise biomechanics teaching and learning within sport-related degree and HND courses. Through the development of a Biomechanics Teaching & Learning Tool Box we hope to facilitate an increase in the opportunities for students to study biomechanics from an entry level through to degree level three and beyond. Site content includes: sample materials for download, project background, contact info & links to biomechanics related internet resources.

The International Society of Biomechanics in Sports (ISBS) Teachers' Information Service (TIS)

www.usfca.edu/ess/tis/

This site is similar to Biomechanics Classes on the Web in that it provides links to biomechanics and kinesiology university courses. Although there is a large overlap between many of the resources on the two sites, this one has the advantage of categorizing them into Guidelines and Tutorials, Homework Problems, and Laboratory Exercises to making searching a little easier.

Altis – Sport & Exercise Science – Biomechanics

altis.ac.uk/browse/126/13.html

This provides links to a wide variety of sport and exercise biomechanics related sites, including links to journals, societies and articles as well as synopses on the biomechanics of various sports. The latter are made available from the Coaches' Infoservice.

ISBS Coaches' Infoservice

www.coachesinfo.com/

This site provides links to articles and discussions on the biomechanics of a wide variety of sports. The articles are written by biomechanics experts who are also experienced in working within the relevant sport, and are an excellent resource.

Multimedia Physics Studios

www.glenbrook.k12.il.us/gbssci/phys/mmedia/index.html

A collection of GIF animations and accompanying explanations of major physics concepts. Whilst many of these won't be relevant to those teaching sport & exercise

biomechanics some of those listed under, for example Newton's Laws, and Vectors and Projectiles will provide useful and amusing inserts to PowerPoint slide shows.

Interactive Physics
www.interactivephysics.com/simulationlibrary/
This site is similar to the Multimedia Physics Studios in that it provides a library of GIF animations that can be inserted into PowerPoint presentations. Most useful for the sport and exercise biomechanist are the Projectiles, Vectors, and Work and Energy libraries.

Animated Stick Figure
www.biomotionlab.ca/Demos/BMLwalker.html
This shows a loop of an interactive walking stick figure. By altering the sex, mass and even the mood of the walker the user can observe the affect these variables have on the kinematics of walking. This is particularly useful for demonstrating the effect of obesity on gait.

Projectile Motion Simulation
galileo.phys.virginia.edu/classes/109N/more_stuff/Applets/ProjectileMotion/enapplet.html
This is an interactive applet that allows the user to change the input parameters of a simple projectile and observe the influence that they have on the range, height and time of flight.

DelSys – Surface Electromyography.
www.delsys.com/library/library.htm
Despite being the site of a commercial company, the DelSys library link provides a number of excellent tutorials about best practices in surface electromyography.

KAVideo
www.kavideo.sfsu.edu/
This site contains a free download of KAVideo software developed by Professor Robert Schleihauf from San Francisco State University. KAVideo can be used to digitise videos taken in laboratory sessions and provides linear and angular kinematic data. It can be loaded onto multiple computers and therefore provide an opportunity for students to gain hands-on experience of video digitising and analysis.

TEACHING AND LEARNING STRATEGIES

Teaching and learning strategies for modules in biomechanics are similar to those outlined in the HEA Sport and Exercise Physiology Resource Guide by Dr Richard Tong:

- Learning outcomes of the programme/module.
- Associated modules within the programme.
- Background knowledge of the students.
- Group size and available resources and facilities.

Biomechanics should be a major element, alongside physiology, psychology and research methods, in undergraduate courses relating to sport and exercise science. Such courses should include biomechanical principals relating to kinematics and kinetics of both linear and angular motion at levels 1 and 2. Students should also be able to gain experience of the major measurement techniques used in biomechanics

during the early years of the course. If primarily a science based course, students should also be exposed to biomechanics using both qualitative and quantitative approaches. An underpinning scientific foundation should be provided in the former approach by the use of (e.g.) hierarchical, deterministic models that link the performance outcome to the factors that cause that outcome (see Hay and Reid, 1988) Students should also appreciate how biomechanics can be used to solve problems in sport and exercise along with other subjects using multi or ideally interdisciplinary approaches. More specialist topics such as material biomechanics and biomechanical modelling should also be introduced at levels 2 and 3 if the course allows. For students who are studying on a sport related course with less scientific emphasis (e.g. Sports Coaching or Sports Studies), the amount of biomechanics on the curriculum may be reduced due to the greater importance of other topics. It is advised that for such students a more qualitative approach should be adopted for teaching and learning.

As biomechanics can be defined as “the application of the principles of mechanics to the study of biological systems” (Enoka, 2002, p. 1), students studying sport and exercise related degree topics should also develop knowledge and understanding of skeletal, muscular and neurological considerations as well as a functional anatomy of major joints. Whilst these are more than adequately covered in many of the Introductory Biomechanics Texts listed above, they are not always covered in biomechanics modules. Often these topics form a single module at Level 1, or some aspects are covered in biomechanics, others in physiology or psychology modules. Regardless of where the material is included, it is vital that students studying biomechanics also cover these topics and appreciate how they complement each other.

The mathematical background of students on introductory biomechanics modules often varies from those who have A Levels in mathematics and physics to those who have not reached GCSE Level. As a minimum, teaching and learning of quantitative biomechanics at Level 1 should require students to be able to perform simple trigonometry, Pythagoras’ Theorem and to rearrange and solve simple equations. In my experience the use of websites that are designed to refresh these skills in conjunction with group and individual tutorials are usually sufficient to allow students to reach this level.

In most HEIs biomechanics is still taught by delivering a lead lecture and following this up with laboratory and/or tutorial sessions. On-line learning software such as WebCT or Blackboard is ideal for teaching and learning in biomechanics, not only as a repository for lecture and laboratory notes and data, but as a platform for formative tests at Level 1 and discussion groups at higher levels. Lectures should be supported by laboratory sessions containing, ideally, less than 20 students to allow theoretical concepts and principals to be applied to sport or exercise situations; and therefore facilitate students’ knowledge and understanding. The best equipped laboratories will include one or more force platforms, 2D and 3D video digitising and analysis equipment and software, an electromyography system and dynamometers. However, laboratory sessions can be run using less sophisticated equipment such as stop watches, tape measures and timing gates. Most education establishments have access to video cameras and playback facilities, and digitising and analysis software can be downloaded for free (see KA Video in Annotated Guide to Internet Resources).

ASSESSMENT

The methods of assessment used in biomechanics related modules are again similar to those outlined in the HEA Sport and Exercise Physiology Resource Guide. At

Level 1 students are typically assessed using short answer or multiple choice questions, often administered electronically through on-line learning software (e.g. WebCT) It is also important that students begin to develop academic, scientific writing skills as early as possible. Writing up a complete laboratory report is often too onerous for students at Level 1, so a way around this is to assess them only on the (e.g.) results section in one laboratory session and then develop this into both the results and discussion sections in the next assessment. To reduce the risk of over assessing students, this developmental assessment technique can be spread over modules (e.g. physiology and biomechanics) that share the same skills. This approach ensures that students are better equipped to write full laboratory reports at Level 2. Particularly at undergraduate levels 2 and 3, and at postgraduate level, students can be assessed by a variety of means including posters, oral presentations, debates and even practical assessments.

ABOUT THE AUTHOR

Dr Adrian Burden is a Principal Lecturer in Biomechanics at Manchester Metropolitan University, Cheshire, where he has the role of co-ordinating activity in Learning & Teaching and Staff Development within the Department of Exercise & Sport Science. Adrian is also currently the Programme Leader for the BSc (Hons) Sport, Exercise and Coaching Science degree at MMU, having previously worked at Brunel and Brighton Universities. He has been involved in the BASES Education & Training Committee since 1998 and served as its Chair in 2004/5. He is research accredited by BASES and his main research interests involve applications of electromyography in sport, exercise and clinical settings.