

# **10th Biennial Conference on the Engineering of Sport 2014**

**Procedia Engineering Volume 72**

**Sheffield, United Kingdom  
14-17 July 2014**

**Editors:**

**David James**

**ISBN: 978-1-63266-905-6**

# TABLE OF CONTENTS

<b>PREFACE</b> .....	1
<i>David James</i>	
 <b><u>ATHLETE MEASUREMENT</u></b>	
<b>A STUDY OF WIRELESS COMMUNICATION LINKS ON A BODY CENTRIC NETWORK DURING RUNNING</b> .....	3
<i>Haider A. Sabti</i>	
<b>A METHOD TO OPTIMIZE A TYPOLOGY-BASED CLASSIFICATION SYSTEM</b> .....	9
<i>Christophe Schnitzler</i>	
<b>ACCELEROMETER BASED PERFORMANCE ASSESSMENT OF BASIC ROUTINES IN CLASSICAL BALLET</b> .....	14
<i>David V. Thiel</i>	
<b>A NOVEL METHOD TO FIND THE NEUTRAL POSITION OF THE BREAST</b> .....	20
<i>Miranda Knight</i>	
<b>ANALYSING SPLASH IN COMPETITIVE DIVING</b> .....	26
<i>Heather Driscoll</i>	
<b>ASSESSMENT OF FOOT KINEMATICS DURING STEADY STATE RUNNING USING A FOOT-MOUNTED IMU</b> .....	32
<i>G. P. Bailey</i>	
<b>DESIGN AND TEST OF A CUSTOM INSTRUMENTED LEG PRESS FOR INJURY AND RECOVERY INTERVENTION</b> .....	38
<i>Daniel A. James</i>	
<b>CHARACTERISTICS OF MOVEMENT AND FORCE EXERTED BY SOCCER GOALKEEPERS DURING DIVING MOTION</b> .....	44
<i>Keita Matsukura</i>	
<b>COMPARISON OF KICKING SPEED BETWEEN FEMALE AND MALE SOCCER PLAYERS</b> .....	50
<i>Keiko Sakamoto</i>	
<b>COMPARISON OF KINEMATIC ACQUISITION METHODS FOR MUSCULOSKELETAL ANALYSIS OF UNDERWATER FLYKICK</b> .....	56
<i>Christopher W. G. Phillips</i>	
<b>CONTACT STATE BETWEEN FINGERTIP AND BALL BEFORE BALL-RELEASE OBSERVED THROUGH STRAIN OF NAILS DURING BASEBALL PITCH</b> .....	62
<i>Kenji Saitou</i>	
<b>CYCLING POWER OPTIMIZATION SYSTEM USING LINK MODELS OF LOWER LIMBS WITH CLEAT-SHAPED BIAXIAL LOAD CELLS</b> .....	68
<i>Akihiro Matsuda</i>	
<b>A CAMERA CALIBRATION METHOD FOR A HAMMER THROW ANALYSIS TOOL</b> .....	74
<i>John Kelley</i>	
<b>DEVELOPMENT OF A DYNAMOMETER TO MEASURE GRIP FORCES AT A BICYCLE HANDLEBAR</b> .....	80
<i>Dominik Krumm</i>	
<b>AN ATTEMPT FOR MEASURING SNOWBOARDING PERFORMANCE USING COMPACT FORCE SENSORS</b> .....	86
<i>Akiko Kondo</i>	
<b>DOES THE USE OF A LIGHT SHOT PUT MODIFY THE THROWING PATTERN OF ELITE ATHLETES?</b> .....	92
<i>Daniel Dinu</i>	
<b>DYNAMIC CONTRIBUTION ANALYSIS OF TENNIS-SERVE-MOTION IN CONSIDERATION OF TORQUE GENERATING MODE</b> .....	97
<i>Sekiya Koike</i>	
<b>DYNAMIC THERMAL RECEPTOR RESPONSE AND COMFORT IN COLD AND WARM ENVIRONMENTS</b> .....	103
<i>Marius Janta</i>	

<b>DYNAMIC TRACKING OF A 2.4GHZ WAIST MOUNTED BEACON FOR INDOOR BASKETBALL PLAYER POSITIONING .....</b>	<b>108</b>
<i>James A. Kirkup</i>	
<b>EFFECTS OF ELASTIC COMPRESSION SLEEVES ON THE BIODYNAMIC RESPONSE TO EXTERNAL VIBRATION OF THE HAND-ARM SYSTEM.....</b>	<b>114</b>
<i>Stephan Odenwald</i>	
<b>EFFECTS OF TEXTURED SOCKS ON BALANCE CONTROL DURING SINGLE-LEG STANDING IN HEALTHY ADULTS .....</b>	<b>120</b>
<i>Jonathan S. Wheat</i>	
<b>A NOVEL, REAL-TIME BIOMECHANICAL FEEDBACK SYSTEM FOR USE IN ROWING .....</b>	<b>126</b>
<i>Philip Harfield</i>	
<b>ESTIMATING ENERGY EXPENDITURE DURING FRONT CRAWL SWIMMING USING ACCELEROMETERS.....</b>	<b>132</b>
<i>Nikolai B. Nordsborg</i>	
<b>A MODERN APPROACH TO DETERMINE THE OFFSIDE LAW IN INTERNATIONAL FOOTBALL.....</b>	<b>138</b>
<i>Alexander Henderson</i>	
<b>CHANGES IN CLUB HEAD TRAJECTORY AND PLANARITY THROUGHOUT THE GOLF SWING .....</b>	<b>144</b>
<i>Andrew Morrison</i>	
<b>IMPACT OF ELECTRICAL ASSISTANCE ON PHYSIOLOGICAL PARAMETERS DURING CYCLING .....</b>	<b>150</b>
<i>Daniel Meyer</i>	
<b>INTEGRATING ADVANCED VISUAL INFORMATION WITH BALL PROJECTION TECHNOLOGY CONSTRAINS DYNAMIC INTERCEPTIVE ACTIONS.....</b>	<b>156</b>
<i>J. A. Stone</i>	
<b>EFFECTS OF TEXTURED COMPRESSION SOCKS ON POSTURAL CONTROL IN PHYSICALLY ACTIVE ELDERLY INDIVIDUALS .....</b>	<b>162</b>
<i>M. T. Woo</i>	
<b>VISUAL TRACKING OF A GPS TARGET WITHIN A FIELDLAB .....</b>	<b>168</b>
<i>Leon Foster</i>	
<b>MEASUREMENTS OF TENNIS PLAYERS' SPECIFIC FOREARM MUSCLE FORCE IMBALANCE TO ASSESS THE POTENTIAL RISK OF LATERAL EPICONDYLITIS.....</b>	<b>174</b>
<i>Chris Hayot</i>	
<b>MODEL BASED AUTOMATED CYCLING ERGOMETER.....</b>	<b>180</b>
<i>N. Chakravorti</i>	
<b>MODERATE EFFORT INSTEP KICK IN FUTSAL .....</b>	<b>186</b>
<i>Shariman Ismadi Ismail</i>	
<b>INTER-ANALYST VARIABILITY IN SWIMMING COMPETITION ANALYSIS.....</b>	<b>192</b>
<i>Chris Hudson</i>	
<b>PATTERN RECOGNITION IN CYCLIC AND DISCRETE SKILLS PERFORMANCE FROM INERTIAL MEASUREMENT UNITS.....</b>	<b>196</b>
<i>Ludovic Seifert</i>	
<b>PERMANENT RFID TIMING SYSTEM IN A TRACK AND FIELD ATHLETIC STADIUM FOR TRAINING AND ANALYSING PURPOSES.....</b>	<b>202</b>
<i>H. Woellik</i>	
<b>PORTABLE INERTIAL MOTION UNIT FOR CONTINUOUS ASSESSMENT OF IN-SHOE FOOT MOVEMENT.....</b>	<b>208</b>
<i>Nicolai L. Mifsud</i>	
<b>BIOMECHANICAL MEASUREMENTS OF HUMAN IMPACTS IN BASKETBALL.....</b>	<b>214</b>
<i>Benjamin Halkon</i>	
<b>THE EFFECTS OF DIFFERENT DELIVERY METHODS ON THE MOVEMENT KINEMATICS OF ELITE CRICKET BATSMEN IN REPEATED FRONT FOOT DRIVES.....</b>	<b>220</b>
<i>Chris Peploe</i>	
<b>THE SMARTFLOOR: A LARGE AREA FORCE-MEASURING FLOOR FOR INVESTIGATING DYNAMIC BALANCE AND MOTIVATING EXERCISE.....</b>	<b>226</b>
<i>Ben Heller</i>	
<b>THREE WAYS OF ASSESSING THE INERTIAL BIOMECHANICS OF A CYCLIST'S LEG .....</b>	<b>232</b>
<i>E. F. Rios Soltero</i>	
<b>USING DISTINCTIVE COLOUR SIGNATURES TO CAPTURE TEAM BEHAVIOUR DURING MATCHES .....</b>	<b>238</b>
<i>José Pedro Silva</i>	

<b>VALIDATION OF A SINGLE CAMERA, SPATIO-TEMPORAL GAIT ANALYSIS SYSTEM</b> .....	243
<i>Marcus Dunn</i>	
<b>WINDSURF ERGOMETER FOR SAIL PUMPING ANALYSIS AND MECHANICAL POWER MEASUREMENT</b> .....	249
<i>Nazim Ouadahi</i>	
<b>WRIST INJURIES IN SNOWBOARDING – SIMULATION OF A WORST CASE SCENARIO OF SNOWBOARD FALLS</b> .....	255
<i>Stefan Lehner</i>	

**SPORTS EQUIPMENT MEASUREMENT**

<b>3-DIMENSIONAL STRESS CALCULATION OF COMPETITIVE SWIMWEAR USING ANISOTROPIC HYPERELASTIC MODEL CONSIDERING STRESS SOFTENING</b> .....	261
<i>Hirokazu Tanaka</i>	
<b>A TRIBOLOGICAL STUDY OF UHMWPE SKI BASE TREATED WITH NANO SKI WAX AND ITS EFFECTS AND BENEFITS ON PERFORMANCE</b> .....	267
<i>Felix Breitschädel</i>	
<b>ACCROWLIVE: A MULTIPLATFORM TELEMETRY AND SONIFICATION SOLUTION FOR ROWING</b> .....	273
<i>Daniel Cesarini</i>	
<b>ANALYSIS OF GOAL LINE TECHNOLOGY FROM THE PERSPECTIVE OF AN ELECTROMAGNETIC FIELD BASED APPROACH</b> .....	279
<i>Rafael Psiuk</i>	
<b>MECHANICAL AGEING PROTOCOL SELECTION AFFECTS MACROSCOPIC PERFORMANCE AND MOLECULAR LEVEL PROPERTIES OF ETHYLENE VINYL ACETATE (EVA) RUNNING SHOE MIDSOLE FOAM</b> .....	285
<i>Nadine Lippa</i>	
<b>CORRELATION BETWEEN QUALITY OF GOLF DRIVE AND IMPACT SENSATION IN DEPENDENCE OF SHAFT WEIGHT AND SHAFT FLEXIBILITY</b> .....	292
<i>Marco Burger</i>	
<b>DEALING WITH STIFFNESS: SHAFT DYNAMICS IN THE GOLF SWING</b> .....	298
<i>Ken Ohta</i>	
<b>DESIGNING A STRAIN GAUGE TRANSDUCER FOR DYNAMIC LOAD MEASUREMENT IN CYCLING USING NUMERICAL SIMULATION</b> .....	304
<i>Jean-Marc Drouet</i>	
<b>KINETIC FRICTION OF BOARDERCROSS-SNOWBOARDS</b> .....	310
<i>Michael Hasler</i>	
<b>A STUDY OF FOOTBALL FOOTWEAR BENDING STIFFNESS</b> .....	315
<i>Sam Fraser</i>	
<b>DEVELOPMENT OF A MULTI-DIRECTIONAL RATING TEST METHOD FOR BICYCLE STIFFNESS</b> .....	321
<i>Joachim Vanwallegem</i>	
<b>EFFECT OF KNEE BRACES ON BALANCE ABILITY WEARING SKI BOOTS (A PILOT STUDY)</b> .....	327
<i>Giuliamarta Bottoni</i>	
<b>EVALUATION OF BENDING AND TORSIONAL PROPERTIES OF DIFFERENT ICE HOCKEY STICKS</b> .....	332
<i>Lasse Behrmann</i>	
<b>INFLUENCE OF A NEWLY-DEVELOPED TRIATHLON SUIT ON THE PASSIVE DRAG AND BODY POSITION</b> .....	338
<i>Keisuke Ishikura</i>	
<b>MARKERLESS TRACKING OF TENNIS RACKET MOTION USING A CAMERA</b> .....	344
<i>Nathan Elliott</i>	
<b>MEASUREMENT AND ANALYSIS SYSTEM FOR BICYCLE FIELD TEST STUDIES</b> .....	350
<i>Anton Koellner</i>	
<b>MECHANICAL AND DYNAMICAL PROPERTIES OF RACING SNOWBOARDS AND THEIR MODIFICATION BY DIFFERENT BINDING PLATES</b> .....	356
<i>Fabian Wolfspurger</i>	
<b>ON BENDING CHARACTERISTICS OF SKIS IN USE</b> .....	362
<i>Rolf Adelsberger</i>	

<b>QUANTIFICATION OF THE USER-WHEELCHAIR SYSTEM STABILITY BASED ON THE COP TRAJECTORY WITHIN THE BASE OF SUPPORT</b> .....	368
<i>Matteo Cognolato</i>	
<b>VIBRO-ACOUSTIC OF TABLE TENNIS RACKETS. INFLUENCE OF THE PLYWOOD DESIGN PARAMETERS. EXPERIMENTAL AND SENSORY ANALYSES</b> .....	374
<i>Lionel Manin</i>	
<b>TEMPERATURE BELOW A GLIDING CROSS COUNTRY SKI</b> .....	380
<i>K. Schindelwig</i>	
<b>THERMAL BEHAVIOUR OF SKI-BOOT LINERS: EFFECT OF MATERIALS ON THERMAL COMFORT IN REAL AND SIMULATED SKIING CONDITIONS</b> .....	386
<i>Martino Colonna</i>	
<b>USING POWER AS A METRIC TO QUANTIFY VIBRATION TRANSMITTED TO THE CYCLIST</b> .....	392
<i>Jean-Philippe Pelland-Leblanc</i>	
<b>WIRELESS COMMUNICATION WITH MINIATURIZED SENSOR DEVICES IN SWIMMING</b> .....	398
<i>Jeroen Lecoutere</i>	

### **SPORTS EQUIPMENT MECHANICS**

<b>A METHOD FOR SPORTS SHOE MACHINERY ENDURANCE TESTING: MODIFICATION OF ISO 22675 PROSTHETIC FOOT TEST MACHINE FOR HEEL-TO-TOE RUNNING MOVEMENT</b> .....	405
<i>Felix Starker</i>	
<b>A NEW INSTRUMENT FOR PUNCH ANALYSIS IN BOXING</b> .....	411
<i>Samir Chadli</i>	
<b>INVESTIGATION AND ASSESSMENT OF THE EDGE GRIP OF SNOWBOARDS WITH LASER VIBROMETRY – A PROPOSAL OF A STANDARDISED METHOD</b> .....	417
<i>Franz Konstantin Fuss</i>	
<b>A STUDY OF IMPACT FORCE ON MODERN SOCCER BALLS</b> .....	423
<i>Asaka Koizumi</i>	
<b>A VOLUMETRIC CONTACT MODEL TO STUDY THE EFFECT OF LANE FRICTION AND THE RADII OF GYRATION ON THE “HOOK SHOT” IN INDOOR BOWLING</b> .....	429
<i>Joydeep Banerjee</i>	
<b>ACCURACY PERFORMANCE PARAMETERS OF SEAM BOWLING, MEASURED WITH A SMART CRICKET BALL</b> .....	435
<i>Franz Konstantin Fuss</i>	
<b>PARAMETRIC FINITE ELEMENT ANALYSIS OF BICYCLE FRAME GEOMETRIES</b> .....	441
<i>Derek Covill</i>	
<b>ASSESSMENT OF AN EMPIRICAL BOB-SKELETON STEERING MODEL</b> .....	447
<i>Caleb Sawade</i>	
<b>AUXETIC MATERIALS FOR SPORTS APPLICATIONS</b> .....	453
<i>Mohammad Sanami</i>	
<b>BALANCE AND CONTROL OF A REAR-WHEEL STEERED SPEED-RECORD RECUMBENT BICYCLE</b> .....	459
<i>A. L. Schwab</i>	
<b>BATTED-BALL PERFORMANCE OF A COMPOSITE SOFTBALL BAT AS A FUNCTION OF BALL TYPE</b> .....	465
<i>Jennifer Yee</i>	
<b>BIKE BRAKING VIBRATION MODELLING AND MEASUREMENT</b> .....	471
<i>Rob Redfield</i>	
<b>A SMARTPHONE BASED SYSTEM FOR KITE AND BOARD MEASUREMENTS IN KITESURFING</b> .....	477
<i>Tim Nebas</i>	
<b>DEVELOPMENT OF A NEW METHOD FOR THE ENGINEERING PRE-DESIGN OF SPORT HELMETS</b> .....	483
<i>Enrico Cherubina</i>	
<b>ENGINEERING EVALUATION OF “REACTIVITY” OF RACING BICYCLE WHEELS</b> .....	489
<i>Federico Giubilato</i>	

<b>DYNAMIC CONTRIBUTION ANALYSIS OF BADMINTON-SMASH-MOTION WITH CONSIDERATION OF RACKET SHAFT DEFORMATION (A MODEL CONSISTED OF RACKET-SIDE UPPER LIMB AND A RACKET)</b> .....	496
<i>Sekiya Koike</i>	
<b>EFFECT OF PROPERTIES OF SPORTS SURFACE AND CLOTHING MATERIALS ON HUMAN THERMAL LOAD UNDER HOT ENVIRONMENT</b> .....	502
<i>Yasuhiro Shimazaki</i>	
<b>EFFECTS OF SOLVENT EXPOSURE ON MATERIAL PROPERTIES AND IMPACT PERFORMANCE OF AN AMERICAN FOOTBALL HELMET OUTER SHELL MATERIAL</b> .....	508
<i>David Krzeminski</i>	
<b>IMPACT-ABSORBING MATERIALS IN REDUCING BRAIN VIBRATION CAUSED BY BALL-TO-HEAD IMPACT IN SOCCER</b> .....	515
<i>Zahari Taha</i>	
<b>FINITE ELEMENT MODEL OF A CRICKET BALL IMPACTING A BAT</b> .....	521
<i>Tom Allen</i>	
<b>FINITE ELEMENT MODELING OF WOOD BAT PROFILES FOR DURABILITY</b> .....	527
<i>Eric Ruggiero</i>	
<b>INITIAL VALIDATION OF A RELAXED HUMAN SOFT TISSUE SIMULANT FOR SPORTS IMPACT SURROGATES</b> .....	533
<i>Thomas Payne</i>	
<b>GLIDING-INDUCED SKI VIBRATIONS: APPROACHING PROPER MODELING</b> .....	539
<i>Andrey Koptuyug</i>	
<b>HEAD IMPACT RESPONSE TO SIMULATED BALL-TO-HEAD COLLISIONS</b> .....	545
<i>Derek Nevins</i>	
<b>INFLUENCE OF WEARING IMPACT PROTECTIVE GARMENT ON THERMOPHYSIOLOGICAL COMFORT OF THE WEARER</b> .....	551
<i>Wiah Wardiningsih</i>	
<b>MEASUREMENT OF MAIN STRINGS MOVEMENT AND ITS EFFECT ON TENNIS BALL SPIN</b> .....	557
<i>Yudai Washida</i>	
<b>FIELD MEASUREMENTS OF ICE HOCKEY STICK PERFORMANCE AND PLAYER MOTION</b> .....	563
<i>Brendan Kays</i>	
<b>MEASURING THE INERTIAL PROPERTIES OF A TENNIS RACKET</b> .....	569
<i>James Spurr</i>	
<b>EXPERIMENTAL STUDY OF HEAT DISSIPATION IN INDOOR SPORTS SHOES</b> .....	575
<i>Olaf Dessing</i>	
<b>MODELLING HEAD IMPACT SAFETY PERFORMANCE OF POLYMER-BASED FOAM PROTECTIVE DEVICES</b> .....	581
<i>Stefan Schwanitz, Gianluca Costabile, Giuseppe Amodeo, Stephan Odenwald, Antonio Lanzotti</i>	
<b>MODELLING THE ACOUSTICS OF A GOLF BALL IMPACTING A TITANIUM PLATE</b> .....	587
<i>Tom Allen</i>	
<b>EFFECT OF MOMENT OF INERTIA AND PHYSICAL PROFILE ON RESTRICTED MOTION SWING SPEED</b> .....	593
<i>Dave Schorah</i>	
<b>THE BEHAVIOR OF GOLF BALL PUTTING ON ARTIFICIAL TURF</b> .....	599
<i>Patrick Drane</i>	
<b>SUPERHYDROPHOBIC SKI BASES FOR REDUCED WATER ADHESION</b> .....	605
<i>Nurul A. Nordin</i>	
<b>SKIN FRICTION AT THE INTERFACE BETWEEN HANDS AND SPORTS EQUIPMENT</b> .....	611
<i>R. Lewis</i>	
<b>STRUCTURAL RESPONSES ON A BMX RACING BICYCLE</b> .....	618
<i>Anton Koellner</i>	
<b>SWING PROFILES IN SPORT: AN ACCELEROMETER ANALYSIS</b> .....	624
<i>David V. Thiel</i>	
<b>THE EFFECT OF BUCKLE CLOSURE AND TEMPERATURE ON THE IN-VIVO FLEXIBILITY OF SKI-BOOTS: A PILOT STUDY</b> .....	630
<i>Nicola Petrone</i>	
<b>STRESS ANALYSIS OF BICYCLE SADDLES STRUCTURAL COMPONENTS DURING DIFFERENT CYCLING CONDITIONS</b> .....	636
<i>Federico Giubilato</i>	
<b>THE EFFECT OF SKID DISTANCE ON DISTANCE CONTROL IN GOLF PUTTING</b> .....	642
<i>Jeremy Pope</i>	

<b>THE EFFECT OF STUD SHAPE ON PENETRATION CHARACTERISTICS THROUGH SYNTHESIZED NATURAL TURF IN FOOTBALL</b> .....	648
<i>Robindronath Dé</i>	
<b>THE FRICTION FORCE BETWEEN THE SOCCER BALL AND THE GOALKEEPER GLOVE MATERIAL</b> .....	654
<i>Ryota Sasaki</i>	
<b>DOES PEDALLING ON A RECUMBENT BICYCLE INFLUENCE THE CYCLIST'S STEERING BEHAVIOUR?</b> .....	660
<i>K. M. Boon</i>	
<b>THE RELIABILITY OF A TAPPING TEST AS AN INDICATOR OF CRICKET BAT PERFORMANCE</b> .....	666
<i>David Curtis</i>	
<b>THERMAL SIMULATION OF A DINGHY SAILOR</b> .....	672
<i>J. J. Joustra</i>	
<b>THERMO-MECHANICAL AND IMPACT PROPERTIES OF POLYMERIC FOAMS USED FOR SNOW SPORTS PROTECTIVE EQUIPMENT</b> .....	678
<i>Marco Nicotra</i>	

### **FLUID MECHANICS IN SPORT**

<b>A CFD ANALYSIS OF FLOW AROUND A DISC</b> .....	685
<i>R. A. Lukes</i>	
<b>AERODYNAMICS OF RIBBED BICYCLE RACING HELMETS</b> .....	691
<i>Firoz Alam</i>	
<b>AIR PERMEABILITY OF SPORTS FABRICS AT RUNNING SPEEDS</b> .....	697
<i>Len Brownlie</i>	
<b>AERODYNAMIC DRAG MEASUREMENTS OF FIFA-APPROVED FOOTBALLS</b> .....	703
<i>Firoz Alam</i>	
<b>THE EFFECT OF SWIMSUIT RESISTANCE ON FREESTYLE SWIMMING RACE TIME</b> .....	709
<i>A. P. Webb</i>	
<b>EFFECT OF BUBBLES AROUND AN UNDERWATER ROBOT ARM ON THRUST DURING THE CRAWL STROKE MOTION</b> .....	715
<i>Motomu Nakashima</i>	
<b>THE EFFECT OF CROSSWINDS ON CYCLISTS: AN EXPERIMENTAL STUDY</b> .....	720
<i>D. M. Fintelman</i>	
<b>EXPERIMENTAL INVESTIGATION OF GOLF DRIVER CLUB HEAD DRAG REDUCTION THROUGH THE USE OF AERODYNAMIC FEATURES ON THE DRIVER CROWN</b> .....	726
<i>Erik Henrikson</i>	
<b>ROTATION PROPERTIES OF FEATHER SHUTTLECOCKS IN MOTION</b> .....	732
<i>Xiaoshan Cao</i>	
<b>FLOW VISUALISATION EXPERIMENTS ON SPORTS BALLS</b> .....	738
<i>James A. Scobie</i>	
<b>FLUID MECHANICS IN ROWING: THE CASE OF THE FLOW AROUND THE BLADES</b> .....	744
<i>Yoann Robert</i>	
<b>HANDBIKE AERODYNAMICS: WIND TUNNEL VERSUS TRACK TESTS</b> .....	750
<i>Marco Belloli</i>	
<b>OPTIMIZATION OF THE SIZE AND LAUNCH CONDITIONS OF A DISCUS</b> .....	756
<i>Kazuya Seo</i>	
<b>RACE-TIME PREDICTION FOR THE VA'A PARALYMPIC SPRINT CANOE</b> .....	762
<i>D. A. Hudson</i>	
<b>SIMULATION AND UNDERSTANDING OF THE AERODYNAMIC CHARACTERISTICS OF A BADMINTON SHUTTLE</b> .....	768
<i>John Hart Dr</i>	
<b>THE EFFECT OF SPATIAL POSITION ON THE AERODYNAMIC INTERACTIONS BETWEEN CYCLISTS</b> .....	774
<i>Nathan Barry</i>	
<b>THE INFLUENCE OF GOLF BALL DIMPLES ON AERODYNAMIC CHARACTERISTICS</b> .....	780
<i>Takeshi Naruo</i>	
<b>THE INFLUENCE OF PANEL ORIENTATION ON THE AERODYNAMICS OF SOCCER BALLS</b> .....	786
<i>Sungchan Hong</i>	

<b>THE TURBULENT FLOW FIELD RELEVANT TO OUTDOOR SPORTS</b> .....	792
<i>Simon Watkins</i>	

**SPORTS PERFORMANCE STRATEGY**

<b>PREDICTIVE DYNAMIC SIMULATION OF THE GOLF SWING, INCLUDING GOLFER BIOMECHANICS AND DISTRIBUTED FLEXIBILITY IN THE SHAFT</b> .....	799
<i>Daniel Johnson</i>	
<b>EXPLORING THE RELATIVE AGE EFFECT AND NATION DOMINANCE IN OLYMPIC BOXING, A REVIEW OF THE LAST DECADE</b> .....	805
<i>Rebecca Edginton</i>	
<b>INVESTIGATION OF TACKING STRATEGIES USING AN AMERICA'S CUP 45 CATAMARAN SIMULATOR</b> .....	811
<i>Laura Marimon Giovannetti</i>	
<b>PROGRAMMED INNOVATION IN TEAM SPORT USING NEEDS DRIVEN INNOVATION</b> .....	817
<i>Caroline Ringuet-Riot</i>	
<b>REBOUNDING STRATEGIES IN BASKETBALL</b> .....	823
<i>Hiroki Okubo</i>	
<b>SENSOR DATA MINING ON THE KINEMATICAL CHARACTERISTICS OF THE COMPETITIVE SWIMMING</b> .....	829
<i>Yuji Ohgi</i>	
<b>THE INFLUENCE OF COURSE BENDS ON PACING STRATEGY IN ROAD CYCLING</b> .....	835
<i>David Sundström</i>	
<b>THE R &amp; D OF A SWIMMER TRAINING SPEED NAVIGATOR BASED ON THE 13TH FINA WORLD CHAMPIONSHIPS</b> .....	841
<i>Yang Hong-Chun</i>	

**SPORTS SURFACES**

<b>A FINITE ELEMENT MODEL FOR THE PREDICTION OF FORCE REDUCTION OF ATHLETICS TRACKS</b> .....	847
<i>Luca Andena</i>	
<b>ROTATIONAL TRACTION BEHAVIOUR OF ARTIFICIAL TURF</b> .....	853
<i>Carolyn Webb</i>	
<b>SLIDING ALLOWS FASTER REPOSITIONING DURING TENNIS SPECIFIC MOVEMENTS ON HARD COURT</b> .....	859
<i>Sébastien Pavailler</i>	
<b>ADVANCED MEASUREMENT OF SPORTS SURFACE SYSTEM BEHAVIOUR UNDER PLAYER LOADING</b> .....	865
<i>X. Wang</i>	
<b>ARTIFICIAL GRASS: A LONGITUDINAL STUDY ON BALL ROLL AND FREE PILE HEIGHT</b> .....	871
<i>N. J. McLaren</i>	
<b>EFFECT OF VARYING THE VOLUME INFILL SAND ON SYNTHETIC CLAY SURFACES IN TERMS OF THE SHOE-SURFACE FRICTION</b> .....	877
<i>Daniel Ura</i>	
<b>FRICTION AT THE TENNIS SHOE-COURT INTERFACE: HOW BIOMECHANICALLY INFORMED LAB-BASED TESTING CAN ENHANCE UNDERSTANDING</b> .....	883
<i>Matt J. Carré</i>	
<b>INFLUENCE OF CLAY PROPERTIES ON SHOE-KINEMATICS AND FRICTION DURING TENNIS MOVEMENTS</b> .....	889
<i>Daniel Ura</i>	
<b>MODELS FOR PREDICTING SURFACE TEMPERATURES ON SYNTHETIC TURF PLAYING SURFACES</b> .....	895
<i>Adam W. Thoms</i>	
<b>NANOSILICA AND POLYETHYLENE BASED ARTIFICIAL TURF-ABRASION RESISTANCE AND MECHANICAL PROPERTIES</b> .....	901
<i>Yi Hongling</i>	
<b>ELITE FOOTBALL PLAYERS' PERCEPTIONS OF FOOTBALL TURF AND NATURAL GRASS SURFACE PROPERTIES</b> .....	907
<i>Jonathan Roberts</i>	



<b>RACE SURFACE MODEL DEVELOPMENT IN A MUSCULOSKELETAL MODELLING ENVIRONMENT .....</b>	<b>913</b>
<i>Jennifer E. Symons</i>	
<b>ROTATIONAL TRACTION TESTING: HOW CAN WE IMPROVE THE CURRENT TEST DEVICE?.....</b>	<b>919</b>
<i>Dara M. Twomey</i>	
<b>ARTIFICIAL TURF RESEARCH AT LOUGHBOROUGH UNIVERSITY .....</b>	<b>925</b>
<i>Paul Fleming</i>	
<b>DO DANCE FLOOR FORCE REDUCTION AND STATIC STIFFNESS REPRESENT DYNAMIC FLOOR STIFFNESS DURING DANCE LANDINGS? .....</b>	<b>931</b>
<i>Luke S. Hopper</i>	
<b>TWO-DIMENSIONAL SHOCK ATTENUATION PROPERTIES OF SPORTS SURFACES WITHOUT SLIPPERY CONDITION .....</b>	<b>937</b>
<i>Harutoshi Yukawa</i>	
<b>UNDERSTANDING HOW THE COMPONENTS OF A SYNTHETIC TURF SYSTEM CONTRIBUTE TO INCREASED SURFACE TEMPERATURE .....</b>	<b>943</b>
<i>Lauren A. Petrass</i>	
<b>USE OF SURFACE TESTING DEVICES TO IDENTIFY POTENTIAL RISK FACTORS FOR SYNTHETIC EQUESTRIAN SURFACES .....</b>	<b>949</b>
<i>D. Holt</i>	
<b>Author Index</b>	