5th International Autumn School on Movement Science

Berlin, 8th to 12th October 2018

Programme

BSMS
Berlin School of Movement Science

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Movement Science

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DAAD

Hosted by

Humboldt-Universität zu Berlin, Institute of Sports Science

BSMS – Berlin School of Movement Science
Organisation

Scientific Coordination
Prof. Adamantios Arampatzis (Spokesperson)

Administrative Coordination
Martina Piotrowski

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Prof. Kirsten Legerlotz

Scientific Advisory Board
Prof. Vasilios Baltzopoulos (GBR)
Prof. Walter Herzog (CAN)
Prof. Paavo Komi (FIN)

General Information
Venues

Lectures will take place from Monday 8th until Friday 12th October.

Address (map at page 33).

Humboldt-Universität zu Berlin
Department of Training and Movement Sciences
Philippstr. 13, Haus 11
Lecture Hall 5 (Room 1.26)
10115 Berlin
Web: www.dtms.hu-berlin.de

The Wi-Fi network eduroam (education roaming) is available at the venue. Students, researchers and staff can obtain Internet connectivity across the campus using the respective institutional credentials.

Supported by

General Information

The Autumn School and the BSMS

The Berlin School of Movement Science (BSMS) is an interdisciplinary education programme based on scientific exchange and interaction, supporting PhD students to become highly skilled scientists in the fields of motor control and movement science. Our main research objectives are:

(a) to acquire knowledge about the fundamental principles of motor control in human movement,
(b) to investigate the effects of the musculoskeletal properties on the motor control strategies used during movement and
(c) to understand how the sensory-motor system controls biomechanical features and lead to adaptation on a structural level in tissues such as bone and muscle.

The BSMS organises yearly an International Autumn School on Movement Science for young scientists to give first-hand experience of the unique graduate training programme in the field of movement science.

In this Autumn School we want to provide an overview on movement and ageing from different perspectives such as the brain, central nervous system, muscle and tendon as well as the associated diseases and therapeutic options using physical activity.

The participation to the Autumn School is free of charge and is of particular interest to those Master's and PhD students who are considering doing their doctoral or post-doctoral research in the field of movement science within the BSMS network.

Sessions
Scientific Programme

Coffee breaks from 10:30 to 11:00 and from 14:30 to 15:00

Monday 8th October
Day 1

09:30 to 10:30 **Jaap van Dieen** – *VU University Amsterdam, NLD*
11:00 to 12:00 **Manny Azizi** – *University of California, USA*
13:30 to 14:30 **Yasuo Kawakami** – *Waseda University, JAP*
15:00 to 16:00 **James Wakeling** – *Simon Fraser University, CAN*

Tuesday 9th October
Day 2

09:30 to 10:30 **Walter Herzog** – *University of Calgary, CAN*
11:00 to 12:00 **Bill Baltzopoulos** – *LJMU, GBR*
13:30 to 14:30 **Michael Kjær** – *University of Copenhagen, DEN*
15:00 to 16:00 **Thomas Roberts** – *Brown University, USA*

Wednesday 10th October
Day 3

09:30 to 10:30 **Olivier Seynnes** – *Norwegian School of Sport Sciences, NOR*
11:00 to 12:00 **Keith Baar** – *UC Davis School of Medicine, USA*
13:30 to 14:30 **Anthony Blazevich** – *Edith Cowan University, AUS*
15:00 to 16:00 **Helen Birch** – *University College London, GBR*

Thursday 11th October
Day 4

09:30 to 10:30 **Nicola Maffulli** – *Queen Mary University of London, GBR*
11:00 to 12:00 **Ray Vanderby** – *University of Wisconsin-Madison, USA*
13:30 to 14:30 **Nicholas Stergiou** – *University of Nebraska Omaha, USA*
15:00 to 16:00 **Eduardo Palermo** – *Sapienza University of Rome, ITA*

Friday 12th October
Day 5

09:30 to 10:30 **André Seyfarth** – *Universität Darmstadt, GER*
11:00 to 12:00 **Alexandra Voloshina** – *Stanford University, USA*
13:30 to 14:30 **Stefano Rossi** – *Università degli Studi della Tuscia, ITA*
15:00 to 16:00 **Conor Walsh** – *Harvard University, USA*

Sessions

Social Programme

The students at the BSMS thought of organising a parallel social programme based almost exclusively on donations and free activities. Please feel free to join us in any of the event planned for the Autumn School's week!

Monday 8th October

16:30 to 17:30 **Meet our department: the gait lab**
Philippstr. 13, Haus 11, 10115 Berlin

Tuesday 9th October

17:00 to 19:30 **Get-together party**
"Alte Schmiede" building in the Campus Nord
With live music by "Never rewind"
Philippstr. 13, Haus 10, 10115 Berlin

Friday 11th October

16:30 to 18:30 **A walk through history: the Berlin Wall**
Philippstr. 13, Haus 11, 10115 Berlin

20:00 **Farewell dinner**
Brauhaus Südstern
Hasenheide 69, 10967 Berlin
Limited places available, please confirm your presence

Monday 8th October
Scientific Programme

Humboldt-Universität zu Berlin | Philippstr. 13, Haus 11 | Room 1.26

09:15 to 09:30	Welcome and introduction
09:30 to 10:30	Mediolateral foot placement for control of gait stability **Jaap van Dieen** – *VU University of Amsterdam, NLD*
10:30 to 11:00	Coffee break
11:00 to 12:00	Mechanical & energetic consequences of age-related remodeling in muscles and tendons **Manny Azizi** – *University of California, USA*
12:00 to 13:30	Break
13:30 to 14:30	Muscle-tendon-fascia unit as a functional entity in humans: in vivo and ex-situ evidence **Yasuo Kawakami** – *Waseda University, JAP*
14:30 to 15:00	Coffee break
15:00 to 16:00	MTU function is more than the sum of its parts: non-linear interactions between the contractile elements and the MTU tissue properties **James Wakeling** – *Simon Fraser University, CAN*

Social Programme

16:30 to 17:30	**Meet our department: the gait lab** Philippstr. 13, Haus 11, 10115 Berlin

Monday 8th October

Abstracts

Mediolateral foot placement for control of gait stability

Jaap van Dieen – *VU University of Amsterdam, NLD*

In human bipedal walking, the body center of mass (CoM) is outside the base of support (BoS) for most of the time, and stability is specifically challenged in the mediolateral direction. Most of us are able to maintain a stable gait pattern without conscious effort, but problems with gait stability are common in old adults and several pathologies. We will provide an overview of how people cope with this challenge by using foot placement to adjust their BoS to the kinematic state of their CoM. In addition, we will compare the quality of control between young and old adults and investigate the role of proprioceptive information in control of foot placement in these groups.

Foot placement is crucial in maintaining a stable gait pattern. Mechanical models, used mainly in robotics, provide explicit predictions on where to place the foot relative to the body at each step, such that gait is stabilized. Foot placement during human gait is, to a large extent, in line with these models. That is, foot placement can be predicted based on CoM kinematics in the preceding stance phase and studies indicate that active control underlies this coordination. This obviously requires estimation of CoM kinematics, for which visual, vestibular and proprioceptive information could be used.

We show that muscle spindle afference from the stance leg hip abductors, induced by mechanical vibration, leads to predictable adjustments of foot placement. This supports the idea that coordination of foot placement relative to CoM kinematics is the outcome of an active control process, to which proprioceptive information contributes. In addition, we show that vestibular stimulation leads to phase-dependent changes in muscle activity in line with effects on foot placement. Our results highlight the importance of coordination of mediolateral foot placement to ongoing CoM kinematics and the role of proprioceptive and vestibular information in this control process. Furthermore, we provide evidence that this control process is impaired in healthy older adults.

Monday 8th October

Abstracts

Mechanical & energetic consequences of age-related remodeling in muscles and tendons

Manny Azizi – *University of California, USA*

The process of aging has been shown to induce significant changes to the connective tissue structures associated with skeletal muscle. The most commonly observed consequence of these changes is a reduction in muscle quality such that a relatively larger proportion of a muscle's cross-sectional area is composed of intramuscular connective tissues resulting in a reduction in maximum isometric stress. However, the mechanical interaction between contractile tissues and connective tissue structures within skeletal muscle are likely to have far reaching effects beyond a simple reduction in relative force. Here we use an animal model to examine how age-related remodeling of connective tissue structures are likely to impact musculoskeletal performance at varying levels of organizations. First, we examine how changes to tendons and aponeuroses compromise the ability to utilize elastic energy storage and recovery thereby decreasing locomotor economy. By combining modeling and empirical approaches we show that age-related increase in muscle and tendon tissue stiffness and reduction in active force capacity of the muscle compromise elastic energy utilization and positive work production during cyclical movements in older individuals. Second, we examine how the changes to connective structures may limit the dynamic changes to muscle architecture during contractions. We show that as connective tissue structures limit a muscles ability to change shape, old muscle lose the capacity to operate with varying architectural gear ratio across a range of contractile conditions. Finally, we examine how an increase in connective tissue structure may limit the ability of muscle fibers and fascicles to shorten and generate mechanical work. We show that an age-related increase in connective tissue load restricts the ability of muscle fibers and fascicles to expand radially during shortening thereby setting an upper limit on mechanical work production. Taken together, our results show that age-related changes in the mechanical interactions between contractile and connective tissues provide a novel explanation for the observed increase in the energetic cost of movement in older individuals.

Monday 8th October

Abstracts

Muscle-tendon-fascia unit as a functional entity in humans: in vivo and ex-situ evidence

Yasuo Kawakami – *Waseda University, JAP*

Skeletal muscle fibers are packed in bundles (fascicles) extending from proximal to distal tendinous tissues (tendons and aponeuroses). A skeletal muscle therefore should be regarded as a muscle-tendon unit (MTU). Fascicles as actuators within MTU stretch the tendinous tissues like springs during contraction (Kawakami & Fukunaga, 2006). We have provided evidence for this muscle-tendon interaction during walking (Fukunaga et al. 2001) and ankle hopping (Kawakami et al. 2002, Sakuma et al. 2012). During exercises involving stretch-shortening cycles (SSC) of MTU, fascicles are responsible for force and tendinous tissues for speed (Kawakami 2012). One learns through practice to effectively operate MTU to optimize the endowed roles of fascicles and tendinous tissues through modulating activation strategy of muscle fibers (Hirayama et al. 2012). SSC exercise performance can be improved through plyometric training by optimization of muscle-tendon interaction during SSC exercise and an increase in tendon stiffness (Hirayama et al. 2017).

The MTU never exists alone and together with the adjacent MTUs it is covered with the deep fascia. As a base and a mechanical interface of fascicles, the deep fascia may act as a mediator of MTU forces. Recently we found in the fascia late of the thigh site- and gender- dependence of the morphological characteristics and elastic properties (Otsuka et al. 2018). It appears that these features of the deep fascia are designed to match the functions of underlying MTUs.

Fukunaga T. et al. Proc Roy Soc Lond B. 268: 229-233, 2001.
Hirayama K et al. Front Physiol. 2017, 8:16.
Hirayama K et al. Med Sci Sports Exerc. 44: 1512-1518, 2012.
Kawakami Y. J Phys Fit Sports Med. 1: 1512-1518, 2012.
Kawakami Y, Fukunaga T. Exerc Sport Sci Rev. 34, 16-21, 2006.
Sakuma J et al. Eur J Appl Physiol. 112: 887-898, 2012.
Otsuka S et al. J Biomech. 77: 69-75, 2018.

Monday 8th October

Abstracts

MTU function is more than the sum of its parts: non-linear interactions between the contractile elements and the MTU tissue properties

James Wakeling – *Simon Fraser University, CAN*

The mechanical output from a muscle depends on both the contractile forces actively generated by the cross-bridges between the myofilaments, and additionally on the material properties of the tissue within and surrounding the muscle fibres. This presentation will discuss some recent findings and theories of these interactions within the muscle tendon unit. In particular: the intrinsic properties of the muscle fibres result in different contractile fibre-types. The effect of different muscle fibre-types on the output from the whole muscle is not simply a function of which fibre-types are active, but additionally involves the interaction between their contractile elements and the whole muscle tissue. When the muscle is not fully activated there is a mechanical cost to moving the inactive tissue, and this depends on the density and mass of the MTU. The effect of moving the inactive tissue also depends on the intrinsic properties of the fibres that are active, and the size of the MTU. As the fibres try to contract, their tendency to bulge is resisted by elasticity from tissues such as the extra cellular matrix and internal tendons: this affects the deformations of the contracting fibres, and ultimately the forces that they can generate. Furthermore, alterations to the MTU properties by inclusion of intramuscular fat can cause a reduction in the force and power generated during contractions, and this can be of particular concern with sarcopenia. The net output from the muscle tendon complex is thus shaped by interactions and dynamics between the different types of tissue. Describing these interactions is a complex but important part to understanding the function of the muscle tendon unit.

Tuesday 9th October
Scientific Programme

Humboldt-Universität zu Berlin | Philippstr. 13, Haus 11 | Room 1.26

09:30 to 10:30	A new look at muscle contraction **Walter Herzog** – *University of Calgary, CAN*
10:30 to 11:00	Coffee break
11:00 to 12:00	Dynamic gear ratio in children and adults during gait and implications for muscle mechanical efficiency **Bill Baltzopoulos** – *Liverpool John Moores University, GBR*
12:00 to 13:30	Break
13:30 to 14:30	Physiological adaptation of tendon to exercise **Michael Kjær** – *University of Copenhagen, DEN*
14:30 to 15:00	Coffee break
15:00 to 16:00	Sling-shots, pogo-sticks, and shock absorbers: how an energy flow approach reveals the roles of elastic elements in muscle-powered movement **Thomas Roberts** – *Brown University, USA*

Social Programme

17:00 to 19:30	**Get-together party** "Alte Schmiede" building in the Campus Nord With live music by "Never rewind" Philippstr. 13, Haus 10, 10115 Berlin

Tuesday 9th October
Abstracts

A new look at muscle contraction

Walter Herzog – *University of Calgary, CAN*

Prior to the 1950s, muscle contraction was thought to occur through a shortening of the myosin filaments1. In 1953, Hugh Huxley suggested that maybe muscle contraction occurred through the sliding of two sets of interdigitating filamentous molecules, actin and myosin[2]. This notion was then confirmed and cemented into our consciousness through two simultaneous, but independent, publications in the May 1954 issue of Nature by Hugh Huxley working with rabbit psoas myofibrils and Andrew Huxley working with single, intact frog fibres[3;4]. The way how this sliding between actin and myosin might occur was then proposed in a classic article by Andrew Huxley in 1957: the cross-bridge theory was born[5].

The cross-bridge theory was then refined over the next sixty years, but in essence remained the same as proposed initially in 1957: myosin based cross-bridges attach in a cyclic manner to specific attachment sites on actin and pull the actin past the myosin through a rotational motion that is associated with the hydrolysis of adenosine triphosphate (ATP): one ATP per cross-bridge cycle.

Although this mechanism could account for the well-accepted force-length property of skeletal muscle, agreement with the force-velocity relationship could only be achieved through what we would today call a "curve fitting" procedure; that is, by selection of appropriate, asymmetric rate functions for the attachment to, and detachment from actin. Furthermore, the third basic property of skeletal muscle, the history dependence of skeletal muscle contraction, reflected in residual force enhancement and force depression[6], could not be predicted without fundamentally altering the assumptions of the cross-bridge theory.

Although many suggestions have been made on how this deficiency of the cross-bridge theory could be accounted for, there is no accepted mechanism of muscle contraction that accounts simultaneously for the force-length, force-velocity and history-dependent properties of skeletal muscles. One suggested mechanism that would do that in a simple and "beautiful" way, is the idea of an engagement of a passive structural element upon muscle activation.

In my presentation, I will discuss this possibility, proposing that the structural, filamentous, sarcomeric protein titin may play this role[7], and in fact, may play an important role in muscle contraction in general[8]. Specifically, I will discuss the possibility of titin's role in the residual force enhancement property, and discuss recent evidence on titin's role in contributing mechanical work in concentric contractions[9].

1. Harrington WF. A mechanochemical mechanism for muscle contraction. Proc Natl Acad Sci U S A 1971;68:685-89.

2. Huxley HE. Electron microscope studies of the organization of the filaments in striated muscle. Biochim Biophys Acta 1953;12:387-94.

3. Huxley AF, Niedergerke R. Structural changes in muscle during contraction. Interference microscopy of living muscle fibres. Nature 1954;173:971-73.

4. Huxley HE, Hanson J. Changes in cross-striations of muscle during contraction and stretch and their structural implications. Nature 1954;173:973-76.

5. Huxley AF. Muscle structure and theories of contraction. Prog Biophys Biophys Chem 1957;7:255-318.

6. Abbott BC, Aubert XM. The force exerted by active striated muscle during and after change of length. J Physiol (Lond) 1952;117:77-86.

7. Herzog W. Skeletal muscle mechanics: questions, problems and possible solutions. Journal of neuroengineering and rehabilitation 2017;14:98.

8. Herzog W. The multiple roles of titin in muscle contraction and force production. Biophysical Reviews 2018;1-13.

9. Eckels EC, Tapia-Rojo R, Rivas-Pardo JA, Fernández JM. The work of titin protein folding as a major driver in muscle contraction. Annu Rev Physiol 2018;80:327-51.

Tuesday 9th October

Abstracts

Dynamic gear ratio in children and adults during gait and implications for muscle mechanical efficiency

Bill Baltzopoulos – *Liverpool John Moores University, GBR*

Muscles provide the "engine" for human movement acting with a leverage or moment arm around joint axes of rotation. This leverage in combination with the external leverage provided by the environment has important implications for muscle length and shortening velocity, which, in turn, affects its capability to generate forces. This presentation will highlight our work on muscle-tendon dynamics to gain a better understanding of how skeletal geometry and muscle leverage determine muscle function and movement. We have examined various groups of adults and children during different gait speeds on instrumented treadmills. Reflective markers placed on the lower leg and foot provided lower body and Achilles tendon (AT) movement kinematics. Gait cycle events were determined from treadmill ground reaction force data. The results show that the gear ratio is affected mainly by the change in external moment arm given its large variation and the relatively constant AT moment arm. The external moment arms and gear ratios were maximum near the end of the stance phase and minimum at ~25% stance phase in adults and ~35% in children. Since the muscle efficiency is optimised when the muscle is working close to isometric conditions without a great change in fascicle length and the gear ratio influences muscle-tendon and fascicle length changes, the differences in gear ratio between adults and children may affect fascicle length and velocity changes and hence muscle efficiency. Furthermore, since the main change in gear ratio was due to the external GRF vector moment arm, this might have implications for practice because a modification of running technique and the resulting changes in GRFs can influence gear ratios and potentially muscle efficiency when running. Fascicle length and velocity loops during walking are being currently analysed to be linked to gear ratios and muscle efficiency.

Tuesday 9th October

Abstracts

Physiological adaptation of tendon to exercise

Michael Kjær – *University of Copenhagen, DEN*

The overall turnover of the tendon in humans seems to be taking place primarily within the first 17 years of life, indicating that the basic structure remains relatively unchanged through adult life. Nevertheless, mechanical loading of adult human tendon results in tendon cells responses by producing growth factors and some support for loading-induced increase in tendon collagen synthesis. Comparing tissue turnover in different tissues simultaneously suggests that a combination of a more basic structure that remains relatively unchanged through adult life, and a smaller pool of collagen that is more quickly turned over and can be influenced by mechanical loading.

Mechanical loading of adult human tendon results in release of tendon tissue stimulating factors, whereas inactivity down regulates phenotypic tendon characteristics. Adjustment of the tendon mechanical properties in the form of increased stiffness and modulus after strength training, and the reverse after period of immobilization occurs relatively fast and is potentially coupled to molecular changes in relation to e.g. cross link formation.

Development of tendinopathy is suggested to be coupled to a mismatch between loading and adaptation, and results in pain, palpatory soreness, tendon thickening, rounded cells, disorganized matrix and GAG accumulation, plus angiogenesis. However, the early time pattern of the various pathological adaptations are nor described in detail, but lack of effect of anti-inflammatory treatment in late stage tendinopathy suggests that inflammation primarily is an early phenomenon in tendinopathy.

Tuesday 9th October

Abstracts

Sling-shots, pogo-sticks, and shock absorbers: how an energy flow approach reveals the roles of elastic elements in muscle-powered movement

Thomas Roberts – *Brown University, USA*

Muscle sarcomeres are the ultimate source of force and power for movement, but the mechanical output of muscles depends on much more than sarcomere properties. The arrangement of sarcomeres within a muscle, the mechanical behavior of elastic elements, and even fluid pressures developed during contraction all influence muscle contractile performance. Some of the earliest studies of elastic mechanisms in locomotion recognized that tendons could store and recover energy during running to reduce muscle work. Since then, we have come to understand that a broad repertoire of tasks can be accomplished by the effective interaction of muscles and elastic tendons, including the amplification of muscle power for activities like jumping and the attenuation of power into muscle for activities like landing or descending. Such interactions expand the mechanical range of muscles, provide protective mechanisms that may reduce the risk of muscle damage, and allow for movements that would be impossible without elastic elements.

Tendon elasticity has been the focus of most studies, but elastic structures within the muscle have the potential to store and recover elastic strain energy as well. Typical Hill-type models suggest that the storage and recovery of energy intramuscular springs may be limited, because loading these springs requires that muscle fibers are stretched to long lengths. We have been testing an alternative model motivated by the observation that three-dimensional deformations in muscle shape during contraction can load elastic elements. The model demonstrates that such deformation can allow for useful cycling of elastic strain energy within intramuscular elements, even at short muscle lengths, and that intramuscular springs can provide both power amplification and power attenuation. Experiments indicate that the transmission of force via fluid pressure is essential for loading elastic elements, and may play an important role in the mechanics of contraction.

Wednesday 10th October

Scientific Programme

Humboldt-Universität zu Berlin | Philippstr. 13, Haus 11 | Room 1.26

09:30 to 10:30	Training-induced tendon adaptation and muscle-tendon interaction **Olivier Seynnes** – *Norwegian School of Sport Sciences, NOR*
10:30 to 11:00	Coffee break
11:00 to 12:00	Using load and nutrition to improve tendon structure and function **Keith Baar** – *UC Davis School of Medicine, USA*
12:00 to 13:30	Break
13:30 to 14:30	The effect of strength training on muscle architecture and its relation to function **Anthony Blazevich** – *Edith Cowan University, AUS*
14:30 to 15:00	Coffee break
15:00 to 16:00	Tendon ageing: from molecules to whole tendon **Helen Birch** – *University College London, GBR*

Wednesday 10th October
Abstracts

Training-induced tendon adaptation and muscle-tendon interaction

Olivier Seynnes – *Norwegian School of Sport Sciences, NOR*

Tendon mechanical properties are inextricably linked to muscle work. During locomotion, lower limb tendons stretch and recoil, enabling favourable conditions of contraction and the utilisation of elastic energy. Despite the slow adaptability of tendons to chronic changes in stress, numerous studies have shown differences in stiffness between certain athletes and following a period of training. These differences are often associated with changes in the function of the muscle-tendon unit (MTU), the rationale being a direct influence of in series elasticity on the strain and strain velocity of muscle fascicles. Although this theory fits with the comparison of the structure of MTUs within individuals or between animal species, evidence for its relevance to adaptations in the human MTUs is lacking. After summarising the above theoretical background, this presentation will give an overview of the cross-sectional studies comparing lower limb tendon properties and athletes with contrasting types of training, or with different levels of performance. In a second part, recent intervention studies investigating training-induced changes in Achilles tendon stiffness and MTU function during running and landing will be presented and discussed. The sum of the available findings indicates that 1) a different tendon stiffness can be found in athletes with different patterns of daily loading or performance levels and, 2) training-induced increases in stiffness can alter the behaviour of the tendon and muscle fascicles during certain tasks. However, these observations are not universal and their impact on locomotor performance remains unclear.

Wednesday 10th October

Abstracts

Using load and nutrition to improve tendon structure and function

Keith Baar – *UC Davis School of Medicine, USA*

Musculoskeletal injuries account for more than 70% of time away from sports. One of the reasons for the high number of injuries and long return to play is that we have only a very basic understanding of how our training and nutrition alters tendon and ligament (sinew) structure and function. Using engineered ligaments as a guide to understanding sinew physiology and function, we have learned that sinews, like bone, quickly become refractory to an exercise stimulus, suggesting that short (~10 min) periods of activity with relatively long (6h) periods of rest are best to train these tissues. However, when loading a damaged tendon, the process of stress shielding prevents proper loading of cells within the injured region. Therefore, simple loading programs may not be able to reverse tendinopathy. Instead, specialized programs that focus on stressrelaxation are needed to provide directional load to cells within a damaged extracellular matrix. Once loaded, the cells within the matrix begin to synthesize directional collagen and this can be augmented by nutritional interventions, such as gelatin or hydrolyzed collagen. We have combined these interventions to develop a program to reverse patellar tendinopathy in elite athletes. In the initial case study, a professional basketball player with a central core patellar tendinopathy underwent a stress relaxation program focusing on 3 isometric exercises one hour after consuming 15g of gelatin in a drink containing 250mg of vitamin C. After 2 basketball seasons, the program had helped eliminate pain and reverse the central core tendinopathy (measured by MRI). This case study provides evidence that nutrition and rehabilitation programs targeted at improving connective tissue may reverse chronic tendon pathology.

Wednesday 10th October
Abstracts

The effect of strength training on muscle architecture and its relation to function

Anthony Blazevich – *Edith Cowan University, AUS*

A muscle’s architecture critically influences its force production behaviour. In particular, fibre (or fascicle) lengths and angles within a muscle are thought to influence force production through their effects on the muscle length change-to-sarcomere length change relationship. Fascicle angle in particular should also affect the total amount of contractile tissue that can attach to a tendon or aponeurosis, and thus the peak force production of the muscle. However, much of the information relating muscle architecture to function comes from studies imposing electrical stimulation onto animal muscles, and the conclusions reached generally relate to between-muscle differences, or changes after interventions that substantially alter architecture, in which large variability exists. In humans, within-muscle comparisons between individuals show a more moderate variability in architecture, and this variability does not appear to reliably predict muscle, or system, function. This may be because: (a) numerous other factors influence voluntary muscle force production characteristics in addition to architecture in vivo in humans, (b) in many studies, architecture is measured only from single muscle regions within complex muscle groups, (c) measurement techniques are often suboptimum, and/or (d) muscle architecture measured at rest provides little information about muscle function during activity. Another important research goal is to determine whether specific exercise training interventions might reliably influence muscle architecture, and in turn influence muscle function. Despite numerous attempts, it is not yet clear whether this goal has been reached. In this presentation, a review of current research will be presented to demonstrate our current understanding of the relationships between physical training interventions, muscle architecture, and physical function. Suggestions for future avenues of research will be provided.

Wednesday 10th October

Abstracts

Tendon ageing: from molecules to whole tendon

Helen Birch – *University College London, GBR*

Increasing age is a well-known risk factor for tendon injury in both human and equine species. As muscle strength and activity levels generally decline with age, this suggests a change in the properties of tendon that reduce the ability of tendon to withstand mechanical load. Interestingly, mechanical testing of the gross tendon structure does not reveal a clear change in properties with increasing age with several studies showing conflicting results. These studies indicate that a better understanding of tendon behaviour in response to mechanical load is required. Tendons are composite materials, composed predominantly of the protein collagen, which is arranged into a complex hierarchical structure. Collagen molecules align to form fibrils, fibres, fascicles and finally the whole tendon. In addition, some tendons such as the Achilles tendon, are composed from contributions from more than one muscle belly, which adds to the complexity. In our studies we have investigated properties of these different sub-levels of the tendon hierarchy in energy storing and positional tendons and sought to understand how these properties change during ageing. Collagen has a number of characteristics that make it particularly well suited to providing a mechanical scaffold in tendon; one of these being a slow turnover. As a consequence of this relatively long half-life, the collagen is susceptible to adventitious chemical modifications, such as the addition of sugars in a process known as glycation. Glycation can result in the formation of advanced glycation end-products (AGE) some of which form crosslinks between adjacent molecules and these chemical modifications accumulate with age. Although their presence is not disputed, AGEs have been poorly characterised and the impact on tendon properties not well understood. In our work we have used a combination of computational and experimental studies to identify a major AGE crosslink in tendon and to determine the impact on tendon properties.

Thursday 11th October
Scientific Programme

Humboldt-Universität zu Berlin | Philippstr. 13, Haus 11 | Room 1.26

09:30 to 10:30	Tendon injury and regeneration **Nicola Maffulli** – *Queen Mary University of London, GBR*
10:30 to 11:00	Coffee break
11:00 to 12:00	Tendon injury and regeneration – a biomechanical perspective **Ray Vanderby** – *University of Wisconsin-Madison, USA*
12:00 to 13:30	Break
13:30 to 14:30	Harnessing movement variability to treat and prevent motor related disorders **Nicholas Stergiou** – *University of Nebraska Omaha, USA*
14:30 to 15:00	Coffee break
15:00 to 16:00	Muscle synergies in neurodegenerative diseases and rehabilitation **Eduardo Palermo** – *Sapienza University of Rome, ITA*

Thursday 11th October

Abstracts

Tendon injury and regeneration

Nicola Maffulli – *Queen Mary University of London, GBR*

Tendons can undergo degenerative and traumatic processes. In the United Kingdom, soft tissues disorders have a prevalence of 18 cases for 1000 habitants and represent the causes of 40% of new rheumatologic consultations. The most vulnerable tendons are those of rotator cuff, posterior tibial tendon, the patellar tendon, and the Achilles tendon. At least 50% of tendon problems are secondary to overload. Achilles tendon injuries are common in football, tennis, badminton, and jumping and have a prevalence in running athletes of 11%, but 1/3 of patients with this pathology do not practice intensive physical activity. Pathology of the patellar tendon is common in jumping sports such as basketball, tennis, football, hockey, and volleyball.

Tendon rupture can be either acute, in the case of an individual experiencing a rupture from a single high-load impact, or chronic, when the tendon is weakened due to tendinopathy or aging, and the tendon ruptures at lower loads. The location of rupture varies with tendon type. For example, the Achilles tendon commonly tears at the mid-substance. An acceleration-deceleration mechanism has been reported in up to 90% of sports-related Achilles tendon ruptures. Malfunction of the normal protective inhibitory pathway of the musculotendinous unit may result in injury.

The etiology of tendon rupture remains unclear. Degenerative tendinopathy is the most common histological finding in spontaneous tendon ruptures. This causes repetitive microtrauma on the tendon which can occur from stresses within the physiological limits of the tendon itself. The subclinical damages can accumulate before the tendon becomes symptomatic with pain.

Tendon injuries can be acute or chronic and are caused by intrinsic or extrinsic factors, either alone or in combination. The intrinsic factors are represented by limited flexibility, muscle weakness, and joint instability. The extrinsic factors are incorrect sport technique, inappropriate equipment, and use of drug.

Thursday 11th October
Abstracts

Tendon injury and regeneration – a biomechanical perspective

Ray Vanderby – *University of Wisconsin-Madison, USA*

Tendon injuries are common, but despite extensive research, the quality and speed of healing remain problematic. This issue can be understood by first examining the fundamental biomechanical behavior of tendon via its structure-function relationships. Then, the post-injury changes in tendon structure can predict functional changes and mechanical deficits. Finally, tendon regeneration will be discussed – what is it, and what are the challenges.

Normal tendon is a highly organized, hierarchical structure with type I collagen as its primary structural (load-bearing) element. However, other molecules (collagens III and VI, elastin, and proteoglycans) as well as tendon's intrinsic cells are essential in its hierarchical assembly and the resulting functional behaviors at fibril, fiber, fascicle, and tendon levels. These interrelationships combine for the well-defined, composite tendon behavior. Some phenomena of interest are fibril length and packing, shear lag, fiber crimping, fiber and fibril orientations, all of which affect the nonlinear, time-dependent behavior of tendon.

Pathological or healed tendon is compositionally and organizationally compromised. The effect of these changes diminish the functional behavior of tendon. Examination of these will elucidate the benefit of complete tissue regeneration over the scar-like neo-tissue that is formed in normal healing.

Several attempts to regenerate damaged tendon in animal models will be discussed, emphasizing the wound healing cascade, its predictable outcome, and how it might be beneficially altered. In particular, the potentially benefits for modulating inflammation and immune cells during healing will be discussed. Experimental treatments that include: leukocyte ablation, exogenous anti-inflammatory cytokines, MSC therapy, and leukocytes therapy will be broadly examined. Lessons and observations from these experiments will be summarized along with some of the remaining challenges.

Thursday 11th October

Abstracts

Harnessing movement variability to treat and prevent motor related disorders

Nicholas Stergiou – *University of Nebraska Omaha, USA*

An optimal level of variability enables us to interact adaptively and safely to a continuously changing environment, where often our movements must be adjusted in a matter of milliseconds. A large body of research exists that demonstrates natural variability in healthy movement such as gait and posture (along with variability in other, healthy biological signals e.g. heart rate), and a loss of this variability in ageing and injury, as well as in a variety of neurodegenerative and physiological disorders. In this seminar I submit that this field of research is now in pressing need of an innovative "next step" that goes beyond the many descriptive studies that characterize levels of variability in various patient populations. We need to devise novel therapies that will harness the existing knowledge on biological variability and create new possibilities for those in the grip of disease. I also propose that the nature of the specific physiological limitations present in the neuromuscular apparatus may be less important in the physiological complexity framework than the control mechanisms adopted by the affected individual in the coordination of the available degrees of freedom. The theoretical underpinnings of this framework suggest that interventions designed to restore healthy system dynamics may optimize functional improvements in affected individuals. I submit that interventions based on the restoration of optimal variability and movement complexity could potentially be applied across a range of diseases or dysfunctions as it addresses the adaptability and coordination of available degrees of freedom, regardless of the internal constraints of the individual (1-6).

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Thursday 11th October

Abstracts

Muscle synergies in neurodegenerative diseases and rehabilitation

Eduardo Palermo – *Sapienza University of Rome, ITA*

Muscle synergies aim at unveiling inherent coordination in the activation of different muscles involved in complex movements. Recently, muscle synergy extraction revealed itself as a precious tool for evaluating alteration in movements of subjects with neurodegenerative diseases. Parkinson's disease (PD) causes loss of dopaminergic cells in the basal ganglia, an area which is considered fundamental for the activation of the motor and premotor cortex. PD patients exhibit slower and smaller movements, short and shuffling steps, postural instability and tendency to fall. In a recent study, a postural task requiring quick release of a load from extended arms, was designed to investigate motor synergies operating in whole-body and multi- muscle postural motor control. In the same vein, we conducted an experimental study in which the postural response of 16 muscles of the trunk and the upper limb, to a rapid heading perturbation coming from the feet was analyzed, in terms of muscle synergies, in younger and older adults, and patients with PD. Such kind of rotation, in fact, is considered able to induce fall in PD patients.

Other than investigating disrupted circuits in motor activation, muscle synergies could provide important insights into the physical rehabilitation process, which tackles the problem of the recovery from motor impairment, by means of controlled exercises. Recently, low-cost and portable solutions for rehabilitation have been introduced to enhance motor re-learning during the chronic phase, by often leveraging virtual reality (VR). Despite those solutions are equivalent to real exercise in terms of kinematics, their property of inducing a physiological muscle activation pattern has to be investigated. Towards this aim, we conducted a comparison study in which muscle synergies activated by the same subjects while performing a real throwing gesture, and its corresponding VR task, were analyzed.

Friday 12th October

Scientific Programme

Humboldt-Universität zu Berlin | Philippstr. 13, Haus 11 | Room 1.26

09:30 to 10:30	Modular Composition of Human Gaits Through Locomotor Subfunctions and Sensor-Motor-Maps **André Seyfarth** – *Universität Darmstadt, GER*
10:30 to 11:00	Coffee break
11:00 to 12:00	The biomechanics and energetics of locomotion on uneven terrain **Alexandra Voloshina** – *Stanford University, USA*
12:00 to 13:30	Break
13:30 to 14:30	Feasibility of muscle synergy in clinics, sports and robotics: metrological aspects **Stefano Rossi** – *Università degli Studi della Tuscia, ITA*
14:30 to 15:00	Coffee break
15:00 to 16:00	Soft wearable robots for everyday wear **Conor Walsh** – *Harvard University, USA*

Social Programme

16:30 to 18:30	**A walk through history: the Berlin Wall** Philippstr. 13, Haus 11, 10115 Berlin
20:00	**Farewell dinner** Brauhaus Südstern Hasenheide 69, 10967 Berlin The places for this event are limited. Please confirm your presence to the team (alessandro.santuz@hu-berlin.de).

Friday 12th October

Abstracts

Modular Composition of Human Gaits Through Locomotor Subfunctions and Sensor-Motor-Maps

André Seyfarth – *Universität Darmstadt, GER*

Human locomotion is a complex movement task, which can be divided into a set of locomotor subfunctions. These subfunction comprise stance leg function, swing leg function and balance. Each of these locomotor subfunctions requires a specific control of individual muscles in the human body. We propose a novel method based on sensor-motor-maps to identify the appropriate motor control settings based on sensory feedback loops. Based on template models, both the biomechanical as well as the neuromuscular dynamics of gait can be studies and described at different levels of detail.

Friday 12th October

Abstracts

The biomechanics and energetics of locomotion on uneven terrain

Alexandra Voloshina – *Stanford University, USA*

Humans navigate uneven terrain in their everyday lives. From uneven sidewalks to rocky trails, we are constantly adapting our gait dynamics to compensate for uneven terrain. Past research has shown that walking and running on uneven terrain leads to increased energy expenditure and decreased balance, although the particular biomechanical mechanisms behind these changes are unclear. Human compensation strategies on uneven ground have seldom been studied, as most locomotion research is conducted in laboratory and clinical settings with smooth, level surfaces. An improved understanding of human locomotion on uneven terrain could lead to the development of improved clinical rehabilitation interventions, and more effective assistive and prosthetic devices.

I will present the experimental and modeling studies we have conducted in order to quantify the biomechanical and energetic changes seen in humans during walking and running on uneven surfaces. In these works, we have demonstrated that human adaptation strategies to uneven terrain vary based on gait type, with walking and running gaits relying on different lower-limb joints to mitigate continuous perturbations. I will also address how biological impairments, such as lower-limb amputation, affect an individual's ability to traverse uneven ground. Finally, I will discuss the implications these findings have for future locomotion and rehabilitation research.

Friday 12th October

Abstracts

Feasibility of muscle synergy in clinics, sports and robotics: metrological aspects

Stefano Rossi – *Università degli Studi della Tuscia, ITA*

Understanding how the human brain generates neural commands to control muscles during motor tasks still arouses great interest and curiosity among researchers. In the last decades, the factorization of the EMG signals by means of muscle synergies has been proposed to understand the neurophysiological mechanisms related to the Central Nervous System ability in reducing the dimensionality of muscle control. The EMG factorization is used in several research fields, such as clinics, robotics, and sport [1]. To evaluate the viability of using muscle synergy parameters as neurophysiological indices, several studies investigated the methodological issues related to EMG factorization, such as the effects of: (i) number of muscles[2], (ii) different factorization algorithms[3],[4], (iii) filter parameters required for the EMG pre-processing[3],[5]; and, (iv) averaging or concatenating repetitions of the same task[6].

Taking into account metrological aspects, repeatability of the muscle synergy represents an important point of discussion for validating the use of muscle synergy outcomes. Towards this aim, we analyzed the repeatability of the muscle synergies in several daily life activities both within- and between-subjects to identify the most potential neurophysiological index among the muscle synergy parameters. Eight healthy subjects performed walking, stepping, running, ascending and descending stairs trials for five repetitions in three sessions. Twelve muscles of the dominant leg were analyzed. Cosine similarity and coefficient of determination were computed to assess the repeatability of the muscle synergy vectors and the temporal activity patterns, respectively. Three repeatability analyses were performed: within-subject/within-session, within-subject/between-sessions, and between-subjects. Within the presentation, the results of this study will be discussed and a literature overview on the tangible applications of muscle synergies will be showed.

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Friday 12th October

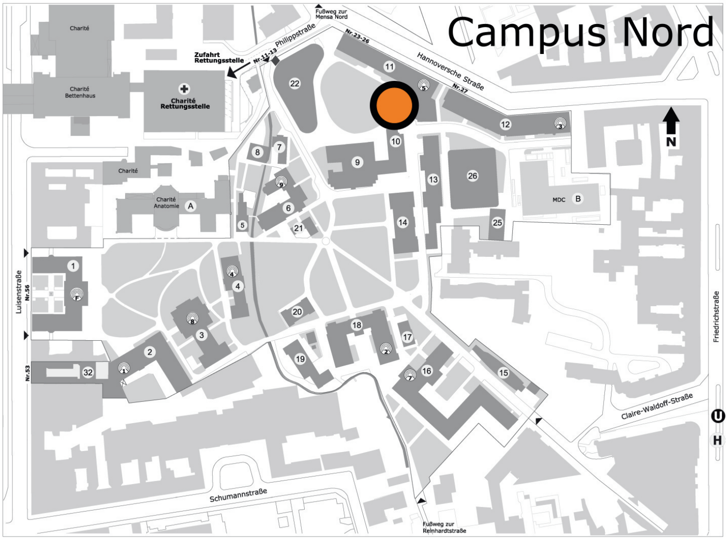
Abstracts

Soft wearable robots for everyday wear

Conor Walsh – *Harvard University, USA*

It is exciting to imagine a future when we can use wearable robots to increase strength or efficiency, restore or repair ability after injury or prevent injuries from happening in the first place. This vision is currently challenging to achieve due to limitations in current technology and a lack of understanding of how humans will respond to physical assistance. This talk will give an overview of our work on developing disruptive soft wearable robot technologies for augmenting and restoring human performance and what we have learned from biomechanical and physiological studies that furthers the scientific understanding of how humans interact with such machines. Our efforts are the result of a multidisciplinary team of students and research staff with backgrounds in engineering, materials science, apparel design, industrial design, biomechanics, and physical therapy, in addition to valuable collaborations with colleagues from Harvard, Boston University, and beyond. Our long-term vision is for ubiquitous soft wearable robots that can be worn all day, every day underneath clothing, in both the community, home, sporting and workplace environments. This would enable a change in the paradigm of how we currently assist mobility for those with physical impairments (i.e. replacing plastic braces with active assistance), and how we rehabilitate those after injury (i.e. training programs outside of a clinic environment) as well as how we protect healthy individuals with physical tasks (i.e. protecting military personnel, athletes or factory workers performing high risk tasks).

Lecture hall location



Address and GPS coordinates

Philippstr. 13, Haus 11, 10115 Berlin
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5th International Autumn School on Movement Science

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Berlin School of Movement Science • Coordination Office
Tel +49 30 209346045 • Fax +49 30 209346046
www.bsms.hu-berlin.de