

8th



UNIVERSITÀ
di **VERONA**



COMUNE DI
ROVERETO

INTERNATIONAL CONGRESS **MOUNTAIN, SPORT & HEALTH**

UPDATING STUDY AND RESEARCH
FROM LABORATORY TO FIELD

7-8 NOVEMBER 2019 - ROVERETO (TN) - ITALY

Sponsored by:



COSMED
The Metabolic Company

With the patronage:



COMUNITÀ DELLA
VALLAGARINA



PROVINCIA
AUTONOMA DI TRENTO

TRENTINOSVILUPPO
IMPRESA INNOVAZIONE MARKETING TERRITORIALE



BOOK OF ABSTRACTS

ORGANIZING COMMITTEE

Federico Schena
Barbara Pellegrini
Lorenzo Bortolan
Chiara Zoppirolli
Aldo Savoldelli



8th International Congress
MOUNTAIN SPORT & HEALTH
Updating Study and Research from Laboratory to Field

7-8 November 2019
Rovereto (TN) - Italy

PROGRAMME
and
BOOK OF ABSTRACTS



UNIVERSITÀ
di **VERONA**



COMUNE DI
ROVERETO

Sponsored by



Partnership:



WELCOME

Mountain and Health is an amazing couple which turn to be joined by Sport in an active life perspective. There are a number of different fields, ranging from the top high-level performance to the promotion of health and wellbeing that find a specific development in this framework.

With this regard, the eighth edition of the Congress will be focused on the physiology of exercise in special environment, going from cold to warm and with special focus on hypoxic conditions. It would be also the occasion to focus the attention to cutting edge knowledge of training and conditioning and to talk about a new perspective of accademic organization systems that would support dual career projects.

Thanks to this approach, the congress will be multidisciplinary and valuable occasion not only for researchers but also for trainers, mountain experts and students to be engaged in very active discussions and cutting edge lectures by the best scientists on physiology and sport science.

The Congress is held in Rovereto, a City that has always supported the knowledge, the technology and the sport and that is surrounded by an amazing region devoted to outdoor sport and that will host many of the competitions scheduled in the Olympic Games 2026. The present congress will be an occasion to plan future scientific perspective in this field.

Thank you all for participating and I give you my very best wishes for a successful Congress and outcome.

Professor Federico Schena



SPEAKERS*(in alphabetic order)*

Valeria Azzini	<i>Dipartimento di Area Medica University of Udine, Italy</i>
Gennaro Boccia	<i>NeuroMuscular Function Research Group, University of Torino, Italy</i>
Lorenzo Bortolan	<i>CeRiSM, University of Verona, Italy</i>
Paolo Bouquet	<i>Dipartimento di Ingegneria e Scienza dell'Informazione University of Trento, Italy</i>
Alfredo Brighenti	<i>University of Verona, Italy and University of Franche-Comté, Besançon, France</i>
Alexa Callovini	<i>CeRiSM, University of Verona, Italy</i>
Emanuele Carniel	<i>Department of industrial Engineering ,University of Padova, Italy</i>
Valentina Cavedon	<i>Department of Neuroscience, Biomedicine and movement science University of Verona, Italy</i>
Saša CeciĆ Erpič	<i>Faculty of Sport, University of Ljubljana, Slovenia</i>
Giuseppe Coratella	<i>Department of Biomedical Sciences for Health, University of Milano, Italy</i>
Samuel D'Emanuele	<i>Department of Neuroscience, Biomedicine and movement science University of Verona, Italy</i>
Davide Filingeri	<i>Environmental Ergonomics Research Centre, Loughborough University, UK</i>
Matteo Fiorenza	<i>University of Copenhagen, Denmark</i>
Alessandro Fornasiero	<i>CeRiSM, University of Verona, Italy</i>
Hannes Gatterer	<i>EURAC Research, Bolzano, Italy</i>
Nicola Giovanelli	<i>Dipartimento di Area Medica, University of Udine, Italy</i>
Gaia Giuriato	<i>Department of Neuroscience, Biomedicine and movement science, University of Verona, Italy</i>
Hans-Christer Holmberg	<i>Swedish Winter Sports Research Centre, Mid Sweden University, Sweden</i>

Justin Lawley	<i>Department of Sport Science, University of Innsbruck, Austria</i>
David Low	<i>Research Institute for Sport and Exercise Science Liverpool John Moores University, UK</i>
Aldo Savoldelli	<i>CeRiSM, University of Verona, Italy</i>
Gianluca Vernillo	<i>Department of Biomedical Sciences for Health, University of Milano, Italy</i>
Francesca Vitali	<i>Department of Neuroscience, Biomedicine and movement science, University of Verona, Italy</i>
Eivind Wang	<i>Norwegian University of Science and Technology, Norway</i>
Andrea Zignoli	<i>Department of Industrial Engineering University of Trento, Italy</i>

	PROGRAMME THURSDAY, 7 NOVEMBER	
8.30 – 9.00	Registration	
9.00 – 11.00	Thematic session 1 – Muscle endurance and fatigue	
	<u>Eivind Wang (NOR) – Strength training effects on aerobic endurance</u>	p.28
	<u>Gennaro Boccia (Torino) - The neuromuscular fatigue in endurance performance, the relevance of the rate of force development</u>	p.9
	<u>Matteo Fiorenza (Copenhagen) - Skeletal muscle adaptations underlying performance-enhancing effects of high-intensity interval training</u>	p.19
	<u>Giuseppe Coratella (Milano) - Short- and long-term eccentric training-induced adaptations</u>	p.16
11.15 - 11.45	Coffee break	
11.45 – 12.15	Official opening	
12.15 – 13.00	Short Talk – Session 1	
	<u>Alexa Callovini (Rovereto) - Very short-term heat acclimation: are 3 exercise sessions in the heat enough to partially reduce heat-induced performance decrements?</u>	p.12
	<u>Gaia Giuriato (Verona) - Molecular and functional basis of successful aging and frailty: a study protocol exploring positive behaviors to counteract age-related physical and cognitive decline</u>	p.22
	<u>Samuel D'Emanuele (Verona) - What high density surface electromyography can teach us about the postural activation of erector spinae muscles? The case of violinists</u>	p.17
	<u>Alfredo Brighenti (Rovereto) - Postural stability response, in dominant and nondominant one-legged stance, after a warm-up</u>	p.11
13.00 – 14.15	LUNCH	
14.15 – 15.15	Thematic session 2 – Exercise and thermoregulation	
	<u>Davide Filingeri (Loughborough) -Thermal challenges of sport performance at altitude: from human thermoregulation to technical solutions for thermal protection</u>	p.18
	<u>David Low (Liverpool) - Acute responses and solutions to adapt to a hot environment</u>	p.25
15.15 – 15.45	Coffee break	
15.45 – 17.15	Thematic session 3 – Trail running and performance	
	<u>Gianluca Vernillo (Milano) - Downhill running: strategies to improve performance</u>	p.27
	<u>Nicola Giovanelli (Udine) - Uphill walking and running: strategies to improve performance</u>	p.21
	<u>Aldo Savoldelli (Rovereto) - Uphill performance: with poles, or not with poles, this is the question</u>	p.25

	FRIDAY, 8 NOVEMBER	
9.00 – 10.30	Thematic session 4 – Integrating elite sport and education supporting dualcareer	
	<u>Francesca Vitali (Verona) - Enhancing athletes' employability: The development and Initial Validation of the ACQE</u>	p.28
	<u>Saša CeciĆ Erpič (Slovenia) - Meta-analysis of dual career studies from the viewpoint of European discourse</u>	p.18
	<u>Paolo Bouquet (Trento) - Dual Career projects: UniSport Trento</u>	p.11
10.30– 11.00	Coffee break	
11.00 - 12.00	Short Talk - Session 2	
	<u>Valentina Cavedon (Verona) - Regional distribution of DXA-measured body fat mass in athletes with a locomotor impairment</u>	p.15
	<u>Valeria Azzini (Udine) - Specificity of test for predicting acute mountain sickness: could it be used for optimizing altitude exercise?</u>	p.8
	<u>Andrea Zignoli (Trento) ,Ciro Malacarne (ProM Facility, Trentino Sviluppo) - DeMotu project: design and production of a 3D printed human knee for research in biomechanics</u>	p.30
11.00 – 12.00	Keynote Lecturer	
	<u>Hans-Christer Holmberg (Sweden) - Fast, faster, and even faster</u>	p.23
13.00 – 14.00	LUNCH	
14.00 – 15.30	Thematic session 5 – Hypoxia, health and performance	
	<u>Hannes Gatterer (Xcube/ Bolzano) – Effects of intermittent (interval) hypoxia on health</u>	p.20
	<u>Justin Lawley (Innsbruck) - Health at high altitude, acute mountain sickness</u>	p.24
	<u>Alessandro Fornasiero (Rovereto) - Cardiac autonomic and physiological responses to hypoxic exercise of different intensities</u>	p.19
15.30 – 16.30	Thematic session 6 – Technology in Sports	
	<u>Carniel Emanuele (ITA) – Computational approach to the investigation of lower leg biomechanics and ski boot ergonomics</u>	p.14
	<u>Lorenzo Bortolan (Rovereto) - The ankle ROM during the walking phase of Ski mountaineering: the role of different ski boots</u>	p.10
16.30	Closing	

Specificity of test for predicting acute mountain sickness: could it be used for optimizing altitude exercise?

Giovanelli N.¹, Cigalotto A.², Lesa B.¹, Azzini V.³, Lazzer S.³

¹Dipartimento di Area Medica, Università di Udine

²Dipartimento di Prevenzione, Presidio Ospedaliero di Gemona del Friuli

³Scuola di Specializzazione in Medicina dello Sport, Università di Padova

Introduction. Acute altitude illnesses are potentially serious conditions that can affect otherwise fit individuals who ascend to high altitude. They include high altitude headache, acute mountain sickness (AMS), high altitude cerebral edema (HACE) and high altitude pulmonary edema (HAPE). These conditions may occur as a result of poor acclimatization to the lower oxygen partial pressure or due to a higher individual risk; there are general guidelines for people approaching the altitude which include slow ascent, rest days and pre-acclimatization, however these guidelines are not always sufficient since there is a great inter-individual variability. The test, proposed by Richalet et al. (2012) [1], is the best way to identify subjects who are more suitable to develop AMS, by analysing their cardiac and respiratory response to hypoxia both at rest and during exercise. Richalet's test, which is performed on cycle ergometer, is however not specific for mountaineers, because most people travel to the mountains by hiking. For this reason, we proposed a comparison between the test performed on the cycle ergometer and an equivalent test performed on a treadmill.

Methods. We recruited 12 healthy, young subjects (age 29.7 ± 8.9 yr) each of whom underwent an incremental test and a Richalet test, both on a cycle ergometer and on a treadmill. We then compared results from the 2 tests to identify the possible differences between the responses to hypoxia.

Results. Comparing the 2 different incremental tests, $\dot{V}O_{2peak}$ and HR_{peak} were significantly higher during walking than cycling (+9 and +3%, $p < 0.05$, respectively). On the other hand, no significant difference was found when we checked the desaturation and the cardiac and respiratory responses to hypoxia with the 2 different ergometers.

Discussions. We can conclude that there is no difference in the parameters identified by Richalet test to estimate the risk to develop AMS by using a cycle ergometer or a treadmill.

Conclusions. For this reason, treadmill could be taken into account, as it represents a more specific pattern of exercise for mountaineers or hikers, while cycle ergometer remains a more manageable tool in lab conditions.

References:

1. Richalet JP, Larmignat P, Poitrine E, Letournel M, Canouï-Poitrine F. Physiological risk factors for severe high-altitude illness: a prospective cohort study. *Am J Respir Crit Care Med*. 2012 Jan 15;185(2):192-8.

The neuromuscular fatigue in endurance performance, the relevance of the rate of force development

Boccia G.

NeuroMuscular Function Research Group, School of Exercise and Sport Sciences, Department of Medical Sciences, University of Torino, 10143 Turin, Italy

Muscle fatigue can be defined as an exercise-induced decreased capacity to generate maximal force. Thus, measuring reductions in maximal voluntary contraction force is considered as the most valid and widespread approach to measure muscle fatigue (Place et al., 2010). Strength loss is a common finding after endurance running in ecological race conditions: it increases non-linearly with the duration of exercises and it may vary between 8 and 41% (Place et al., 2010; Giandolini et al., 2016). The decrease in maximal force is usually associated with a reduced capacity to voluntarily activate the knee extensors in maximal contraction and reflect the presence of central fatigue. Central fatigue constitutes an important limitation to performance and is the major cause of the maximal force decrease induced by a prolonged whole body exercise such as running (Saldanha et al., 2008). The amount of central fatigue depends on many exercise parameters, such as intensity, duration, and contraction modality, among others. However, it is evident in the literature that central fatigue is overall greater for extreme-duration running (Martin et al., 2010; Temesi et al., 2014) rather than for shorter, more intense bouts like half-marathons (Boccia et al., 2018).

Together with decrease in maximal strength, endurance sport races induce a considerable decrease in rate of force development (RFD) of locomotor muscles (Boccia et al., 2016; Boccia et al., 2018). The RFD reflects the ability to rapidly increase muscle force after the onset of an explosive voluntary contraction (Maffiuletti et al., 2016; Rodriguez-Rosell et al., 2017). This is an important feature when the time required to develop maximal force (300 ms or more) is longer than the time available to develop force (Maffiuletti et al., 2016). For example, runners repeatedly cope with the transient of the vertical ground reaction force within the first 100-150 ms of stance (Lieberman et al., 2010), thus the capacity to produce force in brief and fast muscle contractions likely influence running mechanics. The detrimental effects of prolonged exercise on RFD was showed to be related to both central and peripheral fatigue (Boccia et al., 2018). Furthermore, it was shown that the capacity to maintain a rapid force production is important in fatigued states, even though this aspect has received little attention in the literature so far. Nevertheless, if the decrease in RFD during a prolonged running is an epiphenomenon or it is relevant to the final performance is still to be clearly determined.

References:

1. Boccia et al. (2018). *Eur J Sport Sci*, 1-10
2. Boccia et al. (2016). *Scand J Med Sci Sports*. 12718.
3. Giandolini et al. (2016). *Eur J Appl Physiol*, 1645212.
4. Lieberman et al. (2010). *Nature* 463(7280), 531-U149.
5. Maffiuletti et al. *Eur J Appl Physiol* 116(6), 1091-1116.
6. Place et al. (2010). *Eur J Appl Physiol* 110(1), 1-15.
7. Rodriguez-Rosell et al. (2017). *Clin Physiol Funct Imaging*. 12495.
8. Ross et al. (2010). *Med Sci Sports Exerc* 42(6), 1184-1190.
9. Saldanha et al. (2008). *Scand J Med Sci Sports* 18(3), 383-388.
10. Temesi et al. (2014). *Medicine and Science in Sports and Exercise* 46(6), 1166-1175.

The ankle ROM during the walking phase of Ski mountaineering: the role of different ski boots.

Bortolan L.1,2, Savoldelli A.1, Stella F.1,

¹CeRiSM Research Center "Sport, Mountain, and Health", University of Verona, Rovereto, Italy

²Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, University of Verona, Italy

Introduction: The popularity of ski mountaineering as an alternative winter activity to more traditional winter sport, like alpine and cross-country skiing, is growing in the last few years. Despite that, the number of scientific researches per year remains low and mainly focused on physiological and performance aspects in addition to the injury's studies. Only few studies have been published concerning biomechanical aspects like spatio-temporal^{1,2} parameters and foot loading³ during the walking phase.

During the uphill, the ski's bases are covered with special skins to prevent backsliding during the ascent. In these parts of the track, the ski boots are free to rotate around the tiptoe to allow the rear extension of the leg. The leg's mobility is allowed also through the upper part of the ski boot that, only during walking phases, can rotate around the linchpins and that, during the downhill, is fixed using a locking mechanism. Even though the range of motion of the ankle is one of the parameters considered by the skiers when they choose their ski boots, no studies analyzing the flex-extension angle allowed by the boots has been found. This study aims to investigate the effects on the ankle range of motion using different ski boots, on flat (F) and uphill (H) terrain.

Methods: A preliminary study has been done to estimate the correlation between the angle acquired with a 3D kinematic system and two IMUs placed 5cm under of the tibial tuberosity, and over the tip of different ski boots, respectively. Then, a trained subject with more than 10 years' experience was asked to perform on two ski mountaineering paths (a flat one, and a straight uphill one with 35% of slope) with 7 different ski boots. The angle between the inclination of the ski boot and tibias has been calculated on the sagittal plane from the IMU's data.

Results: Laboratory tests confirm that the leg's angular ranges calculated from the IMUs data are strictly correlated with the kinematic measurements ($r = 0.996$; $p < 0.001$). On the field, at least a mean value of twenty steps have been analyzed for each condition (flat and uphill). The paired t-test shows that the mean flexion angle is not different between flat and uphill (F: $61.02^\circ \pm 5.09$; H: $61.88^\circ \pm 5.41$; $p = 0.65$) while the mean extension is greater on the flat (F: $96.19^\circ \pm 5.85$; H: $90.34^\circ \pm 6.07$; $p = 0.04$). The mean range is higher on the flat track (F: $32.18^\circ \pm 5.49$; H: $28.46^\circ \pm 4.20$; $p = 0.017$).

Discussion: The high correlation between kinematic and IMUs data supports the opportunity to use the IMUs to evaluate the articular angles on the field. This methodology was used to acquire the leg's angle compared to the ski boot on the sagittal plane during ski mountaineering, showing a remarkable difference among the ski boots used for the trials. These differences, although related to the different vocations of the boots' models, underline the benefit to have a higher extension angle particularly useful on the flat sessions.

Conclusion: This study shows how, with suitable devices, it is possible to investigate ski mountaineering on field. Indeed, this activity is replicable in the laboratory only accepting the high limitations that inevitably will change the biomechanical pattern of the locomotion.

References

1. Gellaerts, J., (2018). In-Field Validation of an Inertial Sensor-Based System for Movement Analysis and Classification in Ski Mountaineering. *Sensors* (Basel, Switzerland), 18(3).

2. Fasel, B., (2016). Measuring spatio-temporal parameters of uphill ski-mountaineering with ski-fixed inertial sensors. *Journal of Biomechanics*, 49(13), 3052–3055.
3. Haselbacher, (2014). Effect of ski mountaineering track on foot sole loading pattern. *Wilderness and Environmental Medicine*, 25(3), 335–339.

Dual Career projects: UniSport Trento

Paolo Bouquet

Delegato per lo sport, Università degli Studi di Trento
Dipartimento di Ingegneria e Scienza dell'Informazione, Università di Trento.

(testo tratto dal sito <https://www.unitn.it/servizi/60741/dual-career>)

L'Università di Trento è particolarmente attenta allo sport come parte integrante ed attiva del percorso universitario. Dal 2008 ha lanciato UNITrento Sport, la rete universitaria di servizi e strutture sportive che comprende, tra le sue iniziative, anche i programmi a sostegno della dual career di studenti-atleti.

Con la creazione del programma TOPSport, l'Ateneo di Trento è diventato la prima università in Italia a prevedere concreti supporti per atleti e atlete interessati a costruire una carriera professionale oltre a quella sportiva. Dal 2012, inoltre l'Ateneo è partner della rete europea della dual career: EAS - The Dual Career Network

Nato nel 2011, il programma TOPSport si rivolge ad atleti e atlete di alto o altissimo livello di ogni disciplina sportiva, interessati a studiare presso l'Ateneo. Il programma fornisce un supporto costante per la gestione del proprio percorso universitario e diversi benefit, tra cui la flessibilità delle sessioni d'esame.

Il programma TOP Team, nato nell'a.a. 2015/2016 grazie a una sperimentazione con Aquila Basket Trento, si rivolge alle società sportive del territorio di alto livello che intendono offrire a giocatori e giocatrici motivati la possibilità di conciliare l'impegno agonistico con la formazione universitaria. Nel 2017 oltre ad Aquila Basket, ha investito in TOP Team anche la società sportiva Hockey Pergine, mentre nel 2018 è arrivata la sottoscrizione del programma da parte di Trentino Volley.

Postural stability response, in dominant and nondominant one-legged stance, after a warm-up

Brighenti A.^{1,2}, Stella F.², Noè F.³, Schena F.², Mourot L.¹

¹Research Unit EA3920, Univ. Bourgogne Franche-Comté, France

² CeRiSM, Sport Mountain and Health Research Centre, University of Verona, Rovereto, Italy

³Research Unit EA 4445, Univ. de Pau et des Pays de l'Adour, France

Introduction: Dominant (D-leg) and nondominant (ND-leg) legs exhibited differences in terms of postural control. Warm-up increased temperature elevation improves the output of sensory, integration, and motor functions. The aim of the present study was to evaluate the postural control between D-leg and ND-leg over time after a warm-up.

Methods: Twelve well trained students (8 m, 4 f) participated. The experiment consisted in a basal balance assessment (pre) followed by a warm-up (10 min of cycle ergometer at an intensity of 20 on the CR-100 Borg's scale) then, balance assessments after 2 (post), 5 (p5), 10 (p10), 15 (p15) and 20 (p20) minutes. The balance was assessed standing one-legged barefoot and as motionless as possible during 25.6 sec on a force platform. Were measured displacements center of foot pressure (COP_{tot} sway) in antero-posterior (COP_{AP} sway), medio-lateral (COP_{ML} sway) directions and calculated the ellipse (COP_{ellipse}).

Results: The Wilcoxon sign rank test showed a positive warm-up effect on D-leg after 20 min in all the parameters considered: COP_{tot} sway ($p=0.0009$), COP_{AP} sway ($p=0.002$), COP_{ML} sway ($p=0.009$) and COP_{ellipse} ($p=0.002$). Friedman's ANOVA showed a warm-up effect on the D-leg for the variables: COP_{tot} sway ($p=0.005$), COP_{AP} sway ($p=0.008$) and COP_{ML} sway ($p=0.02$) no significance differences were observed for ND-leg. The multiple comparison obtained by the Nemenyi post hoc test shows significant decrease in COP_{tot} sway in D-leg between pre and p20 ($p=0.005$), COP_{AP} sway D-leg between pre and p20 ($p=0.02$) and COP_{ML} sway D-leg between pre and p20 ($p=0.008$).

Conclusion: the results suggested that Warm-up induced an improvement of postural control 20 min after the end of the exercise but not in the same way between D-leg and ND-leg. This might due to a different physiological response to the warm-up between the two legs.

References

1. Paillard T (2017) Plasticity of the postural function to sport and/or motor experience. *Neurosci Biobehav R* 72: 129-152
2. Paillard et al. (2018) Warm-up optimizes postural control but requires some minutes of recovery. *J Strength Cond Res* 32 (10): 2725–2729

Very short-term heat acclimation: are 3 exercise sessions in the heat enough to partially reduce heat-induced performance decrements?

Callovin A.^{1,2}, Fornasiero A.^{1,2}, Savoldelli A.^{1,2}, Stella F.^{1,2}, Bortolan L.^{1,2}, Pellegrini B.^{1,2}, Schena F.^{1,2}

¹ CeRiSM, Sport Mountain and Health Research Centre, University of Verona, Rovereto, Italy

² Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Verona, Italy

Introduction: Many sporting events are held every year in hot environments, with temperatures upwards of 35°C and above 50% of relative humidity. In order to limit heat-induced performance decrements (ranging from 6 to 16% in trained athletes)¹, heat acclimatization/acclimation (HA) protocols have been proposed². Although complete physiological adaptation to hot environments may require up to 14 days to occur², cardiovascular and perceptual adaptations have been noticed even after only 3 days of heat exposures³. Despite being short-term acclimations protocols of interest to elite athletes, in order to limit costs and modifications of training programs, the expected performance enhancements, as well as the physiological adaptation induced by this kind of programs are not completely understood. In this study, we investigated the effects of a 3-day very short-term heat acclimation protocol (VSTAP) on performance, physiological and perceptual responses to exercise in the heat.

Methods: 6 well trained male cyclists (age: 30.9±8; weight: 75.5±7) performed a preliminary normothermic (18°C- 50% RH) maximal cardiopulmonary exercise test (CPET) in order to define individual Peak Power Output (PPO). CPET was followed by normothermic and a hot (35°C-50% RH) Time to Exhaustion tests (nTTE vs hTTE, interspersed by at least 48-72 hours) with a relative intensity set at 75% of PPO. Performance tests were repeated after the VSTAP, consisting of 3 days- 1,5 hours training at 50% of PPO. During TTE tests, final performance time, blood lactate [La], maximal and mean Heart Rate (HR), Rate of Perceived Exertion (RPE), Thermal Sensation (TS) and Ear Temperature (Et) were evaluated. Moreover, we monitored HR, TS, RPE and Et throughout the training sessions (1,2,3). All data from TTE and training sessions were analyzed using ANOVA for repeated measures.

Results: TTE performance increased at POST both in H (+38%) and N (14%) (general condition effect $p<0.05$). A similar general condition effect ($p<0.05$) was reported for TSend, that decreased at POST in both conditions. Maximal RPE and HR were similar in N and H both at PRE and POST. No effect of time was reported on Et, which was higher in H. [La] decreased at POST in N. Both mean Et and HR decreased during training 3 compared to training 1 ($p<0.05$) (-0.4 °C and -6% during training 3, respectively).

Conclusion: Considering preliminary data, a VSTAP seems to induce performance improvements in both normothermic and hot conditions. This could be related to improved thermoregulation processes (partially seen in decreased mean Et at training 3) and some cardiovascular adaptations (decrease in HR). This is probably due to an increase in plasma volume and consequently increased CO with a contemporary reduction in sympathetic nervous system activity³. Improvements also in nTTE need further investigations to ensure the effect of heat training on temperate performance.

References:

1. Casadio JR et al. From Lab to Real World: Heat Acclimation Considerations for Elite Athletes. *Sport Med.* 2017;47(8):1467-1476. doi:10.1007/s40279-016-0668-9
2. Tyler CJ et al. The Effects of Heat Adaptation on Physiology, Perception and Exercise Performance in the Heat: A Meta-Analysis. *Sport Med.* 2016;46(11):1699-1724. doi:10.1007/s40279-016-0538-5
3. Chalmers S et al. Short-term heat acclimation training improves physical performance: A systematic review, and exploration of physiological adaptations and application for team sports. *Sport Med.* 2014;44(7):971-988. doi:10.1007/s40279-014-0178-6

Computational approach to the investigation of lower leg biomechanics and ski boot ergonomics

Fontanella C.G.¹, Toniolo I.¹, Carniel E.L.¹

¹Center for Mechanics of Biological Materials, Department of industrial Engineering, University of Padova, Italy

Introduction. Nowadays, computer methods provide reliable support for the investigation of the mechanical functionality of biological structures. Computational models can be further exploited to analyze interaction phenomena between biological tissues and devices, providing data that allow for their reliability assessment and optimal design. With specific regard to ski boots, the methods of computational biomechanics allow analyzing the stress and the strain fields that occur within lower leg and foot tissues, depending on ski boot conformation, buckling level and skiing actions. Such mechanical stimuli determine relevant phenomena, with particular regard to vasoconstriction effects.

Methods. A specific computational framework is provided aiming to analyze interaction phenomena between lower leg and ski boot. The development of the leg model entails the morphometrical investigation of the building tissues and structures. The action is performed starting from CT and MRI biomedical images, together with anthropometric data, and leads to virtual solid and finite element models of the system. Further efforts pertain to the characterization of tissues mechanics, as the constitutive analysis. Coupled experimental and computational activities are performed, aiming to the identification and the validation of the models. Contemporarily, a computational model of a ski boot is developed and accounts for the different building components and materials. Finally, specific computational algorithms are exploited to simulate ski boot buckling.

Results. The developed model allows evaluating stress and strain fields within biological tissues because of ski boot buckling. The intensity of such mechanical stimuli may induce vasoconstriction phenomena, jeopardizing the ergonomics of the device.

Discussion. Nowadays, computational methods provide reliable tools and information for a rational approach to the design and the optimization of sport devices. In detail, computational methods proved their suitability for the actual investigation of ski boot ergonomics.

Conclusions. The principal challenges of computational modeling pertain to models identification and validation, the solving time because of model complexity, the availability of powerful and efficient hardware and software relives, the requirement of dedicated technicians and engineers.

References:

1. Fontanella, C.G., Natali, A.N., Carniel, E.L., Numerical analysis of the foot in healthy and degenerative conditions (2017) *Journal of Mechanics in Medicine and Biology*, 17 (6), art. no. 1750095. DOI: 10.1142/S0219519417500956
2. Fontanella, C.G., Nalesso, F., Carniel, E.L., Natali, A.N., Biomechanical behavior of plantar fat pad in healthy and degenerative foot conditions (2016) *Medical and Biological Engineering and Computing*, 54 (4), pp. 653-661. DOI: 10.1007/s11517-015-1356-x
3. Forestiero, A., Raumer, A., Carniel, E.L., Natali, A.N., Investigation of the interaction phenomena between foot and insole by means of a numerical approach (2015) *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*, 229 (1), pp. 3-9. DOI: 10.1177/1754337114560579

Regional distribution of DXA-measured body fat mass in athletes with a locomotor impairment

Cavedon V.¹, Zancanaro C.¹, Milanese C.¹

¹Department of Neuroscience, Biomedicine and Movement Sciences, University of Verona, Verona, Italy.

Introduction. In athletes with a locomotor impairment, the use of anthropometric predictive equations to assess body composition is of limited use because of their low accuracy. A satisfactory explanation for such a drawback is not available. A possible factor is an altered body distribution of fat mass (FM) in this athletic population and/or the presence of body asymmetry. This hypothesis was tested by assessing regional %FM in 52 athletes with a locomotor impairment (wheelchair-bound [WB; n = 25] and walkers [Walk; n = 27]) in comparison each with an age- and %FM-matched group of able-bodied athletes (AB).

Methods. Whole-body and regional (upper limbs, lower limbs and trunk) %FM was assessed in all participants by means of Dual-Energy X-ray Absorptiometry. The independent-samples T-test was used to evaluate differences in the regional distribution of %FM between WB and Walk and their respective AB control group. A mixed-design 4 x 2 Analysis of Variance (ANOVA) with group (WB, Walk and their respective AB) and body side (right and left) as the factors was performed to assess group by side interaction for %FM in the appendicular regions. If a significant interaction was detected, post-hoc pairwise comparisons with Bonferroni correction were carried out. In the case of impairment predominantly affecting one lower limb, the non-affected lower limb was considered as “right” while the affected lower limb was considered as “left”.

Results. %FM in the trunk region was similar between the two groups of athletes with a locomotor impairment and their respective control group. The WB group had significantly lower (-5.5%, $P = 0.01$) %FM in the upper limbs vs. the corresponding AB group, while the Walk group had similar %FM in the upper limbs vs. the corresponding AB group. Both groups of athletes with a locomotor impairment had higher (+8.5%, $P = 0.001$ and +4.9%, $P = 0.01$, respectively) %FM in the lower limbs vs. their respective AB group. In the lower limbs, ANOVA showed a significant main effect of group x side interaction for %FM ($F = 11.01$, $P < 0.001$). Post hoc analysis revealed that %FM was significantly lower (-7.9%, $P < 0.001$) in the non-affected versus the affected side in the Walk group only.

Discussion. The results of the present study revealed that %FM at the regional level is differently distributed in athletes with locomotor impairment in comparison with their matched AB groups, especially in WB. Moreover, the Walk group have substantial body %FM asymmetry in the lower limbs. Taken together these results may offer substantial explanation for the low accuracy of anthropometric predictive equations validated in AB when used for predicting %FM in athletes with a locomotor impairment.

Conclusions. These results prompt for the development of population-specific anthropometric equations in order to more accurately estimate body composition in athletes with a locomotor impairment.

Short- and long-term eccentric training-induced adaptations

Coratella G

Department of Biomedical Sciences for Health, Università degli Studi di Milano, Milano, Italy

Eccentric exercise is widely implemented in training routine, both to improve performance¹ and in rehabilitation². Notwithstanding, it is well known that a first eccentric session results typically in exercise-induced muscle damage, whatever the eccentric exercise modality (e.g. isokinetic, dynamic-constant external load or iso-inertial eccentric exercise)^{3,4}. Indeed, the forcibly-lengthened sarcomeres that are ruptured by the active muscle lengthening, trigger a reparation process that could last several days. Such a recovery process can be monitored using different non-invasive markers, as strength loss, decrease in passive range of movement, increase in muscle girth, echo-intensity, increase in creatin-kinase or myoglobin blood concentration, acute shift in optimum angle towards longer muscle length and delayed-onset of muscle soreness^{5,6}. Particularly, this last may be an economic, simple and effective method to evaluate the time-course of the recovery process. Quantifying the delayed-onset of muscle soreness require few important familiarization steps to avoid the subjects misunderstand or falsify the measure. Exercise-induced muscle damage is more marked when eccentric exercise is performed with high-volume and/or high-intensity, high-velocity⁷, or at long vs short muscle length⁸. Thus, manipulating these factors and understanding how to monitor the recovery process is warranted in both training and rehabilitation periods. Lastly, a first bout of eccentric exercise, albeit inducing muscle damage, protects from a following eccentric bout performed on a subsequent session^{3,4}. This phenomenon has been named “repeated bout effect” and it was proposed to depend on mechanical, cellular, inflammatory and/or neural mechanisms⁹. Therefore, safely implementing eccentric exercise within a training or rehabilitation routine should take into account the acute and the long-lasting muscle response to the eccentric stimulus.

References:

1. Roig M, O'Brien K, Kirk G, Murray R, McKinnon P, Shadgan B, Reid WD. The effects of eccentric versus concentric resistance training on muscle strength and mass in healthy adults: a systematic review with meta-analysis. *Br J Sports Med* 2009;43:556–68.
2. Tesch PA, Fernandez-Gonzalo R, Lundberg TR. Clinical applications of iso-inertial, eccentric-overload (YoYoTM) resistance exercise. *Front Physiol* 2017;8:.
3. Coratella G, Bertinato L. Isoload vs isokinetic eccentric exercise: a direct comparison of exercise-induced muscle damage and repeated bout effect. *Sport Sci Health* 2015;11:87–96.
4. Coratella G, Chemello A, Schena F. Muscle damage and repeated bout effect induced by enhanced eccentric squats. *J Sports Med Phys Fitness* 2016;56:1540–1546.
5. Chen TC, Chen HL, Lin MJ, Wu CJ, Nosaka K. Muscle damage responses of the elbow flexors to four maximal eccentric exercise bouts performed every 4 weeks. *Eur J Appl Physiol* 2009;106:267–75.
6. Chapman DW, Newton M, McGuigan MR, Nosaka K. Comparison between old and young men for responses to fast velocity maximal lengthening contractions of the elbow flexors. *Eur J Appl Physiol* 2008;104:531–9.
7. Chapman DW, Newton M, McGuigan M, Nosaka K. Effect of lengthening contraction velocity on muscle damage of the elbow flexors. *Med Sci Sports Exerc* 2008;40:926–33.
8. Nosaka K, Newton M, Sacco P, Chapman D, Lavender A. Partial Protection against Muscle Damage by Eccentric Actions at Short Muscle Lengths. *Med Sci Sport Exerc* 2005;37:746–753.
9. Hyldahl RD, Chen TC, Nosaka K. Mechanisms and Mediators of the Skeletal Muscle Repeated Bout Effect. *Exerc Sport Sci Rev* 2017;45:24–33.

What high density surface electromyography can teach us about the postural activation of erector spinae muscles? The case of violinists

D'Emanuele S.¹, Russo A.², Aranceta-Garza A.³, Serafino F.², Merletti R.²

¹Department of Neuroscience, Biomedicine and Movement, University of Verona, Italy

²LISiN, Dept of Electronics and Telecommunications, Politecnico di Torino, Italy

³Biomedical Engineering Department, University of Strathclyde, Glasgow, United Kingdom

Musicians are a small category of professional workers with a high percentage of work-related neuro-muscular and musculo-skeletal disorders which are referred to as Playing Related Musculoskeletal Disorders (PRMD) [1]. Risk factors are intrinsic (anthropometric characteristics, strength, previous problems) and extrinsic (training, chairs, environmental issues, postural habits). Some authors claim that proper chairs may prevent the development of PRMD [2,3]. The purpose of this study was to compare an “ergonomic” alternative chair (A-chair), with a standard orchestra chair (O-chair) used by a group of nine violinists (8F and 1M). The violinists played the same pieces of music for 2 hours without interruptions, on each chair, in two different days. High-density surface electromyography (HDsEMG) was used to record signals for 20s every 5 minutes using two electrode arrays of 16x8 electrodes each, placed on erector spinae between T11 and L4. The root mean square (RMS) and mean spectral frequency (MNF) values over the region of activity (ROA), the centroid of the ROA, the rates of change in time of the spatial mean of the RMS and MNF values associated to the two chairs, were compared. Statistically significant reductions were observed in all violinists between the spatial mean RMS value of the ROA computed for the O-chair and the A-chair. Such reductions ranged between 11.8% and 78.36%. No significant changes of other spatial or spectral sEMG features were observed versus time or between chairs. It is concluded that the A-chair is associated to a decrease of the sEMG amplitude of the erector spinae without modifying the spatial and temporal patterns of muscle activation.

References:

1. Zaza, C. (1998). Playing-related musculoskeletal disorders in musicians: a systematic review of incidence and prevalence. *Cmaj*, 158(8), 1019-1025.
2. Foxman, I., & Burgel, B. J. (2006). Musician health and safety: Preventing playing-related musculoskeletal disorders. *AAOHN journal*, 54(7), 309-316.
3. Cattarello, P., Vinelli, S., D'Emanuele, S., Gazzoni, M., & Merletti, R. (2018). Comparison of chairs based on HDsEMG of back muscles, biomechanical and comfort indices, for violin and viola players: A short-term study. *Journal of Electromyography and Kinesiology*, 42, 92-103.

Meta-analysis of dual career studies from the viewpoint of European discourse

Saša Cecić Erpič,
Faculty of Sport, University of Ljubljana, Slovenia

The purpose of the paper is to present a meta-analysis of the findings of recent studies in the field of dual career that have taken place in Europe over the last five years. Review studies of dual career (see Stambulova and Wylleman, 2019) show that dual career characteristics are influenced not only by the heterogeneity of the European context itself, but also by the characteristics of the sport (e.g., winter - summer sports, high - low professionalization), educational environment (e.g., high schools - universities), sports environment (e.g., national sports school - general high school) and social support networks (e.g., parents). All of these environmental factors, which are manifested differently at each of the stages of the development of a sports career, interact with one another and have a stimulating and /or inhibitory effect on the success of dual career. The findings of some recent large European studies of dual career will be presented.

Thermal challenges of sport performance at altitude: from human thermoregulation to technical solutions for thermal protection

Filingeri D.

THERMOSENSELAB, Environmental Ergonomics Research Centre, Loughborough University

The ability to optimally regulate body temperature is key to ensure appropriate physiological function that can sustain exercise performance. Performing at altitude and under cold stress poses an additional challenge to the thermoregulatory and cardiovascular systems, and this is well known to be a key driver of performance decrements.

An understanding of the physiology of human autonomic and behavioural thermoregulation during exercise and of the thermal protection strategies available to maintain performance under cold stress is therefore essential to ensure athletes are fully prepared to perform under thermal stress.

The aim of this talk is to provide an overview of the human thermoregulatory system, with emphasis on the mechanisms of skin temperature and wetness sensing that support behavioural thermoregulation at rest and during exercise.

The implications of these fundamental insights will be discussed in the context of their application to optimize the design of sport and protective clothing aimed at optimizing exercise performance in the cold.

Skeletal muscle adaptations underlying performance-enhancing effects of high-intensity interval training

Fiorenza M.

Section of Integrative Physiology, Department of Nutrition, Exercise and Sports, University of Copenhagen, Denmark

In recent years, high-intensity interval training (HIIT) has received considerable attention from the scientific community owing to its effectiveness in enhancing exercise performance and improving cardiovascular and metabolic health. HIIT promotes a number of adaptations resembling those associated with traditional endurance exercise, including quantitative and qualitative changes at the skeletal muscle mitochondrial level. However, the mechanisms underlying these similar adaptive responses in spite of divergent exercise stimuli are not completely clear. Hence, we explored the acute effects of different exercise stimuli on muscle metabolism and the molecular cascade promoting mitochondrial adaptations; an experimental approach that allowed us to gain insights into the events that initiate the hormetic process leading to increased muscle oxidative capacity. Thereafter, we investigated the long-term effects of HIIT on muscle mitochondrial function and exercise performance. I will present results from these studies and others that suggest a prominent role of skeletal muscle mitochondria in the performance-enhancing effects of HIIT.

Cardiac autonomic and physiological responses to hypoxic exercise of different intensities

Fornasiero A.^{1,2}, Skafidas S.^{1,2}, Stella F.^{1,2}, Zignoli A.^{1,3}, Savoldelli A.^{1,2}, Bortolan L.^{1,2}, Rakobowchuk M.⁴, Pellegrini B.^{1,2}, Schena F.^{1,2}, Mourot L.^{5,6}

¹ CeRiSM, Sport Mountain and Health Research Centre, University of Verona, Rovereto, Italy

² Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Verona, Italy

³ Department of Industrial Engineering, University of Trento, Trento, Italy

⁴ Department of Biological Sciences, Thompson Rivers University Faculty of Science, Kamloops, Canada

⁵ EA3920 Prognostic Factors and Regulatory Factors of Cardiac and Vascular Pathologies, Exercise Performance Health Innovation (EPHI) platform, University of Bourgogne Franche-Comté, Besançon, France

⁶ National Research Tomsk Polytechnic University, Tomsk, Russia

Hypoxic exercise (i.e. exercise under reduced oxygen availability) has been shown to represent a valid alternative to normoxic exercise to provide an adequate training stimulus, promoting beneficial physiological training adaptations as well as positive health-related outcomes. Nowadays, hypoxic exercise of various intensities is implemented within the training programs of different athletic and special populations. Different types of high-intensity hypoxic exercise are commonly employed to maximize the performance enhancement in athletes involved in endurance and intermittent sports, whilst moderate-intensity hypoxic exercise is adopted to increase the physiological load while reducing the mechanical load both in obese and geriatric patients, as well as a therapeutic tool for weight loss and type 2 diabetes prevention.

Both at maximal and sub-maximal exercise intensities, acute hypoxic exercise can result in markedly altered cardiac, ventilatory and metabolic responses, which may lead to increased

exercise-induced homeostatic perturbation, greater autonomic disturbance and delayed post-exercise cardiac autonomic recovery. Some of these aspects must be carefully considered when prescribing hypoxic exercise.

The purpose of this presentation is to examine the exercise and recovery physiological and cardiac autonomic responses to 1) a maximal hypoxic exercise and 2) to sub-maximal hypoxic exercises performed at the same absolute (based on mechanical load) or same relative (based on heart rate) normoxic exercise intensity. Current evidence suggests that increased exercise-induced homeostatic perturbation and delayed cardiac autonomic recovery mainly occur in response to maximal hypoxic exercise and sub-maximal hypoxic exercise performed at the same absolute normoxic exercise intensity. Differently, when performed at the same relative normoxic exercise intensity (based on heart rate) hypoxic exercise triggers similar cardiac autonomic and physiological responses to normoxic exercise, with a reduced mechanical load.

References:

1. Millet, G. P., Debevec, T., Brocherie, F., Malatesta, D., & Girard, O. (2016). Therapeutic use of exercising in hypoxia: promises and limitations. *Frontiers in physiology*, 7, 224.
2. Girard, O., Malatesta, D., & Millet, G. P. (2017). Walking in hypoxia: an efficient treatment to lessen mechanical constraints and improve health in obese individuals?. *Frontiers in physiology*, 8, 73.
3. Pramsöhler, S., Bartscher, M., Faulhaber, M., Gatterer, H., Rausch, L., Eliasson, A., & Netzer, N. C. (2017). Endurance training in normobaric hypoxia imposes less physical stress for geriatric rehabilitation. *Frontiers in physiology*, 8, 514.
4. Chacaroun, S., y Gonzalez, I. V. E., Flore, P., Doutreleau, S., & Verges, S. (2019). Physiological responses to hypoxic constant-load and high-intensity interval exercise sessions in healthy subjects. *European journal of applied physiology*, 119(1), 123-134.

Effects of intermittent (interval) hypoxia on health

Hannes Gatterer¹, Rachel Turner¹, Marika Falla², Giacomo Strapazzon¹

¹Institute of Mountain Emergency Medicine, Eurac Research, Bolzano

²Centro Interdipartimentale Mente/Cervello (CIMeC), Università di Trento

Intermittent hypoxia (IH) is defined as repeated episodes of hypoxia interspersed with normoxic periods. Since IH is generally associated with obstructive sleep apnoea (OSA) and the related adverse effects, the term interval hypoxic therapy / training (IHT) was introduced to distinguish between OSA and the therapeutic use of IH. For many years Russian physicians used short-term interval hypoxia for clinical purposes (Serebrovskaya, 2002). The training program mostly consists of interval hypoxic-normoxic cycles of short duration (approximately 5 min) performed for 1 hour a day, up to 5 times a week for several weeks. The main rationale for its use is the potential cross-protective effect, which infers that adaptations to one stressor may provide resistance to another. During many years of clinical experience, various positive effects have been described in mostly uncontrolled study settings. Interval hypoxia training for instance has been found to provoke health beneficial ventilatory, metabolic and sympathetic nervous system adaptations (Serebrovskaya, 2002; Serebrovskaya et al., 2008). Recently, randomised controlled trials confirmed the potential positive effects of interval hypoxia. Bartscher et al. found that IHT reduced heart rate, systolic blood pressure, blood lactate, and rate of perceived exertion, and increased arterial oxygen saturation and arterial oxygen content in patients with COPD or CAD (Bartscher et al., 2010). Additionally, IHT

increased total hemoglobin mass and improved lung diffusion capacity in COPD patient (Burtscher et al., 2009). Moreover, activation of the HIF pathway may further contribute to the positive health effects (Dale et al., 2014) even though potential detrimental effects (e.g., tumor growth) have to be equally considered (Schito and Semenza, 2016), especially when IHT is applied in patient groups. In summary, literature suggests that repeated and well-dosed hypoxic-normoxic cycles might evoke beneficial adaptations of the haematological, the neurohumoral, the antioxidant, and cardio-respiratory systems, resulting in improved health and exercise tolerance (Burtscher et al., 2010). Mechanisms pertaining to beneficial adaptations for health remain speculative and need to be addressed further in future investigations.

References:

1. Burtscher et al. (2010). Effects of interval hypoxia on exercise tolerance: special focus on patients with CAD or COPD. *Sleep and Breathing* 14(3),209-220.
2. Burtscher et al. (2009). Intermittent hypoxia increases exercise tolerance in patients at risk for or with mild COPD. *Respiratory Physiology & Neurobiology* 165(1),97-103.
3. Dale et al. (2014). Unexpected benefits of intermittent hypoxia: enhanced respiratory and nonrespiratory motor function. *Physiology (Bethesda)* 29(1),39-48.
4. Schito et al. (2016). Hypoxia-Inducible Factors: Master Regulators of Cancer Progression. *Trends Cancer* 2(12),758-770.
5. Serebrovskaya (2002). Intermittent hypoxia research in the former soviet union and the commonwealth of independent States: history and review of the concept and selected applications. *High Alt Med Biol* 3(2),205-221.
6. Serebrovskaya et al. (2008). Intermittent hypoxia: cause of or therapy for systemic hypertension? *Exp Biol Med (Maywood)* 233(6),627-650.

Uphill walking and running: strategies to improve performance

Giovanelli N.

Dipartimento di Area Medica, Università di Udine

Trail running (mountain running) races include uphill and downhill sections that requires continuous adaptations in walking/running mechanics and energetics. Among other factors (such as maximal oxygen uptake (VO₂max) and fraction of VO₂max (F)), the cost or transport (CoT) is one of the most important in determining the endurance performance (Lazzer et al. 2012). In particular, to optimize the performance athletes should increase their VO₂max and/or F or to decrease their CoT. Thus, adopting specific strategies to improve CoT leads to a better performance (Hoogkamer et al. 2016). One of the most important aspect that affect the CoT is the power of the lower limbs (Lazzer et al. 2014). In turn, this is related to a lower increase of CoT during uphill marathon and an increase in power of the lower limbs leads to a lower CoT in endurance athletes. Different training strategies may be used for obtaining an increase in power, such as adding plyometric and explosive exercise to the normal training plan (Giovanelli et al. 2017; Spurrs et al. 2003). (Barnes and Kilding 2015) suggested some strategies for improving the CoT in runners but for trail runners it is important to adopt specific methods. Recent studies suggested some strategies to optimize the CoT during uphill locomotion. In particular it is suggested that walking is cheaper than running above a certain incline and below a certain speed (Giovanelli et al. 2016; Ortiz et al. 2017). Also, the use of

poles, which increases the CoT during level walking (Pellegrini et al. 2015) seems to decrease the CoT during steep uphill walking (Giovanelli et al. 2019). In conclusion, there are specific strategies to be adopted during training sessions and competitions that leads to a lower CoT, allowing athletes to achieve a better performance.

References:

1. Barnes KR, Kilding AE (2015) Strategies to improve running economy. *Sports Med* 45 (1):37-56. doi:10.1007/s40279-014-0246-y
2. Giovanelli N, Ortiz AL, Henninger K, Kram R (2016) Energetics of vertical kilometer foot races; is steeper cheaper? *J Appl Physiol* (1985) 120 (3):370-375. doi:10.1152/japplphysiol.00546.2015
3. Giovanelli N, Sulli M, Kram R, Lazzer S (2019) Do poles save energy during steep uphill walking? *Eur J Appl Physiol*. doi:10.1007/s00421-019-04145-2
4. Giovanelli N, Taboga P, Rejc E, Lazzer S (2017) Effects of strength, explosive and plyometric training on energy cost of running in ultra-endurance athletes. *Eur J Sport Sci*:1-9. doi:10.1080/17461391.2017.1305454
5. Hoogkamer W, Kipp S, Spiering BA, Kram R (2016) Altered Running Economy Directly Translates to Altered Distance-Running Performance. *Med Sci Sports Exerc*. doi:10.1249/MSS.0000000000001012
6. Lazzer S, Salvadego D, Rejc E, Buglione A, Antonutto G, di Prampero PE (2012) The energetics of ultra-endurance running. *Eur J Appl Physiol* 112 (5):1709-1715. doi:10.1007/s00421-011-2120-z
7. Lazzer S, Taboga P, Salvadego D, Rejc E, Simunic B, Narici MV, Buglione A, Giovanelli N, Antonutto G, Grassi B, Pisot R, di Prampero PE (2014) Factors affecting metabolic cost of transport during a multi-stage running race. *J Exp Biol* 217 (Pt 5):787-795. doi:10.1242/jeb.091645
8. Ortiz ALR, Giovanelli N, Kram R (2017) The metabolic costs of walking and running up a 30-degree incline: implications for vertical kilometer foot races. *Eur J Appl Physiol* 117 (9):1869-1876. doi:10.1007/s00421-017-3677-y
9. Pellegrini B, Peyre-Tartaruga LA, Zoppiroli C, Bortolan L, Bacchi E, Figard-Fabre H, Schena F (2015) Exploring Muscle Activation during Nordic Walking: A Comparison between Conventional and Uphill Walking. *PLoS One* 10 (9):e0138906. doi:10.1371/journal.pone.0138906
10. Spurr RW, Murphy AJ, Watsford ML (2003) The effect of plyometric training on distance running performance. *Eur J Appl Physiol* 89 (1):1-7. doi:10.1007/s00421-002-0741-y

Molecular and functional basis of successful aging and frailty: a study protocol exploring positive behaviors to counteract age-related physical and cognitive decline.

Venturelli M.¹, Giuriato G.¹, Fochi S.¹, Gomez-Lira M.¹, Del Piccolo L.¹, Schena F.¹, Romanelli M.G.¹

¹Department of Neurosciences, Biomedicine and Movement Sciences. University of Verona.

Introduction. Frailty is the term utilized to describe a syndrome that exposes the old people to increased risk of negative health-related outcomes. Biological mechanisms underlying physical (PF) and cognitive (CF) frailty, have only been partially elucidated, thus a better understanding of these factors is needed. Indeed, the propensity to recover, optimize functions or develop behaviors to overcome age-related loss-of-function or disease, is central in successful aging. However, limited research focused on understanding how these capacities can be improved. Therefore, the aim of this project will be to determine whether behaviors characterized by physical exercise (ET) or exercise+cognitive engagement (ET+CT) may mitigate the symptoms of PF and CF. The biological mechanisms triggered by these behaviors will be also investigated.

Methods. For this purpose, we will recruit 120 people: 30 young healthy (YH), 30 old healthy (OH), 30 old PF and 30 old CF.

Results. At baseline, biomarkers (genes expression and circulating microRNAs (miRNAs)) of PF and CF frailty severity will be measured on all the groups. After 9 months of intervention involving only the PF and CF groups, the above mentioned molecular and functional parameters will be newly evaluated.

Discussions. Specifically, the intervention will be organized in: i) 10 PF (and 10 CF) individuals assigned to the ET group, ii) 10 PF (and 10 CF) to the ET+CT group, iii) 10 PF (and 10 CF) to a control (CTRL) no training group.

Conclusions. The present project will help to understand the exercise and cognitive-induced adaptations and the behaviors that may contribute to reduce the physical and cognitive frailty condition.

Fast, faster and even faster

H.-C. Holmberg

Swedish Winter Sports Research Centre, Mid Sweden University, Sweden

This presentation consists of three parts.

First, I present a brief overview of an Olympic system for the development of athletic talent, from the club level to a high school to, potentially, becoming a member of the national team. The development of, for example, skiers involves a complex combination of various types of training that optimize load, recovery and progression. In this context, the probability of success is enhanced by educating coaches and athletes, in addition to systemic organization.

The second segment will focus more specifically on XC skiing, an Olympic discipline involving several different sub-techniques, as well as complex technical and cognitive challenges. In response to changes in velocity, the inclination of the slope, and snow conditions, a XC skier must continuously alternate between various sub-techniques that differ with respect to kinematics, kinetics, and the distribution of workload between the muscles of the upper- and lower-body. Recent physiological investigations on the mechanical demands associated with these sub-techniques have provided considerable new knowledge concerning the responses of the arms and legs to the competing needs of different types of exercise. Furthermore, elite skiers demonstrate unique combinations of well-developed aerobic and anaerobic capacities. Recently, field studies on snow and/or during competitions have provided novel insights into the determinants of XC racing performance, as well as why and when skiers utilize the different sub-techniques during a race.

Finally, certain aspects, including environmental and technical challenges, of preparation for the next Winter Olympics in Beijing 2022 will be considered.

All in all, integration of biomechanical and physiological evaluations employing modern technology in a systematic manner has provided knowledge that can improve the performance of Olympic athletes.

References:

1. Holmberg HC The elite cross-country skier provides unique insights into human exercise physiology. *Scand J Med Sci Sports*. 2015 Dec;25 Suppl 4:100-9. doi: 10.1111/sms.12601.
2. Sandbakk Ø, Holmberg HC. Physiological Capacity and Training Routines of Elite Cross-Country Skiers: Approaching the Upper Limits of Human Endurance. *Int J Sports Physiol Perform*. 2017 Sep;12(8):1003-1011.
3. Pellegrini B, Stöggl TL, Holmberg HC. Developments in the Biomechanics and Equipment of Olympic Cross-Country Skiers. *Front Physiol*. 2018 Jul 24;9:976.

Health at high altitude, acute mountain sickness

Lawley J.S.

Department of Sport Science, University of Innsbruck, Innsbruck, Austria

Introduction. Acute mountain sickness and high altitude cerebral edema are both neurological syndromes associated with rapid ascent to high altitude.

Methods. Symptoms of acute mountain sickness include headache, nausea/vomiting, dizziness and fatigue (Roach et al., 2018), whereas symptoms of HACE are more serious such altered levels of confusion, altered consciousness, ataxia, papilledema and even symptoms consistent with organic brain injury (i.e. delirium and coma) (Hackett and Roach 2004).

Results. Both syndromes are neurological in nature, the time course in symptom development is similar (AMS, 6-24 hours and HACE, 24-72 hours) and individuals with HACE commonly report severe headache and previous symptoms of AMS. Thus, there has long been a speculation that HACE is the end-stage of AMS. However, the exact pathological mechanisms of both disorders remain unclear, which makes identifying divergence or a link between both entities difficult.

Discussion. During the development of AMS, it is well established that hypoxia causes profound cerebral vasodilation due to extracranial and intracranial artery dilation (Hoiland et al., 2015), resulting in an elevation in intracranial blood volume (Lawley et al., 2014). Over the time course of these experiments, an increase in brain water (edema) has rarely been noteworthy, but fluid shifts between brain cellular compartments, interpreted from changes in diffusion indices within white matter are observed consistently (Lawley et al., 2013; Kallenberg et al., 2017). Thus, if extracranial or intracranial artery dilation activates the trigeminal vascular system, known as the 'vascular hypothesis', to cause high altitude headache, then a shared common pathology between AMS and HACE is unlikely. However, the increase in intracranial blood volume may predispose the brain to a modest elevation or transient fluctuations in intracranial pressure (causing symptoms of AMS, Lawley et al., 2016) and the initial fluid shifts within white matter may influence the development vasogenic edema (Stokum et al., 2016). In this situation, a heamo- and hydrodynamic cascade in the early stages of hypoxia could predispose individuals to HACE and support the continuum between both entities.

Conclusions. Ultimately, even if AMS and HACE do not represent the two clinical ends of the exact same pathological spectrum, they likely share common pathological processes that ultimately lead to divergent endpoints.

References:

1. Roach, R.C., Hackett, P.H., Oelz, O., et al., (2018). The 2018 Lake Louise Acute Mountain Sickness Score. *HAMB*, 19(1), 4-6.
2. Hackett, P.H., & Roach, R.C (2001). High-altitude illness. *New Eng J Med*, 345(2), 107-114.
3. Hoiland, R.L., Bain, A.R., Rieger, M.G., et al., (2015). Hypoxemia, oxygen content, and the regulation of cerebral blood flow. *Am J Physiol Regul Integr Comp Physiol*, 310(5), R398-R413.
4. Lawley, J.S., Alperin N, Bagci A.M, et al., (2014). Normobaric hypoxia and symptoms of acute mountain sickness: Elevated brain volume and intracranial hypertension *Ann Neurol*,
5. Lawley, J.S., Oliver S.J, Mullins P.G et al., (2013). Investigation of whole brain white matter identifies altered water mobility in the pathogenesis of high-altitude headache. *J Cereb blood metab*,
6. Kallenberg, K., Bailey, D.M., Christ, S., et al., (2007). Magnetic resonance imaging evidence of cytotoxic cerebral edema in acute mountain sickness. *J Cereb Blood Flow Metab*, 27(5), 1064-1071.
7. Lawley, J.S., Levine, B.D., Williams, M. A., et al., (2016). Cerebral spinal fluid dynamics: effect of hypoxia and implications for high-altitude illness. *J Appl Physiol* (1985), 120(2), 251-262.
8. Stokum J.A., Gerzanich V, Simard J.M (2016). Molecular pathophysiology of cerebral edema. *J Cereb Blood Flow Metab*, 36(3):513-38

Acute responses and solutions to adapt to a hot environment

Low D.A.

Research Institute for Sport and Exercise Science, Liverpool John Moores University, Liverpool, UK

Heat stress environments, such as those with a high ambient temperature and/or high relative humidity, impair exercise performance and can be detrimental to health and wellbeing and even fatal, especially in at risk populations, through increased body heat storage and perceptual strain. The increased heat gain from a hot environment requires elevations in heat loss in order to maintain internal body temperature within safe limits and restrain reductions in exercise capacity and/or avoid heat-related illness. Appropriate autonomic nervous system adjustments are critical for cardiovascular and thermoregulatory responses to heat stress to facilitate heat dissipation. Elevations in cutaneous sympathetic sudomotor and vasodilator activities are key responses to heat gain and at the same time, elevations in cardiac output and vascular resistance of non-cutaneous beds ensure the maintenance of arterial blood pressure within safe limits. Such autonomic adjustments to support elevated heat loss in heat stress environments may not be of the magnitude required to balance heat gain, however, especially if the environmental conditions are uncompensable. Given the recent increased scheduling of athletic events in heat stress environments and global climate change there is an increased focus on the efficacy of various interventions that can mitigate the negative effects of heat stress on exercise performance and health and wellbeing. Such interventions are either acute or chronic but the aim of both are to accentuate heat loss and reduce thermoregulatory, cardiovascular and perceptual strain. Acute strategies include the use of pre- or per-cooling techniques, such as ice slurry ingestion, ice garments, localised cold-water immersion or fanning to either lower internal temperature before or limit the elevations in internal temperature as well as perceptual strain during the exercise-heat stress exposure. Chronic strategies include the use of heat acclimation or acclimatization programmes involving regular exposure to heat stress prior to the athletic event, which result in a range of beneficial physiological and perceptual adaptations. The aim of this presentation will be to 1) briefly outline the acute responses to exposure to a hot environment and 2) critically discuss the solutions to mitigate the effects of a hot environment.

Uphill performance: with poles, or not with poles, this is the question

Savoldelli A.^{1,2}, Fait A.¹, Callovin A.^{1,2}, Stella F.^{1,2}, Fornasiero A.^{1,2}, Bortolan L.^{1,2}.

¹ CeRiSM, Sport Mountain and Health Research Centre, University of Verona, Rovereto, Italy

² Department of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Verona, Italy

Introduction: During the last three decades there was a widespread use of poles during walking especially thanks to two different schools/techniques: Nordic Walking and Exerstriding. The use of poles seems to be beneficial for increasing fitness level due to the increase in energy cost and in total energy expenditure when compared with conventional walking (Figard-Fabre et al., 2010). Despite having a reduced energy cost (i.e. increased economy) is a recognized determinant of endurance performance (Bassett & Howley, 2000), the use of poles is also typical during trekking and vertical performances. Accordingly, it seems that people may decide to sacrifice their walking/running economy in order to improve/ameliorate their ultra-marathon performances (Millet et al., 2012). Interestingly, when

we analyse the scientific literature, we can point out that using poles in uphill is not such detrimental such using them in flat conditions (Perrey & Fabre, 2008). Recently, Giovanelli and colleagues (Giovanelli et al. 2019) investigated the effects of using poles on steep uphill, showing that walking with poles on steep inclines is slightly more economical than walking during sub-maximal exercise. Less is known about the effects of using poles on maximal exercise capacity (i.e. maximal oxygen uptake (VO₂max)) and maximal uphill performance (e.g. vertical speed). The aim of this work was to investigate the effects of using poles at different speeds (from submaximal to maximal) on energy cost, rate of perceived exertion (RPE), oxygen uptake and performance. We either aimed to investigate the effects of speed on the force applied through the poles.

Methods: Nine trained athletes (Performance Level 3 according to De Pauw et al., 2013), aged 25 to 45 years old, completed two GXT at a constant slope (25%), one with and one without poles, in a randomized order. We planned a 0.7 km/h increase of speed among the steps. Subjects performed five submaximal steps of four minutes duration (from 2.5 to 5.3 km/h), followed by subsequent steps of one-minute duration till volitional exhaustion. Subjects were asked to walk during the submaximal steps of the protocol.

Results: The use of poles allowed the subjects to reach a higher VO₂max (63.3 mlO₂*kg⁻¹*min⁻¹ and 60.3 mlO₂*kg⁻¹*min⁻¹, with and without poles, respectively; +4.7%, p=0.022, d = 0.43, small) and a higher ascensional speed (1798 m/h and 1727 m/h, with and without poles, respectively; +4.0%, p=0.004, d = 0.29, small) at maximal exertion. During sub-maximal intensities energy cost was not affected using poles, but RPE at some speeds was lower when using poles. Poles frequency and the mean force applied through the poles increase with the increase of speed.

Conclusion: The use of poles seems to be beneficial not only for fitness purposes but also for submaximal and maximal uphill performances. The use of poles seems to enhance maximal performance and reduce RPE at submaximal intensities without affecting energy cost that is partially in line with Perrey and Fabre (2008) and with Giovanelli and colleagues (Giovanelli et al., 2019). Further research is needed to verify the present results in outdoor settings.

References:

1. Figard-Fabre H, Fabre N, Leonardi A, Schena F. Physiological and perceptual responses to Nordic walking in obese middle-aged women in comparison with the normal walk. *Eur J Appl Physiol.* 2010 Apr;108(6):1141-51. doi: 10.1007/s00421-009-1315-z. Epub 2009 Dec 20. PubMed PMID: 20091181.
2. Bassett DR Jr, Howley ET. Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Med Sci Sports Exerc.* 2000 Jan;32(1):70-84. Review. PubMed PMID: 10647532.
3. Millet GY, Hoffman MD, Morin JB. Sacrificing economy to improve running performance--a reality in the ultramarathon? *J Appl Physiol* (1985). 2012 Aug;113(3):507-9. doi: 10.1152/jappphysiol.00016.2012. Epub 2012 Apr 5. PubMed PMID: 22492933.
4. Perrey S, Fabre N. exertion during uphill, level and downhill walking with and without hiking poles. *J Sports Sci Med.* 2008 Mar 1;7(1):32-8. eCollection 2008. PubMed PMID: 24150131; PubMed Central PMCID: PMC3763349.
6. Giovanelli N, Sulli M, Kram R, Lazzer S. Do poles save energy during steep uphill walking? *Eur J Appl Physiol.* 2019 Jul;119(7):1557-1563. doi: 10.1007/s00421-019-04145-2. Epub 2019 Apr 24. PubMed PMID: 31020400.
7. De Pauw K, Roelands B, Cheung SS, de Geus B, Rietjens G, Meeusen R. Guidelines to classify subject groups in sport-science research. *Int J Sports Physiol Perform.* 2013 Mar;8(2):111-22. Review. PubMed PMID: 23428482.

Downhill running: strategies to improve performance

Vernillo G.

Department of Biomedical Sciences for Health, Università degli Studi di Milano, Milan, Italy.

Downhill running is characterized by larger eccentric contractions of lower-limb extensor muscles, greater impact shocks and ground reaction forces.¹ Considerable mechanical stress is then placed on the lower-limb muscles (particularly the knee extensors and plantar flexors) as a result of the repeated eccentric contractions necessary for controlling the descent on steep gradients during downhill running.¹ This may induce lower limb tissue stress, short-term neuromuscular fatigue, and/or muscle damage.² The combination of high-mileage and large sections of downhill running associated with trail and ultratrail racing has been hypothesized to induce deleterious alterations in the neuromuscular,^{3,4} energetic,⁵ biomechanical,⁶ and skeletal-muscle oxygenation response.^{7,8} In downhill running, muscle fatigue and skeletal muscle damage is compensated by a greater neural input to the muscle to produce the same amount of force,^{9,10} particularly during the push-off phase of the running cycle. This increased neural input to the muscle may result in higher O₂ demand¹¹ and consequently a poorer running economy.^{4,12} Among all known strategies to attenuate the negative effects of downhill running,² training seems to be the best option. Indeed, several studies have demonstrated that an a priori bout of eccentric exercise produces protective adaptations such that, after a subsequent bout of similar exercise (the so-called repeated bout effect¹³), neuromuscular function adapts (e.g. muscle and neural adaptations) such that it is partially protected from subsequent damaging stimuli.¹⁴ However, the specific applications for trail and ultratrail training are still scanty and there is the need to assess the effectiveness of training strategies to minimize fatigue and damage. This would have important implications for trail and ultratrail runners in order to minimize the deleterious effects of downhill running and, therefore, to better model training and running technique prescriptions with the ultimate goal of improving the trail and ultratrail performance.

References:

1. Vernillo G, Giandolini M, Edwards WB et al. Biomechanics and physiology of uphill and downhill running. *Sports Med.* 2017;47(4):615-29.
2. Giandolini M, Vernillo G, Samozino P et al. Fatigue associated with prolonged graded running. *Eur J Appl Physiol.* 2016;116(10):1859-73.
3. Millet GY, Tomazin K, Verges S et al. Neuromuscular consequences of an extreme mountain ultramarathon. *PLoS One.* 2017;6(2):e17059.
4. Vernillo G, Aguiar M, Savoldelli A et al. Regular changes in foot strike pattern during prolonged downhill running do not influence neuromuscular, energetics, or biomechanical parameters. *Eur J Sport Sci.* 2019. DOI: 10.1080/17461391.2019.1645212
5. Vernillo G, Savoldelli A, Zignoli A et al. Energy cost and kinematics of level, uphill and downhill running: fatigue-induced changes after a mountain ultramarathon. *J Sports Sci.* 2015;33(19):1998-2005.
6. Morin JB, Samozino P, Zameziati K, Belli A. Effects of altered stride frequency and contact time on leg-spring behavior in human running. *J Biomech.* 2007;40(15):3341-48.
7. Vernillo G, Brighenti A, Limonta E et al. Effects of ultratrail running on skeletal-muscle oxygenation dynamics. *Int J Sports Physiol Perform.* 2017;12(4):496-504.
8. Giovanelli N, Biasutti L, Salvadego D, Alemayehu HK, Grassi B, Lazzer S. Changes in skeletal muscle oxidative capacity after a trail running race. *Int J Sports Physiol Perform.* 2019. DOI: 10.1123/ijsp.2018-0882.
9. Komi PV. Stretch-shortening cycle: a powerful model to study normal and fatigued muscle. *J Biomech.* 2000;33(10):1197-1206.
10. Nicol C, Avela J, Komi PV. (2006). The stretch-shortening cycle: a model to study naturally occurring neuromuscular fatigue. *Sports Med.* 2006;36(11):977-99.
11. Bigland-Ritchie B, Woods JJ. Integrated EMG and oxygen uptake during dynamic contractions of human muscles. *J Appl Physiol.* 1974;36(4):475-79.

12. Vernillo G, Millet GP, Millet GY. Does the running economy really increase after ultra-marathons? *Front Physiol.* 2017;8:783.
13. Nosaka K, Clarkson PM. Muscle damage following repeated bouts of high force eccentric exercise. *Med Sci Sports Exerc.* 1995;27(9):1263-69.
14. Hyldahl RD, Chen TC, Nosaka K. Mechanisms and mediators of the skeletal muscle repeated bout effect. *Exerc Sport Sci Rev.* 2017;45(1):24-33.

Enhancing athletes' employability after retirement from sport: the importance of competencies

Vitali F.

Department of Neurosciences, Biomedicine, and Movement Sciences, University of Verona, Verona, Italy

Introduction. Enhancing the employability after sport retirement is a key challenge for elite athletes (Torregrosa et al, 2015). The aim of the European project "Be a Winner in elite sports and Employment before and after athletic Retirement" (B-WISER), coordinated by the Vrije Universiteit Brussel, was to optimize the employability of elite athletes. There is a lack of empirical data and specific actions regarding the employability and employment of elite athletes during as well after athletic career. The second part (WP2) of the project was aimed at identifying the competencies required and developed by elite athletes in three final stages of their careers: active (D), former (R), and preparing for first-time employment (P).

Methods. A sample of 954 elite athletes, 17-to-69-year-old (Mage=26.3, SD=10.0; 46% female) from six European countries (Belgium, Germany, Italy, Slovenia, Spain, Sweden) filled the Athletes' Competency Questionnaire for Employability (ACQE).

Results. Participants reported average-to-strong possession of their competencies (M=3.77). Former elite athletes who were employed perceived the strongest possession of their competencies (M=3.90). Overall, participants reported the strongest possession for their ability to be goal-oriented, dedicated to succeeding in different life domains, and collaborative with colleagues. Participants reported the weakest possession for their ability to create a professional network, to identify themselves with the culture of their organization, and the understanding of their own career interests and options.

Conclusions. The findings can be used as an evidence base for stakeholders (e.g., career counselors, employers, sport federations, educational institutions) to target specific competencies in different career stages, addressing athletes' strengths and weaknesses in preparing for and/or securing employment.

Strength training effects on aerobic endurance

Wang E.¹

¹Department of Circulation and Medical Imaging, Norwegian University of Science and Technology, Trondheim, Norway

Strength training has the potential to improve work economy, defined as the oxygen uptake ($\dot{V}O_2$) during a given submaximal exercise. Work economy is one of three factors determining aerobic endurance performance (Pate and Kriska 1984), and if $\dot{V}O_2$ is seen in relation to the energy cost of the work performed, it is commonly referred to as work efficiency (Barret O'Keefe et al. 2012).

When aiming for strength training-induced improvements in work efficiency, intensity appears to be a key component, with high intensity (85-90% of 1RM) being more effective than moderate or low intensity (< 60-70% of 1RM) (Heggelund et al. 2013). As a model of the former, maximal strength training (MST) has been applied in healthy young (Hoff et al. 1999) and old individuals (Wang et al. 2017), and patient populations (Hoff et al. 2007; Husby et al. 2010; Wang et al. 2010). MST is performed at ~90% of one repetition maximum (1RM) with 3-5 repetitions, 4-5 sets, and maximal intended velocity in the concentric phase of movement.

While the majority of the studies that have investigated MST-induced effects on work efficiency have measured pulmonary $\dot{V}O_2$ during steady-state whole body work, recent studies have provided evidence for the origin or mechanisms of the improvement in work efficiency following MST (Barrett O'Keefe et al. 2012; Wang et al. 2017; Berg et al. 2018). These studies have revealed that 1) the reduction in pulmonary $\dot{V}O_2$ is caused by a reduction in skeletal muscle $\dot{V}O_2$, indicating that the mechanisms responsible for the improved work efficiency originate in the trained muscle bed, and are not caused by central adaptations (Barrett-O'Keefe, Helgerud et al. 2012); 2) despite metabolic and vascular limb-specific differences, MST-induced improved work efficiency appears to yield similar adaptations in upper and lower extremities, reducing blood flow without changing arteriovenous oxygen difference (Barrett O'Keefe et al. 2012; Berg et al. 2018); 3) MST-induced improvements in work efficiency can be achieved despite increases in both percentage and size of Type II muscle fibers and unaltered capillary density (Wang et al. 2017). These findings advocate that MST not only is a great strategy to increase skeletal muscle force-generating capacity, but also to improve aerobic endurance performance, in combination contributing to enhanced health and performance.

References:

1. Barrett-O'Keefe Z, Helgerud J, Wagner PD, and Richardson RS. Maximal strength training and increased work efficiency: contribution from the trained muscle bed. *J Applied Physiology* 113: 1846-1851, 2012.
2. Berg OK, Nyberg S, Windedal TM, Wang E. Maximal strength training-induced improvements in forearm work efficiency are associated with reduced blood flow. *Am J Physiol Heart Circ Physiol* 314: H853-H862, 2018.
3. Heggelund J, Fimland MS, Helgerud J, and Hoff J. Maximal strength training improves work economy, rate of force development and maximal strength more than conventional strength training. *European J Applied Physiology* 113: 1565-1573, 2013.
4. Hoff J, Helgerud J, and Wisloff U. Maximal strength training improves work economy in trained female cross-country skiers. *Med Sci Sports and Exercise* 31: 870-877, 1999.
5. Hoff J, Tjonna AE, Steinshamn S, Hoydal M, Richardson RS, and Helgerud J. Maximal strength training of the legs in COPD: a therapy for mechanical inefficiency. *Med Sci Sports and Exercise* 39: 220-226, 2007.
6. Husby VS, Helgerud J, Bjørgen S, Husby OS, Benum P, Hoff J. Early postoperative maximal strength training improves work efficiency 6-12 months after osteoarthritis-induced total hip arthroplasty in patients younger than 60 years. *Am J Phys Med Rehabil* 89: 304-314, 2010.
7. Pate RR, and Kriska A. Physiological basis of the sex difference in cardiorespiratory endurance. *Sports Medicine* 1: 87-98, 1984.
8. Wang, E, Helgerud J, Loe H, Indseth K, Kaehler N, and Hoff, J. Maximal strength training improves walking performance in peripheral arterial disease patients. *Scand. J. Med. Sci. Sports* 20: 764-770, 2010.
9. Wang E, Nyberg SK, Hoff J, Zhao J, Leivseth G, Torhaug T, Husby OS, Helgerud J, and Richardson RS. Impact of maximal strength training on work efficiency and muscle fiber type in the elderly: Implications for physical function and fall prevention. *Experimental gerontology* 91: 64-71, 2017.

DeMotu project: design and production of a 3D printed human knee for research in biomechanics

Zignoli A.¹, Malacarne C.², Bosetti P.^{1,2}, Bortolan L.³, Tombolato D.⁴, Biral F.¹

¹ Department of Industrial Engineering, University of Trento, Trento, Italy

² ProM Facility, Trentino Sviluppo, Rovereto, Trento, Italy

³ Cerism Research Centre, University of Verona, Rovereto, Trento, Italy

⁴ MUSE Science Museum, Trento, Italy

Introduction: Through the utilisation of rapid prototyping technologies and computational models, researchers can gain a better understanding of the biomechanics of the knee joint. Particularly, 3D printed models are emerging as a possible alternative to cadavers and specimens in research in biomechanics, education and training [1]. We set out to design and prototype a new anatomical model of a human knee joint to study the joint kinematics and the in situ forces in the ligaments.

Methods: An MRI scan (2 mm of thickness) of an adult knee was manually segmented (Slicer 3d). 3D virtual models (stl files) were created for: patellar bone and cartilage, head of the tibial bone and cartilage, head of the fibula, femoral lower extremity and femoral cartilage, and the menisci. The virtual models were refined (MeshLab) and exported to the 3D printers of our prototyping facility. Bony parts were produced using a PA11 powder-based HP Multi-Jet Fusion printer, while the cartilage and meniscal structures were reproduced using a Flexible UV-sensitive resin with a FormLabs SLA printer (flex and elastic resin, respectively). Other elastic connective elements (e.g. patellar reticulum, tendons and ligaments) were produced by injection moulding techniques with polyurethane rubber. Materials were selected based on: technology availability, material mechanical properties (e.g. Young's modulus and compressive strength).

Results: One-off costs of creating the artificial knee joint model are here separated by time and material/production (i.e. man labour, polishing, removing supports, finishing) costs. Segmentation and mesh refinement is not included. 1) Bony parts + moulds: 16-16.5 hs, 851 €; 2) soft parts: 4-8 hs, 116 €; 3) connective tissue: 2 hs, 94 € (including 2 hs of two men labour for assembling). During the assembling phase, 3D printed structures demonstrated high geometrical congruency. Elastic connective elements are able to restrain the extension movement correctly.

Discussion: The production of this individualised replica of a knee joint required a considerable multidisciplinary effort. The composition of the model with soft and rigid materials mimics the natural anatomy of the human knee. However, the actual absolute values of the mechanical properties of the printed parts have yet to be confirmed by laboratory tests. The high levels of friction between soft parts represent a big concern that needs to be addressed in the next future.

Conclusions: 3D printing is a relatively new technology that offers immense potential in biomechanical research. Nevertheless, more work is needed to establish the extent to which 3D printed knee models can be used as a substitute for cadaveric specimens in producing data for research in knee biomechanics. We hope that this project will prompt others to select models and methods necessary for further progress.

References:

1. Bücking et al, Plos One, 45:1-10, 2017



CeRiSM –via Matteo del Ben 5/B, 38068 Rovereto (TN, Italy)

Tel +39 0464 483511 Fax +39 0464 483520

www.cerism.it – cerism@ateneo.univr.it





ORGANIZING SECRETARIAT

CeRiSM – University of Verona
v. Matteo del Ben, 5b -
38068 Rovereto TN, Italy
www.cerism.it
e-mail: cerism@ateneo.univr.it