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Abstract Book

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Oral session 1: Clinical Biomechanics

Giulio Sacchetti, Alberto Leardini, Lisa Berti, Maurizio Ortolani, Marco Miceli and Claudio Belvedere

3D flatfoot characterization in weight-bearing condition before and after correction surgery

Adult-acquired flatfoot is a frequent condition involving multiplanar morphological changes. Investigations should necessarily be performed in 3D and in loading conditions. This is now possible via weight-bearing computed-tomography providing 3D-scans in up-right posture. This study aims at exploiting these scans for original 3D measurements to characterize foot bone and joint alignments, before and after correction surgery. Eleven flatfoot patients were selected for corrective surgery via modified Grice-Green procedure. Before surgery and at 9-month follow-up, these underwent weight-bearing computed-tomography scans (slicing: 0.26-mm, matrix-resolution: 884x884x960) in single-leg upright posture. A control-group of seven normal feet was analyzed. A semi-automatic segmentation procedure was used for 3D bone models reconstruction. These were used to generate colour-coded distance maps of talonavicular, calcaneocuboid, and subtalar joints to analyze bone-to-bone coverage. The foot vault was characterized with a multi-polygonal structure based on the most plantar bone landmarks and relevant 3D volume was calculated. Pre-operative vault volume was ~47% of total foot volume, which increased post-operatively to 53% ($p = 0.002$), control data being 63%. Post-operatively, a 35% ($p= 0.007$) improvement was observed for the coverage maps in the subtalar joint, but a decreased from 46% to 40% for the talonavicular joint. For the calcaneocuboid joint the coverage compared well with the control (~80%). The present study demonstrates the potential of 3D measurements from weight-bearing computed-tomography. The reported coverage and volumetric investigations provides a better comprehension of the mechanism underlying the foot bone interactions, both in the presence of deformity and downstream of correction surgery.

Carlos Cruz-Montecinos and Huub Maas

Increased Intermuscular Coherence During Gait Reflects Neural Adaptations in Non-Neurological Knee Flexion Contracture

Muscle synchronization during movement is essential for motor control and can be measured using intermuscular coherence (IMC), which reflects the central neuronal drive across muscles. While IMC has been studied in neurological conditions, it remains underexplored in chronic musculoskeletal disorders. This study investigated whether individuals with non-neurological knee flexion contracture present altered IMC patterns during gait compared to controls. The study hypothesizes that non-neurological knee flexion contracture results in higher IMC between the plantar flexors and knee extensors. These antagonistic muscle groups have been linked to knee flexion contracture. A case-control study was conducted with 8 male patients with non-neurological knee flexion contracture (haemophilic arthropathy, 39.1 ± 16 yrs) and 15 male controls (31.1 ± 10 yrs). Surface bipolar electromyography was recorded during a 30-meter walk at a comfortable speed. IMC was assessed over 20 gait cycles using rectified EMG with a 400 ms sliding window and 5 ms increments. Group differences were analyzed using a permutation-based statistical method. Increased coherence in alpha (10-15 Hz), beta (15-35 Hz) and gamma bands (35-60 Hz) was observed during the stance and stance-swing transition in patients, particularly in the biarticular muscle pairs. This increased IMC suggests neural adaptations in patients with non-neurological knee flexion contracture, involving cortical and spinal changes, which may indicate underlying neuroplastic changes. These findings highlight the importance of addressing neurophysiological adaptations along with musculoskeletal changes in this condition. Future research should explore treatments targeting both neural and musculoskeletal systems to improve rehabilitation and surgical outcomes.

Bela Agarwal and Dr Rajani Mullerpatan

Instance of peak knee flexion and adduction moment during deep-squat

External knee adduction-moment (KAM) and knee flexion moment(KFM) are established biomechanical markers of tibio-femoral joint loading. However, influence of habitual squat adopted for performing activities of daily living, on instance of peak KAM and KFM during deep-squat, is unknown. Hence, present study explored instance of peak KAM and KFM during deep-squat in people with varying squat exposure in healthy adults aged 30-45 years. Thirty adults were categorized based on daily squat exposure as non-squatters (nil squat exposure), ADL-Squatters (upto 60 min of exposure) and occupational-squatters (>60 min of exposure). 3D motion capture of deep-squat was performed at a Human Movement Science laboratory. We observed that KAM and KFM increased with increase in knee flexion angle during squat descent. Knee moments peaked at 109.8 ± 48.2^0 in non-squatters, at 123.5 ± 37.8^0 in ADL squatters and at 135.7 ± 30.9^0 of knee flexion in occupational squatters,

and plateaued thereafter. During ascent, knee moments peaked at 136.1 ± 21.5^0, 122.9 ± 42.9^0, and 149.5 ± 21.9^0, respectively. Peak KFM decreased linearly with increase in squat exposure; however, KAM did not show similar trend. These findings indicate that lack of adequate eccentric muscle control required to maintain knee stability in deep-squat result in higher knee joint moments at lower knee flexion angle in non-squatters compared to habitual-squatters, which could result in musculoskeletal injuries and may serve as a risk factor for developing knee osteoarthritis. Therefore, rehabilitation programs must focus on exercises to develop eccentric and concentric control in this vulnerable range of motion to prevent knee instability in people with musculoskeletal disorders

Shishir Shah, Sagar Joshi, Abhishek Gupta, Deepshika Raut and Dr Rajani Mullerpatan

Development of a Powered Transtibial Prosthesis

People with transtibial amputation face a challenge of natural gait because in the absence of gastrocnemius (bi-articular muscle), the prosthesis is unable to mimic natural human gait. Currently, uni-articular actuators are used to simulate function of soleus muscle for aiding push off during gait. Therefore, present study aimed to develop a prototype for powered trans-tibial prosthesis informed by the difference in gait biomechanics between the unaffected limb and the prosthetic limb in individuals with transtibial amputation. An unpowered ankle exoskeleton was developed, incorporating actuators that simulate natural function of gastrocnemius muscle, providing torque to the knee and ankle joints during walking. This powered device was tested on one healthy participant using a novel bi-articular spring mechanism that optimizes muscle force distribution and reduces metabolic energy consumption. The results indicated substantial reduction in muscle activity during walking with orthosis compared to walking without orthosis. The gastrocnemius muscle demonstrated 76.32% reduction in average root mean square value on S-EMG (from 14.54 μV during barefoot walking to 3.44 μV with orthosis). Hamstring muscle activity decreased by 39.92%, while the quadriceps and tibialis anterior demonstrated 15.98% and 35.4% reduction respectively. The gluteus maximus demonstrated 27.72% lesser activity compared to barefoot walking. The preliminary results of the powered orthosis demonstrated significant reduction in muscle activity and improved walking economy, suggesting that such a powered orthosis can inform design of a powered transtibial prosthesis, which holds potential in minimizing the biomechanical differences between prosthetic limb and unaffected limb during level walking in people with transtibial amputation.

Marco Lagones, Victoria E. Abarca and Dante A. Elias

Design and Validation of a Prosthetic Foot Adaptable to Sagittal Plane Ground Irregularity

Amputation involves the removal of a limb or a part of it. In the case of the lower limb, amputation affects not only the ankle joint but also the metatarsophalangeal and intertarsal joints, which improve the foot's adaptability on uneven terrain. Therefore, based on the state of the art technology that does not address the other joints of the foot to a large extent, a prosthetic foot has been developed that integrates the support structure of the foot through a foot arch with an extension analogous to the forefoot and an elastic element that mimics the plantar fascia that deforms against obstacles and provides stability to the prosthetic arch foot. The work addresses the design of the prosthetic foot from its design to its prototyping and validation, where the foot was shown to withstand the loads recommended for the P5 category of the ISO 22675 standard and to provide a return energy equal to 95.72\%, 77.13\%, and 90.21\%, in the heel strike, mid-stance and toe-off stages, respectively. In addition to showing linear (66.95kN/m) and torsional (2.05kN.m/rad) stiffness properties in the forefoot analog element, values that are comparable with those recorded in commercial tests such as LP Variflex categories 7 and 8.

Gonzalo Gianneechini, Renata Bona and Carlo M. Biancardi

Does Diabetes Mellitus type II affect the mechanics of walking?

Diabetes Mellitus type II (DM2) is a widespread disease that can significantly impact the functional status of older adults, leading to reduced mobility and independence. Aim of this work was to compare the spatio-temporal and mechanical parameters of gait at different speeds (self-selected walking speed and ±20%, ±40%) between an experimental group with DM2 and a control group (CG) paired for age and gender. Only volunteers without severe neuropathic complications, amputations and other pathologies affecting gait were included. Protocol was approved by the correspondent Ethical Committee. Methods: 28 volunteers between 64 and 75 years old participated in this preliminary study, 14 in each group. 3D kinematics was assessed using a motion capture system (Vicon, UK), with 18 reflective markers model. Statistics: U Mann-Whitney test. Results: With respect to DM2, CG exhibited significant higher walking speed, stride frequency and internal kinetic work. No significant differences were found in the relative stance time, energy recovery and external work. Conclusions: In absence of neuropathic complications, speed related walking parameters of DM2 group were affected, similarly to what described in other pathology and in severe DM2. Mechanics parameters associated to the pendular motion of the centre of mass were not significantly affected at this time. Therefore, some gait parameters could be already affected at an early stage of DM2. These are encouraging findings, as they are preliminary results of a wider project, where we aim to incorporate more patients and evaluate the muscle activity with surface electromyography.

Ayaka Hobo, Tempei Tominaga and Natsuki Sado

Non-invasive evaluation of plantar fascia strain during locomotion considering its insertion site by motion capture-ultrasound combination

The human foot functions are primarily achieved by the elastic plantar fascia (PF), whereas plantar fasciitis is often caused by daily walking and running. PF strain is its potential risk factor. The PF is strained when the foot arch lowers and/or the toe dorsiflexes, as the PF spans the foot arch and the metatarsophalangeal joint. However, PF strain has often been alternatively assessed by the relative length change between the first metatarsal and the calcaneus (εMH1-CAL) in 3D motion capture studies, without accounting for the effect of metatarsophalangeal dorsiflexion. Although some studies assessed PF strain including the effect of metatarsophalangeal movement, they did not consider the sesamoid potentially increasing PF moment arm. Here we propose a motion capture-based method for estimating PF strain (εPF) during locomotion with considering the location of PF insertion and sesamoid bone under the first metatarsal as PF path by combining ultrasound measurements. We compare εPF and εMH1-CAL in walking at preferred speed in eight females. The profiles of εPF and εMH1-CAL overlap during loading response, but then εPF increases while εMH1-CAL decreases. The peak εPF is significantly greater than peak εMH1-CAL (5.6±1.5% vs 2.8±1.0%). The moment arm calculated from the metatarsophalangeal angle and the metatarsophalangeal movement-inducing PF lengthening is significantly greater than that calculated by pre-existing methods without considering sesamoid (relative difference: 25–45%). We emphasize the importance of considering the metatarsophalangeal movement and the moment arm to metatarsophalangeal joint for PF strain evaluation. Our method offers PF strain assessment satisfying these requirements.

Oral session 2: Locomotion General and Clinical Gaits

Carol Torres, Carlo M. Biancardi, Alberto E. Minetti and Gabriel Fábrica

Biomechanics of Tango walking

Tango is a popular style of music and dance recognized as Intangible Cultural Heritage by UNESCO. Few studies have explored the applications of Tango to motor rehabilitation strategies. Our project explored the metabolic and mechanical energy aspects of Tango walking, specifically in the leader role. Eighteen tango dancers participated in the study, performing both self-selected walking (W) and Tango walking (Tw), in the leader role, to the song "La Puñalada". Participants weared a portable metabolimeter to monitor the

oxygen consumption and respiratory quotient during each trial. Through a Vicon motion capture system, the displacement of 11 body segments have been recorded at 100 Hz and used to determine the body centre of mass (CoM) 3D position. Self-selected speeds and spatiotemporal variables were not significantly different between W and Tw, while both metabolic power and cost of transport (CoT) were significantly higher in Tw than in W. The internal and external mechanical work, obtained from the CoM trajectory and from the trajectories of the body segments, did not show significant differences and therefore did not justify the increasing metabolic cost in Tw. Nevertheless, analysis of potential and kinetic energy variations during one stride revealed smoothed oscillations of potential energy in Tw. This behaviour affected the inverted pendulum energy saving mechanism, characteristics of walking gait, with percentage of energy recovery and mechanical efficiency significantly lower in Tw than in W. Walking at Tango rhythm produces a smoothing gait where the relaxing experience of music is counterbalanced by higher energetic cost.

Andressa Lemos, Karine Stoelben, Inaê de Oliveira and Felipe Carpes

Joint stiffness during jump landing tasks with or without a condition of muscle soreness

Joint stiffness is estimated by the ratio between the joint moment and the joint angular displacement. Stiffness plays an important role in joint stability. Delayed onset muscle soreness (DOMS) can increase joint stiffness during passive movements, but its effects during dynamic actions are unclear. We investigated whether DOMS alters lower limb joint stiffness during jump landings. 3D kinematics and kinetics of drop jumps were captured in 26 healthy adults (15 women, 11 men) using a Vicon Motion System (15 cameras, 200 Hz) and two force plates (AMTI, 2 kHz) before and 48 hours after participants performed a squat protocol to induce DOMS in the quadriceps muscles. Joint stiffness was determined during the landing phase. The exercise protocol induced mild DOMS (3.95 ± 2.94 points on the numerical pain scale). We found no difference in joint stiffness between the baseline and DOMS conditions for the hip ($F = 0.426$, $p = 0.520$), knee ($F = 2.408$, $p = 0.133$), and ankle ($F = 0.302$, $p = 0.265$). Although the presence of DOMS causes a sensation of reduced mobility and stiffness in the joints, DOMS does not alter the joint stiffness of the lower limbs. We suggest that mild magnitudes of exercise-induced delayed onset muscle soreness have little effect on the joints' ability to handle the mechanical loads from impact during jumps.

Gaspare Pavei, James Cowburn, Valentina Natalucci, Francesco Luciano, Dario Cazzola and Alberto Minetti

Hypogravity-driven kinematic and dynamic changes in bouncing gaits

Low gravity is known to affect human locomotion, impairing mechanical parameters and reducing metabolic cost. The aim of this study was to analyse the gravity-driven changes in kinematics and dynamics of the bouncing gaits: Running and Skipping. Hypogravity was emulated with a body weight suspension system in the L.O.O.P., ESA Ground-Based Facility in Milan. Five participants (2Women/3Men) were asked to run and skip at 1.39, 1.94 and 2.50 m/s on an instrumented treadmill (Bertec) at Earth, Mars and Moon gravity levels, while motion capture (Vicon) recorded the position of 66 markers. Spatiotemporal parameters and joint angles were calculated using a OpenSim inverse kinematics routine. Stride frequency decreased moving from Earth to Mars (-25% Running, -31% Skipping) and to Moon (-40% Running, -43% Skipping). Duty factor showed even greater decay with gravity reduction (Earth-Mars: -34% Running, -37% Skipping; Earth-Moon: -53% Running and Skipping). With these spatiotemporal changes, the vertical peak of ground reaction forces decreased moving from Earth to Mars (-36% Running and Skipping) and to Moon (-47% Running, -54% Skipping), along with the propulsive peak (Earth-Mars: -39% Running, -37% Skipping; Earth-Moon: -53% Running; -58% Skipping). Overall, the lower limbs angular displacement (hip, knee, ankle) showed a smaller range of motion, highlighting a straight position in hypogravity. Decreasing gravity led to a greater flight phase and lower contact time in both bouncing gaits. These changes affected also the ground reaction forces peaks (smaller reduction) and a more upright posture.

Aline Dalfito Gava and Ana Cristina de David

Traumatic brachial plexus injuries affect spatiotemporal gait parameters

The loss of arm swing during gait can affect individual's movement. This study investigated the effects of traumatic brachial plexus injury on shoulder range of motion (RoM) and spatiotemporal gait parameters. An observational cross-sectional study was conducted involving 17 patients with unilateral traumatic brachial plexus injury and 17 sex-matched healthy controls (14 males and three females). The patient group had 29.29+6.55 years, 74.74+16.97 kg, and 1.72+0.09 m. The control group had 27.12+8.47 years, 80.25+10 kg, and 1.77+0.07 m. Kinematic data were recorded using the Vicon System with 11 cameras and a full-body Plug-in Gait model. Data analysis utilized independent samples t-test with a significance level of 5%, and effect size (ES) according to Cohen's criteria (Hopkins, 2002). The mean RoM for flexion-extension in the affected shoulder was lower than controls (7.65+4.55 versus 28.29+8.32°; mean diff: -20.65 [-269.9%], 95%CI:-25.33 to –15.96; p<.000; ES: very large). The patient group walked slower (111±9.96 versus 122.88±13.73

cm/s; mean diff: -11.88 [-10.7%], 95%CI:-20.26 to –3.5; p: 0.007, ES: moderate) and had shorter step lengths on the affected side (61.47±4.74 versus 66.71±5.22 cm; mean diff: -5.23 [-8.51%], 95%CI:-8.72 to –-1.75; p: 0.004, ES: large). The simple support on the affected side was 39.47±1.42 versus 40.41±1.06% in the controls (mean diff: -0.94 [-2.38%], 95%CI:-1.82 to – -0.06; p: 0.036; ES: small). Patients with traumatic brachial plexus injury exhibited altered shoulder RoM and spatiotemporal gait parameters on both the affected and unaffected sides. These findings indicate the need for rehabilitation programs that extend beyond the upper limb.

Gustavo Grinspan, Darío Santos, Andrés Rey, Franco Simini and Nicolás Benech

Rectus Femoris Shear Elasticity Varies with Flexio-Extension of Hip and Knee During Gait

Surface wave elastography is a new elastographic method that offers relevant advantages for biomechanical research. Unlike classic shear wave elastography (sampling rate ~ 1-2 Hz), it can be used in dynamic conditions as its sampling rate is ~15 Hz. Thus, this work shows preliminary results of applying this method to measure the shear elasticity of Rectus Femoris (RF) muscle during gait. We measured a volunteer during three independent gait cycles and measured the hip and knee flexion-extension angles with a 3D motion capture system. Such variables were characterized as [{RF elasticity}; {knee angle, hip angle}]. The results showed that the mucle elasticity is maximal in the middle of the cycle (first right heel contact - left heel contact) according to the following joint angles: [{102.57 ± 22.24 kPa}; {13.04 ± 2.93º, -15.48 ± 1.12º}]. Besides, at the beginning and end of the gait (first and second right heel contact, respectively) the RF muscle exhibited resting elasticity levels according to the following joint angles, respectively: [{5.66 ± 0.99 kPa }; {12.64 ± 0.23º, 24.67 ± 1.53º}] and [{6.66 ± 2.53 kPa }; {10.81 ± 0.59º, 24.92 ± 0.52º}]. These data show the tendency of the RF elasticity to increase during the support phase, and conversely to decrease during the swing phase, according to the muscular work needed to vary the knee and hip angles during gait. This study shows the first attempt to characterize muscle elasticity during walking, whose connotations could be important for both basic and clinical research.

Raphael Mesquita and Arthur Dewolf

Upper and lower limb coordination in running at different step frequencies

Running at a given speed can be achieved with either large steps at a low frequency or small steps at a high frequency. Step frequency (SF) is critical in fine-tuning lower limb positioning, affecting mechanical demand and inter-segmental coordination. At low SFs, runners decrease knee flexion to increase the swing leg inertia, contributing to greater

propulsive forces but also posing the risk of destabilization. While the fine-tuning of lower limb segment positioning has been extensively studied, if and how the upper-limb segment's temporal coordination and movements are tuned to changing SF has, to our knowledge, never been explored. Eight participants ran on a treadmill at five speeds and five SFs (2.0-3.6 Hz). We measured the phase-shift of the first harmonic between foot and hand motion and the range of motion (ROM) at the elbow joint. At the preferred SF, hand-foot coordination is out of phase and does not change with speed. However, at high SFs, especially at faster speeds, runners struggle to maintain this phase opposition and elbow ROM decreases. This position stabilizes the upper body, as the arms are closer to the center of mass and limits the increase in total mechanical energy. At low SFs, elbow ROM increases and the hand-foot coordination is more in phase, balancing the swing leg inertia. At low SFs, the upper limb contributes up to 28% of internal mechanical work versus 12% at preferred SF. These findings highlight the importance of upper and lower limb coordination in understanding CNS adaptation to challenging situations.

Natsuki Sado, Tempei Tominaga, Haruka Okuyama, Ayaka Hobo and Yoshino Shinabe

Asymmetric kinematic responses to verbal gait instructions: stooped posture induces shorter steps, but not vice versa

Gait and posture are effective indicators of mood state. This relationship is bi-directional: improvements in gait and/or posture can improve mood, and vice versa. Previous studies have described spatiotemporal and kinematic features of gait and posture in individuals with depression or negative mood (e.g., stooped posture, shorter stride, lower speed) in parallel, without specifying whether these features are dependent of each other. However, some of the features may not be independent but secondary to other features. Here we show asymmetric kinematic responses to verbal instructions during overground walking in 20 healthy adults (10 females, 10 males), measured using a motion capture system with markers attached to the limbs and individual spinous processes. In the 'stooped posture' condition, the thoracic kyphosis is more pronounced (quasi-Cobb angle: -37.3 ± 5.6°), as instructed, and the stride length (1.22 ± 0.11 m) and the speed (1.16 ± 0.11 m/s) are lower than normal walking (-29.1 ± 5.6°, 1.29 ± 0.12 m, 1.23 ± 0.13 m/s), even without specific instructions on stride parameters. In the 'shorter stride' condition, the stride is shorter (0.96 ± 0.15 m) as instructed and the speed is lower (0.92 ± 0.17 m/s), while the thoracic kyphosis is similar (-28.8 ± 6.1°) to that of normal walking. In our observation, we can interpret the unidirectionality existence that a shorter stride can occur secondary to a stooped posture but not vice versa. We suggest recognizing that some of gait features in negative mood may simply be secondary to other kinematic features.

Heron Baptista de Oliveira Medeiros, Felipe Neumann, Gabriela Willinghoefer, Walter Herzog and Heiliane de Brito Fontana

Influence of Multiplanar Shoulder Position on Transverse-Plane Torque Generation Capacity

This study evaluated the influence of three-dimensional shoulder positioning on internal (IR) and external (ER) rotator muscle strength. Ten young adults were tested at full IR, full ER, and three interpolated angles between these extremes, across two arm elevation positions (45° and 90° in the scapular plane). Maximal torque and optimal angles for IR and ER were determined using second-order polynomial regression. We hypothesized that the optimal angles for IR and ER torque production do not coincide, and that the ER/IR torque ratio peaks at the optimal ER angle and reaches its minimum at the optimal IR angle in both positions. Additionally, we expected that arm elevation would influence torque ratios. The results showed a 30° difference between the optimal IR and ER angles, with significant differences in ER/IR ratios ($p = 0.012$) exclusively in the 45° elevation position. However, no significant differences in ER/IR ratios were found between the optimal IR angle and full ER, or between the optimal ER angle and full IR ($p > 0.315$) in either position. IR torque at the optimal IR angle was significantly higher in the 45° elevation position (median = 34.3 Nm) compared to the 90° elevation position (median = 31.3 Nm; $p = 0.027$). Despite this, arm elevation in the scapular plane did not significantly affect ER/IR ratios at any tested angle ($p > 0.105$). These findings suggest that ER/IR torque ratios are relatively stable across different shoulder configurations and are largely independent of arm elevation.

Luis Alberto Parada, Renata Bona and Carlo M. Biancardi

Parameters and mechanical description of lateral walking

Lateral walking (LW) presents an asymmetric pattern, with a different mechanical and kinematic behavior than usual (sagittal) walking. Although unusual, LW is used in sports and in some specific job tasks. Purpose of our study was to quantitatively describe the mechanics of such gait. A sample of 24 men and women, between 20 and 27 years old (24± 2), physically active, were evaluated while lateral walking on a treadmill at 4 different speeds, self-selected walking speed, 20% below, 20% and 40% above it in both directions. A motion capture system (Vicon, UK) was used to record at 100 Hz the displacement of 11 body segments. The trajectories of the body centre of mass and the segments were reconstructed and the mechanical work determined. The LW strides were identified and cut by analysing the vertical velocity of the 5th metatarsal marker. Step frequency and length increased with speed in both directions, while the duty factor decreased with increasing speed. Total mechanical work (Wtot) and recovery percentage increased with speed and were lower than in conventional walking. The external working accounted for 68.6 and 61.4% of the Wtot left and right respectively. Vertical energy variations, unlike conventional

walking, displayed a single peak during the entire cycle, while horizontal energy dropped to a value close to zero at a point close to 50% of the cycle complete. This particular pattern of energy oscillations indicates a modified inverted pendulum mechanism in lateral walking and could explain the increased metabolic cost of this unusual gait.

Nicoletta Sileoni, Andrea Varaschin, Alberto Leardini, Alessandro Di Martino, Gina Lisignoli, Stefano Zaffagnini, Elena Gabusi, Valentina Matti and Claudio Belvedere

Knee osteotomy alone and combined with meniscal allograft transplantation: a clinical trial merging clinical, biological and biomechanical evaluations

Abnormal varus/valgus knee deformity, often concurrently with meniscal deficit, results in compartment overload, gonarthrosis, and pain. In young patients, knee-osteotomy is frequently performed to restore proper knee alignment by preserving original knee anatomy. Despite satisfactory results, post-operative residual disability and pain are reported. These could be overcome by additional meniscal-allograft-transplantation. This study's aim is to provide new insight on knee-osteotomy alone or combined with meniscal-allograft-transplantation via an original methodology combining clinical, biomechanical, and biological evaluations. Fifty-two patients were recruited for knee-osteotomy alone (26 patients) or combined with meniscal-allograft (26 patients); so far 6 and 5 patients were treated, respectively. Pre- and post-operative (at 12-month follow-up) examinations involved clinical scoring systems, biomarker assessments of cartilage turnover and inflammation (including synovitis level), magnetic-resonance-imaging and gait-analysis during daily-living activities, using a novel procedure to calculate the intersection of ground-reaction-force with patient-specific tibial-plateau. To this, gait-analysis data and image-based morphological reconstruction were combined by four additional bimodal 3D-printed markers placed around the tibia-plateau rim. Pre-operative examinations confirmed gonarthrosis, knee varus/valgus deformity (8°-valgus to 9°-varus), altered knee frontal/sagittal rotations and moments, and inflammatory trend. Before surgery, patients with mild meniscal deficit exhibited intersections outside the medial or lateral plateau-edge (~60% medial-to-lateral tibial-plateau width); with marked meniscal deficit these were outside the anterior plateau-edge (~50% anterior-to-posterior width). Post-op examinations revealed neutral knee realignment and improvements in functional performance, slightly better with meniscal–allograft. This cross-disciplinary study allows in-depth investigations of native knee deformity and postoperative realignment, preliminarily demonstrating better efficacy of knee osteotomy combined with meniscal-allograft-transplantation.

Oral session 3: Biomedical Engineering and Wireless Sensors

Vinish Yogesh, Jan Willem A. Rook, Thomas Keizers, Carsten Voort, Jaap H. Buurke and Chris Baten

Comprehensive Study of UWB Distance Estimation Errors in LOS and NLOS Caused by the Human Body in 3D-AHM Scenario

Integrated Ultrawideband (UWB) and Magnetic Inertial Measurement Unit (MIMU) could improve on-body position estimation in 3D Analysis of Human Movement (3D-AHM), as their combination can provide a higher accuracy than these sensors can individually. For this systematic errors are required as low as 0.01m. Currently, typical estimation errors reported are 0.3m in pedestrian localization applications at distances of 5m - 50m. The higher errors in position estimates are attributed to low accuracy in UWB distance estimate updates, being both limited by its base accuracy and by human body-related Non-Line of Sight (NLOS) effects. This paper therefore studies UWB distance error characteristics at distances relevant to 3D-AHM application (0.2-2m). This is done in both LOS and NLOS conditions typically caused by a human body in extensive evaluation experiments conducted against a VICON system. Human body segment NLOS conditions were simulated by placing sensors at different relative positions and distances of PVC pipes of different diameters filled with water. Also, experiments were done with sensors on the front and back side of the trunk and an off-body sensor in front of a subject. The errors of UWB distance estimates in LOS situations were highly reproducible and showed a consistent systematic bias of around 6cm and an SD of 5cm. For NLOS situation by human body, there was a reproducible and consistent overestimation of the distance estimates that varied with the size of the body segment. This comprehensive error characterization of UWB distance estimates would help further mitigation of these errors.

Mauro Callejas Cuervo, Carlos Uriel Suárez-Rubiano, Yanneth Saavedra-Castelblanco and Andrea Catherine Alarcón-Aldana

Active Video Game Using an Inertial-Magnetic System for Kinematic Analysis in Older Adults

The objective of this research was to develop a video game that obtains kinematic values of activities of daily living using an inertial and magnetic motion capture system, thereby promoting functional autonomy in older adults. To achieve this objective, the project was structured into three phases: i) identification and characterization of movements in the upper and lower extremities involved in the instrumental activities of daily living of elderly individuals; ii) design and implementation of a serious video game incorporating a motion

capture system to quantify movements associated with the instrumental activities of daily living in older adults; and iii) implementation of a test plan to validate the operation of the video game in a laboratory environment. Additionally, the development process of the video game followed the classic life cycle. The principal outcome of this research was the development of the video game "Funny Senior," which integrates a set of mini-games that evaluate the level of functional autonomy in older adults. The use of the video game demonstrated that motion capture systems based on inertial and magnetic sensors, combined with virtual environments such as video games, create engaging environments that promote functional autonomy in older adults. Furthermore, these games quantify mobility by assessing various physical capacities based on exercises developed from test batteries that evaluate the physical condition of older adults

Vinish Yogesh, Jaap H. Buurke, Bert-Jan F. van Beijnum, Peter H. Veltink and Chris T.M. Baten

Position Estimation with a Swarm of Integrated UWB/MIMU Sensors within the Context of 3D Analysis of Human Movement

This paper studies the potential of Integrated Ultrawideband (UWB) and Magnetic Inertial Measurement Unit (MIMU) sensors for improving position estimation in 3D analysis of human movement. This approach is widely used in pedestrian tracking applications with typical estimation errors of 0.3m (used at distances of 5m - 50m). For analysis of human movement estimation errors of around 0.01m are required (used at on-body distances of 0.2m to 1.5m). The main error sources are the errors in the distance estimates of UWB sensors and limited synchronization in time and position between the (separate) hardware UWB and MIMU. Therefore, we propose (1) a custom-built integrated UWB/MIMU sensor (UMIMU) with optimized internal synchronization, (2) a distance bias calibration to maximally remove systematic UWB distance errors, (3) an optimized position estimation through an Extended Kalman Filter. The position estimating performance was validated against position estimates from a Vicon system, once when using simulated UWB distance updates (a) and once for measured updates (b). In (a) distance updates were derived from Vicon data at typical UWB update rates and with added uniform distributed errors (SD = 0.05m). In (b) multiple measurements were made with freely moving UWB sensors in LOS situation. 3D position estimation mean errors were found at 0.04m (SD 0.02m to 0.05m) for simulated UWB distance updates and 0.3m with SD 0.3m for the experimental UWB distance updates. The main error in (b) stems from combining multiple ranging updates for position estimation, and alternatives to the current simple trilateration method are being explored.

Paolo Brasiliano, Gaspare Pavei and Elena Bergamini

Gait smoothness estimation during walking: indexes and walking speed influences

Movement smoothness is a clinically meaningful parameter. One of the most used indices is the log dimensionless jerk derived from linear velocities (LDLJ-V). Recently, this index has also been obtained from accelerometric data collected at the pelvis level through an inertial measurement unit (IMU) during walking (LDLJ-A). In this case, the implicit assumption is that LDLJ-A describes the smoothness of the whole body during locomotion, i.e., the smoothness of the body center of mass (BCoM). However, this assumption has never been verified. Furthermore, no consensus exists on the effect of walking speed on both indices. To answer these questions, ten healthy participants were asked to walk on a treadmill at seven different speeds (from 0.28 to 1.95 m/s) for 60s. Each participant was also asked to simulate a pathological gait at 0.83 m/s. Three-dimensional LDLJ-V was calculated from the BCoM trajectory obtained through a motion capture system (Vicon, 200 Hz) recording the position of 18 reflective markers, while three-dimensional LDLJ-A was estimated using a single IMU (APMD, Opal, 200 Hz) placed on the lower back of each participant. A two-way repeated measure ANOVA was implemented and significant interactions between walking speed and smoothness indexes were found. Post-Hoc test with Bonferroni correction showed significant differences between LDLJ-V and LDLJ-A for all walking speed (including the pathological gait simulation) on all the three components. The results of this research show that gait smoothness is both index- and walking speed-dependent and suggest caution when clinically interpreting results obtained with different populations and/or metrics.

Oral session 4: AI Modelling

Beatrice De Lazzari, Enrico De Bartolo, Emanuele Cannizzo, Andrea Baldazzi and Valentina Camomilla

Smartphone-based Classifier for ACL Injury Risk Assessment Using Vertical Drop Jump Tasks and the Landing Error Scoring System

This study focuses on developing a classifier for assessing Anterior Cruciate Ligament (ACL) injury risk based on two Vertical Drop Jump (VDJ) tasks—double support (DS) and single support (SS). Using the Landing Error Scoring System (LESS), 102 participants were analyzed to compare the jumps, while 42 were included in the classifier development. The VDJs were recorded using OpenCap, an iOS-based open markerless motion capture system, and evaluated through both traditional methods, where expert operators manually scored each jump based on 17 LESS items, and a machine learning classifier using the Fine Gaussian Support Vector Machine (SVM) optimized in MATLAB. Each participant performed

three jumps, and the dataset was split with 80% (34 participants) for training and 20% (8 participants) for testing. The OpenCap system enabled the extraction of 16 biomechanical features, which were used to train the SVM classifier, achieving a 92% accuracy in identifying ACL injury risk without expert intervention. The results indicated no significant differences between DS and SS tasks in ACL risk assessment, suggesting both can be used interchangeably. However, SS tasks showed higher LESS scores, indicating a potentially greater challenge. Future work will aim to refine the classifier by expanding the dataset and exploring deep learning approaches. Additionally, the impact of sports-specific factors, skill levels, and sex on ACL injury risk assessment through these tasks will be explored. This smartphone-based approach democratizes injury risk screening, offering a scalable solution particularly valuable in amateur sports and settings with limited access to expert evaluators.

Diego Vicente Contreras, Victor Castañeda Zeman and Steffen Hartel

Automatic Counting of Dynamic Technical Actions Using Computer Vision in the Biomechanical Risk Assessment of Work-Related Musculoskeletal Disorders of the Upper Limb

Work-related musculoskeletal disorders (WRMSD) constitute a huge cost to economies, with 30-40% of affected workers in EU and US reporting WRMSDs over the last decade. Human observation methods used for biomechanical risks assessment are inherently subjective. Inertial sensors can measure posture and motion variables for ergonomic assessments, but their operational use is limited due to the need for specialized knowledge, calibration, and potential to interfere with worker’s movement and performance. Computer vision offers a non-invasive alternative to assess human motion variables, yet literature on using this method for counting "dynamic technical actions" (DTA) remains scarce. This study adapts and validates the use of computer vision, Mediapipe Pose, a ready-to-use computer vision solution from Google, with video data and an algorithm initially designed by Taborri et al. [1] for inertial sensors, to automatically count DTAs and determine the "Frequency Factor" (FF) of the Occupational Repetitive Action (OCRA-Checklist) method. The performance is compared against "human consensus count" to assess validity. Videos of repetitive tasks and 3D joint coordinates from the University of Washington Indoor Object Manipulation Dataset were used. Three trained evaluators determined a human consensus count of DTAs, against which the adapted algorithm's counting was compared by using statistical analyses. The adapted algorithm, with optimal threshold settings, produced DTA counts and FFs that were statistically equal from the human consensus, with errors below the standard deviations of the human counts. The adapted algorithm offers a promising tool for assessing WRMSD risks, potentially improving the reproducibility of ergonomic evaluations using computer vision.

Zoé Pomarat, Kahina Chalabi, Maxime Sabbah, John-Eric Dufour, Jean-Charles Passieux and Bruno Watier

Estimation of ground reaction forces in rugby scrummaging using instrumented insoles and machine learning

Scrummaging is a critical and intense phase of rugby union, involving considerable forces and presenting the highest risk of injury during a rugby game. Despite its importance as an indicator of game success, the forces generated by individual players within the scrummaging have yet to be investigated. Studies have mainly focused on individual and collective pushing forces against scrummaging machines, with little attention to the ground reaction forces. However, these ground reaction forces are essential for dynamic biomechanical analyses, particularly in sports performance and reduction of injury risks. While instrumented insoles have been validated for gait and movements involving primarily vertical forces, their application in rugby scrummaging remains unexplored. The objective of this paper was to develop a method to estimate the three components of ground reaction forces, particularly the horizontal forward component, using a combination of instrumented insoles and machine learning. A neural network (MLP) was trained to estimate ground reaction forces from data collected by instrumented insoles and inertial measurement units, with validation performed against forceplates, during a thrust against an individual scrum machine. The root mean square error between the estimated horizontal forward force and the reference forceplate data was 11.5% of the mean resultant force on the left foot and 14.5% on the right foot. These findings demonstrate the potential of using instrumented insoles to accurately estimate the ground reaction forces, particularly the thrust force, of rugby players during scrummaging.

Néstor Duque, Aldemir Vargas-Eudor and Eder Peña

Machine learning en el análisis de la velocidad de la marcha en personas de la tercera edad

El análisis de la velocidad de marcha en personas de la tercera edad utilizando algoritmos de aprendizaje automático (ML) ofrece una herramienta poderosa para la evaluación y mejora de la movilidad en esta población. Este estudio se centra en la aplicación de ML para analizar datos de velocidad de marcha y predecir riesgos de caídas y otros problemas de movilidad. Se tienen datos de 105 ancianos, de 4 hospitales. La población se encontraba dividida así: 63 mujeres y 42 hombres y los criterios de inclusión fueron que la edad estuviese entre los 60 y 94 años, que los pacientes residieran en un pueblo pequeño, no reportar discapacidad para las actividades de la vida diaria y aceptar/firmar el consentimiento informado. Los participantes fueron seleccionados aleatoriamente de la base de datos de una institución de salud. El estudio fue aprobado por el Comité de Bioética de la Facultad de Ciencias de la Salud con el documento CBCS-036-16. El objetivo principal es desarrollar un modelo predictivo utilizando algoritmos de aprendizaje automático que

pueda identificar patrones en la velocidad de marcha que estén asociados con un mayor riesgo de caídas. Este modelo permitirá la detección temprana de problemas de movilidad y la implementación de intervenciones preventivas personalizadas. Como aportes del trabajo se tiene la identificación de individuos con alto riesgo de caídas antes de que ocurran, permitiendo intervenciones preventivas y pueden ser utilizados para el desarrollo de programas de rehabilitación y ejercicios personalizados basados en los patrones de marcha específicos de cada individuo.

Oral session 5: Methodology

Rosario Ulloa, Esteban Pino, Mónica Morante, Lorena Llorente and Manuela Galli

Data Standardization for Gait Analysis in the Oritel Network.

Gait, a complex process unique to everyone, has been extensively studied in fields such as medicine, rehabilitation, and biomechanics. Gait laboratories, like those at Teletón centers, play a crucial role in analyzing and diagnosing human movement patterns during locomotion. This report focuses on standardizing data from different gait laboratories. This initiative addresses the lack of uniformity, which hinders the comparison and exchange of information between different rehabilitation centers. The proposal is part of the Movement Analysis Network project, an initiative by Politecnico di Milano, Oritel, and Universidad de Concepción, promoting collaboration, research, and continuous improvement in movement analysis. The proposed methodology particularly focuses on standardizing data acquired from BTS GaitLab and Vicon Systems. To achieve an effective comparison between data from these two systems, it is essential to define uniform labels and automate the processes that allow for the comparison of the information contained in the files. For this purpose, our script takes C3D and EMT files as input and generates table-formatted files separated by study type as output. Then, those files are used as input for a NoSQL database. This database facilitates further data comparison. This work enables the creation of standardized databases, which can be used to improve the effectiveness and reliability of diagnoses and treatments related to gait pathologies. In a future work, machine learning techniques could be used for gait pattern classification, creating new opportunities for more precise and personalized medical care, thereby positively impacting patients' quality of life by tailoring treatments to their specific needs.

Ariane Lallès, Bruno Watier and Hélène Pillet

Dynamic criterion to quantify instability during locomotion

Notwithstanding several teams proposed to quantify risks of falls during gait, it is surprising to note that few of them use dynamics criteria for quantification of the instability. Indeed, while most studies focus on kinematic criteria (extrapolated center of mass, virtual pivot point, inverted pendulum model, etc.), this study proposes to base instability analysis on a dynamic criterion. In this context, based on theoretical development we propose to quantify the distance between the body center of mass (BCOM) and the minimal moment axis of the external mechanical action applied to the body. This parameter can easily be linked to the variation of the angular momentum of the whole body. So far, six asymptomatic volunteers walked on dual-belt instrumented treadmill equipped with two force platforms (Treadmetrix©). Motion capture system (Vicon©) was used to analyze the three-dimensional kinematics of the subjects. After a stabilized walking gait phase at 1.2m/s, volunteers were subjected to acceleration and deceleration phases at 3m/s2 up to 2.04 and 0.36m/s. While participants were informed about the disruptions, no information was given regarding the type and the timing occurrence. Accelerations and decelerations phases generated slips and trips and produced dynamics perturbations of the whole body. These results show significant variations of the maximal distance during the pre-perturbation phases and the perturbation phases during the slips ($p<.001$) and the trips ($p<.003$). This promising indicator should now be validated with people at high risks of falls and thresholds above which the fall is inevitable should be determined.

Chris Baten, Sanchana Krishnakumar, Martin Oude Alink, Andrea Cereatti and Jaap Buurke

Pointer-based segment calibration facilitates sensor-based gait analysis for more patients

In sensor-based gait analysis the 'flexion', 'rotation' or 'lateroflexion' joint angles presented in a gait report are derived from relative orientation changes of sensors mounted on the joint-adjacent body segments, using a relationship between the axes frames of both sensors and their body segments determined through a 'segment calibration' procedure. This typically requires an accurate and reproducible performance of a 'neutral pose' or 'helical axes rotations' (typically squat-like). More sophisticated approaches assume biomechanical model constraints and/or movement characteristics. Unfortunately multiple patient groups (e.g. CP patients) cannot perform these calibration poses or movements. Also the model constraints and movement assumptions do not apply. Picerno et al. (2008) proposed an alternative 'bony landmark-based' segment calibration method' (BLC) that utilizes a sensorized pointer-device to measure the orientation of several bony landmark connecting vectors in the sensor axis frames. This paper evaluates the BLC method (original and alternative) plus the 'neutral pose' and 'helical axes' methods by extensively comparing segment calibration matrices and gait report angles against those from a Vicon system in

straight walking in 10 normals and 10 physical therapy patients recovering from ACL surgery. Also an improved pointer device was developed, and segment calibration guidance was added to clinical gait analysis software, facilitating segment calibration performance by only one therapist within 10-15 minutes, with gait report data available instantly after each susequent measurement. First experiments were performed in CP patients, for which movement analysis in a more-natural environment would be especially beneficial (less stress, spasms, more natural movement, facilitates multi-moment series).

Anaïs Chaumeil, Pierre Puchaud, Antoine Muller, Raphaël Dumas and Thomas Robert

Is it possible to use confidence information to drive a multibody kinematics optimization in markerless motion capture?

Markerless motion capture methods open the way for lighter motion analysis setups, but efforts are still needed to improve the obtained 3D kinematics. Using videos, point estimation software generate 2D confidence heatmaps. Only the position of the pixel with maximum confidence is usually used for triangulation, which neglects other possible information in the camera plane. We present and evaluate a confidence-based multibody kinematics optimization (MKO) method, which maximizes the summed 3D confidence of the model-derived points. This summed 3D confidence is obtained in a continuous and differentiable form by combining information from 2D confidence heatmaps of the surrounding cameras that were parameterized as 2D Gaussian functions. This confidence-based MKO method was evaluated using synthetic data. Typical noise of point estimation software was added to reference data in order to generate the synthetic data. Confidence-based and classical distance-based MKO methods were applied to the synthetic data. Results (joint angles and 3D point positions) were compared to those obtained with a distance-based MKO applied to the reference data. It showed a better agreement for the confidence-based MKO method and robustness to missing data, suggesting that the confidence-based MKO method performs well.

Oral session 6: Balance and Posture

Magalí Sganga, Otar Akayenti, Federico Villagra and Emiliano Pablo Ravera

Comparative methodological approaches for analyzing margin of stability during walking

Comprehensive evaluation of pathologic gait patterns is essential for understanding the underlying pathology and, its progression, delivering personalized treatments. One quantitative indicator for assessing fall risks during walking is margin of stability (MoS), which is a measure of instantaneous mechanical stability derived from the dynamic relationship between the extrapolated Center of Mass (CoM) and the center of pressure. However, extrapolating CoM during movement is not straightforward, and there is an undesired variability induced by the selected measurement protocol, which often depends on the available technology. Up until now, the extent of this variability has not been investigated systematically. This study compares four different CoM estimation methods. The first two methods, based on Conventional Gait Model, estimate CoM using virtual sacrum (1) and pelvis centroid (2). The third method estimates CoM from ground reaction force (3), and the last one, and the last one, uses the accelerometer and gyroscope data from a smartphone mounted on the lower back. 21 healthy subjects (10 female, 11 male, age: 31.7 ± 9.0 years; BMI: 24.7 ± 3.5) walked on an instrumented treadmill at a fixed speed at 1.3 m s-1 for 6 minutes. Descriptive statistical analysis was performed, including temporal and normalized gait cycle analysis, focusing on the minimum and maximum MoS, and its ranges during walking. SPM1d with paired t-tests was employed for the analysis. Our results suggest that CoM estimation varies significantly depending on the selected measurement protocol and technology which should be considered while reporting and interpreting MoS results.

Pablo Eduardo Caicedo Rodríguez, Wilson Alexander Sierra Arevalo, Jorge Clavijo, Luís Eduardo Rodríguez Cheu and Mateo Alejandro López García

The foot impact in human gait. A definition.

Human movements, particularly those related to walking, are significant indicators of human health status. Consequently, a current task of healthcare professionals involves assessing gait patterns. This assessment is conducted through the measurement and analysis of gait parameters, which are biomechanical variables that describe human walking. These parameters include spatial measures that describe the displacement of body parts, temporal measures that gauge movement rhythm, dynamic measures that represent forces interacting with the moving body, and mixed measures that combine categories.

Technologies have been developed for measuring spatial and temporal parameters, encompassing features ranging from three-dimensional representations to survey-based evaluations. Dynamic gait parameters, which involve the measurement of forces interacting with the body during movement, pose a challenge and typically require specialized laboratory settings equipped with force measurement devices such as force platforms or dynamometers. One specific aspect of these measurements involves extracting information regarding the ground reaction forces under the foot. This study aimed to define the impact, a parameter closely tied to the floor reaction force, it measured using inertial units offering a portable data source for gait analyses. For validation purposes, this paper introduces a methodology centered on an experimental procedure conducted in a 3D human analysis laboratory involving 5 participants. The results demonstrate minimal variability and low error, indicating a consistent pattern in the measurement and highlighting the effectiveness of assessing gait deviations.

Giorgio Poletto, Eduardo Gonçalves, Daiani de Campos, Eduardo Martins and Heiliane Fontana

Effect of weightlifting shoes on stability during barbell squat in high intensity cross training athletes

The use of weightlifting shoes with the aim of improving stability during high-intensity barbell squats is common. The shoes have a heel lift that favors ankle dorsiflexion range of motion while potentially reducing trunk range of motion. Assuming they increase stability, we aimed to test the hypothesis that wearing weightlifting shoes, compared to conventional shoes, would reduce the variation and peak velocity of the center of pressure during the squat movement. An experimental, laboratory-based study with 3-dimensional movement analysis was conducted. Sixteen competitive athletes (8 females and 8 males; 27 ± 3 years; 72 ± 11kg) performed barbell squats with three different loads (50%, 70%, and 90% of 3-repetition maximum) and two types of footwear. Kinematic and kinetic data were collected using eight infrared cameras (Vicon Motion Systems) and two force plates (AMTI). The magnitude of center of pressure variation (RMS) was calculated and expressed as a percentage of foot size. Center of pressure peak velocity and RMS were verified for the concentric and eccentric phases. Comparisons were drawn using Wilcoxon tests. We found a reduction in the magnitude of center of pressure variation for the weightlifting compared to conventional shoes during the concentric phase of the 90% of 3-repetition maximum squat (mean difference = 1.75% p=0.025). All other comparisons did not yield significant effects. The results suggest that weightlifting shoes may enhance stability in high load barbell squats, which can contribute to better control, body alignment, and to a more efficient transfer of force in the squats.

Manami Fujii, Sophia Chirumbole, Andrew Wagner, Jaclyn Cacesse, Ajit Chaudhari and Daniel Merfeld

Repeatability of a three-dimensional pseudorandom balance perturbation assessment

Pseudo-random perturbations have been used to evoke and quantify postural sway, which can predict fall risk. We have developed a three-dimensional balance assessment that provides pseudorandom perturbations using sum of sinusoids (SoS) for simultaneous earth-vertical translations (Heave) and vestibular coordinate (Right Anterior-Left Posterior and Left Anterior-Right Posterior) tilts. The aim of this study was to determine the repeatability of our balance assessment and investigate balance performance for different motion trajectories having identical spectra. For each of the three dimensions, our SoS motion stimuli were generated by summing five sinusoidal signals having a bandwidth of 0.06-1.54 Hz and a peak-to-peak amplitude of 3 cm for translations and 2 degrees for tilts. We tested the postural sway of 12 naïve (25±4 years) and 12 experienced (38±14years) healthy participants while they stood on a motion platform (Virtualis, Motion VR, France). All the participants completed four trials with arms crossed and eyes closed. Center of pressure (CoP) data were analyzed using a discrete Fourier transform yielding magnitude and phase as a function of frequency. CoP spectral data showed sway responses at all frequencies stimulated were clearly distinguishable from one another and response components were observed at each of the perturbation frequencies. Mean Velocity (MVELO) of CoP postural sway of both naïve and experienced subjects significantly decreased across the four trials ($p<0.05$). Intraclass Correlation Coefficients (ICC) were greater than 0.75 in both naïve and experienced groups. This study suggests that our repetitive balance assessment was reliable enough to quantify postural sway for the healthy adults.

Oral session 7: Ergonomics

Rajani Mullerpatan and Triveni Shetty

Lower extremity joint Kinematics of Cross-legged sitting posture: A preliminary study report

Cross-legged sitting is a commonly practiced posture for meditation and yoga that demands multi-planar motion of lower-extremity joints. Negligible information on the biomechanical demands of cross-legged sitting motivated the present study to evaluate lower extremity joint kinematics in cross-legged sitting in order to inform therapeutic applications. A 12-camera 3-D motion capture system was used to evaluate the kinematics of cross-legged sitting in 10 professional yoga practitioners. Data were processed using an existing plug-in-gait model and filtered at 10 Hz. Lower-extremity joint angles and centre of mass (CoM) were computed. Kinematic analyses revealed tri-planar motion at lower extremity joints,

namely: hip flexion [82°(11.2°)], hip abduction [28°(3.6°)], and hip external rotation [14°(8.4°)], knee flexion [150°(6.6°)] with knee varus [36.8° (8.4°)], and ankle plantarflexion of 17.4°(7.3°) with ankle inversion [16.4°(13.2°)]. The CoM travelled 60 cm during the transition from erect standing posture to cross-legged sitting posture. The preliminary findings unravel kinematic demands of the complex cross-legged sitting posture based on the plug-in-gait model. Further biomechanical exploration of this posture using a specific musculo-skeletal model will provide valuable insights in the understanding of this posture and open doors to wider therapeutic applications of the posture and enhanced prosthetic and orthotic design for maximization of lower extremity function.

Sneha Kirve, Dr Rajani Mullerpatan, Ashish Ghadge and Abhishek Gupta

Influence of Spring Loaded Passive Exoskeleton on Erector Spinae Muscle Activity in Mathadi Workers with and without Low Back Pain

Mathadi workers carry a load on the head (Matha), back, neck and or shoulders and stack it at the appropriate place. High prevalence of low back pain and musculo-skeletal injuries caused by manual material handling, lifting heavy-weights and prolonged stooped postures has prompted research interest in novel orthotic solutions for improving occupational health of manual workers. Hence, present study aimed to develop a novel spring-loaded passive exoskeleton to reduce trunk muscle activity and prolong muscle fatigability in Mathadi workers. A passive-spring-loaded spine exoskeleton was developed using a shoulder harness, a lumbar corset and spring. The stiffness of spring (114N) was determined in quiet stance with 3 different weights using surface-EMG(S-EMG). Following ethical approval, exoskeleton was tested in 20 Mathadi workers; 10 workers with low back pain(LBP) and 10 workers without LBP after signed informed consent. Trunk muscle activity was recorded using S-EMG of lumbar erector spinae during Sorensen's trunk holding test with and without exoskeleton. Median frequency was recorded to indicate muscle fatigue. During Sorensen fatigue test, both groups demonstrated 24% increase in median frequency (MF) of erector spinae muscle when using exoskeleton compared to performing the test without exoskeleton ($p < 0.05$) thereby suggesting reduced trunk muscle activity. Increased median frequency with spring-loaded passive exoskeleton indicated reduced muscle fatigue of the lumbar erector spinae muscles in Mathadi workers with and without low back pain during fatiguing tasks. Further studies are in progress to arrive at an ergonomically sound solution to sustain manual physical labour and minimize musculo-skeletal stress.

Maria Cristina Herrera Valerio, Larissa Brenneman, Kumar Somasundram, Sanjay Veerasammy, Marcus Yung and Amin Yazdani

Estimating overhead postures with Accelerometer Data in skilled trade workers: model validation considerations for in-field application

Introduction: Overhead work is a key risk factor for shoulder injuries among construction workers. Popular wearable motion tracking sensors used to quantify overhead exposures in the field often face limitations associated with connectivity range, compatibility with required personal protective equipment, and set-up time. Tri-axial accelerometers, on the other hand, are inexpensive and unobtrusive, but have not been used extensively to capture full and multi-day workplace overhead exposures. The objective was to validate the accuracy of a model based on accelerometry data collected from the upper arm against Xsens outputs for predicting overhead exposures. Methods: Twelve healthy subjects (8 males, 4 females) performed a set of standardized hammering and drilling tasks against a wooden board in upright and lunged positions, with shoulder elevations of ~90° and >150° while wearing the Xsens system and a single triaxial accelerometer mounted on their dominant upper arm. Shoulder flexion/extension angle outputs were analyzed from the accelerometer-based model and Xsens using cross-correlations. Results: Moderate to strong correlations were observed between outputs from Xsens and the accelerometer-based model for the upright drilling task with shoulder elevation >150° (average $r = 0.61$, $p < 0.01$, offset = 7°). Validation of this model has allowed us to use this minimally invasive data collection method on construction sites to quantify the frequency and duration of overhead tasks among construction workers. Conclusion: With the appropriate signal processing and modeling techniques, it might be possible to use tri-axial accelerometry data collected at the upper-arm to accurately estimate overhead exposures.

Lessby Gómez-Salazar, Jhon Quiñonez and Stefanía Arango

Opencap y Opensim para el análisis cinemático 3D de tareas de manipulación de cargas realizadas en la construcción

Las tareas de construcción están asociadas a una alta exigencia corporal. Sin embargo, frecuentemente el análisis de la exigencia postural queda limitada a la observación directa o videográfica, debido a los altos costos de la tecnología 3D y la dificultad de la valoración en campo. De allí, que el desarrollo de tecnología mocap 3d de código abierto y libre de marcadores, abre posibilidades para evaluar en campo, la cinemática y el riesgo postural en tareas laborales, sobre las que existe poca información. Este estudio tuvo como objetivo, evaluar la cinemática corporal en 3 actividades laborales de la construcción mediante el uso de Opencap y Opensim. Metodología. Estudio descriptivo, en 10 sujetos que realizaron las actividades de palear, levantar y lanzar ladrillos y levantar y transportar bultos, en una obra de construcción. Los datos fueron tomados con 3 celulares con sistema operativo IOS,

filmando a 60f.p.s. con Opencap y fue procesada en la nube. Los datos cinemáticos fueron exportados a Opensim modelo LaiUlrich2022. Resultados: Se evidenció la alta exigencia en tronco y miembro superior y variabilidad intrasujeto en el gesto. Al ser libre de marcadores, algunos datos se afectaron por los objetos empleados en la labor. La exportación directa a Opensim, facilita la simulación pero limita la evaluación al depender de la arquitectura del modelo de Ulrich. Conclusiones: OpenCap y Opensim, posibilitan la evaluación del riesgo postural en actividades laborales de manera rápida, con relativa buena correlación con la realidad y bajo costo.

Oral session 8: Sports Biomechanics

Arthur Dewolf, Raphael Mesquita and Patrick Willems

The bouncing mechanism of running in the wind

During running, the mechanical energy of the body's centre of mass fluctuates throughout the step like a spring-mass system bouncing on the ground. When running against tailwinds or headwinds, negative or positive work is done against air resistance, generating an imbalance between positive and negative muscle-tendon unit work. Such imbalance may affect the vertical stiffness of the bouncing system and in turn the spatiotemporal parameters of the running step. In particular, we measured the ratio between the duration of the lower part and the upper part of the oscillation (on-off ground asymmetry) and the ratio between the duration of the braking and propulsion phases (landing takeoff asymmetry). Eight professional or semi-professional male runners ran at 4 m s-1 on an instrumented treadmill recording ground reaction forces. They ran in still air and against ten different head- (denominated as +) and tailwind (−) velocities of ±5, ±7.5, ±10, ±12.5 and ±15 m s-1. The wind significantly affects the two ratios: from -15 to +15m s-1, the on-off ground and landing takeoff asymmetry changed, suggesting that runners privileged the role of muscle relative to the tendon in the storage-release of elastic energy. Similar modifications of the two ratios have already been observed when the subject is requested to add positive work in a step, as during running uphill. Those observations strongly support the possible relationship between spatiotemporal parameters and the contribution of tendons in the storage-release of elastic energy into the muscle-tendon unit.

Arthur Dewolf and Mario Nunez-Lisboa

Impact of physical activity levels on age-related gait characteristics young and older adults

Introduction: The benefits of physical activity throughout life are well-documented. However, how this influences the mechanics of walking gait in young adults and older adults is less understood. Methods: Thirty-one young and twenty-nine older adults (age:

25.9 ± 3.3 y.o. and 70.7 ± 4.7 y.o., respectively) were classified into less active and more active participants based on the median MET-min/wk according to the Global Physical Activity Questionnaire. Participants walked on an instrumented treadmill at 4 km/h, and the 3D ground reaction forces were recorded. The mechanical work required to move the center of mass relative to the surroundings and the pendular energy exchange allowing a reduction of mechanical work to do were evaluated, as well as the shape of the force under each foot. In particular, the transition from one step to the next was analyzed. Results: An effect between age and physical activity level was found in general gait parameters, external mechanical work and pendular energy exchange ($p < 0.05$) without impact on the step-to-step transition strategy. Specifically, we observed higher contact time and step frequency, lower swing and stride time, and step length in less active older adults compared to more active ones. Also, less active older adults exhibited greater external work than more active ones. In young adults, no differences were reported between less active and more active participants. Conclusion: Physical activity levels influence the age-related gait characteristics, suggesting a direct benefit of physical activity on the cost of locomotion.

Pablo Fabian Moscoso Fernandez-Salvador and Ana Cecilia Villa Parra

Development of a System based Force Load Cells for Measuring Vertical Jump Parameters

In various sports disciplines, the physical abilities of strength, endurance, speed, and flexibility are evaluated to improve athletes' performance through the assessment of vertical jump exercises. In this context, recording parameters such as flight time, jump height, and specific power is crucial for a quantitative assessment of vertical jumps. However, the technology required for this purpose is often expensive, limiting access for many athletes and coaches. This work presents, as a low-cost alternative, the development and reliability evaluation of athe prototype of a system based on load cells and a microcontroller. This system aims to measure force for identify the start and end of the vertical jump, and calculate the aforementioned parameters, in order to generateing a database of the measurements for offline evaluation of the vertical jumps performed by subjects. A protocol for reliability and usability evaluation was designed and conducted, involving physical evaluations of vertical jumps with thirty participants. The system's measurements of flight time (ms), jump height (cm), and specific power (W/kg) were compared with those obtained from an optical data acquisition system, used as the reference device. The results of the statistical analysis indicate a positive correlation of 0.7 for flight time, 0.9 for jump height, and 0.7 for specific power. The meanaverage System Usability Scale (SUS) score was 87.5, indicating good usability. These preliminary results support the validity of the system. Thus, we believe thatTherefore, the developed platform can be effectively used to support sports training based on vertical jump evaluation.

Heron Baptista de Oliveira Medeiros, Felipe Neumann, Géssica Aline Silvano, Marcio de Oliveira Nunes, Walter Herzog and Heiliane de Brito Fontana

The Effect of Elastic Band Positioning on Hip Torques and Electromyographic Activity During Side-Stepping Exercise

This study analyzes the effect of elastic band positioning on hip torques and muscle activation during the side- stepping exercise, which is commonly used with the assumed goal of strengthening the hip abductors and lateral rotators in lower limb rehabilitation. Although previous research has primarily focused on electromyographic activity, our study provides a comprehensive evaluation incorporating 3D kinematic, kinetic, and electromyographic data. Thirty-four participants (18 men, 16 women, age 25±4 years) performed the exercise with a looped resistance band placed at the thighs, knees, and ankles. The Friedman test assessed the effects of band position. Sidestepping results in a muscular (resultant) torque of hip abduction and hip medial rotation for all band positions. Results indicated that medial rotation and abduction torques were significantly greater ($p<0.001$) when the band was positioned at the ankles compared to the knees and thighs. The electromyographic activity of the gluteus medius, tensor fasciae latae, and upper and lower gluteus maximus fibers was also significantly higher ($p<0.001$) with the band at the ankle compared to the thighs. These findings suggest that distal band positioning increases medial rotation and abduction torques, as well as muscle activation. Increasing band stiffness amplifies medial rotation torque when the band is at the ankles but not at the thighs, while abduction torque increases with stiffness at all band positions. If minimizing medial rotation torque is desired, placing the band at the thighs with a stiffer band may be preferable to maintain abduction torque without excessive medial rotation torque.

Bernardo Articardi, Dario Santos, Andres Rey, Fernando Motta and Franco Simini

Knee joint position reproduction and torque measurements in healthy subjects using IMU

ACL reconstruction restores mechanical instability, but brings with it a significant decrease in muscle strength and proprioception. Planning of physiotherapy sessions greatly benefits from evaluating maximum isometric quadriceps strength and knee joint proprioception. By so doing, ACL rehabilitation can be done with objective measurements. However, until recently there were no low-cost devices that allowed these measurements to be performed in clinical settings. We have developed the DINABANG device to measure Strength and Proprioception routinely in clinical use. The recently added pair of IMUs allows DINABANG to track the positions of tibia and femur on which they are affixed. The objective of this work was to obtain normative data as a reference to compare patients undergoing ACL reconstruction rehabilitation. We studied 24 healthy volunteers: 12 women age 26.0 SD 5.7,

and 12 men 26.9, SD 4.7. BMI was 24.4, SD 4.9, and 23.7 SD 2.1 respectively. To measure maximal isometric force and knee joint position reproduction, we used DINABANG. Women showed a maximum isometric strength of Quadriceps 523 N ± 175 N and Hamstrings 268 N ± 66 N, while the values for men were 633 N ± 145 N and 360 N ± 75 N respectively; differences statistically significant (p= 0.001). Knee proprioception was quantified using the joint position reproduction test, targeting the angle of 65º.We not found significant differences in proprioception between women and men p= 0.265. The DINABANG can be used to objectively measure maximum isometric strength and joint position reproduction, during follow-up of ACL rehabilitation.

Agustina María Monzón, Magalí Sganga, Mauro Federico Andreu, Mara Cintia Estévez and Santiago Gómez Argüello

The immediate effects of three different ankle taping on static postural stability in healthy amateur athletes

Functional taping is a widely used intervention for injury prevention. However, it remains unclear how ankle taping affects postural stability. The purpose of this study was to investigate the immediate effect of three different ankle tapings on static postural stability. Non-taping, rigid ankle taping, Mulligan taping and neuromuscular tape were tested during Unipedal Stance Test (US) and Modified Clinical Test of Sensory Interaction in Balance (mCTSIB) using posturography. 68 subjects were included in the final study (55.9% male; 44.1% female; median age 23 years, IQR: 21-25) after excluding 26 for chronic ankle instability. In US with eyes open, no significant differences were observed between taping conditions. Conversely, in US with eyes closed, significant differences were recorded in center of gravity sway and number of falls, with increased values using rigid taping. mCTSIB showed small but significant differences on firm surfaces with eyes open and unstable surfaces with eyes closed, with no falls recorded. Ankle taping shows variable effects depending on postural demands, being trivial in low-demand conditions but significant in challenging situations. On unstable surfaces and closed eyes, taping tends to improve postural stability. However, taping seems to provide no benefits on firm surfaces, and rigid taping might even impair postural stability by increasing fall risk. These findings emphasize the need for contextualized application of ankle taping, carefully considering specific environmental and task demands to optimize their efficacy in injury prevention.

Laura Camila Mayorga Lozada, Wilson Alexander Sierra Arevalo, Pablo Eduardo Caicedo Rodríguez, Jorge Enrique Clavijo Ramírez, Jorge Enrique Buitrago Espitia and Luis Eduardo Rodríguez Cheu

Time-frequency analysis of sEMG signals to assess knee function during drop jump performance

The Drop Jump is a sporting gesture classified as a plyometric exercise that evaluates reactive strength capacity, understood as the ability to quickly perform the muscle stretch-shortening cycle, consisting of an eccentric contraction followed by a concentric contraction during the contact phase. Enhanced comprehension of this cycle involves studying lower limb surface electromyography (sEMG) signals through methodologies typically focused on amplitude analysis. Nonetheless, these methodologies overlook the frequency content of the signals, which could provide valuable information about the frequency bands involved in motor activity. Therefore, methods that provide information in both time and frequency domains, such as the Continuous Wavelet Transform (CWT), have been introduced. This study aims to apply a methodology based on the CWT to process sEMG signals of high-performance athletes during the contact phase of the Drop Jump. The events defining the jump phases were identified, and sEMG signals were processed using the CWT with the Morlet Wavelet as the mother wavelet. The resulting scalograms were segmented using Otsu's method, and a post-processing stage was applied to obtain information about the frequency content of the signals. Kinematic behavior of the center of mass and the knee joint center of the dominant leg were obtained. Results suggested that eccentric and concentric muscle contractions are primarily associated with groups of low and high frequency motor units, respectively. Furthermore, eccentric muscle contraction presents lower energy levels. These findings provide a better understanding of muscle activity and the behavior of kinematic variables during the Drop Jump gesture.

Poster session A

Edith Elgueta Cancino, Ririka Fujiwara, Angela Bassi and Eduardo Cofré Lizama

Non-linear measures of postural control in the low back, mobile phone technology versus gold standard. BackMeUp project

Postural control is the ability to maintain and to correct a posture against the environment and can be quantified as mediolateral and anteroposterior sway. Low back pain individuals are shown to have altered postural control compared to healthy individuals yet research is

limited in whether it can distinguish between healthy and LBP populations. Force plates and motion capture systems are the gold standard to measure postural control but mobile phones could be a cheaper alternative in combination with non-linear methods such as multiscale entropy to provide a greater insight into the complex nature of postural control. Aims: Identify if mobile phones are valid in measuring postural control complexity compared to force plates and motion capture systems; Identify differences in postural control complexity between healthy and LBP participants during a challenging balance task; single-leg-stance. 26 participants were assessed with BTS motion capture system, a mobile phone positioned on the sternum and stood on a force plate. Participants performed 2 trials of single-leg-stance for 30 seconds. Pearson's correlation showed no significant correlation between mobile phone with force plate and multiscale entropy sternum marker acceleration values. Significant difference observed only in multiscale entropy sternum marker acceleration values between healthy and low back pain participants. The results indicate that mobile phones are not valid in measuring postural control complexity compared to gold standard measures. Additionally, healthy and low back pain individuals show some similarities in postural control complexity however further research surrounding non-linear methods of postural control is required.

Carlos De la Fuente, Rony Silvestre, Roberto Yañez, Eduardo Martinez-Valdes, Gustavo André de Andrade and Felipe P Carpes

Quadriceps thickness changes over six months post-anterior cruciate ligament reconstruction: unveiling critical impairments in vastii muscles.

The mechanisms behind the persistent Quadriceps weakness observed after an Anterior Cruciate Ligament reconstruction (ACLr) remain debatable. We described the time course of changes in Quadriceps thickness, strength, and thigh circumference over six months following an ACLr. We also studied the causal relation between Quadriceps thickness, total thickness and strength. Quadriceps thicknesses, Quadriceps strength, and thigh circumference were measured preoperative, 3, and 6 months post-ACLr surgery in 103 patients (77 men and 26 women). Limbs and time were compared with repeated-measures ANOVA and causal relations through mediation analysis ($\alpha = 5\%$). From 0 to 3 months post-surgery, Quadriceps strength ($p<0.05$), and Vastus-Intermedius (VI, $p<0.05$) and Vastus-Lateralis (VL, $p<0.001$) thicknesses were reduced. From 3 to 6 months, Quadriceps strength ($p<0.05$), total Quadriceps thickness ($p<0.001$), and VI ($p<0.001$) and VL ($p<0.05$) thicknesses increased. Vastus-Mediais (VM) and Rectus-Femoris (RF) thicknesses increase to 3 months after ACLr ($p<0.05$). Quadriceps strength, circumference at 5 cm, VI, VL, VM, and total Quadriceps thickness remain lower than the contralateral limb six months following an ACLr ($p<0.05$). The VI thickness is indirectly determined ($p<0.001$) through the total Quadriceps thickness, while the VL thickness is directly determined ($p=0.034$).

Quadriceps thickness adapts heterogeneously, with VI and VL atrophying for up to three months, explaining the post-ACLr quadriceps weakness. By six months, VI does not recover its thickness proportion, and VI and VL do not return to pre-surgery conditions. Both vastii muscles primarily determine Quadriceps strength changes, eliciting the VI thickness as the key biomarker for Quadriceps weakness following ACLr.

Carlos De la Fuente, Alejandro Neira, Gustavo André de Andrade and Felipe P Carpes

Laboratory Activities in a BS Physical Therapy Course: Integrating sEMG and Kinematics Real-time Data with Active Learning across Six Cohorts

Integrating technology and active learning methods into Laboratory activities would be a transformative educational experience to familiarize physical therapy (PT) students with STEM backgrounds and STEM-based new technologies. However, PT students struggle with technology and feel comfortable memorizing under expositive lectures. Thus, we described the difficulties, uncertainties, and advances observed by faculties on students and the perceptions about learning, satisfaction, and grades of students after implementing laboratory activities in a PT undergraduate course, which integrated surface-electromyography (sEMG) and kinematic data combined with active learning methods. Six cohorts of PT students (n = 482) of a second-year PT course were included. The course had expositive lectures and seven laboratory activities. Students interpreted the evidence and addressed different motor control problems related to daily life movements. The difficulties, uncertainties, and advances observed by faculties on students, as well as the students' perceptions about learning, satisfaction with the course activities, and grades of students, were described. The number of students indicating that the methodology was "always" or "almost always," promoting creative, analytical, or critical thinking was 70.5% [61.0% – 88.0%]. Satisfaction with the whole course was 97.0% [93.0% – 98.0%]. Laboratory grades were linearly associated with course grades with a regression coefficient of 0.53 and 0.43 R-squared ($p < 0.001$). In conclusion, integrating sEMG and kinematics technology with active learning into laboratory activities enhances students' engagement and understanding of human movement. This approach holds promises to improve teaching-learning processes, which were observed consistently across the cohorts of students.

Carlos de la Fuente, Rony Silvestre, Roberto Yañez, Matias Roby, Samuel Madera and Alejandro Ortiz-Bernardin

Stress concentration description for Anteromedial portal, Transtibila, and Hybrid Transtibial femoral drillings in anterior cruciate ligament graft: A finite element model.

Stress concentration on the Anterior Cruciate Ligament Reconstruction (ACLr) for femoral drillings is crucial to understanding failures. Therefore, we described the graft stress for transtibial (TT), the anteromedial portal (AM), and hybrid transtibial (HTT) techniques during the anterior tibial translation and medial knee rotation in a finite element model. A healthy participant with a non-medical record of Anterior Cruciate Ligament rupture with regular sports practice underwent finite element analysis. We modeled TT, HTT, AM drillings, and the ACLr as hyperelastic isotropic material. The maximum Von Mises principal stresses and distributions were obtained from anterior tibial translation and medial rotation. During the anterior tibia translation, the HTT, TT, and AM drilling were 31.5 MPa, 34.6 Mpa, and 35.0 MPa, respectively. During the medial knee rotation, the AM, TT, and HTT drilling were 17.3 MPa, 20.3 Mpa, and 21.6 MPa, respectively. The stress was concentrated at the lateral aspect of ACLr, near the femoral tunnel, for all techniques independent of the knee movement. Meanwhile, the AM tunnel concentrates the stress at the medial aspect of the ACLr body under medial rotation. The HTT better constrains the anterior tibia translation than AM and TT drillings, while AM does for medial knee rotation.

Carlos de la Fuente Cancino, Rony Silvestre, Roberto Yañez, Alejandro Neira, Samuel Madera and Alejandro Ortiz-Bernardin

Stress concentration description during knee Rota-tion with and without Iliotibial band-intermuscular septum lateral extra-articular tenodesis for Transtib-ial and Anteromedial Tunnels: A finite element model.

Traditional lateral extra-articular tenodesis (LET) using fixation elements constrains medial knee rotation laxity after anterior cruciate ligament reconstruction (ACLr). However, the mechanical behavior of a LET made with an iliotibial band–intermuscular septum is unknown using different anterior cruciate ligament (ACL) reconstruction drillings and would be crucial for constraining the rotatory components of direction change movements. Thus, this study aimed to explore the maximum principal stresses and their distribution in grafts during medial knee rotation with and without iliotibial band–intermuscular septum lateral extra-articular tenodesis for the transtibial technique (TT), hybrid transtibial technique (HTT), and anteromedial portal technique (AM) in single-bundle ACLr. The maximum von Mises principal stresses and their distribution under medial knee rotation was described using a finite element model generated from a healthy knee. LET with HTT,

TT, and AM decreases stress by 97%, 93%, and 86% during medial rotation compared to each technique without LET, respectively. The stress concentration for the AM portal and TT techniques was located at the femoral tunnel, and for HTT with LET, it was located across the distal thirds of the anterior aspect of the graft. In conclusion, the HTT with LET diminishes graft stress more than the HTT, TT, and AM without LET, and the TT and AM with LET during medial knee rotation. The AM portal, HTT, and TT techniques without LET show higher stress concentration patterns at the femoral tunnel, establishing a biomechanical risk of femoral tunnel enlargement when LET is not performed.

Carlos de la Fuente, Rony Silvestre, Roberto Yañez, Matias Roby and Francisca Jesam-Sarquis

Dynamic valgus classification during landing from 2D videos based on Random Forest.

Frontal knee valgus at landing is associated with knee injuries. Thus, video records may be helpful for injury risk screening. Here, we determine the feature rank importance of knee valgus patterns in the frontal plane during drop jump landing in different Female Chilean national Soccer team categories. Materials and Methods: Thirty-nine soccer players (aged 19.8 ± 1.1 yrs) were included. Ninety drop jumps were included from 142 frontal videos obtained from the injury surveillance assessments of different categories of the national Chilean team from 2018 to 2020. We create a feature vector from 11 binary features which were studied using random forest classification. 10-folder cross-validation was performed. Features weighted > 0.10 were selected for prediction. Results: Hip-knee-ankle alignment in bipedal posture, not a parallel inter-patella and inter-ankle straight line with the ground, and patella inward regarding ankle had 0.256, 0.263, 0.147, and 0.208 coefficients, respectively. Cross-validation accuracy was 0.98. Discussion: The most predictive features are hip-knee-ankle alignment in bipedal posture, not a parallel inter-patella straight line with the ground, not a parallel inter-ankle straight line with the ground, and patella inward regarding the ankle. Furthermore, this study suggests that different female Chilean national soccer team categories develop valgus patterns during landing.

Carlos de la Fuente Cancino, Rony Silvestre, Roberto Yañez and Felipe P Carpes

Anesthesia and intra-operative pivot are suggested to evaluate the rotatory laxity of the knee in Anterior cruciate ruptures.

The knee stiffness acquired following an Anterior Cruciate Ligament (ACL) injury might affect clinical knee tests, i.e., the pivot-shift maneuver. On other hand, the motor effects of spinal anesthesia could favor the identification of rotatory knee deficiencies prior to ACL

reconstruction. Hence, we aimed to determine if the intra-operative pivot-shift maneuver under spinal anesthesia generates more acceleration in the lateral tibial plateau of patients with an injured ACL than without it. Seventy patients with unilateral and acute ACL rupture (62 men and 8 women, IKDC of 55.1±13.8 pts) were assessed using the pivot-shift maneuver before and after receiving spinal anesthesia. A triaxial accelerometer was attached to the skin between Gerdys' tubercle and the anterior tuberosity to measure the subluxation and reduction phases. Mixed ANOVA and multiple comparisons were performed considering the anesthesia and leg as factors (alpha = 5%). We found a higher acceleration in the injured leg measured under anesthesia compared to without anesthesia (5.12±1.56 m*s-2 vs. 2.73±1.19 m*s-2, p<0.001), and compared to the non-injured leg (5.12±1.56 m*s-2 vs. 3.45±1.35 m*s-2, p<0.001). There was a presence of significant interaction between leg and anesthesia conditions (p<0.001). The pivot-shift maneuver performed under anesthesia identifies better rotatory instability than without anesthesia because testing the pivot-shift without anesthesia underestimates the rotatory subluxation of the knee by an increased knee stiffness. Thus, testing under anesthesia provides a unique opportunity to determine the rotational instability prior to ACL reconstruction.

Carlos De la Fuente, Carlos Cruz-Montecinos and Felipe P Carpes

Biomechanical properties between four surgical techniques used in vitro for suturing complete Achilles tendon ruptures.

The Dresden technique preserves the paratenon during Achilles tendon repair and may improve the plantarflexor mechanism when is combined with mobilization during early rehabilitation. However, the surgical repair design for Achilles tendon ruptures can affect rates of re-rupture or lengthening. Therefore, the aim of this study was to determine the biomechanical properties of the Krackow, Double-Kessler, Double-Dresden, and Triple-Dresden techniques used for repairing mid-substance Achilles tendon ruptures during cyclical and maximum traction. Sixty mid-substance bovine tendons repaired after transverse rupturing were divided randomly into four groups by repair technique: Krackow, Double-Kessler, Double-Dresden, and Triple-Dresden. Cyclical tractions of 4.7, 5.8, 7.9, and 11.7 mm (equivalent to 5°, 8°, 10°, and 15° of dorsal flexion, respectively) were applied to determine gapping, tensile strength, nominal suture stress, repair deformation, and specimens with clinical failure (gap > 5 mm). Maximal traction was applied to measure maximum strength and failure type (i.e. suture, knot, or tendon). The Triple-Dresden technique resulted in decreased gapping, nominal suture stress, repair deformation, and quantity of specimens with clinical failure as compared to the other techniques. Furthermore, Triple-Dresden tendons showed greater comparative tensile and maximum strengths. During maximal traction testing, this technique presented tendon failure, whereas the Krackow, Double-Kessler, and Double-Dresden techniques had suture failures. Triple-Dresden repair results in better cyclical and maximum traction strengths, suggesting

that this technique might be more appropriate when performing early mobilization after mid-substance Achilles tendon rupture repair.

Carlos de la Fuente Cancino

In-vitro clinical failure after cyclical tractions of Human Achilles tendon through Laplacian edge detector.

This study describes the angle of clinical failure during cyclical mobilization exercises in the Achilles tendon of human cadaveric specimens. Secondarily we identified the secure limit of mobilization, the type of failure, and the type of apposition. The lower limbs of eight males (mean age: 60.3±6.3 years) were repaired with the Dresden technique following Achilles tendon rupture. A basal tension of 10N at 30° of plantarflexion was placed on each specimen. The angle of the ankle during clinical failure (separation>5mm) was tested via cyclical exercises (100-cycles between 30° and 15°, 15° of plantarflexion and 0°; 0° and 15° of dorsiflexion; and 15° of dorsiflexion and full dorsiflexion). Clinical failure was determined using the Laplacian edge detection-filter, and the angle of clinical failure was obtained using a rotatory potentiometer. The type of failure (knot, tendon, or suture) and apposition (termino-terminal or non-termino-terminal) were determined. We obtain the mean; standard deviation; 95% confidence interval; 1st, 25th, 50th, 75th, and 100th percentiles; and the standard error of the mean for angle data. Proportions were used to describe the type of failure and apposition. The mean angle of clinical failure was 12.5° of plantarflexion, a limit of mobilization equal to 14.0° of plantarflexion. While the mean angle of clinical failure was 12.5° of plantarflexion, after 14.0° of plantarflexion, the technique was found insecure for cyclical mobilization exercises, with a 5% range of error. These findings are clinically relevant as they provide mechanical limits for diminishing the risk of Achilles lengthening during immediate rehabilitation.

Paulina Carcamo, Joaquin Robledo-Medalla, Nicolas Yañez, Rodrigo Venegas, Franco Barraza, Oscar Muñoz, Constanza Besser, Macarena Lopez, Rodrigo Dominguez, Alex Vaisman Burucker and Carlos Cruz Montecinos

Asymmetry in Knee Extensor Power and Single-leg Jump Tests One Year After Anterior Cruciate Ligament Reconstruction

Abstract—Knee extensor strength asymmetry is usually defined as a limb difference of >10% and is used as a criterion to return to sport in different functional tests after an injury or surgery. However, asymmetry in power and jump tests is less frequently reported, and there is a lack of clarity regarding which test is more relevant. This study aimed to compare knee extensor power asymmetry and jump test performance one-year after anterior cruciate ligament reconstruction (ACLR). This cross-sectional study included 23

recreational athletes (8 females) with a history of ACL reconstruction using an autologous patellar tendon or hamstring graft. The participants' mean age was 26.8 ± 8.3 years. Knee extensor power (KEP) was assessed using an isokinetic dynamometer at 60 °/s and 180 °/s. The jump tests included vertical jumps (single-leg drop jump and single-leg countermovement jump) and a horizontal jump (triple hop test), IRB2023-89. All tests showed significant differences between limbs ($p < 0.05$), except for the triple hop test ($p=0.30$). No interaction was found between the type of graft ($p=0.641$). The mean asymmetry between KEP (14.7%), single-leg drop jump (16.8%), and single-leg countermovement jump (18.4%) did not show significant differences. However, the triple hop test (4.2%) demonstrated a significant difference compared to the other tests ($p < 0.05$). In conclusion, persistent asymmetries in KEP and the vertical jump test remain evident one-year post-ACLR, in contrast to the horizontal jump test. These findings could provide insight into which functional assessments may be more sensitive to residual asymmetry following ACLR.

Mathias Ferreira, Nicole Imbert, Matías Míguez and Pablo Iturralde

DEVELOPMENT OF A PORTABLE DEVICE SYSTEM FOR RELATIVE POSITIONING AND MOVEMENT ESTIMATION IN GAIT ANALYSIS

Portable devices for movement analysis are a growing field of research. Typically, these devices rely on inertial measurement units (IMUs) to estimate movement parameters. The relative positioning of limbs is a critical quantity to be estimated in gait analysis, playing a role in calculating step length, gait asymmetry, and other clinically relevant spatiotemporal parameters. However, current devices are limited in estimating relative positions between devices because of integration drift. In this project, we propose a two-device system that uses ultrasound ranging to estimate relative positions between devices. The target application of the system is the characterization of gait (e.g., walking parameters such as walking speed and inter-leg distance through the gait cycle) during everyday activities. The devices are wireless, designed to be placed on the subject's ankles, and have an autonomy of at least 16hrs. Each device in the proposed solution records traditional IMU and magnetometer signals (3-axis acceleration, angular velocity, magnetic field) and has an ultrasound transceiver for ranging. Ranging is achieved by measuring the time-of-flight of ultrasound pulses exchanged between devices. The system is currently in the validation phase, where its estimates are compared with those of a Vicon motion capture system. If successful, the system would permit the collection of data in more naturalistic settings (outside the lab) and for prolonged periods of time. This characterization can serve several clinical applications, including diagnostics and tracking the effects of rehabilitation therapies.

Carlos Cruz and Claudio Tapia

Causal Effect of Lower Limb Acceleration on Electromyographic Activity in Individuals with Arthropathy During Gait

Surface electromyography (sEMG) is commonly used to assess muscle activation during walking. The causal relationship between acceleration and EMG activity is poorly studied, primarily because frequencies below 30 Hz are typically filtered to avoid mechanical artifacts, omitting biomechanically relevant information. The first aim of this study was to investigate the causal relationship between lower extremity acceleration and EMG activity of the tibialis anterior (TA) during gait in individuals with arthropathy. The secondary aims were to explore the clinical associations of causality and inter-day reliability. Using a single sensor, EMG and acceleration signals were simultaneously captured. The causal relationship between signals was analyzed using Ensemble Empirical Mode Decomposition (EEMD) and time series instantaneous phase dependence, quantifying relative causal strength (RCS) as bidirectional ratio. Eleven individuals with arthropathy were included (age 32 ± 11 years) who walked three times in a corridor of 30 meters. The average pain (VAS 0-100 mm) during walking was 12 ±15 mm. In all participants the direction of causality was from vertical acceleration to EMG. The median frequency of causal interaction was 35 ± 7 Hz for EMG and 15 ± 3 Hz for acceleration. The RCS positively correlated with pain intensity during walking (r=0.67, p=0.023). The inter-day reliability was high (coefficients variation 3% and intraclass correlation 0.86). In conclusion, vertical acceleration significantly influences EMG signals, where higher pain levels intensify this effect. Causal assessment is a reliable tool for evaluating the interaction between gait accelerations and muscle activation during gait.

Isabel Morales-Ledezma and Franco Simini

Simultaneous Vertical Force and 3D Shank Orientation during Standing and Stair Climbing

In the design of DIAPODAL, which alerts diabetic patients of a possible imminent injury to the foot sole, we measure vertical forces, 3D ankle movements, and their relationship with plantar pressures. We use one inertial sensor per limb and eight resistive force sensors per foot. We record standing posture for 15 minutes and climbing fifteen 345-step floors. We obtain plantar pressure maps and movement patterns. The vertical force varies according to sole points, with an average range of 17.3 to 98.1 KPa (SD 17.42 KPa), reflecting the load distribution. The sagittal acceleration of the right tibia distal end is 0.95 cm/s^2 ± 0.06 and left 0.85 cm/s^2 ± 0.06. In the transverse direction, the acceleration is 0.13 cm/s^2 ± 0.09 on the right and 0.12 cm/s^2 ± 0.08 on the left tibia. In the vertical axis (y), the acceleration is 0.10 cm/s^2 ± 0.06 on the right and 0.12 cm/s^2 ± 0.02 on the left tibia. In 3D, the movement of the foot in the postero-anterior direction is an order of magnitude greater than in the other two directions. The main foot movement direction with respect to the shoe, i.e. the

sagittal direction, associated with vertical loading patterns in specific areas of the sole, would produced friction energy dissipation between sole and shoe. In contrast, lateral and vertical displacements would have much less impact on friction. Our non-invasive and repeatable methodology allows for three-dimensional biomechanical analysis of the foot during gait.

Alejandra Rial and Franco Simini

Gait Monitor for Parkinson Disease Persons using PARKIBIP

Rehabilitation is important for Parkinson's Disease persons but physiotherapist time is scarce. PARKIBIP is a wearable device to detect the gait phases and to feedback encouragements to the person wearing it in everyday life. This prolongs the benefits of the physiotherapy session after the person leaves the laboratory. So as to be programmed in PARKIBIP device, we have examined a clinical routine performed by physiotherapists recording step length and frequency as well as the messages directed to the person. Gait phase detection allows to define every step as a starting and end point in space and time. A flow chart of the physiotherapist´s action was developed to better understand the professional procedure based on step length/frequency and gait speed. These variables are estimated by PARKIBIP in real time by means of two ankle Inertial Measurement Units (IMU), according to flow charts and will trigger sound or vibration messages for the patient. PARKIBIP does address proprioception, a must for persons with PD because it allows to have better body control. The instantaneous center of pressure either coincident or offset with respect to the center of mass ground projection contributes to select gait feedback messages. The IMUs of PARKIBIP allow to estimate the mutual orientation of shanks in 3D space to help determine the gait phases and projection of the center of mass. A gaze tracker is pending for PARKIBIP to monitor and suggest corrections in real time to train the brain to walk straight with head and eyes looking forward.

Zuliany Y. Urquina, Anny E. Correa, Joaquín M. Díaz, Cristhian F. Ricalde, Isabel C. Soto Cardona and Victoria E. Abarca

Comparative Occupational Biomechanical Analysis in Manicurists: Study of the Colombian and Peruvian Populations

Occupational biomechanical analysis applies biomechanical principles to evaluate and improve working conditions with the aim of preventing injuries and increasing efficiency. The research included two subjects, one from Colombia and one from Peru, who were observed and evaluated while providing manicure services to a client. The Rapid Entire Body Assessment (REBA) and Ovako Working Posture Analysis System (OWAS) methods were used to assess their work-related musculoskeletal discomfort. Additionally, measurements of their workstations were taken to understand the ergonomic factors

contributing to these discomforts. The study compares the results obtained to identify similarities and differences in the evaluations conducted in both contexts. The results reveal that repetitive movements and inadequate postures increase the risk of musculoskeletal disorders in both manicurists. It was found that manicurists in both countries are exposed to high-risk levels due to the repetitiveness of the movements and inadequate postures. The study concludes that it is essential to implement preventive and corrective measures, as well as to promote awareness about the importance of maintaining proper posture. These interventions could significantly improve working conditions and reduce the risk of musculoskeletal disorders.

Renata Bona, Angelina Racedo, Artur Bonezi and Carlo M. Biancardi

Mechanics work of the pregnancy walk

The changes that occur during pregnancy, like increase in body size and mass can cause disturbances in the center of gravity. These changes can lead to alterations in gait development. Aim: to assess the total mechanical work (Wtot), external work (Wext), internal work (Wint) and lateral median deviation (LD) for pregnant, non-pregnant individuals (CG). Methods: Pregnant individuals-19 in 3rd mth; 19 in 6th mth; 17 in 8th mth; CG: 17 healthy women. 3D kinematics were assessed by eight cameras (Vicon, Bonita), using a model with 20 reflexive markers. The measurements were taken at 5 speeds (5 min) selected in a randomized order: the self-select walking speed (SSWS), ±20%, ±40% on the treadmill. Statistics: 2-way ANOVA, Tukey's post-hoc. Results: For Wext, no differences were found, while Wint was higher in CG: 3rd mth at SSWS, +20%, +40%, 8th mth at +20 and at +40%. The highest Wtot was found for the CG at speed +40% compared to all trimesters. For all speeds, the 8th mth showed higher LD than the CG. At SSWS and +20%, 3rd mth had lower LD than 8th mth. At +40%, 6th mth had lower LD than 8th mth. Conclusion: No differences were found in Wtot, Wext or Wint between the different pregnancy trimesters. SSWS was higher for CG. One of the factors that can contribute to the choice of speed is the external rotation of the hip (LD), which is higher with increased abdominal volume and may be related to the search for stability during walking.

Amanda Jakovacz, Fernanda Serighelli, Lauana Maria Miola, Guilherme de Conto Kuhn, Danilo De Oliveira Silva and Alberito Rodrigo Carvalho

Relationship between knee crepitus with thickness and isometric torque of quadriceps in individuals with patellofemoral pain: a cross-sectional study

Introduction: Weakness and atrophy of the quadriceps muscle can lead to abnormal arthrokinematics of the patellofemoral joint, causing patellar maltracking, which may be associated with knee crepitus. Objective: We aimed to determine the relationship between knee crepitus, quadriceps muscle thickness, and isometric torque in individuals with patellofemoral pain (PFP). Methods: In this cross-sectional study, volunteers diagnosed with PFP underwent assessments to evaluate the presence, frequency, and severity of knee crepitus. Real-time ultrasound images of the quadriceps muscles were obtained at rest and during contractions to measure muscle thickness. Maximal isometric contraction tests were conducted at a 60º angle to measure knee extensor torque using a portable dynamometer with an inertial sensor. The relationship between knee crepitus and quadriceps femoris muscle thickness, as well as knee extensor torque, was analyzed using logistic and simple linear regressions. Results: We included 60 participants with PFP (mean age: 24; 60% women; 38% with crepitus). There was no relationship between isometric knee extensor torque and presence, frequency, or severity of knee crepitus. However, higher knee crepitus severity was related to lower thickness of the rectus femoris and vastus medialis at rest (R2 = 0.19 and 0.09, respectively) and during contraction (R2 = 0.16 and 0.07, respectively), as well as with the thickness of the vastus lateralis during contraction (R2 = 0.08). Conclusion: There is no relationship between the presence and frequency of knee crepitus and quadriceps muscle thickness or torque in PFP sufferers. Higher severity of knee crepitus is associated with lower quadriceps muscle thickness.

Lana Brandl, Jaline Rossato, Renata Adam Baioco and Alberito Rodrigo Carvalho

Incidence of sports-related knee injuries in volleyball players: relationship to objective assessment of knee flexor-extensor muscle function

Introduction: Abnormalities in muscle function measures, such as interlimb strength asymmetries or an ischio-quadriceps ratio outside normal limits, are predisposing factors for sports injuries. Objective: To determine the relationship between asymmetries in maximal isometric strength of the knee flexors and the ischio-quadriceps ratio and the incidence of knee injuries in volleyball athletes. Methods: Longitudinal observational study. We followed 39 competitive female athletes, in the under-15 to under-21 categories, from

two federation teams in Paraná, Brazil. A sports injury was defined as one that occurred during training/competition and resulted in time off work. Incidence was determined between February and May 2024. New injuries were reported to the team physiotherapist. Muscle function measurements taken on a traction dynamometer in February 2024 were: i) asymmetries between limbs for maximum isometric strength (%) of the quadriceps and hamstrings, with values greater than 10% considered asymmetry; ii) bilateral ischiosquadriceps ratio (a.u.), with normal values considered between 0.5 and 0.7. Ratios were determined using the GzLM test. Results: Meniscus injuries (n=8), tendinopathies (n=4), sprains (n=2), patellofemoral pain (n=2), and ACL tears (n=1) were reported. The means (95% CI and SD) of the muscle measurements considered without abnormalities were: quadriceps asymmetry (10.9;[7.9-13.9];±9.2), ischial asymmetry (5.7;[4.1-7.4];±5.2), left (0.52;[0.49-0.55];±0.11) and right (0.49;[0.46-0.53];±0.10) ischial-quadriceps ratio. No significant relationships were found between injury incidence and measures of muscle function. Conclusions: Measures of knee flexor-extensor muscle function within normal limits do not appear to influence the incidence of knee sports injuries.

Federico Caramia, Eleonora Bellucci, Emanuele D'Angelantonio, Leandro Lucangeli and Valentina Camomilla

Detection of compensatory movements using prototypical inertial sensor during physical therapy exercises

Telerehab allows the improvement of functional capacity, through home-based physical therapy, by favoring compliance and movement monitoring. This study aims to develop a classifier using low-cost inertial sensors to detect stereotyped compensatory movements. Seven kinesiologists performed five exercises with and without compensations, using prototype and commercial sensors. The classifiers are here presented for two paradigmatic exercises: a middle squat (SQ) with hands on a table and shoulder flexion (SH) while sitting without back support. Both exercises were performed with and without compensation in three trials of ten repetitions each. For SQ, compensation involved a lack of hip flexion and excessive forward knee advancement, monitored with sensors on the lower back and malleoli. For SH, compensation entailed excessive spine lean during arm lift, monitored with a sensor on the lower back. Ninety-five features were calculated per sensor. Lasso regression for feature reduction and leave-one-out for cross validation were performed. After hyperparameter tuning, via grid search technique, and feature reduction (84 for SQ, 73 for SH), Random Fores resulted as best model. For SQ, the prototype sensor had 89% accuracy and 94% precision, while the commercial sensor had 92% accuracy and 95% precision. For SH, the prototype sensor achieved 99% accuracy and precision, and the commercial sensor reached 100% accuracy and precision. Within the limited small sample size of the study, wearable sensors can detect compensations improving the quality of remote treatment. Further tests will demonstrate reliability of these data-simulated models to detect compensatory movements in elderly or people with chronic diseases.

Ana de David, Leandra Leal, Andrea Moraes, Aline Gava,
Gabriela Guenka and Kate Barcelos

Three-dimensional Kinematics During Overground Walking Versus Horseback Riding – A Case Study

The horse's three-dimensional movements transmit mechanical stimuli to the rider, requiring continuous postural adjustments similar to human walking. This study aims to compare the three-dimensional kinematics of the trunk and pelvis of an adult woman during overground walking and horseback riding. A 46-year-old woman (50 kg and 1.60 meters) and a horse (Creole breed, 1.40 meters, 415 kg) participated in the study. Kinematic data were recorded using a Vicon system with eight cameras (200 Hz), and a Plug-in-Gait marker set in a sand arena. The participant was instructed to walk on the ground for ten meters at a self-selected speed during three trials. Additional markers were placed on the horse's limbs and three trials were recorded for the rider's movement through sixteen meters. A Butterworth low-pass filter was used for kinematic data and the curves were normalized to the horse's gait cycle, using the strike of the forelimbs as reference. It was observed that the trunk curves during horseback riding in the sagittal, frontal and transverse planes are similar to overground walking with a greater range in the sagittal plane. For the pelvis, the curves are similar in the sagittal plane with less pelvic anteversion during riding, as well as for pelvic obliquity. In conclusion, the results show a similar pattern for trunk and pelvis kinematics in overground walking and horseback riding in the three planes of movement with greater amplitudes for overground walking. This information could be useful for physical rehabilitation when using therapeutic horse riding or hippotherphy.

Leandra Leal, Andréa Moraes, Gabriela Guenka, Aline Gava,
Kate Barcelos and Ana de David

Horse Walk Amplitudes and Trunk and Pelvis 3-D Kinematics

Horses have been used for rehabilitation purposes in hippotherapy. Each horse has a natural walking amplitude that generates different postural adjustments for the rider. This study compares the three-dimensional kinematics of a rider's trunk and pelvis across different horse walk amplitudes: collected, medium, and extended. A 46-year-old woman (50 kg, 1.60 meters) participated in the study and a Creole breed horse with a natural medium walk (1.40 meters, 415 kg) was used. Medium walk involves the pelvic limb overlapping the thoracic limb's step, collecting the pelvic limb not exceeding it, and extended walk exceeding it. Kinematic data were captured in a sand arena using a Vicon system with eight cameras (200 Hz) and a full-body Plug-in-Gait marker set. Additional markers were placed on the limb´s horse and three trials on each walking step were recorded through sixteen meters. The curves were normalized to the horse's gait cycle, using the strike of the forelimbs as a reference. The speeds (m/s) of the walk amplitudes

were: collected (0.67±0.03), medium (1.14±0.12), and extended (1.55±0.09). It was observed that the trunk curves are similar in all three planes, but in extended walking, the trunk shows greater amplitude in the sagittal and frontal planes, while the pelvis shows greater amplitude in the sagittal plane. In conclusion, the trunk and pelvis curves are similar across all three planes, with increased movement in the sagittal and frontal planes during extended walking. These findings enhance our understanding of how horse walking amplitude affects rider's trunk and pelvis movement.

Angelina Racedo, Paula Radesca, Christian Schneider, Mateo Rodrigues, Carlo M. Biancardi and Renata Bona

Kinematics variability at different velocities of walk during pregnancy

Pregnancy produces body changes that lead to a decrease in physical activity, which affects gait. Objective: to compare the spatio-temporal parameters of gait and the coefficient of variation of pregnant subjects at different speeds (self-selected speed and ±20%, ±40%) and control group (CG). Methods: 15 subjects participated in the study in each group: Pregnant persons (PE) trimester 1; trimester 2; trimester 3 and CG. 3D kinematics was assessed using a motion capture system (Vicon, UK), with 18 reflective markers model. Statistics: Two-way ANOVA. Results: Stride length (Ls) and stride frequency (Fs) were higher in the CG. Stride time (Ts) was longer in PE. Lower articular angle TO and TD (left and right) for PE. Differences were also found in ROM (range of motion at stance) in knee swing and ROM ankle swing being lower in PE (left and right). The coefficients of variability (Ts, Ls and Fs) were higher for pregnant persons. Conclusions: PE walked slower, presented lower Ls and Fs, ROM, HS and TO. The higher coefficient of variability in PE may be related to greater instability leading to risk of falls. These variations are attributed to the need to maintain stability due to greater mass and changes in the centre of gravity. Knowledge of these characteristics is crucial to support the needs of PE, generating a safe gait.

Vanessa Yelós, Germán Pequera and Carlo M. Biancardi

Energy recovery calculation using pose estimation

Clinical gait analysis is a tool used for the diagnosis of diseases that is performed using specialized motion capture and processing systems (MOCAP). Recordings from smartphones and processed with computer vision techniques (Markerless) have shown kinematic parameters similar to those obtained with MOCAP. However, to date there are no works that report the level of error that the Markerless workflow presents in energy parameters associated with the movement of the center of mass during gait. In this work we propose to report the difference in mechanical energy recovery (Recovery) using MOCAP and the Markerless workflow. Images were captured using smartphones at 60 fps for Markerless and at 100 Hz using 8 VICON Bonita cameras for MOCAP. Images captured with

smartphones were treated with rtmpose to acquire 26 keypoints positions. The processing of the keypoints trajectories estimated with rtmpose included interpolation and filtering. The results reported a difference of 10%-20% in the Recovery, showing a high degree of similarity between both techniques. These errors could be attenuated by improving: 1) the calculation of the derivative of the position of the center of mass to calculate the kinetic energy and, 2) optimizing the interpolation and filtering processes in the Markerless flow. The works aimed to improve the quality of the estimation of kinematic parameters during gait using low-cost tools can have an impact on the development of clinical rehabilitation and sport.

Paula Radesca Vener, Christian Schneider, Artur Bonezi, Carlo M. Biancardi and Renata Bona

Cambios en el centro de masa de embarazadas en dos modelos antropométricos diferentes

Los cambios físicos que se producen en la persona embarazada (PE) pueden provocar cambios en las medidas antropométricas utilizadas para estimar las variables mecánicas de la locomoción. Objetivo: Comparar las medidas mecánicas de la marcha en PE utilizando dos tablas antropométricas diferentes (H - Haddox et al., 2020 y D - Dempster 1955). Esta última tabla es ampliamente utilizada en biomecánica, a pesar de cambios en la distribución de la masa corporal, mientras que la primera fue desarrollada específicamente para PE. Métodos: Participaron del estudio 15 sujetos por grupo: PE en trimestre 1; trimestre 2 y trimestre 3. La cinemática 3D se evaluó mediante un sistema de captura de movimiento (Vicon, Reino Unido), con un modelo de 18 marcadores reflexivos. Las medidas se obtuvieron en función de la diferencia entre medidas obtenidas de los dos modelos antropométricos con diferencias en: centro de masa (CM), trabajo mecánico vertical (Wv), horizontal (Wh) y externo (Wext) y recuperación. Estadística: ANOVA de dos vías. Resultados: se encontraron diferencias entre trimestres en la posición del CM (el tercer trimestre mostró una mayor diferencia en la posición del CM entre H y D), mayores medidas para el tercer trimestre con el H Wh y recovery. Conclusiones: El aumento del volumen abdominal durante el embarazo debe ser tenido en cuenta, utilizando parámetros antropométricos e inerciales que consideren los cambios producidos por el embarazo.

Colin Roberts

Navigating Trochlear Osteochondritis Dissecans: A Case Study on Diagnosis, Surgical Intervention, and Gait Rehabilitation

Osteochondritis dissecans (OCD) is a rare joint condition that primarily affects the knee, with lesions most commonly found on the medial femoral condyle. Even more rare are lesions located on the trochlea, accounting for only 2% of knee OCD cases. This case report

details the diagnosis, treatment, and rehabilitation of bilateral trochlear OCD lesions, highlighting the clinical challenges posed by this atypical presentation, including diagnostic delays due to the lesion's rare location. The study examines pre- and post-surgical movement and gait, with a focus on quantifying range of motion progression during rehabilitation, assisted by continuous passive motion therapy. Additionally, it compares the surgical approach, involving fragment fixation and hole drilling to promote additional blood flow and bone growth, with a similar case managed nonsurgically. The pros and cons of both approaches are discussed: surgical intervention offers direct lesion repair and potential for better long-term outcomes but involves significant recovery time and surgical risks, whereas nonsurgical management avoids these risks but may lead to prolonged symptoms or lesion progression. Insights from multiple orthopedic surgeons are included to explore decision-making in the management of trochlear OCD. This report contributes to the limited literature on trochlear OCD by providing a comprehensive analysis of treatment outcomes, while also addressing the implications for gait and movement rehabilitation. (I am willing to present either a poster or oral communication)

Gabriel Galhardo Alves, Guilherme de Conto Kuhn, Júlio Augusto Franzen, Ana Paula Campagnaro, Lauana Maria Miola and Alberito Rodrigo Carvalho

Reproducibility and responsiveness of isometric torque measurements of the knee extensor mechanism using the Dinabang dynamometer

Introduction: The Dinabang dynamometer can optimize measurement functions. Objective: To verify the reproducibility and responsiveness of quadriceps isometric maximum torque (IMT) measurements using the Dinabang. Methods: An observational, ethics-approved, test-retest study with non-probabilistically selected volunteers (n=20/♂=14/24.3±8.1 years). The subject seated in a chair with 60°±5 knee flexion. IMT was measured using a portable dynamometer with an inertial sensor (Dinabang). An inextensible chain was attached at one end to the chair frame and at the other to the anklet connected to the dynamometer. Maximum knee extension force sustained for 5s was requested in 3 trials with 120s intervals, and the average was calculated. Torque (N·m) was the product of the force and lever arm (distance between the knee joint interline and the dynamometer attachment at the ankle). Measurements were taken at three moments: test (Te); repeat test after 1-day (RTe1); repeat test after 7-days (RTe7). Relative reproducibility was assessed by intraclass correlation coefficient (ICC). Absolute reproducibility was calculated using the standard error of measurement (SEM) and responsiveness using the minimum detectable change (MDC): $MDC=SEM \cdot 1.64 \cdot \sqrt{2}$. Results: The ICCs showed excellent relative reproducibility between all combinations (Te/RTe1/RTe7=0.93; Te/RTe1=0.91; Te/RTe7=0.92; RTe1/RTe7=0.90). The coefficients of variation (%), SEM and MDC (N.m), respectively, were Te/RTe1/RTe7= 11.8, 26.3 and 61.0); Te/RTe1= 10.1, 24.2 and 56.1; Te/RTe7= 11.1,

25.9 and 60.1; RTe1/RTe7= 11.6, 27.3 and 63.3). Conclusion: IMT measurements by Dinabang were reproducible, with acceptable SEM, indicating that real changes in IMT should be greater than 63.3 N·m.

Dario Santos, Andres Rey, Bernardo Articardi, Andrea Mattiozzi and Franco Simini

Tibial Axial Rotation and Knee Flexion Extension in Open Chain with IMU Compared to Infrared Marker-Based 3D Motion Capture

Rehabilitation of the lower limb is usually carried out by exercising the flexion-extension muscles. To quantify this work DINABANG, a dynamic dynamometer that provides torque and angular velocity in the sagittal plane, was developed. Due to the anatomical structure of the knee and its 3D movement that includes axial rotation and adduction-abduction in addition to flexion-extension, rehabilitation may in some cases have to correct the muscles responsible for rotation. To expand the monitoring capacity of DINABANG into 3D analysis of articulation movements, an IMU sensor is added to be attached to the tibia. For the first time, angles and angular velocity are recorded in two planes (flexion-extension and axial rotation) as well as torque in the sagittal plane on the sports field or office. To verify the accuracy of the new measurement, the experiment consisted of simultaneous recording of DINABANG and a 3D optical marker-based motion capture system. In normal volunteers, angles showed ranges of 141º (-1.3º;139.8º) of flexion-extension and 25º (-10º;15) of axial rotation of the tibia. Simultaneous recordings of both methods differ on average of the absolute value of the difference between DINABANG and VICON 1.304° (± 0.919°) for flexion-extension, and 0.575° (± 0.694°) for axial rotation. The inclusion of an IMU and appropriate calibration and processing allows to characterize precisely the movement of the knee articulation in 3D. This study opens the possibility of carrying out a real-time monitoring of the 3D movement (screw-home) of the leg during open kinetic chain training exercises.

Natalia Fuentes Concha, Nayli Rodríguez Santos and Leonardo Lagos Hausheer

Influencia de Factores Demográficos en la Eficacia de la Rehabilitación en la Marcha con instrumentos de bajo costo.

Human gait is fundamental for independent mobility and cardiovascular health. Factors such as gender and age influ-ence walking speed, a crucial health indicator. We aimed to investigate the possible implications of gender and age on gait rehabilitation. Methodology: In 10 individuals, we inves-tigated how age, gender, height, weight, and BMI influence self-selected walking speed (SSWS) and optimal walking speed (OWS) evaluated with a 10-

meter test. Participants performed controlled walking tests, and the data were ana-lyzed using ANOVA to compare speeds among different de-mographic groups. Informed consent and data confidentiality were ensured. Result:s Significant differences were found in walking capacity between men and women, and among differ-ent ages. Men showed a greater length of the right lower limb and a faster walking speed compared to women. Individuals under 50 years old exhibited greater walking capacity and a better rehabilitation index than those over 50 years old. Con-clusion: The results indicate that both gender and age signifi-cantly affect walking speed and locomotor rehabilitation. Women presented slower walking speeds and a lower rehabili-tation index, possibly due to physiological and biomechanical differences. These findings highlight the importance of con-sidering gender and age in personalized rehabilitation pro-grams and suggest the need for further studies on the rela-tionship between BMI and walking capacity.

Sibele de Andrade Melo Knaut, Luiz Alfredo Braun Ferreira and Luiz Felipe Munhoz Gois

Interference Of Ankle Joint Mobilization In Free Squat Movement: A Quasi-Experimental Study

Introduction: The squat is a complex movement requiring coordinated synchronization of the trunk and lower limb joints. Increased musculo-articular stiffness in the talocrural joint is a common condition that can reduce joint flexibility, limiting the range of ankle dorsiflexion. This restriction is a known risk factor for a higher incidence of lower extremity injuries.Therefore, the present study aims to investigate the efficiency of ankle joint mobilization by increasing dorsiflexion during the free squat movement, in healthy individuals. Methodology: This is a quasi-experimental study approved by the UNICENTRO Research Ethics Committee (3.560.101/2019). Eight healthy participants initially underwent anthropometric assessment followed by 5-minute stationary bike warm-up. After heating, five 20 mm high projection spheres were attached, using double-sided adhesive tape for fixation, in the regions of the upper iliac crest, femoral trochanter, proximal fibula, lateral malleolus and fifth metatarsal for two-dimensional analysis of the movement of free squat in the sagittal plane. The subjects were submitted to an exercise program, 3 times a week for 4 weeks, consisting of 3 sets of free squat, 20 repetitions, with rest of 1 minute between each set, associated with joint mobilizations by the Maitland concept degrees III and IV in the talocrural region in anteroposterior action. Results: Significant changes in range of motion in the hip ($p=0.016$) and ankle ($p=0.001$) joints could be observed. Conclusion: Joint mobilizations in the anteroposterior aspect of the ankle may contribute to increase range of motion, resulting in greater effectiveness in performing free squats.

Deivid Smarzaro, Victor Ramos, Ana Paula Pagani, Rafhael de Andrade, Douglas Almonfrey and Mariana Rampinelli

Human Gait Analysis: A Comparative Study of Intelligent Space and Inertial Wearable Sensors in Prostheses Users

Human gait analysis (HGA) in Brazil often relies on the subjective assessments of physiotherapy professionals, leading to challenges such as a lack of standardization and high dependence on individual professional's knowledge, which may cause disruptions in patient care when professionals change. To mitigate this limitation, this study explores the potential of computer vision technology as a standardized alternative for gait assessment. Specifically, we evaluate the Intelligent Space (IS) system, which employs four cameras and a communication network to capture patient gait data and compare it with the inertial wearable sensors (IWS) method of data acquisition. Our research focuses on assessing the performance of these systems in the gait analysis of leg amputees using prosthetics. Data were collected from 15 patients at CREFES (Physical Rehabilitation Center of Espírito Santo), measuring key metrics such as knee angle, pelvis angle, chest inclination, and ankle height. These measurements were derived from 3D data of 20 joints, captured from four different perspectives during four standardized movements: Stand Up and Sit, Timed Up and Go, a 5-meter walk, and a 5-meter walk with return. The results provide an initial comparison between IS and IWS in HGA, highlighting their potential as complementary tools in HGA. We believe this work lays the groundwork for more advanced gait analysis systems within the healthcare system, promoting accurate, objective data collection to support physiotherapy professionals in improving patient outcomes.

Josiel Ribeiro, Heron Baptista de Oliveira Medeiros, Felipe Neumann, Vitor Guarda Munari and Heiliane de Brito Fontana

Influence of sagittal plane changes in posture on hip abductor strength and motor unit activity

Traditionally, hip abductor strength, crucial for athletic performance, is assessed through isolated, isometric contractions that do not reflect the complexity of multi-joint movements and fail to identify how posture affects strength. A crouched stance reduces the distance of the hip to the floor, thereby facilitating torque transfer from the hip to distal segments, resulting in greater potential to exert tangential forces on the ground. However, crouching also alters hip muscular lengths, which may impact torque-generating capacity. Here, we aimed to investigate hip abductor strength in a functional context, exploring how different postures influence hip strength. We hypothesized that a crouched compared to an upright posture allows for greater lateral ground force. Ten participants (23±3 years, 64±18 kg) stood on two force platforms in upright, semi-crouched, and crouched postures and were instructed to push the platforms laterally with maximum effort. Postures were based on trochanter height resulting in knee flexion angles of ~58° and 91° for the semi- and

crouched positions. Hip abductor torque, lateral ground forces, and tensor fasciae-latae and gluteus medius high-density myoelectric activity were measured. Measurements demonstrated high reliability (ICC>0.89). We observed a 42% reduction in hip abductor torque and a 49% reduction in motor unit firing rates in the crouched compared to the standing posture (p=0.01). Crouched postures did not result in an increased ability to produce lateral ground forces. This outcome is likely related to a reduction in hip abductor torque capacity associated with changes in muscle lengths and motor unit activation.

Mateo Rodrigues Zabala, Germán Pequera, Valentina Silva-Pereyra, Christian Schneider, Renata Bona and Artur Bonezi

Kinematics of kettlebell swing exercises and aging

The kettlebell swing, effective for improving muscle power, is essential in the aging process (Jay et al., 2013; Lake & Lauder, 2012). This study compared kinematic variables of two variations of the kettlebell swing, american and russian, between young adults (YA) and older adults (OA). The sample consisted of 5 individuals for each group: YA (22.8 ± 4.2 years; BMI: 24.85 ± 5.8) and OA (66.0 ± 4.0 years; BMI 25.8 ± 5.8), all trained. Each subject performed 10 movement cycles in both variants (american: shoulder amplitude up to 180°; russian: shoulder amplitude up to 90°) with 8 kg kettlebell. Joint angles ankle, knee, hip, shoulder and pelvis were analysed using the Vicon Bonita and Nexus systems, applying repeated measures ANOVA. The results showed differences in the coefficient of variation. In the ankle, the YA had lower variability (0.05) compared to the OA (0.15). In hip and shoulder, YA showed higher variability (0.37 and 0.20) than OA (0.15 and 0.06). Aging is associated with alterations in proprioceptors and increased joint instability (Proske & Gandevia, 2012), as well as a reduction in body water. Young people, with greater hydration and better myofascial chain tension transfer (Schleip et al,2012), had greater hip and shoulder variability, providing a basis for understanding the interaction between the kettlebell swing and aging. In turn, electromyography and dynamometry data in the situations evaluated will still be analyses in this study.

Andrea Catherine Alarcón-Aldana, Mauro Callejas-Cuervo and Antonio Padilha Lanari Bo

Motor Rehabilitation Platform Based on a Motion Capture System and Video Games for Upper Limb Functional Recovery

To optimize motor and functional rehabilitation processes, technological tools are required that promote motivation in patients and offer precision in measuring control and monitoring variables during their evolution. This impacts the improvement of aspects such as service, patient satisfaction, and indirectly, the quality of life of people. The objective was

to develop a motor rehabilitation platform by integrating active video games, a motion capture system, and an electronic medical record application, to provide an engaging, motivating, and useful tool for patients and professionals in physical medicine and rehabilitation. The methodological process was developed in four phases: 1) Platform architecture design; 2) Proposal of a signal transformation model; 3) Creation of an active video game and a web application; and finally, 4) Platform integration. The results focus on describing the platform, highlighting the acquisition of kinematic information of the human body from signals generated by an inertial-magnetic motion capture system, as well as the description of the creation process of the video game and the web application that enables the management of the clinical history of patients undergoing motor recovery. In conclusion, the platform creation process is presented, supporting movement rehabilitation activities and upper limb functional recovery, emphasizing the contribution of video games and web resources to patient evolution.

Leonardo A. Peyré-Tartaruga, Alessandro Madama, Luca Correale, Flávia G. Martinez, Edoardo Gatti and André Ivaniski-Mello

Mechanical work and pendulum-like mechanism of walking: a comparison between children and adults at self-selected speed

Children spend more energy walking than adults, and younger children are less efficient at producing positive muscular work. Even comprehending these mechanical determinants at fixed speeds, comparisons of pendulum-like mechanism and mechanical work at self-selected speeds between children and adults are unknown. Analyzing these mechanical determinants in self-selected conditions can provide a more applied framework for health, given that walking speed is a crucial indicator of health. Thus, we sought to compare spatiotemporal, Recovery, and mechanical work parameters between children and adults at self-selected walking speed. Also, we evaluated the locomotor rehabilitation index (how the self-select speed is close to optimal walking speed) based on the Froude number. Thirteen children aged 6 to 12 years and twenty-four adult subjects aged 18 to 64 walked at their self-selected walking speed while their movements were three-dimensionally registered. Children walked at self-selected speed, presenting a shorter stride length and a higher stride frequency than adults, resulting in a similar self-selected walking speed. The pendulum-like mechanism observed directly (Recovery) or indirectly (locomotor rehabilitation index) was greater in children than adults. This higher pendulum-like mechanism results in lower external mechanical work for children, though vertical and forward counterparts of external work were similar between groups. Interestingly, the similar results from the Recovery and locomotor rehabilitation index indicate the practical usage of the former variable in clinical setups. The pendulum-like mechanism improved at self-selected speed in children reinforces the rationale that lower economy in children is related mainly to muscular efficiency than the transmission efficiency factors.

Maria Rene Ledezma, Dario Santos and Franco Simini

Gait and Step-Up Knee Kinematics Using Magneto Inertial Measurement Units

Part of the design of the low cost wearable device ChakaMo is the establishement of 3D kinematics time series of flexo-extension, rotation and abduction-adduction angles during motor tasks. A convenience sample of 11 normal individuals (8 male, 3 female) leading active lives (64%) right handed (91%) wore two ankle straps with Vicon Blue Trident Magneto Inertial Measurement Units. Every individual took five 100 BPM acoustically prompted double steps and six 34 cm step-ups and downs. Under samplig was performed to 100 Hz from the original quaternions manufacturer´s data. Results include gait rate was 1.16 ± 0.04s for volunteers taking the 3 middle steps, discarding first and last. Step-up took 2.38±0.07s for the 4 middle step-ups and downs. Series of flexo-extension, rotation and abduction-adduction angle series were constructed for gait and step-up, normalized to 0% to 100% of step or step-up time. Time series consisted of mean angle and one standard deviation above and below, for the three rotations. Flexo-extension angle time series at normalized percentage of the step were coincident with literature (step range: +0° +48° and step-up range +5° +98°) whereas rotation and abduction-adduction angle ranges we measured are provisional references to compare patients to: +10°-8° step rotation, +10° -20° step abduction-adduction, and +5° -5° step-up rotation, +10° -16° step-up abduction-adduction rotation angles. Our angle ranges as function of normalized step and step-up times are a first reference for the development of ChakaMo to compare individuals during rehabilitation and thus monitor progress of physical therapy.

Lenin Anderson Macas Gusqui and Ana Cecilia Villa Parra

Design and Implementation of a Wireless System for the Acquisition and Analysis of Human Gait Parameters

The technology for recording human gait parameters is important to support tasks such as the diagnosis and treatment of motor disorders, diabetic foot care, physical rehabilitation, and elderly care. In the sports field, gait analysis is crucial for evaluating performance in disciplines such as racewalking, and in the field of assistive technologies, it is fundamental for the development of active orthotics or smart prosthetics. For these reasons, proposing this accessible wireless technology for gait analysis is essential for improving diagnoses, treatments, and medical devices development. In this context, the present work proposes the design and implementation of a wireless insole for the acquisition of gait parameters. The design includes the mechanical structure in TPU and the electronic circuit with eight FSR A402 pressure sensors and a module with an accelerometer for recording plantar pressure, step angle, cadence, step length, and walking speed. A LabView interface is included for the analysis of these parameters, receiving the information via Bluetooth. A testing protocol was carried out to evaluate the insole prototype, yielding error results of 0.1 for step length; 0.5 for step angle measurements; 0.2 in speed and plantar pressure.

Based on these results, the developed system is considered validated, and further tests with a larger sample of participants are expected.

Nestor Duque, Eder Peña-Quimbaya, Luis García, Aldemir Vargas-Eudor and Juan Graell

Cost-effective integrated system for gait analysis at high altitudes

This study presents an integrated and cost-effective system for gait analysis, designed for rural environments at altitudes starting from 2,200 meters above sea level. The system employs inertial measurement units (IMU) to eva- luate step amplitude, with a particular focus on how altitude variations affect this parameter, observing a reduction in step amplitude due to terrain slopes and other geographical features. Additionally, the system incorporates an independent altitude sensor that pro- vides accurate measurements of elevation changes by detecting variations in at- mospheric pressure. This functionality enables tracking of how altitude changes influence the gait pattern. For future work, the incorporation of additional sensors is proposed to measure physiological variables such as blood oxygen saturation and heart rate. This data would allow for a more comprehensive assessment of the combined impact of atmospheric pressure, altitude, and physical conditions on the gait cy- cle. Expanding the analysis in this way would provide a more complete un- derstanding of how high-altitude environments affect both the biomechanical and physiological aspects in natural settings. Currently, the system is focused on evaluating walkers at high altitudes, star- ting at 2,200 meters, with the potential to adapt to other altitudes and conditions in future research.

Poster session B

Carlos de la Fuente Cancino, Rony Silvestre, Roberto Yañez, Matias Roby and Alejandro Neira

Enhanced Pivot-shift grading from isoinertial Gerdy's acceleration resultant using Multiclass SVM.

Rotatory laxity acceleration still lacks objective classification due to interval grading superposition, resulting in a biased pivot shift grading prior to the Anterior Cruciate Ligament (ACL) reconstruction. However, data analysis might help improve data grading in the operative room. Therefore, we described the improvement of the pivot-shift categorization in Gerdy's acceleration under anesthesia prior to ACL surgery using a support vector machine (SVM) classification, surgeon, and literature reference. Methods: Seventy-five patients (aged 30.3 ± 10.2 years, and IKDC 52.0 ± 16.5 points) with acute ACL

rupture under anesthesia prior to ACL surgery were analyzed. Patients were graded with pivot-shift sign glide (+), clunk (++), and (+++) gross by senior orthopedic surgeons. At the same time, the tri-axial tibial plateau acceleration was measured. Categorical data were statistically described, and the accelerometry and categorical data were associated (α=5%). A multiclass SVM kernel with the best accuracy trained by orthopedic surgeons and assisted from literature for missing data was compared with experienced surgeons and literature interval grading. The cubic SVM classifier achieved the best grading. Results: The intra-group proportions were different for each grading in the three compared strategies ($p<0.001$). The inter-group proportions were different for all comparisons ($p<0.001$). There were significant ($p<0.001$) associations (Tau: 0.69, -0.28, and -0.50) between the surgeon and SVM, the surgeon and interval grading, and the interval and SVM, respectively. Conclusion: The multiclass SVM classifier improves the acceleration categorization of the (+), (++), and (+++) pivot shift sign prior to the ACL surgery in agreement with surgeon criteria.

Carlos de la Fuente Cancino and Felipe P Carpes

Achilles tendon rupture mechanism determination from real athletic competition by kinematic 2D Video Analysis: loss of Knee-ankle coordination.

The complete injury of the Achilles tendon is a risk factor for athletes to abandon. and the recovery is long. The return to sport is not guaranteed at the same level as pre-injury. When the rupture happens during natural life, movement analysis can provide useful insights concerning patterns of rupture that can be useful in understanding and preventing Achilles tendon injuries. However, these events are not recorded frequently. Therefore, we determined the pattern of rupture of Achilles tendon (AT) in an elite high-jumper athlete who ruptured AT during the straight-line running phase of preparation for a high-jump attempt. This study was a novel case report on National-level elite athletes. The main outcomes were the knee and ankle angular movements, as well as the ankle-knee angle ratio. The pattern of the rupture was determined by pixel intensity and outlier analysis. The rupture occurred at 44% of the single stance. The injured leg showed higher ankle dorsal flexion with lower knee flexion and ankle-knee ratio. An eccentric pattern of rupture occurred during the transition from the mid to terminal stance phase of running. Lower knee flexion and the increased dorsal flexion of the ankle during the stance suggest a higher elongation in the injured AT elongation. This might have favored a major elongation of the Achilles tendon.

Carlos de la Fuente Cancino, Ireneu Loturco and Felipe P Carpes

Unexpected Achilles tendon rupture in an Olympic sprinter based on 2D Video analysis: The uncon-trolled dorsiflexion.

We used image-processing techniques to biomechanically examine a video record and determine the Achilles tendon (AT) rupture in an Olympic sprinter. This report may be unique due to the difficulty in conducting motion capture analyses during actual injury events. Our report includes one female Olympic sprinter, 29 years old (body mass: 56 kg, height: 1.68 m, and body mass index: 19.8 kg/m2) with a high-competitive profile history (2008 and 2012 Olympic Games participation; South American record holder in 100- and 200-m; Pan-American gold medalist in 200-m and 4 x 100-m relay) who suffered a complete AT rupture in the left leg while exercising in the final phase of rehabilitation following an Achilles tendinopathy in the contralateral limb. The greater dorsiflexion found at the moment of the injury and the delayed control of heel position indicated the presence of uncontrolled dorsiflexion, which potentially generated excessive eccentric stress over the tendon and, thus, the AT rupture. Here, we discuss the relevance of lower leg alignment, the movements' characteristics, and the history of Achilles tendinopathy in the contralateral leg to the occurrence of the AT rupture.

Carlos de la Fuente Cancino, Rony Silvestre, Roberto Yañez and Felipe P Carpes

Fluctuations of quadriceps force training in severe persistent quadriceps weakness after failed 9 month of physiotherapy in Anterior Cruciate Ligament re-construction.

Persistent quadriceps weakness may occur after anterior cruciate ligament reconstruction (ACLr), limiting the strength gain. However, steadiness strengthening (or fluctuations of quadriceps force training) might change the inability to gain strength. Hence, we determined whether strength training with force steadiness and visual biofeedback can improve knee quadriceps torque, self-reported pain and knee stability in patients with persistent quadriceps weakness after ACLr. Twenty-five patients (aged 43.7 ± 12.2 years) with persistent quadriceps weakness following knee ACLr and 34-weeks of physiotherapy performed unilateral strength training for both lower limbs. Four-weeks of conventional physiotherapy at week-30 were given, confirming the inability to gain torque. Then, steadiness training (isometric knee extension with visual biofeedback) was given for 7-weeks. Knee quadriceps peak torque, strength improvement, determination of responders to the intervention, coherence of strength gain between limbs, and self-reported outcomes (pain and knee stability) were obtained. Descriptive statistics and data inference using mixed-ANOVA, McNemar test, and $\chi 2$ test were described. Quadriceps torque in the reconstructed knee improved (98.2 ± 47.2 to 155.2 ± 78.9 Nm; $p = 0.031$) for most patients

(84%). Nevertheless, the torque was lower than the healthy side maintaining asymmetry (155.2 ± 78.9 vs. 209.5 ± 101.8 Nm; p = 0.026). There was high (20%) and medium coherence (80%) between limbs. Knee stability and pain improved in 72% of the patients (p<0.001). Steadiness training after ACLr followed nine months of surgery and failed conventional physiotherapy, improves the persistent weakness and self-reported outcomes, but gain strength was dissimilar between limbs.

Balázs Tusor, Annamária R. Várkonyi-Kóczy and Stefan Gubo

Indexed Fuzzy Inference-based Activity Recognition

Real-time activity detection and recognition is an important field of machine learning, which can provide useful information about the people inhabiting the observed space. This has a wide range of practical applications, be it human-computer interaction, entertainment (e.g. computer assisted sports performance analysis and commentary), Intelligent Space, smart homes, unusual event's detection, like automatic identification of a bank robbery, frontier violation, or the automatic surveillance of people who would otherwise need the constant supervision of a human caretaker (like elderly or sick people, in order to detect dangerous situations, e.g., falling, injuries, accidents, etc.). In this paper, a novel system is proposed that realizes a fast activity recognition. It uses the output of a real-time multi-person keypoint detection framework (e.g. OpenPose) that detects human bodies in image frames and outputs the pose information, which is used as input data for the activity recognition system. The proposed system is based on indexed fuzzy classifiers, implementing flexible expert knowledge-based classification in the form of indexing tables, in order to significantly reduce the search area of the problem space that are needed to be regarded during the recognition phase (i.e., the number of fuzzy rules to be evaluated), and thus, significantly lowering the required operation time. A new algorithm is also presented for the automatic training of the system.

Carlos de la Fuente Cancino, Alejandro Weinstein, Rodrigo Guzman-Venegas and Felipe P Carpes

PCA- Kmeans regional chest movement recognition during tidal breathing in healthies through wearable sensors.

Recognition of breathing patterns helps clinicians to understand acute and chronic adaptations during exercise and pathological conditions. Wearable technologies combined with a proper data analysis provide a low-cost option to monitor chest and abdominal wall movements. Here we set out to determine the feasibility of using accelerometry and machine learning to detect chest-abdominal wall movement patterns during tidal breathing. Furthermore, we determined the accelerometer positions included in the clusters, considering principal component domains. Eleven healthy participants (age: 21 ± 0.2 y, BMI: 23.4 ± 0.7 kg/m2, FEV1: 4.1 ± 0.3 L, VO2: 4.6 ± 0.2 mL/min kg) were included in this cross-

sectional study. Spirometry and ergospirometry assessments were performed with participants seated with 13 accelerometers placed over the thorax. Data collection lasted 10 min. Following signal pre-processing, principal components and clustering analyses were performed. The Euclidean distances with respect to centroids were compared between the clusters ($p<0.05$), identifying two clusters ($p<0.001$). The first cluster included sensors located at the right and left second rib midline, body of sternum, left fourth rib midline, right and left second thoracic vertebra midline, and fifth thoracic vertebra. The second cluster included sensors at the fourth right rib midline, right and left seventh ribs, abdomen at the linea alba, and right and left tenth thoracic vertebra midline. Costal-superior and costal-abdominal patterns were also recognized. We conclude that accelerometers placed on the chest and abdominal wall permit the identification of two clusters of movements regarding respiration biomechanics.

Alrjandro Neira, Rony Silvestre, Luis Peñailillo Peñailillo and Carlos de la Fuente Cancino

Kinematic assessments immediately after competi-tive soccer matches suggests increased rotatory laxity of the knee.

Fatigue induced by soccer playing increases physical efforts, which might alter the transverse knee stability, a known factor that promotes knee injuries, particularly anterior cruciate ligament injury. Thereby, primarily, we aimed to determine whether rotatory knee stability decreases immediately following a competitive soccer match in amateur players. Furthermore, we assessed the role of the preferred and non-preferred limbs to kick a ball in rotatory knee stability and the correlation between performance parameters and rotatory knee stability. We hypothesized that the knee stability decreases immediately after a competitive soccer match in amateur players. Eight healthy amateur soccer players (aged 27.2±4.7 years and with body-mass-index of 23.8±1.2 kg m^{-2}) were included immediately before and after a competitive soccer match. The rotatory knee stability was assessed in the preferred and non-preferred limbs through the acceleration and jerk of the pivot shift maneuver and by the internal knee rotation of a pivoting landing task. Two-way repeated-measures ANOVA for factors time (before and after the soccer match) and limb (preferred and non-preferred) and multiple comparisons were performed using $\alpha = 5\%$. There was a statistical significance for the main factor time in the acceleration (5.04 vs. 6.90 ms^{-2}, $\Delta=1.86$ ms^{-2}, $p=0.020$, $\eta^2=0.331$) and jerk (18.46 vs. 32.10 ms^{-2}, $\Delta=13.64$ ms^{-2}, $p=0.004$, $\eta^2=0.456$) of the pivot shift maneuver. Rotatory stability decreases following a competitive soccer match in amateur soccer players under fatigue. Both the acceleration and jerk during the pivot shift maneuver is increased without significant internal knee rotation changes during the pivoting landing task.

Steven Hirsch, Joshua Shapiro, Jacob Rauch and Giuseppe Barbalinardo

Leveraging Machine Learning to Improve Repetitions in Reserve Estimates During Resistance Training

Repetitions-in-reserve (RIR) quantifies how many repetitions a trainee can complete before reaching volitional failure during resistance training. Although training near failure may enhance muscle hypertrophy, it can also extend recovery time. Thus, accurate estimates of RIR are crucial for trainers as they manipulate a trainee's proximity to failure based on their specific goals. Current RIR models use a linear regression with the mean barbell velocity loss within a set. However, additional feature engineering, like extracting velocity waveform shape, may provide important information regarding a trainee's RIR that is lost when examining only the average velocity. Furthermore, leveraging machine learning algorithms could also improve RIR accuracy. Therefore, this investigation's purpose was to evaluate whether incorporating additional feature engineering and machine learning can improve RIR accuracy. For this initial work, we selected 56,025 bench press repetitions from anonymized, experienced Tonal users (n=4,482) to build and validate our model. Data was collected from the Tonal device, which samples cable position and force data at 50Hz. In addition to building our machine learning (ML) model with various advanced metrics, we built a sample velocity-loss (VL) model to examine how well our model performed relative to the literature standard. The mean absolute error (MAE) of the ML model on the holdout test set was 1.12 reps whereas the MAE of the VL model was 2.31 reps. In conclusion, additional features and machine learning algorithms drastically outperforms the current literature standard for estimating RIR.

Salvador Melgoza Villanueva and Natali Olaya Mira

Biomechanical and Temperature Assessments in Transfemoral Prosthetic Fitting

Between 49% and 95% of lower-limb amputees use prosthetics, but many express dissatisfaction, mainly due to issues with the prosthetic socket. Although quantitative approaches exist to improve prosthetic alignment, it still heavily relies on the technician's experience and user feedback. We propose measuring: 1. Body weight distribution using instrumented platforms. 2. Gait symmetry using inertial sensors and gait cycle duration. 3. Stump temperature using thermography before and after walking. These measurements were taken in four patients with unilateral lower-limb amputation, independent ambulators with prosthetic experience who provided informed consent. The four selected patients had transtibial amputations due to metabolic and other causes, with adaptation times ranging from 6 months to over 30 years . The prosthetic suspension systems used were pin-lock and sleeve-based. Results showed: - Weight distribution centered on the healthy limb during bipedal standing, indicating insufficient support from the prosthesis. - Asymmetric gait with

prolonged support phase on the healthy limb. - Thermograms revealed concentrated temperature areas after walking, suggesting friction issues or poor socket fit. These findings highlight the need for adjustments to improve prosthetic comfort and performance, as well as reviewing the suspension system. Applying these methodologies provides detailed information on prosthetic performance, offering valuable feedback to the prosthetist on user support and gait, and identifying visually imperceptible problem areas during device inspection.

Hamlet Suarez and Rodrigo Salamano

Gait patterns in unstable older patients with vestibular hypofunction. Preliminary results in assessment with time-frequency analysis.

BACKGROUND - Gait instability and falls significantly impact life quality and morbi-mortality in elderly populations. Early diagnosis of gait disorders is one of the most effective approaches to minimize severe injuries. OBJECTIVE- To find a gait instability pattern in older adults through an image representation of data collected by a single sensor. METHODS - A sample of 13 older adults (71-85 years old) with instability by vestibular hypofunction is compared to a sample of 19 adults (21-75 years old) without instability and normal vestibular function. Image representations of the gait signals acquired on a specific walk path were generated using a continuous wavelet transform and analyzed as a texture using grey level co-occurrence matrix metrics as features. A support vector machine (SVM) algorithm was used to discriminate subjects. RESULTS - First results show a good classification performance. According to analysis of extracted features, most information relevant to instability is concentrated in the medio-lateral acceleration (X axis) and the frontal plane angular rotation (Z axis gyroscope). Performing a ten-fold cross-validation through the first ten seconds of the sample dataset, the algorithm achieves a 92,3 F1 score corresponding to 12 true-positives, 1 false positive and 1 false negative. Discussion - This preliminary report suggests that the method has potential use in assessing gait disorders in controlled and non-controlled environments. It suggests that deep learning methods could be explored given the availability of a larger population and data samples.

Agustin Pereyra, Sebastián Sosa and Gustavo Bermúdez

2D Protocol to Identify Asymmetries in Dynamic Knee Q Angle in Amateur Football Players During Unilateral Jumps

This study aimed to analyze asymmetries in the dynamic knee Q angle in amateur football players from the University Sports League of Montevideo, using 2D technology to identify potential risk factors for knee injuries in the training field. Sixteen male football players (mean age 21±1.6 years) were evaluated using unilateral countermovement jumps (CMJ) and Drop Jump tests, employing 2D kinematic analysis with Kinovea software to measure

dynamic Q angles. The results revealed elevated Q angle values, particularly in the eccentric phase of the landing response, with 19.7±8.3º for the right leg and 17.5±5.8º for the left leg, both exceeding the risk threshold (>15º). Additionally, a significant asymmetry in angular velocity was observed during the concentric phase of the jump's positive impulse ($p=0.043$) and the concentric recovery phase ($p=0.042$), suggesting a higher risk of injury in the dominant knee. Dominance did not significantly alter the general behavior of the Q angle. The 2D technology allowed for the collection of objective data that practically and accessibly evaluated risks in amateur athletes, helping coaches anticipate and make timely decisions about player referrals. These findings underscore the importance of incorporating unilateral strength training and proprioceptive exercises to reduce injury risk in amateur athletes.

Carlos Cruz, Camila Barraza-Viluñir, Luis Acuña-Cancino, Jean Arias, Cristina Olivares, Xavier García-Massó and Claudio Tapia

Ankle Intermuscular Coordination in Active and Sedentary Youths: A Causal Analysis through Empirical Mode Decomposition

Intermuscular coordination (IMC) can be defined as the nervous system's ability to synchronize muscle activity, increasing with motor demands. This suggests that regular physical activity may enhance IMC. Given the stochastic nature of biological signals, nonlinear methods may more accurately study IMC than correlation analysis. This study aimed to compare IMC between synergistic and antagonistic ankle muscles during gait in active and sedentary young adults. Twenty-nine participants (12 females, aged 19-34; 15 active, 14 sedentary) were included. The active group engaged in martial arts, cycling, gym, basketball, or football. The muscle activity was collected using bipolar surface electromyography (1000 Hz) in the tibialis anterior (TA), soleus (SOL), and medial gastrocnemius (GM). All subjects walked 9 meters 30 times at 1 m/s, totaling ~4.5 min. Signals were segmented from 200 ms pre- to 600 ms post-heel contact. IMC was evaluated via ensemble empirical mode decomposition, with causal interaction encoded by instantaneous phase dependence. Cross-approximate entropy (XApEn, $m = 1$, $r = 20$) estimated mutual predictability between selected intrinsic mode functions (IMF) of SOL-TA and SOL-GM. A general linear model was used to evaluate the effect of physical activity on XApEn. Significant XApEn differences were found for SOL-TA ($p = 0.013$, $d = 0.98$) and SOL-GM ($p = 0.016$, $d = 0.95$), favoring the active group. The median frequency of IMF ranged from 30 to 80 Hz, averaging 60 ± 21 Hz. These results indicate greater ankle IMC in active than sedentary young adults, suggesting regular physical activity enhances IMC during gait.

Valentina Silva-Pereyra, Gabriel Fábrica and Carlo M. Biancardi

Different methods to get heights and powers of vertical jump, which one should be chosen?

Height and power in jumps are the select variables to evaluate performance through countermovement jumps (CJ) and squat jumps (SJ). They can be computed from dynamic data recorded through force platforms (FP), or kinematic data recorded through motion capture systems (MCS). Unlike other studies, in addition to comparing the parameters, it was investigated whether the effect was different in unloaded and inertial loaded jumps with 20% of body mass. Three standard methods were employed to obtain the jump height (JH) from FP: impulse, flight time and force integral. Two were obtained from MCS, from the displacement of the center of mass and from flight time. Maximum and average power were obtained from FP and MCS and another one average power from a theoretical estimate. For each type of jump, the variables were compared, and paired consistency and bias were analyzed; the reference variables were flight time for JH and powers, both from FP. JH computed from the displacement of center of mass resulted significantly and systematically lower than the others in all jumps, with a constant bias. The results of loaded jumps displayed less agreement than unloaded jumps. Minor agreement was determined in SJ for maximum and average power, and in CJ for the theoretical power estimate. Intra-class correlation showed that, in general, the estimation of power was less reliable than that of JH. Our findings should be taken into account when comparing results from different methodological approaches, or planning for new research goals.

Inaê de Oliveira, Karine Stoelben, Eduarda Tulius, Vitória Ferreira, Luiza Rossdeutscher and Felipe Carpes

Prediction of knee 3D kinematics and kinetics in bilateral drop landing by using physiotherapy clinical tests

3D biomechanical evaluations are among the benchmark tools for helping injury screening, essential to enhance the prevention of sports-related injuries. However, incorporating 3D assessments into sports routines is challenging. Physiotherapy clinical screening tests help monitor injury risk factors and assist physiotherapists in making clinical decisions. Finding clinical tools that can effectively detect 3D knee biomechanical outcomes linked to injury risk remains a challenge. Here, we determine whether clinical screening tests common in physiotherapy practice can predict 3D knee kinematics outcomes electing knee injury risk in bilateral drop landing. Twenty-four participants were assessed using the Modified Star Excursion Balance Test (mSEBT), Lateral Step Down (LSD), Lunge, Hop tests, and knee (flexion, extension, and flexor/extensor ratio) and hip (abduction, adduction, and abductor/adductor ratio) isometric strength. They performed bilateral drop landings to assess 3D knee kinematics and kinetics during critical events of the landing phase. Linear

regression models identified the predictive capacity of clinical tests to biomechanical outcomes. We found that the Flex/Ext strength ratio and LSD predicted the knee frontal plane angle of the non-preferred leg. Lunge predicted knee frontal plane moment of the preferred leg. The knee abductor peak moment was predicted by hip abduction strength. Finally, the Flex/Ext strength ratio, LSD, and mSEBT Anterior predicted the knee's sagittal plane moment. Our results suggest that clinical screening tests to assess movement quality and maximum isometric strength help screen participants showing risk factors for knee injuries. These predictions may help decide which participants should be considered for a 3D biomechanics assessment.

Inaê de Oliveira, Victor Cossich, Conrado Laett, Andressa Lemos, Luiza Rossdeutscher, Bruno Panciera and Felipe Carpes

3D markerless applications in jump landing biomechanics assessments

This study investigates the differences between markerless and marker-based methodologies for jump-landing kinematics assessments. Fourteen adults performed ten countermovement jumps. Motion was captured by a marker-based system (Vicon Motion Systems, 15 Bonita B10 cameras, 100 Hz, 21 reference markers) and simultaneously recorded by 2 Logitech C270 cameras, 30 Hz, as part of a markerless system using a pre-trained artificial intelligence model and a triangulation algorithm in Python. The sagittal knee angle was determined for each jump at the start of the countermovement and at the end of the landing phase. Jump height was determined by the center of mass displacement. Data from each jump from each system were evaluated using the intraclass correlation coefficient (ICC), standard error of measurement (SEM), and the minimal detectable change (MDC). Systems were compared using paired t-tests and Cohen's effect size (alpha at 5%). The knee angle at the start of the countermovement showed a difference of 8.31º (higher in markerless, $p<0.01$, $d = 4.32$, ICC good), and at the end of the landing phase, 1.67º (larger in markerless, $p = 0.05$, $d = 1.00$, ICC excellent). Jump height was higher in markerless ($p<0.01$, $d = 2.04$) with a system difference of 1.4 cm. Differences between the systems were generally smaller than the SEM and MDC, suggesting that the difference between the systems, although statistically significant, may not be very relevant in practice.

Jaime Arista Cutipa, Adrián Hernández Vega, Jesús Juárez Mendoza, Jhon Vásquez González, Mateo Bedoya Torres, Angélica Valencia Perea, Victoria Abarca and Isabel Soto Cardona

Comparative Movement Analysis During the Making of a Rugby Ball Pass Between Peruvian and Colombian Sportsmen Using Videogrammetry

Rugby is a sport with high potential for growth in Latin American countries. In Colombia and Peru, there is support for its professional development. However, there are few biomechanical studies that analyze specific gestures of the players or take into account different regions. The aim of this paper is evaluating similarities and differences between two groups of players of the previously mentioned nations. The focus was on the making of a ball pass, analyzing the shoulder, elbow and wrist by measuring their angles during the making of the action. Video was taken of the frontal plane of four players that have played rugby for more than one year and was processed using the software Kinovea. The movement is divided in three phases: preparation, impulse and finalization. It was found that there are more similarities across all three of these phases in shoulder and wrist, showing a good execution of the action. The angles were analyzed, showing similarities. These kind of studies can be useful to assist on the professional development of sportsmen, aiding them on the training to see and analyze their mistakes and ways they can improve.

Mario Burgos, Tamara Urra and Leonardo Lagos

Optimizing Running Mechanics in Professional Women's Soccer: A Spatiotemporal Analysis with Auditory Feedback Training

Women's soccer is experiencing an increasing incidence of knee injuries with the professionalization of the sport. Sports kinesiology focuses on preventing these injuries through physical conditioning strategies, which include planned adjustments to running technique. This study explored the feasibility of modifying spatiotemporal variables through strength exercises and auditory feedback training to control cadence during running. Method: Two types of training were implemented over 10 sessions. The first included strength, power, plyometrics, and running technique blocks, while the second aimed to increase cadence by 10% above baseline running pace, using a metronome for auditory feedback, along with specific instructions on metatarsal support. Pre- and post-intervention analysis was conducted using the VICON Bonita system on an HP Cosmos LE200 CE treadmill, set at 3.88 m/s according to recommendations for sprinting in women's soccer. Results: Six professional soccer players volunteered. The results showed that post-training cadence was significantly lower than pre-training ($p<0.05$), with a large

effect size (d=1.16). Additionally, significant reductions were observed in stride time and double support time ($p<0.05$), both with large effect sizes (-1.17 and -1.18 respectively), as well as a significant decrease in stride length ($p=0.03$, d=1.03). Conclusion: A 10-session program based on strength and running technique with auditory feedback successfully modified relevant spatiotemporal variables for the prevention of injuries in professional women's soccer players.

Felipe Carpes, Inaê de Oliveira and André de Andrade

The use of probability of agreement to quantify asymmetries in jump landing

Lower limb asymmetries are a risk factor for different injuries in sports. Employing various indexes to quantify the asymmetries hinders methodological reproducibility without consideration of clinically acceptable differences and inter and intra-limb variability. Here, we show the applications of the probability of agreement (PoA) statistical approach to quantify leg asymmetries in unilateral and bilateral landings. PoA considers the clinically acceptable difference, intra and inter-limb variability, and potential systematic bias, with values closer to 0 indicating poor agreement between the limbs (asymmetry). PoA was determined for peak vertical ground reaction forces recorded with two force plates (AMTI OR6-2000, 2 kHz) from 26 professional futsal athletes performing three repetitions of both unilateral drop jump and bilateral vertical jump, using the equation $\theta(s)= \Phi((c- \alpha-(\beta-1)s)/\sqrt{(\sigma_1^2+\sigma_2^2)})-\Phi((-c- \alpha-(\beta-1)s)/\sqrt{(\sigma_1^2+\sigma_2^2)})$, where $\Phi(x)$ is the standard normal cumulative distribution function evaluated at x; α is the fixed bias, β is the proportional bias, and σj quantifies the measurement variation, or repeatability, of limb j. Comparison between legs showed a PoA of 0.72 (CI95% 0.62 – 0.81) in the bilateral landings and 0.42 (CI95% 0.37 – 0.55) in the unilateral landings. The PoA ranges from 0 to 1, which facilitates comparisons across different motor tasks without a need for a reference value (such as asymmetry indexes, which in this were in mean ▯ standard deviation 19.06 ± 17.1% in bilateral and 11.24± 13.1% in unilateral landings). Our proposal highlights the necessity of integrating both statistical and clinical significance in asymmetry quantification.

Eder Peña Quimbaya, Néstor Darío Duque-Méndez, Luis Felipe Garcia Arias, Aldemir Vargas Eudor and Camilo Castillo Benavides

DISPOSITO ELECTRÓNICO PARA EVALUACIÓN DE ALCANCE FUNCIONAL EN PERSONA MAYOR

La prueba de alcance funcional evalúa la estabilidad de una persona en posición de pie. Para realizar esta evaluación, se pide al evaluado extender uno de sus brazos, con el puño cerrado, tanto como le sea posible en un plano horizontal y sin dar un paso. El sistema se

compone de una cámara RGB-D, una plataforma con sensores de presión y una manilla. La cámara RGB-D permitirá realizar seguimiento del puño de la persona a evaluar. La manilla incorpora un indicador infrarrojo que permitirá el funcionamiento planteado para la cámara. Se propone esta estrategia conjunta entre la cámara y la manilla con el fin de tener un algoritmo más sencillo y robusto en comparación a los resultados esperados con una estrategia basada en la identificación de la mano. La plataforma permitirá identificar y realizar seguimiento la ubicación de los pies mientras se ejecuta la prueba. La unidad de medida inercial (IMU) y la plataforma con sensores de presión. A través del primer dispositivo se esperan obtener la posición inicial y el desplazamiento de la mano. La medición del alcance funcional se realizara a partir de la integración de las medidas obtenidas de la IMU: aceleración y velocidad angular. En este caso, se propone el diseño de una manilla en la que se encuentre una unidad de procesamiento y una IMU. Además, esta medida podría ser obtenida a partir de la variación en las señales del magnetómetro.

Ariel Andres Antonio Braidot, Elisa Pérez, Héctor Alejandro Rodrigo Yanadel and Natalia Martina López

Study of coordination patterns in repeated upper limb movements

Motor coordination is essential for basic functions such as eating, bathing, and interacting with the environment. Motor rehabilitation therapies aim to improve coordination patterns through repetition, intensity, and motivation. The constant repetition of a movement in the upper limb tends to resemble semi-cyclical movements, where each repetition cycle can be compared to the previous one. However, therapist observation cannot provide a precise evaluation of each coordination pattern due to the ephemeral nature of the observed movements. A method for evaluating coordination patterns in repetitive functional upper limb movements is proposed. The tooth-brushing movement was analyzed in 27 healthy volunteers, performed with both the dominant and non-dominant limb. Phase angles (PAs) of elbow flexion-extension and shoulder elevation-depression movements were calculated, and then continuous relative phase (CRP) between these movements was determined. From this information, parameters related to coordination patterns, such as motor consistency and sequence, were extracted. The results show a range of motor consistency between 2.2° and 9.3°, and a motor sequence preceded by elbow movements at both the beginning and end of the movement. These findings provide a basis for developing more precise evaluation tools, improving the effectiveness of motor rehabilitation therapies through a quantitative and detailed analysis of coordination patterns in repetitive movements.

Salvador Melgoza Villanueva, Marc Anthony Pena, Natali Olaya Mira, Citlalli Jessica Trujillo Romero and Carolina Viloria Barragan

Biomechanical gait parameters as an evaluation tool for prosthetic fitting

Between 49% and 95% of lower limb amputees use prostheses and most of them present dissatisfaction primarily due to issues with the prosthetic socket. Although there are quantitative approaches to aligning prosthetics for better fitting, these methods largely rely on prosthetic technicians' experience and user feedback. To enhance prosthetic adjustment, a new process that include three methodologies was proposed: 1) using instrumented platforms to assess body weight distribution, 2) employing an inertial sensor to evaluate gait symmetry based on gait cycle duration, and 3) capturing stump thermograms before and after walking with a thermal imaging camera. This study was implemented on four unilateral lower limb amputee patients who are independent walkers with prosthetic experience; all of them signed the informed consent. The results indicated greater weight distribution on the sound limb during standing, suggesting inadequate prosthesis support. Moreover, there was asymmetrical gait characterized by a longer stance phase duration on the healthy limb. Additionally, post-walk thermograms revealed regions of higher temperature concentration, possibly indicating frictional issues with the stump or poor socket fit. These findings highlight the need for adjustments to address stump friction areas caused by pistoning effects or socket fitting problems, along with a review of the suspension system. Implementing these process yields detailed insights into prosthetic performance, providing prosthetic technicians with critical information about weight bearing and walking dynamics with the device. This approach also identifies socket areas requiring attention that may not be visible during routine visual inspections.

Imma Ceriello, Riccardo Borzuola, Andrea Macaluso and Valentina Camomilla

Impact of Hip Joint Centre Estimation on Lower Limb Kinematics During Functional Reach: A Comparison of CGM2 and PiG Models

A key difference between the Conventional Gait Model 2 (CGM2) and Plug-in Gait (PiG) model lies in the Hip Joint Centre (HJC) estimation, which is crucial for accurate data interpretation in clinical settings. Both models estimate HJC within the pelvic coordinate system using regression equations. In the PiG model, leg length and inter-anterior superior iliac spine distance are used as input, while the CGM2.x model solely uses leg length in favour of greater accuracy of the sagittal plane angles during walking. The proven agreement in joint kinematics between these models for gait analysis does not necessarily extend to other fundamental tests commonly used in clinical practice. This study

investigates the effects of HJC estimation on hip and knee kinematics in both sagittal and coronal planes during unilateral Functional Reach test in able-bodied volunteers, equipped with PiG and CGM2.5 marker sets. We evaluated the absolute mean differences between the two models for specific joint angles with respect to the mean aggregate hip range of motion. Results show that the known differences between HJC regressions do affect the estimate of hip and knee flexion/extension. Coherently, as HJC inaccuracies primarily occur in the coronal plane, hip abduction/adduction affects both hip and, to a greater extent, knee flexion/extension. Additionally, knee flexion/extension of the tested arm side is more affected by hip abduction/adduction. Overall, the CGM2.5 aligns well with the PiG in the sagittal plane. However, when analysing movements involving substantial hip abduction/adduction, its potential impact on knee kinematics should be carefully considered.

Valeria Belluscio, Andree Rossi, Amaranta Soledad Orejel Bustos, Patrizio Manzari, Alice Manzo, Roberta Annicchiarico, Maria Gabriella Buzzi and Giuseppe Vannozzi

Can real-world scenarios and complex motor tasks identify potential fallers? A sensor-based approach in elderly and neurological patients

Clinical assessments of balance and gait in controlled laboratory settings often involve simple measurement protocols (e.g., walking along a 10-meter straight path). While these methods capture important gait characteristics, they may not effectively predict real-world fall risk, as they do not reflect the everyday challenges individuals face. Sensor-based assessments of gait patterns through more complex motor tasks simulating daily scenarios could uncover new biomarkers indicating subtle motor impairments associated with fall risk, which may not be detectable with standardized clinical tests. To identify possible biomarkers, elderly and neurological patients, considered at high falling risk, performed the following motor tasks: linear and curvilinear walking; timed up and go test; upright posture. Different environmental conditions were proposed, as the use of different unstable surfaces or of visual/auditory feedback, aiming at mimicking real-world settings (e.g., supermarket, house environment, mountain path). Sixteen inertial measurement units were located on participant's body and used to extract gait and postural parameters possibly indicating fallers. Patients with a history of falls clearly showed different values (e.g., reduced cadence and walking speed) compared to other participants. Notably, a participant with a recent Parkinson's disease diagnosis but normal clinical scale values also exhibited faller-like values. Further research is needed to determine if these biomarkers can reliably predict fall events. However, real-world gait patterns and complex motor tasks appear to be more effective at distinguishing fallers from non-fallers than standard gait assessments. Early-fallers identification could help mitigate the increasing prevalence of falls, negative-related consequences, and reduce the overall associated healthcare costs.

Wilber Rosales, Ailín Tibado, Marcos José Crespo and Emiliano Pablo Ravera

Effect of Musculoskeletal Models on Gait Analysis Outcomes in Children with Cerebral Palsy Undergoing Femoral Derotation Osteotomy

Cerebral palsy (CP) is caused by a non-progressive brain injury that affects neuromuscular control, leading to progressive changes in muscle tissue composition and morphology, resulting in bone deformities and movement abnormalities. For this reason, children with CP are often treated with orthopedic surgery as femoral derotation osteotomy (FDO) with the aim to correct excessive femur rotations. Currently, children with CP are evaluated using the conventional gait model (CGM) to determine the need for an FDO. However, the CGM does not take account of femur rotation degree. Considering these limitations, this study evaluates how different computational models can impact on gait analysis outcomes in children with CP who were treated with a FDO. Three models were compared: CGM and two musculoskeletal models: the gait2392 from OpenSim (generic-NMSK) and an adapted version of gait2392, which introduced femoral rotation (rotated-NMSK). Walking simulations of 19 children with CP (before and after FDO) were performed based on three models. We compared angles, forces, and joint moments using the paired t-test from the spm1d library. Our results showed that generic-NMSK outcomes are equivalents to CGM. However, rotated-NMSK showed significant statistical differences in knee and hip reaction forces in contrast to the other two models. These findings highlight the importance of introducing certain degree of personalization in models to achieve reliable outcomes in clinical the gait analysis of children with CP.

Manami Fujii, Sophia Chirumbole, Andrew Wagner, Jaclyn Cacesse, Ajit Chaudhari and Daniel Merfeld

Impact of vestibular coordinate tilts on postural sway during a three-dimensional pseudorandom balance perturbation assessment

Postural sway is evoked by pseudo-random perturbations and has a high potential to predict fall risk. Our three-dimensional balance assessment provides pseudorandom perturbations using sum of sinusoids for simultaneous earth-vertical translations and vestibular coordinate (Right Anterior-Left Posterior and Left Anterior-Right Posterior) tilts. The purpose of this study was to find how each of the translations and tilts evokes postural sway in four different conditions of peak-to-peak amplitudes: (i) 3cm translation-1 degree tilts, (ii)6cm translation-1 degree tilts, (iii) 3cm translaton-2 degree tilts, and (iv) 6cm translation-2degree tilts. The sum of sinusoids trajectories were generated by summing signals at each of five frequencies having a bandwidth of 0.06-1.41 Hz. Postural sway data were collected from 24 healthy adults (40.7±13.6 years) (Virtualis, Motion VR, France). We

randomized the order of the four conditions to mitigate order effects. Center of pressure (CoP) data were analyzed using a discrete Fourier transform yielding amplitude and phase as a function of frequency. CoP spectral data showed sway responses were clearly distinguishable from one another. Response components were observed at each of the perturbation frequencies. The earth-vertical translations evoked primarily AP postural sway, while the tilt perturbations evoked both Medial-Lateral (ML) and Anterior-Posterior (AP) postural sway. Normalized CoP spectral response magnitude and phase and CoP Root Mean Square Distance showed no significant difference between (i) and (ii) or (iii) and (iv) ($p > 0.05$). These results suggest that the postural sway of healthy adults increased with increased peak-to-peak amplitudes of vestibular coordinate tilts, but not earth-vertical translations.

Leonardo Ariel Mensi Malerba, Magalí Sganga and Franco Ezequiel Liotino

Force, power, speed and mechanical effectiveness profile during sprint in amateur football players

This study aims to describe the kinetic variables of the sprint gesture in amateur football players. Several studies showed that sprint is one of the most common hamstring injury mechanisms. The description of individual variations on horizontal force application, power, and speed might help understanding these potential risk factors. This research establishes the force, power, speed, and mechanical effectiveness profile of male amateur football players, a population previously undescribed in the literature to our knowledge. Sprint filming and temporal-spatial data were collected following Samozino´s protocol. Force, power, speed, and mechanical effectiveness profile were calculated for each player using video analysis software to determine the center of mass position during the sprint. The profile was then correlated with demographic and sports variables. 24 male football players with no impairments were included (age: 29.25 ± 6.98 years, BMI: 24.83 2.46). Mean values (± SD) were as follows: horizontal force 7.7 ± 1.21 N/kg, velocity 7.9 ± 0.57 m/s, relative power output 15.25 ± 2.97 W/kg, maximal horizontal force ratio 42.71 ± 3.44%, and linear decrease of horizontal force ratio -9.22 ± 1.34%. The values obtained are lower than those found in populations with higher weekly training loads. This is the first biomechanical description of sprint kinetics in this understudied population. Its clinical relevance lies in its potential to help trainers and physiotherapists develop tailored training load and prevention strategies for hamstring injuries based on the most frequent ecological environment.

Konstantinos Vrongistinos, Taeyou Jung and Young Hwang

Accuracy of Calculating Three-Dimensional Angular Velocities from Linear Velocities

Calculating three-dimensional angular velocities from linear velocities is not as straightforward as in two-dimensional space, which is given as linear velocity over the radius. Computing the angular velocities using the derivatives of the Euler Angles introduces errors during the trio stepwise process. Furthermore, there are three robust ways to calculate the angular velocities. One uses the directional cosine transformational matrix and its inverse derivative matrix; the second uses Euler parameters (or normalized quaternions); and the third uses the linear velocities of three non-colinear markers and the corresponding inter-marker distances. The accuracy of its method was verified with experimental data derived from three non-colinear markers of the upper arm during wheelchair propulsion and data from a simulated pendulum. All three methods calculated the angular velocities with minimal error, where the angular velocity calculated by differentiating the transformation matrix had the least mean square error, similar to the quaternion method, followed by the three linear velocities method. However, when the inter-marker distance was computed from the static trials or calculated as an average rather than the instantaneous inter-marker distance, the accuracy of the three linear velocities method improved to the mean square error level of the other two methods. Therefore, using the linear velocities of three markers derived by differentiating position data or integrating accelerometer data simplifies the angular velocities computation. Thus, devices can use fewer orientation sensors when three accelerometers per segment are present when angular velocities are necessary.

Juan Agustín Beret, Leandro Bugnon and Emiliano Pablo Ravera

Assessment of a Probabilistic Musculoskeletal Algorithm for Estimating Gait Kinetics Without Ground Reaction Force Data

Performing kinetic estimations during walking without ground reaction force data remains a challenge. One approach to address this issue is to combine neuro-musculoskeletal models with machine learning. Tanghe et al. (J Biomech 19(11):109327, 2019. https://doi.org/10.1016/j.jbiomech.2019.109327) proposed a method based on probabilistic principal component analysis to estimate net joint moments without ground reaction force data. These authors used OpenSim to determine the gait dynamics of a population of healthy subjects, demonstrating high repeatability, accurate estimates, and the potential for applying this method in new situations. However, this method has not yet been applied to pathological gait, possibly due to the unavailability of the method and dataset to the community. Given these limitations, the aim of this study was to evaluate the algorithm developed by Tanghe et al. using two datasets (DS1: 12 subjects, 24 trials, pathological, not open access; DS2: 8 subjects, 32 trials, unimpaired gait, open access). A post hoc scalar field paired t-test with Bonferroni correction (alpha = 0.05) was used to

compute a statistical parametric map for each parameter and comparison. Our results showed errors of less than 0.2 Nm/kg for net joint moments and 0.6 N/kg for ground reaction forces, with the model fitting similarly for both normal and pathological gaits. Finally, further studies with datasets of subjects exhibiting pathological gait patterns are needed to bring this algorithm closer to clinical applications.

Mariano Miguel Perdomo, Ariel Andrés Antonio Braidot, Gabriel Villaverde, Luis Alberto Clementi, Lucas Pianigiani, Jean Pierre Arotcharen, Bruno Zorzet and Josefina Giorgi Insaurralde

An Innovative Methodology for Taekwondo Kick Diagnosis Using Recurrent Neural Networks

In general, the analysis of specific complex sport techniques is qualitatively assessed by expert trainers, occasionally supported by biomechanical analysis obtained from ad-hoc acquisition systems. However, this standard methodology often relies on subjective evaluation and requires the analysis of numerous biomechanical parameters, which hinders the identification of technical errors. This work aims to develop a methodology for quantitatively evaluating and diagnosing complex techniques, in particular, Taekwondo kicking techniques, using an autoencoder implemented through a Gated Recurrent Unit (GRU) neural network. To this end, hip, knee, and ankle joint angles and angular velocities of both lower limbs were captured from multiple kicking executions performed by Taekwondo experts (black belt holders). Subsequently, the GRU-based autoencoder was employed to categorize kicks based on the technical accuracy of their execution as standard or non-standard. Finally, an ad-hoc error analysis was conducted on kicks classified as non-standard to identify the biomechanical parameters contributing most to the differences between standard and non-standard kicks. Based on the F1-score, a metric that combines precision and recall, the results showed that the implemented autoencoder accurately detected non-standard kicks with a score exceeding 90%. Furthermore, error analysis successfully identified the parameters most influential in non-standards classification, enabling the improvement of kicking technique in non-expert individuals.

Ariel Andrés Antonio Braidot, Joaquín Monti, Marco López Ibarra, Guillermina Sáenz and Alejandro Hadad

Characterization of Human Weight Distribution in Baropodometry

Proper distribution of plantar pressure is essential to prevent injuries caused by muscular overload throughout the musculoskeletal chain. Orthopedic insoles are the primary treatment for improving foot biomechanics. Baropodometry studies provide quantitative

information on foot load distribution. However, prescribing orthopedic insoles is highly subjective due to the lack of a direct correlation between baropodometry data and insole design, and the absence of a consensus on design criteria. In this study, a database of 300 baropodometry studies was compiled to characterize plantar pressure distributions. The volunteers signed an informed consent form approved by the ethics committee of the Dr. Esteban Laureano Maradona Rehabilitation and Research Center. A preprocessing step was conducted on the plantar pressure records, and two alternative approaches are presented. The first approach considers the pressure distributions as RGB images, extracts features using the pre-trained VGG-16 convolutional network, reduces dimensions with principal component analysis, and clusters them using a clustering algorithm. The second approach treats the pressure distributions as matrices, uses a matrix distance metric to form the hierarchical structure and determine group division with the agglomerative hierarchical clustering algorithm, and combines the results to determine average pressure distribution matrices. The results show five groups of plantar pressure distributions, both for the right and left sides, which are visually and statistically distinct. The methodology and the results obtained provide a basis for the development of tools that support clinical decision-making.

Luis Ricardo Soria, Jorge Alberto Herrera, Carlos Rodolfo Arcuri, Fernando Daniel Brizuela del Moral, Mauricio Borda and Martín Edgardo Cejas

USE OF SIMULATION SOFTWARE AND VIRTUAL CLASSROOM IN SPORTS BIOMECHANICS

The present study investigated how the Kinovea software and the virtual classroom mediated the learning of the Biomechanics subject in the Bachelor of Physical Education at UNCa during the 2020 academic year. Data were collected through class observation, participation in the virtual classroom, and surveys from 22 students. In the virtual classes, students selected a gesture to analyze. The selected gestures were rugby tackle, javelin throw, volleyball spike, among others. Using the virtual classroom, students described the phases of the selected gesture, the most important muscle actions, and alterations in the correct execution. Through Kinovea, students were able to measure angles, distances, and times, as well as specify spatial and temporal references. They were also able to describe the trajectory of one or more markers in the gesture video. On this trajectory, the analysis of the variation in distances and speeds of at least a portion of the movement was performed. Furthermore, the student was able to calculate at least an average acceleration in a portion of the selected gesture. The results of the surveys indicated that 100% of the students positively valued the use of the virtual classroom, highlighting its impact on the organization of the material and communication. In addition, 45% of the respondents indicated that Kinovea facilitated the practical understanding of the theoretical concepts of Biomechanics. The conclusions suggest that the virtual classroom favors exchange. The Kinovea software is effective in analyzing a wide variety of sports gestures.

Ana Carolina Morais, Gabriel del Rosso, Bruno Panciera, Carlos Sendra-Pérez, Inaê de Oliveira, Eduarda Tulius and Felipe Carpes

Exercise intensity and knee mechanics during squat exercises: pilot study

Rate of perceived exertion (RPE) is useful to assess the exercise intensity. We hypothesize that increases in RPE during fatigue exercise can be accompanied by changes in movement mechanics. This pilot study investigates whether a higher RPE is accompanied by changes in knee mechanics during squats performed to fatigue. A physically active 20-year-old female, with body mass of 52 kg and height of 163 cm, performed bodyweight squats to exhaustion. Kinematic and kinetic measurements were taken using a 3D motion capture system (Vicon Motion Systems, 15 Bonita B10 cameras, 200 Hz, 23 markers) to assess sagittal plane knee joint angles and moments. RPE was monitored using the Borg Scale [6 to 20 u.a.] throughout the exercise. Five squat repetitions were recorded whenever the participant reported RPE increase. The lower vs. higher RPE (6 vs. 20) elicited reduction in knee flexion amplitude (120.67 ± 2.45° vs. 113.75 ± 4.65°) and moment at the maximal knee flexion (119.9 ± 4.4 Nm·kg-1 vs. 106.9 ± 4.5 Nm·kg-1, $p<0.001$, paired t-test). These pilot findings suggest that as the RPE increases, there is a possible redistribution of joint moments among the major joints involved in the squat movement. This ongoing project will consider analyzing other joints to test this hypothesis.

Mariana Alonso Etchemendy and Fernando Diefenthaeler

Torque-angle relationship of the shoulder joint in female pole dancers: Preliminary study

Pole dance is currently considered a high-performance sport with a significant incidence of injuries,particularly in the shoulder, as the upper limbs are subjected to a high load. Due to the need to generate force with the shoulder in 180° flexion, functional adaptations in the shoulder joint in this sport are expected. However, no studies have described the biomechanical characteristics of the shoulder joint in pole dance. Objective: To describe the torque-angle relationship during shoulder flexion-extension in pole dance practitioners in the sagittal and scapular planes. Methods: Preliminary analysis of the torque-angle curve in the sagittal and scapular planes of three advanced-level female athletes, examining the mean and standard deviation of the isometric peak torque at five different angles using an isokinetic dynamometer. The data were normalized by body mass. Results: The angle at which the peak torque occurred in the sagittal plane was 40° (0.83±0.12 N·m·kg-1) for flexion and 100° (1.02±0.17 N·m·kg-1) for extension. In the scapular plane, the angle at which the peak torque occurred was 70° (0.96±0.46 N·m·kg-1) for flexion and 100° (1.04±0.26 N·m·kg-1) for extension. This is the first study aimed at describing the torque-angle relationship of pole dance athletes, contributing to the advancement of a rapidly

growing sport, as well as expanding knowledge about the shoulder joint, known for its complexity.

Emiliano Ravera

Subject-specific pediatric musculoskeletal model based on machine learning

Musculoskeletal models (MSK) are valuable for clinical decision-making but have notable limitations. A key issue is the use of non-pediatric datasets to build these models, which may not accurately represent the bone morphology of children. To address this, methods to scale and adjust MSK parameters for pediatric bone morphology have been proposed, though they often require large databases not available in clinical settings. Thus, there is a need for MSK models that can accurately replicate the bone morphology of children's lower limbs and adapt to existing clinical gait analysis protocols. This study aimed to develop a subject-specific MSK model for children using only data from standard clinical gait analysis. The machine learning algorithm proposed by Carman et al. (2022, https://doi.org/10.1038/s41598-022-07267-4) was employed to generate bone meshes from anthropometric data, and the STAPLE algorithm's library was used to automatically create an MSK model compatible with OpenSim. The model's performance was evaluated using gait trials from 5 children with cerebral palsy. Joint angles, forces, torques, and muscle lengths from the generic gait2392 model and the specific MSK model were compared using paired t-tests with the spm1d tool. Results showed differences in muscle lengths estimation of children with cerebral palsy. Further research is needed to confirm these findings and investigate bone rotation and deformation integration.

Gabriel Palermo Del Rosso Barbosa, Karine Jv Stoelben and Felipe P Carpes

Intra-limb agreement between impact forces and joint angular velocity in drop landings

Abstract - Ground reaction forces (GRF) and angular velocity (ω) are variables used in the biomechanics analysis of jump-landings. An inverse relationship between lower limbs ω and the GRF peak in the landing phase of jumps may favor impact absorption. However, most studies did not address the strength of agreement between these variables. Here we verified the association between GRF and joint ω during the landing phase of drop jumps. Fifty-five men (mean age 25±3 years) without a history of lower limb injuries were evaluated. The vertical GRF and knee ω were measured at the initial contact of bilateral drop jumps using a motion capture system (Vicon Motion Systems, 15 infrared Bonita B10 cameras at 200 Hz, and two AMTI force plates at 2 kHz). Subsequently, we identified which lower limb had the higher peak GRF and whether the knee ω was higher in the same limb compared to the contralateral. Kappa test was performed to verify the agreement. We found

that 36 out of 55 individuals showed higher knee ω and higher peak GRF in the same lower limb (weak agreement, Kappa = 0.31). A large portion (65%) of the individuals showed higher GRF and ω in the same lower limb, which suggest an effective strategy to minimize impact forces. However, this agreement was weak, which could be due to differences in neuromuscular control, strength, or technique. We recommend caution when interpreting GRF and ω outcomes, given the participant-dependent nature of these variables.

Natali Olaya Mira, Isabel C. Soto Cardona, Gustavo A. Bacca Insuasty, Adriana C. Guerrero Peña and Jubelly A. Amariles

Prospective study into the influence of foot type in asymptomatic young adults using baropodometry

The human foot displays complex behavior when walking and standing. Although this topic is of vital importance because it concerns all human beings, few conclusive studies have related the different baropodometric variables associated with biomechanics. Therefore, the objective of this study was to connect these variables to the foot patterns exhibited by a population of asymptomatic young adults. A protocol was implemented to evaluate the foot of 142 young people in static and dynamic positions. Data were obtained using the Ecowalk plantar pressure platform. Afterwards, SPSS v. software was used. 25 to establish the relationship between different variables associated with foot type. This study found that, among a young adult population, only the COP trajectory depends on foot type. In turn, sex, stabilometry and body weight distribution are not determinants of foot type. However, the weight distribution predominates towards the left back of the foot. These results support the findings of similar studies and the importance of using plantar pressure platforms, since studies on biomechanical behavior using digital platforms are not common, therefore, there is little information available in the literature on the variables that can be obtained. with this technology and that would facilitate the clinical diagnosis of plantar disorders. Further evaluations should be carried out to analyze some of the measured parameters and in future studies, consider the support base, as well as longer measurements of at least 60 seconds on the platform.

Artur Bonezi, Manuel Urteaga and Renata Bona

Kinematic variability of Parkour's kong jump

Traceur is practitioner of Parkour that moves quickly and skillful around objects. Movement variability describes the intentional and unintentional adjustments of the body between repetitions within the same strategy. Aim was to determine kinematic variability during the support phase of jump called kong. Fifteen male with 9 years experienced Parkour were tested at five jumps. In the kong jump, the traceur projects himself above and in front of the wall using both arms as support to propel himself. Six triaxial accelerometers (Delsys Trigno Wireless) were adhered to the subject’s at level of C7, L5 and arm. After low-pass

filter and a sampling rate of 1,000 Hz, peak acceleration and peak velocity from the component horizontal (Y) and vertical (Z) axes were the outcome variables. As results, mean deviation of data were very low (between min 3.2 and max 8.7). A multiple correlation coefficient (R greater than 0.94) can distinguish techniques. Highest position of L5 and hight peak at touch down providing bigger take off of velocity during support phase. Often parkour movements must be adjusted in a matter of milliseconds. Minimize variability of execution allows for more consistent results. As a result, these movements are highly predictable allowing to anticipate what will happen next, providing feedback on technique training, and exploit this for traceur.

Maria J. Rojas-Caballero and Rosy P. Cárdenas-Sandoval

Análisis Biomecánico del gesto de baile en universitarios: enfoque de prevención de lesiones para los bailarines de salsa de la Universidad del Rosario

El baile de salsa latina requiere de un alto nivel de complejidad neuromuscular debido a los movimientos articulares rápidos y repetitivos y a las fuerzas de reacción producidas durante el gesto. Las alteraciones en activación muscular y en la cinemática articular como la oblicuidad pélvica, el valgo de rodilla y la pronación del pie aumentan el riesgo de lesiones musculo esqueléticas en los bailarines. Por consiguiente, el objetivo de este proyecto de investigación es evaluar el rango de movimiento articular y la activación neuromuscular de los miembros inferiores, así como en la región del CORE en dos gestos técnicos del baile de salsa en mujeres y hombres universitarios. Se utilizó un sistema de análisis de movimiento conformado por diez cámaras optoelectrónicas Vero 2.2 Vicon y software Vicon Nexus versión 2.16 y un sistema de electromiografía de superficie marca Ultium Noraxon de 4 KHz en los gestos de “Lijas” y “Básico Caleño” ó “Colombiano”. Hasta ahora, los resultados muestran que en ambos gestos realizados se obtuvieron porcentajes de asimetría mayores al 20% en los músculos oblicuos internos, glúteos mayores y glúteos medios, sin embargo, los porcentajes de asimetría aumentan cuando emplean tacones a comparación de cuando utilizan zapatillas. De igual forma, en la evaluación cinemática se confirmó la presencia de oblicuidad pélvica, valgo de rodilla y pronación del pie. Se concluye que los bailaren presentan riesgo de lesión musculoesqulética como esguinces y tendinopatías. Este estudio descriptivo permitirá crear protocolos de prevención de lesiones musculo esqueléticas en los bailarines de salsa caleña.

Rosy P. Cárdenas-Sandoval, Sebastian Jaramillo-Isaza, Laura V. Rivera-Amezquita, Camilo A. Tenjo, Miguel A. Cifuentes-Santamaria, Camila A. Rivera-Blanco, Juan Daniel Pisso-Durango and Juan José Alemán

Machine learning prediction of musculoskeletal injury risk in female student-athletes

Anterior cruciate ligament (ACL) injury is common in female collegiate athletes and accounts for a high percentage of non-contact musculoskeletal injuries, especially during jumping, deceleration, and change of direction tasks. Recent approaches have incorporated Machine Learning, Artificial Intelligence, and kinetic and kinematic data analysis to assess the risk of ACL injury in high-performance athletes. Likewise, the Landing Error Scoring System stands out as a kinematic evaluation tool to identify biomechanical and neuromuscular alterations associated with injury risk factors. A comprehensive assessment of the movement, employing both 3D and 2D analysis systems, enables the acquisition of precise and objective measurements of jumping movements. The objective of this project is to utilize surface electromyography to examine the activity of the rectus femoris and biceps femoris muscles, and to employ an Inertial Measurement Unit in the sacral region to monitor the displacement of the center of mass. Furthermore, force platforms will be employed to assess jump kinetics and range of motion in accordance with the ROM Sport Battery I protocol. For this reason, a transdisciplinary research project between physical therapists, educators, bioengineers and college athletes is proposed with the purpose of developing a machine learning model to predict the risk of anterior cruciate ligament injury in female college athletes through the creation of predictive algorithms trained with clinical, biomechanical and physiological data representative of college athletes. It is hoped that the resulting models can correlate with Landing Error Scoring System assessments and improve ACL injury prediction and prevention.

Monica J. Vargas-Rodríguez and Rosy P. Cárdenas-Sandoval

Análisis biomecánico del suelo pélvico en en ciclistas de ruta femeninas

En el ciclismo de ruta, la aerodinámica y el confort son aspectos clave para mejorar el rendimiento. Con el creciente número de ciclistas femeninas y el aumento de reportes de lesiones pelviperineales, surge la necesidad de investigar estos problemas. Este estudio descriptivo tiene como objetivo analizar, desde una perspectiva biomecánica y clínica, el comportamiento de la pelvis en ciclistas de ruta femeninas que entrenan al menos tres veces por semana. Se empleó tecnología avanzada para el análisis del movimiento, incluyendo electromiografía de superficie (EMG Ultium Noraxon 4KHz) para evaluar la activación de los músculos superficiales de la pelvis y el tronco durante el pedaleo. También se utilizaron cámaras VICON Vero 2.2 con el fin de medir el rango de movimiento funcional

de la columna, pelvis, cadera y tobillo. Los resultados preliminares indican que hay relación entre la sensibilidad perineal y síntomas incontinencia urinaria por esfuerzo. Además, la activación del glúteo mayor está vinculada con la orientación pélvica, mostrando una asimetría superior al 26%. Se concluye que las características individuales de cada ciclista influyen en la ejecución del gesto deportivo y que existe una relación entre la actividad pélvica y el riesgo de lesiones pelviperineales. Este estudio busca proporcionar herramientas para desarrollar protocolos de prevención de lesiones y potencializar el rendimiento de las ciclistas de ruta femeninas.

Natalia Garay Badenian, Alejandra Rial and Franco Simini

Review of quantitative movement analysis in epilepsy seizures

The quantification of movement in epileptic seizures is important for improving the diagnosis and treatment of epilepsy. In this study, we compare five methodological approaches used in the scientific literature to analyze movement during epileptic seizures: (a) video analysis and image processing to quantify characteristics such as movement speed and amplitude, (b) inertial sensors combined with machine learning techniques to identify movement patterns, (c) electromyography (EMG) integrated with video analysis to obtain a comprehensive evaluation of muscle movement, (d) artificial intelligence to classify large volumes of video data, and (e) real-time monitoring devices and time-series analysis. The results show that each technique offers specific advantages: machine learning algorithms and artificial intelligence enhance predictive accuracy, while EMG provides a strong correlation between electrical activity and movement. However, these approaches also present limitations such as dependence on video quality, equipment costs, and the need for large data volumes. In conclusion, the selection of the optimal methodology depends on the specific objectives of the study and patient characteristics, highlighting the importance of a multidisciplinary approach for effective evaluation.

Linnette Jara Román, Darío Santos and Franco Simini

Evaluation of the Six-Minute Walk Test: a Literature Review

Gait studies are prescribed by physicians and other health professional to diagnose or establish treatment plans. The aim of this review is an analysis of seven articles on the 6-minute gait or walk test, 6MWT, and its quantitative evaluations in healthy and cardio-vascular rehab patients of all ages. Bibliographic search starting with the American Thoracic Society (ATS) guidelines. for 6MWT and articles with keywords 6MWT, adults, older adults and children and teenagers in all journals and scientific societies of Cardiology, Pneumology and Physiotherapy. The papers were classified into three age categories and ordered by year to highlight the importance of the ATS guidelines, in addition to other protocols such as Butland et al (1982), Guyatt et al (1984), & Redelmeier et al (1997). Result of the 6MWT is

expressed as distance covered, hearth rate, oxygen consumption, dyspnea. The following variables affect the distance covered during the 6MWT: socio-anthropometric (weight, height, BMI, age, gender), altitude and chronic diseases. Men walk more meters compared to women. This test not only evaluates exercise capacity, but also allows for a therapeutic approach, as in the case of cardiac rehabilitation.