The new era of rehabilitation is now
Movendo Technology is a medical company that develops innovative and easy-to-use rehabilitation solutions thanks to the use of the most advanced robotic technology. Movendo Technology operates worldwide, with a dedicated clinical team resident at MT headquarters, focused on facilitating collaborations with the Movendo clinical international network. MT clinical team collaborates with all its partners for data collection and data analysis and for the creation of literature and scientific evidence. Objective evaluation and scientific approach are part of the innovation at the core of Movendo DNA, and are combined with machine learning and Artificial Intelligence to create new solutions for rehabilitation and diagnostics.
VALENTINA SQUERI
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Graduated in biomedical engineering at the University of Genova, Genova, Italy, in 2004, with a thesis concerning the analysis of upper arm’s movements in patients with hemicrania and received the M.S. degree in bioengineering from the University of Genova, in 2006, studying the development and validation of a robot therapy rehabilitation protocol for patients with Multiple Sclerosis. In 2010 she received the Ph.D. degree in humanoid technologies from the University of Genova, with a thesis concerning how to use robots to study sensorimotor performance and promote neuromotor recovery. From 2010 to 2016, she worked as Post Doctoral Researcher at the Italian Institute of Technology (IIT), Genova. The scientific aim of her research was to investigate with robotic devices the neural control of movements and motor learning mechanisms, with the technological goal of develop robots and algorithms that can support and optimize rehabilitation. During her scientific carrier she published papers on peer-reviewed journals. She works currently as Clinical affairs and product development manager in Movendo Technology.
Graduated in biomedical engineering in 2008 at University of Genoa and received the M.S. degree in bioengineering in 2010 from the University of Genoa. In 2016 she received the PhD degree in bioengineering from the University of Genoa with a research project focused on rehabilitation and compensatory strategies in stroke and spinal cord injury survivors. From 2011 to 2016 she worked in the Rehabilitation Department of the Santa Corona Hospital with a specific activity related to motion analysis and robotic rehabilitation in neurologic field. Since 2017, Alice is working in Movendo Technology as part of the product development and clinical application team and is currently in charge of coordinating the activities related to clinical projects. She is author and co-author of many publications on peer-reviewed journals.

ALICE DE LUCA
Clinical projects coordinator
Design and Development of a Novel Core, Balance and Lower Limb Rehabilitation Robot: hunova®

Paper summary
This article describes the technical aspects at the basis of the development of hunova®. The robot design has been described in detail, starting from the hardware mechanisms, the system electronic and control components as well as the software. hunova® has been ergonomically designed to maximize the number of the possible rehabilitation exercises and evaluations, in all areas as neuro, ortho, geriatrics and sport.

hunova® allows to measure significant parameters of static and dynamic stability and can centralize a complex progression of exercises to recover trunk control and reactive balance after traumatic injuries.

The complete paper shall be sent upon request.

Citation
Development and validation of a robotic multifactorial fall-risk predictive model: A one-year prospective study in community-dwelling older adults

Background
Falls in the elderly are a major public health concern because of their high incidence, the involvement of many risk factors, the considerable post-fall morbidity and mortality, and the health-related and social costs. Given that many falls are preventable, the early identification of older adults at risk of falling is crucial in order to develop tailored interventions to prevent such falls. To date, however, the fall-risk assessment tools currently used in the elderly have not shown sufficiently high predictive validity to distinguish between subjects at high and low fall risk. Consequently, predicting the risk of falling remains an unsolved issue in geriatric medicine. This one-year prospective study aims to develop and validate, by means of a cross-validation method, a multifactorial fall-risk model based on clinical and robotic parameters in older adults.

Methods
Community-dwelling subjects aged ≥ 65 years were enrolled. At the baseline, all subjects were evaluated for history of falling and number of drugs taken daily, and their gait and balance were evaluated by means of the Timed “Up & Go” test (TUG), Gait Speed (GS), Short Physical Performance Battery (SPPB) and Performance-Oriented Mobility Assessment (POMA). They also underwent robotic assessment by means of the hunova robotic device to evaluate the various components of balance. All subjects were followed up for one-year and the number of falls was recorded. The models that best predicted falls—on the basis of: i) only clinical parameters; ii) only robotic parameters; iii) clinical plus robotic parameters—were identified by means of a cross-validation method.

Results
Of the 100 subjects initially enrolled, 96 (62 females, mean age 77.17±.49 years) completed the follow-up and were included. Within one year, 32 participants (33%) experienced at least one fall (“fallers”), while 64 (67%) did not (“non-fallers”). The best classifier model to emerge from cross-validated fall-risk estimation included eight clinical variables (age, sex, history of falling in the previous 12 months, TUG, Tinetti, SPPB, Low GS, number of drugs) and 20 robotic parameters, and displayed an area under the receiver operator characteristic (ROC) curve of 0.81 (95% CI: 0.72–0.90). Notably, the model that included only three of these clinical variables (age, history of falls and low GS) plus the robotic parameters showed similar accuracy (ROC AUC 0.80, 95% CI: 0.71–0.89). In
comparison with the best classifier model that comprised only clinical parameters (ROC AUC: 0.67; 95% CI: 0.55–0.79), both models performed better in predicting fall risk, with an estimated Net Reclassification Improvement (NRI) of 0.30 and 0.31 (p = 0.02), respectively, and an estimated Integrated Discrimination Improvement (IDI) of 0.32 and 0.27 (p<0.001), respectively. The best model that comprised only robotic parameters (the 20 parameters identified in the final model) achieved a better performance than the clinical parameters alone, but worse than the combination of both clinical and robotic variables (ROC AUC: 0.73, 95% CI 0.63–0.83).

Conclusions
A multifactorial fall-risk assessment that includes clinical and hunova robotic variables significantly improves the accuracy of predicting the risk of falling in community-dwelling older people. Our data suggest that combining clinical and robotic assessments can more accurately identify older people at high risk of falls, thereby enabling personalized fall-prevention interventions to be undertaken.

The complete paper is available at the following link:

Citation
https://doi.org/10.1371/journal.pone.0234904

Conference presentations


Robotic balance assessment in community-dwelling older people with different grades of impairment of physical performance

Background
Impaired physical performance is common in older adults and has been identified as a major risk factor for falls. To date, there are no conclusive data on the impairment of balance parameters in older subjects with different levels of physical performance. The aim of this study was to investigate the relationship between different grades of physical performance, as assessed by the Short Physical Performance Battery (SPPB), and the multidimensional balance control parameters, as measured by means of a robotic system, in community-dwelling older adults.

Methods
In this study, subjects aged ≥ 65 years were enrolled. Balance parameters were assessed by the hunova robot in static, dynamic (unstable and perturbing) conditions, in both standing and seated positions and with the eyes open/closed.

Results
The study population consisted of 96 subjects (62 females, mean age 77.2±6.5 years). According to the SPPB score, subjects were separated into poor performers (SPPB<8, n=29), intermediate performers (SPPB=8-9, n=29) and good performers (SPPB>9, n=38). Poor performers showed a statistically significant worse balance control, showing impaired trunk control in most of the standing and sitting balance tests, especially in dynamic (both with unstable and perturbing platform/seat) conditions.

Conclusions
For the first time, multidimensional balance parameters, as detected by the hunova robotic system, were significantly correlated with SPPB functional performances in community-dwelling older subjects. In addition, balance parameters in dynamic conditions proved to be more sensitive in detecting balance impairments than static tests.

The complete paper shall be sent upon request.
Citation

Conference presentations
Effect of a robotic training focused on balance and core stability in Parkinson’s disease: a pilot study

Background
In Parkinson’s disease, rehabilitation aims to improve patients’ quality of life by promoting their independence, safety and well-being. To achieve these goals, rehabilitation first aims to prevent and/or delay inactivity, fear of moving or falling and to maintain and enhance physical capacity; as the disease progresses, the goal becomes to improve transfers, posture, balance, walking and functional gestures. The aim of this pilot study is to verify the feasibility and effectiveness of an integrated traditional-robotic rehabilitation treatment in Parkinson's disease patients, using hunova, a robotic device developed for the rehabilitation of lower limbs and trunk.

Methods
Ten subjects (8M, 2F, mean age 72±6.84SD) with a clinical diagnosis of Parkinson's disease were included in this study. Subjects were treated for a first period (16 sessions, 2/week) with group neuromotor rehabilitation and occupational therapy exercises. At the end of this first period, the same patients started a training based on the integration of group rehabilitation and exercises with hunova (20 sessions, 2/week). Hunova is a robotic device composed of two robotized and sensorized platforms, one at the level of the feet and one at the level of the seat. Training on hunova included exercises focused on balance, limits of stability, lower limbs strengthening, trunk control, pelvis mobility, core strengthening. Subjects were evaluated at T0 (treatment beginning), T1 (robotic treatment introduction), and T2 (combined treatment end) with clinical scales (UPDRS -at T0 and T2 - Short Physical Performance Battery (SPPB), hand grip, timed up and go (TUG)) and instrumental evaluations carried out with hunova focused on balance, limits of stability, mobility (ankle and pelvis) and ankle force. Statistical analysis was performed using ANOVA for repeated measures and post hoc analysis with Bonferroni’s test.

Results
All patients have well perceived and appreciated the robotic rehabilitation treatment with hunova referring at the end of treatment a subjective feeling of improvement, especially in the perception of balance during daily life activities. At T2 a slight but significant improvement in the UPDRS score (p=0.01) was found. Following the first part of the traditional treatment subjects reported a significant improvement - maintained at T2- in the SPPB score (p=0.004), mainly due to an improvement in the equilibrium sub-score (p=0.005), in the walking speed (p=0.004), in the standing limits of stability (p= 0.001) and in the forward trunk movement range (p=0.008). Following the integrated treatment with robotic therapy, improvements in the TUG time (p <0.001,), in pelvic mobility (p=0.008), and in seated limits of stability (p <0.001) were found.
Conclusions
The integration of traditional and robotic treatment has led, compared to traditional treatment only, to an improvement in the TUG test, to greater pelvis mobility and stability with an improvement in managing the load in sitting position, besides the maintenance of the improvements already highlighted in the first part of the treatment on balance, walking speed, stability limits and trunk mobility. For these reasons the rehabilitation treatment with hunova seems to offer an innovative therapeutic opportunity to be combined with traditional rehabilitation in subjects affected by Parkinson’s disease.

Conference presentations

Robot-based assessment of sitting and standing balance: preliminary results in Parkinson’s disease

Background
Postural responses to unstable conditions or perturbations are important predictors of the risk of falling and can reveal balance deficits in people with neurological disorders, such as Parkinson’s Disease (PD). However, there is a lack of evidences related to devices and protocols providing a comprehensive and quantitative evaluation of postural responses in different stability conditions.

Methods
We tested ten people with PD and ten controls on a robotic platform capable to provide different mechanical interactions and to measure the center of pressure displacement, while trunk acceleration was recorded with a sensor placed on the sternum. We evaluated performance while maintaining upright posture in unperturbed, perturbed, and unstable conditions. The latter was tested while standing and sitting. We measured whether the proposed exercises and metrics could highlight differences in postural control. Participants with PD had worse performance metrics when standing under unperturbed or unstable conditions, and when sitting on the unstable platform.

Results
PD subjects in response to a forward perturbation showed bigger trunk oscillations coupled with a sharper increase of the CoP backward displacement. These responses could be due to higher stiffness of lower limb which leads to postural instability.

Conclusions
The exercises and the proposed metrics highlighted differences in postural control, hence they can be used in clinical environment for the assessment and progression of postural impairments.

The complete paper shall be sent upon request.

Citation

Background
Stroke survivors show greater postural oscillations and altered muscular activation compared to healthy controls. This results in difficulties in walking and standing, and in an increased risk of falls. A proper control of the trunk is related to a stable walk and to a lower falling risk; to this extent, rehabilitative protocols are currently working on core stability. The main objective of this work was to evaluate the effectiveness of trunk and balance training performed with a new robotic device designed for evaluation and training of balance and core stability, in improving the recovery of chronic stroke patients compared with a traditional physical therapy program.

Methods
Thirty chronic stroke patients, randomly divided in two groups, either underwent a traditional rehabilitative protocol, or a robot-based program. Each patient was assessed before and after the rehabilitation and at 3-months follow-up with clinical and robot-based evaluation exercises focused on static and dynamic balance and trunk control.

Main Results
Results from clinical scores showed an improvement in both groups in balance and trunk control. Robot-based indices analysis indicated that the experimental group showed greater improvements in proprioceptive control, reactive balance and postural control in unstable conditions, compared to the control group, showing an improved trunk control with reduced compensatory strategies at the end of the training. Moreover, the experimental group had an increased retention of the benefits obtained with training at 3 months follow up.

Conclusions
These results support the idea that such robotic device is a promising tool for stroke rehabilitation.

The complete paper is available at the following link:
Citation
A robot-based assessment of trunk control in Spinal Cord Injured athletes

Background
Spinal Cord Injury (SCI) affects trunk control and determines altered or absent neuromuscular activity and sensory feedback below the lesioned spinal segment. The practice of sport or of any physical activity are key elements for improving the health and quality of life of people with SCI. Paralympic athletes overcome limits related to their injuries, achieving high neuromuscular control and coordination. Among the sports that have been adapted for people with disabilities, sit-skiing is a sport that requires good trunk control. However, there is a lack of instruments and protocols for its quantitative assessment. In this work we describe a robot-based protocol designed to assess trunk control and tested with two expert sit-skiers and eight unimpaired subjects.

Methods
We used the robotic platform hunova® to evaluate both the active and the reactive component of trunk control through two different exercises. We investigated the strategy adopted by subjects to perform these exercises and the changes due to their repetition.

Results
All unimpaired subjects successfully completed the proposed protocol. The repetition of both exercises induced a learning process leading to differences in motor performance. Similar results could be observed also in the two athletes, whose performance was characterized by differences due to the severity of their lesion and their skiing skills.

The complete paper shall be sent upon request.

Citation
The use of the robotic device hunova as rehabilitation and evaluation tool for functional balance in individuals with spinal cord injury

Background
Postural control is a very important and basic requirement in daily human life. The robotic device hunova allows to evaluate and practice postural control using different exercises both in upright stance and seated position. While most functional tasks are not isolated to the trunk, the ones that challenge balance and sitting postural control require a high level of trunk control. When trunk control is impaired the development of less effective compensatory strategies is required. Impaired trunk control functional implications are most evident in neurological conditions such as spinal cord injury. This study aims to investigate the use of hunova for the assessment and training of SCI subjects.

Methods
Eight subjects (5M 3F, mean time from disease 12±5.74, mean age 46±10.6 years) in chronic condition, with complete lesion (ASIA A-B) and different level of lesion (between T4 and L1) were enrolled in the study. Evaluation and training sessions were performed with hunova, a new robotic device designed to assist the sensorimotor rehabilitation process and the functional evaluation of lower limbs and trunk. Subjects were evaluated at the beginning (T0) and at the end of the training (T1) with clinical scales (SBASCI scale, Sitting Balance Assessment; SCIM scale, Spinal Cord Independence Measure) and instrumented tests with hunova focused on sitting balance (with a static, unstable and moving seat) and trunk control. Subjects were trained for 20 sessions (3 session/week) with hunova in sitting position; exercises were focused on balance, trunk control, dual-motor-task with movements of the upper limbs, strengthening, core stability. Level of difficulty of the activities was increased across sessions depending on subject’s improvement,

Main results
Subjects with different level of lesion showed different strategies in postural control: in all the evaluated conditions balance performance and trunk control were correlated with the level of lesion. After the training with hunova subjects showed improvements in trunk control measured both by clinical scales and by hunova during active control tasks and balance tasks in seated position. The SBASCI score changed significantly (from 27.8±9.8 to 32.6±9.2, p=0.007), and the trunk oscillation area decreased in both the dynamic sitting balance tests (with unstable (p=0.02) and moving (p=0.01) seat).
Conclusions
Subjects improved in trunk control after the training with hunova. Evaluation results were well correlated with subjects’ clinical conditions and were useful to personalize and tailor the rehabilitation program.

Conference presentations
Leo A., Zarbo M., Cassinis A., Pometto D., Re L., Bianocni T., Gambirasio C., Spinelli M. Ipotesi di utilizzo del device robotico hunova® per la valutazione e il training della persona con lesione midollare. XVIII Congresso Nazionale SIMS (10-12 maggio 2018, Firenze).
Ankle rehabilitation using the high-performance robotic device ARBOT\(^1\): results from a randomised controlled trial

**Background**
Little is known about the effects of robotic training in orthopaedic conditions. A pilot study has been conducted in the INAIL Rehabilitation Center using ARBOT, a prototypal robotic system for ankle rehabilitation that consists of a 2-DOF electromechanical platform able to perform most of the exercises foreseen by the standard rehabilitation programs. The aim of the study was to compare a traditional and a robotic aided rehabilitation training after ankle injuries.

**Methods**
Thirty-two subjects with work related ankle and/or hindfoot fractures were enrolled in this randomized controlled trial after the immobilization phase. Each participant was randomly allocated to the experimental or the control group and received a 4-week rehabilitation program, and weekly robotic and clinical assessments. Subjects in the experimental group were treated using ARBOT with passive, active and active assisted range of motion exercise, resistive exercises in isometric, isotonic, isokinetic, elastic and fluid-dynamic conditions, and proprioceptive training. Control subjects were assisted by a physiotherapist during range of motion recovery exercises and performed resistive and proprioceptive training using Biodex System 3 dynamometer and Prokin PK254 mobile electronic platform. Subjects were evaluated before treatment (T0), after 14 days from the beginning of the treatment (T1), and at the end of the treatment (T2) with functional tests and robotic measures. The assessment session included measurements of dorsiflexion ROM, isometric and isokinetic plantar-flexion torque and proprioceptive performance with ARBOT and 3 minutes walking and timed stair climbing test, LEFS-Lower Extremity Functional Scale and AOFAS-Ankle-Hindfoot Scale.

**Results**
The experimental treatment was well perceived, and no adverse events were recorded. Thirty-one subjects (15 in the experimental group) completed the study. Both groups benefited the proposed training protocol and increased ROM (p<0.0001) and maximum torque in isometric (p<0.001) and isokinetic tests (p<0.001). Functional tests also showed improvements in both groups: the two minutes walking test (p<0.001), the stair climbing test (p=0.01), LEFS (p<0.001) and AOFAS (p<0.001) showed better performance at T1. The experimental group significantly improve in the

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\(^1\) ARBOT is a robotic prototypal device for ankle rehabilitation, from which evolution has been developed hunova. We can consider the robot-aided activities performed with ARBOT for ankle rehabilitation equivalent to those performed with hunova.
proprioceptive test with respect to the control group (time*group interaction p<0.05).

Conclusions
ARBOT demonstrated to be safe, reliable and easy to manage. The obtained results showed that the training with ARBOT was totally comparable to traditional methods. Given the importance of dynamic stability and proprioception in functional recovery and prevention of injuries, significant was the trend in the experimental group of better recovery in movement control and proprioception.

Conference presentations
Proprioceptive and motor training using the high-performance robotic device hunova: preliminary results of a randomized, controlled trial in patients with lower limb post-traumatic conditions

Background
Lower limb trauma can cause kinetic chains impairments that compromise quality of movement and postural stability. A pilot study was conducted in INAIL Rehabilitation Center of Volterra using hunova, a robotic system for lower limbs and core stability training and evaluation, to examine whether robot assisted therapy is effective in motor control and gait performance recovery when compared to conventional rehabilitation programs.

Methods
The ongoing open randomized controlled trial foresees the enrolment of 56 patients with functional locomotor impairments following work-related injury of the lower limbs. So far 44 subjects (mean age 45.34 ± 10.41 years) were enrolled in the study: 22 subjects (19 M, 3 F, mean age 45.86±10.93, 10 with proximal and 12 with distal injury) were in experimental group, 22 subjects (16 M, 6 F, mean age 44.81±10.09, 9 with proximal and 13 with distal injury). Subjects performed 3 weeks of individualized rehabilitation program tailored on specific patient needs and injury characteristics: the experimental group performed a rehabilitation training with hunova, the control group performed a training program using traditional non-robotic equipment. Subjects were evaluated before (T0) and after treatment (T1) with robotic (balance in static and dynamic conditions, reactive balance, limits of stability, proprioceptive test) and clinical (two minutes walking test, Timed up ad go test, one leg stance, lower extremity functional test) evaluations.

Main Results (presented at ISPRM congress)
Robotic therapy was well tolerated and easy to manage; subjects of the experimental group appreciated the treatment with hunova. Both groups improved their dynamic balance (sway area decreased, p=0.02), endurance (the meters walked in two minutes increased, p=0.001), perceived limits of stability (the area of stability increased, p=0.02) and the functional score for the lower extremity (p=0.008). The experimental group significantly improved its performance in the robotic proprioceptive tests (figural error in the drawing task decreased, p=0.03; the number of targets reached in the reaching test increased, p=0.02) with respect to the control group. Looking at the difference between proximal and distal lesions we found that subjects with proximal lesion treated with hunova significantly improved the one leg stance test (p=0.02).
Conclusions
hunova allows to measure significant parameters of static and dynamic stability and can centralize a complex progression of exercises to recover trunk control and reactive balance after traumatic injuries. Training with hunova was as effective as traditional treatment. Relevant is the tendency of the experimental group to a better recovery of the movement control - the capacity to execute dexterity tasks is a fundamental aspect for the functional recovery - and of the one leg stance test - the ability to maintain postural stability while transiently standing on a single limb is essential for normal gait and activities of daily living.

Conference presentations
Evaluation and rehabilitation training with hunova robotic system for the recovery of dynamic postural stability: open randomized interventional protocol, on patients after ACL surgical reconstruction

**Background**
The anterior cruciate ligament (ACL) is strongly stressed during sports activity and is subject to frequent rupture events, often followed by a reconstruction surgery. The purpose of a rehabilitation program, after such an intervention, is to recover the range of movement, strengthen the musculature of the affected limb and stimulate the proprioceptive system, to bring the limb back to similar performance to those prior to the injury. The personalization of the rehabilitation after a ACL reconstruction is fundamental for both a conservative or accelerated approach. For this reason, the purpose of this work is to evaluate the effectiveness of a rehabilitative path mediated by hunova, able to provide, both in static and dynamic conditions, a precise evaluation of performance in terms of stability and balance in both bipodal and monopodalic standing. In addition, in the present work, hunova has been tested as a tool for proprioceptive, neuromotor and muscle strengthening training. The results of the assisted robot treatment are compared with those of the treatment conventionally provided by the structure.

**Methods**
In the current randomized controlled trial, 10 people have been enrolled to date out of the 44 expected and were randomly assigned to one of two study groups: experimental group (S, 5 subjects) and the control group (C, 5 subjects). During the 8 weeks of therapy the subjects of the experimental group performed with hunova exercises reinforcement, balancing, proprioceptive and core stability. The subjects of the control group have performed similar exercises but with the following tools traditional (tablets, Bobath ball). The protocol requires that each participant undergoes an evaluation session at the beginning of the treatment (T0) and one at the end of the course (T1). With hunova, patients performed static and elastic balance tests in standing station in bipodalic (T0, T1) and monopodalic (T1, both limbs) support, dexterity tests measured as the ability of the patient in moving the platform to reach targets and the stability limit test.

**Preliminary results**
The results have shown that robotic rehabilitation after surgical ACL reconstruction has been well tolerated and appreciated. A preliminary analysis of the sample of 10 patients shows that both the control group and the experimental group benefited from the proposed rehabilitation protocol and the robotic type therapy was equally effective as the conventional type.
Conclusions
The hunova device has proven to be safe, easy to use, as effective as conventional treatment and highly efficient, supporting with its functions all programs of joint mobilization, muscle work and proprioceptive recovery that in the control group required the manual intervention of the physiotherapist and the use of multiple non-robotic tools and instrumentation. hunova has effectively supported the work of the physiotherapist, optimizing the planning of treatment programs and allowing to modulate the training according to the patient's improvements.


Conference presentations
The new era of rehabilitation is now