



# Summary of Clinical Research

## AlterG® Anti-Gravity Treadmill™ Technology

January 2019

At AlterG we are committed to proper scientific investigation of the potential clinical and athletic performance benefits of using our device. We are pleased to have multiple studies in clinically relevant areas currently underway by independent researchers at highly reputable institutions in the U.S. and internationally.

Due to the large expansion of the number of installed Anti-Gravity Treadmill™ devices worldwide, many independently produced studies are proceeding without the knowledge of our company. We encourage researchers to make us aware of concluded studies for inclusion in future Research Summaries.

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## What is Differential Air Pressure (DAP) Technology?

Differential Air Pressure (DAP) is a pressurized, variable lifting force using air to decrease the impact of gravitational forces and body weight during walking, running, or exercise. Patented DAP utilizes a special air chamber and an advanced calibration system to uniformly reduce gravitational load for unweighting users from 100% to as low as 20% of body weight (BW) in precise 1% increments – creating a body weight supported environment without impeding natural gait mechanics.

These early studies specifically using patented AlterG DAP technology show that the technology is:

- Capable of accurate, precise and consistently safe unweighting across a variety of body types and throughout dynamic aspects of the gait cycle.
- Comfortable and safe for most individuals, including those with stable cardiac, vascular, and respiratory disorders.
- Able to reduce ground reaction force (GRF) for walking and running in proportion to the amount of unweighting.
- Effective in reducing pain in individuals whose lower extremity symptoms are related to full weight bearing ambulation or exercise.

Studies within the following patient populations highlight the Anti-Gravity Treadmill™ technology benefits and are detailed on the following pages:

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#### **BASIC SCIENCE** | Page - 3

- Ground reaction forces are reduced at all levels of weight support.
- Surface electromyography (EMG) electrode activity shows that muscle firing patterns and gait mechanics are maintained for all levels of weight support and speeds.
- With less ground reaction force from body weight support, muscles working in the Anti-Gravity Treadmill need not work as hard to attenuate forces, resulting in less muscle strain and increased safety for a patient not at full strength capacity.

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#### **CARDIAC** | Page - 9

- No significant change in heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure.
- Enable those that are deconditioned to get cardiovascular exercise.
- Allow those that have lower extremity pain to participate in a treadmill stress test.

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#### **GERIATRIC** | Page - 11

- Safe gait training to work on cardiovascular endurance.
- Improved walking speed and gait kinematics to assist with fall-risk reduction.
- Improved balance, mobility, lower extremity strength.

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#### **NEUROLOGIC** | Page - 13

- Safe and effective gait training allows for higher repetition of task-specific skills.
- Improved gait kinematics possibly highlighting better motor learning due to longer periods of massed practice.
- Gait and functional improvements are seen in several adult neurologic conditions such as Parkinson's Disease, Cerebral Palsy, Cerebrovascular Accidents, Traumatic Brain Injury.

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#### **ORTHOPEDIC** | Page - 18

- Decreased pain to lower extremities post-injury/post-operatively.
- Early initiation of closed-kinetic activities and restoration of gait mechanics.
- Effective for encouraging walking/exercise and managing pain for those with knee osteoarthritis.
- Incorporation into post-operative protocols (achilles repair, meniscus repair, microfracture, ACL reconstruction, TKA, THA) to encourage progressive loading/return to full weight bearing.

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#### **SPORTS/PERFORMANCE TRAINING** | Page - 24

- For any given amount of walking or running speed, weight support reduced metabolic demand for the individual.
- Enabling appropriate cardiovascular training intensity for individuals who are overweight, obese or injured can be achieved by reducing ground reaction forces.
- Effective tool for Overspeed or HIIT training.
- Assisting with return to athletic performance post-injury and training with decreased load to prevent injury.

# Basic Science

## Published

### **Coactivation of Lower Leg Muscles During Body Weight Supported Treadmill Walking Decreases with Age in Adolescents**

Deffeyes, J., Stuberg, W., Karst, G., Kurz, M.: Perceptual and Motor Skills. 2012 Aug;115(1):241-60.

- Coactivation was found to be higher in adolescents than in adults, but only for the lower leg muscles.
- Results show the importance of using age-matched controls in adolescent studies of pathologic agonist/antagonist coactivation of lower leg muscles during walking.

### **Effects of Velocity and Weight Support on Ground Reaction Forces and Metabolic Power During Running**

Grabowski, A., Kram, R.: Journal of Applied Biomechanics 24:288-297, 2008.

- As runners increase velocity, the GRF and metabolic power required to produce greater muscular forces increase, posing great risk of overuse injury.
- Running with weight support decreases GRF forces, but also reduces the metabolic forces used for normally weighted running.

- Running in the Anti-Gravity Treadmill with weight support at fast velocities can reduce impact of peak vertical GRFs, but still maintain aerobic stimulus, providing unique lower-body positive pressure to assist people in training or rehabilitation.
- Running kinematics are much more similar to normal overground running than are water running kinematics.

### **Metabolic and Biomechanical Effects of Velocity and Weight Support Using a Lower Body Positive Pressure Device During Walking**

Grabowski, A.: Archives of Physical Medicine and Rehabilitation, 91:951-957, 2010.

- Study uses similar methods to the running study by Dr. Grabowski referenced above but now focusing on individuals during walking.
- Proof of basic principles during walking is very important for the post-injury, post-operative, and other groups who would not be expected to run on the Anti-Gravity Treadmill.
- Many combinations of velocity and BW resulted in similar aerobic demands, yet walking faster with weight support lowered peak GRFs compared to normal weight walking.

- Manipulating velocity and weight support during walking with the Anti-Gravity Treadmill may be a highly effective strategy for rehabilitation, recovery following surgery and gait re-training.

### **Influence of Lower Body Pressure Support on the Walking Patterns of Healthy Children and Adults**

Kurz, M., Deffeyes, J.E., Karst, G.M.: Journal of Applied Biomechanics, 2012 Nov; 28(5):530-4.

- Lower extremity joint angles and activity of the lower extremity extensor anti-gravity muscles of children did not differ from those of adults.
- Lower body positive pressure support resulted in reduced activation of the extensor anti-gravity musculature, and reduced range of motion of the knee and ankle joints.
- Magnitude of changes in the lower extremity joint motion and extensor anti-gravity muscle activity was dependent upon an interaction between body weight support and walking speed. Generally speaking, for any given amount of body weight support, knee and ankle joint ranges of motion are smaller with slower walking speeds.

- Amount of body weight support is used as a target for the patient's body weight reduction.

### **Determination of Muscle Activity During Running at Reduced Body Weight**

Liebenberg, J., Scharf, J., Forrest, D., Dufek, J.S., Masumoto, K., Mercer, J.A.: Journal of Sports Sciences 29(2): 207-214, 2011.

- Reducing BW leads to a reduction in muscle activity with no changes in muscle activity patterns.
- Training with body weight support may provide benefits of decreasing overuse injuries for runners.

### **Accuracy of Unloading With the Anti-Gravity Treadmill**

McNeill, David K.P., deHeer, Hendrik D., Bounds, Roger G., Coast, J.R.: Journal of Strength Conditioning Research. 2015 Mar; 29(3): 863-8.

- There is less than 5% difference between predicted and actual unloading with the most commonly used body weight unloading percentages from 90% to 40%.

### **Muscle Activity During Running With Different Body-Weight Support Mechanisms: Aquatic Environment Versus Body-Weight-Support Treadmill**

Mercer, J.A., Applequist, B., Masumoto, K.: Journal of Sports Rehabilitation 2014 Aug; DOI: 10.1123/JSR.2013-0032.

- Muscle activation in water is dependent on running style.
- No difference in muscle activation of gastroc and tibialis anterior with any deep water running style vs. AlterG Anti-Gravity Treadmill.
- No difference in muscle activation of rectus femoris in deep water running with high knee style and AlterG Anti-Gravity Treadmill.

### **Simulations of Gravitational Stress on Normo- and Hypovolemic Men and Women**

Zhang, Q., Evans, J.M. et al.: Aviat Space Environ. Med 85(4) 407-413.doi: 10.3357/ASEM.3828.2014

- Investigated cardiovascular responses to lower body positive pressure for Mars and Moon gravities.
- Cardiovascular responses were predictable and consistent for normovolemic and hypovolemic subjects.

- AlterG Anti-Gravity Treadmill is a suitable modality to study cardiovascular effects in reduced gravity.

### **Utilization of the Anti-Gravity Treadmill in a Physical Activity Program with Female Breast Cancer Survivors: A Pilot Study**

Fairman, C.M., Kendall, K.L., Harris, B.S., Crandall, K.J., McMillan, J.: International Journal of Exercise Science. 2016: 9(1): 101-109.

- Six female breast cancer survivors attended three 60-min sessions per week of muscular strength/endurance and cardiovascular endurance exercises.
- Improvements in cardiovascular endurance and body composition were observed.
- Use of the Anti-Gravity Treadmill may provide practical and meaningful improvements in physiological and psychological variables in breast cancer survivors.
- The AlterG Anti-Gravity Treadmill can be used as an enabler of exercise in multiple clinical rehabilitative situations to provide practical and meaningful improvements in measures of cardiovascular endurance and body composition.

## **Presented**

### **The Effect of Simulated Anti-Gravity on Muscle Activity**

Applequist, B, Mercer, J.A.: (University of Nevada, Las Vegas) Presented at Southwest Meeting of ACSM, San Diego, CA, October 2009.

- Joint loads are reduced at the knee and ankle, with knee reduced slightly more than the ankle (data estimated).
- Surface EMG activity reveals reduced muscle contraction amplitudes with weight support; quadriceps and gastroc/soleus are reduced more than hamstrings and tibialis anterior.

### **Muscle Activity During Running at Reduced Body Weight**

Forrest, Dana M., Dufek, J.S., Masumoto, K., Mercer, and J.A.: (University of Nevada, Las Vegas) Presented at American College of Sports Medicine Annual Meeting, Indianapolis, IN, May 2008.

### **Muscle Activity During Running at Reduced Body Weight**

Liebenberg, J., Scharf, J., Forrest, D., Dufek, J., Mercer, J.A.: Presented at Southwest Meeting of ACSM, San Diego, October 2009.

### **Effects of Lower Body Positive Pressure on Muscle Activity and Joint Loads**

Jensen, B.R., Hovgaard-Hansen, L., Cappelen, K.L.: University of Copenhagen, Denmark. Presented at The International Society of Biomechanics meeting, South Africa, July 2009.

- Ground reaction forces are reduced for running with weight support.
- Running mechanics are maintained with weight support.
- Surface EMG activity reveals normal muscle firing patterns during running.
- Muscle EMG peak amplitude is decreased with reduced body weight but can be maintained with increased running speed.
- Pressure inside the AlterG does not change muscle-firing patterns by itself.

- Vertical ground reaction forces are decreased with weight support, but horizontal ground reaction forces are maintained, thus leading to normal gait patterns at all levels of support.
- Maintained horizontal ground reaction forces are most likely responsible for the normal gait patterns seen with all levels of weight support.

## **Muscle Activity During Different Body-Weight Support Mechanisms**

Mercer, J.A., and Masumoto, K.:  
Presented at ACSM Annual Meeting, San Francisco, CA, May 2012.

- Gastroc/soleus and tibialis anterior activity are unchanged with deep water running and AlterG.
- Rectus femoris activity is higher with high-knee running in deep water but is not different from AlterG with cross-country running style.

## **Effect of Unweighting Using the AlterG Trainer on VO<sub>2</sub>, Heart Rate, and Perceived Exertion**

Yates, J.W., Mohny, L.E., Abel, M.G., Shapiro, R.: Presented at American College of Sports Medicine, Denver, CO, July 2011.

- Understand both the independent and interaction effects of un-weighted ambulatory activity at a range of treadmill velocities and grades on VO<sub>2</sub>, HR, and RPE.
- Assisted treadmill devices are used as a rehabilitative modality to decrease the mechanical and physiological stress placed on the patient. The AlterG Anti-Gravity Treadmill, used as a rehabilitative modality uses lower body positive pressure to unload subjects thereby decreasing mechanical and physiological stress on the body.

## **Premarketing Studies**

### **Partial Body Weight Support Using Air Pressure: Safety and Unloading**

Buckley, E.L., Bugar, C.G., Cao, Y., Schwandt, D.F.: Second National Department of Veterans Affairs Rehabilitation Research and Development Conference Proceedings, 2000.

- Understand the use of the Anti-Gravity Treadmill for supported gait training to restore ambulation in various patient populations.
- Explores the physiological effects of walking in the Anti-Gravity Treadmill to define the relationship among intra-chamber pressure, body size, and ground reaction forces.

### **Differential Walking Assist: An Inflatable Walking Support**

Bugar, C.G., Schwandt, D., Anderson, J., Whalen, R., Breit, G.: Rehabilitation R&D Center Progress Report, 1994.

- Investigate lower body differential pressure chambers and application of differential pressure to exercise in space, and to simulate hypo- and hyper-gravity locomotion.
- Lower body positive pressure is a comfortable way to reduce the effects of gravitational forces.

### **Ambulation in Simulated Fractional Gravity Using Lower Body Positive Pressure: Cardiovascular Safety and Gait Analyses**

Cutuk, A., Groppo, E.R., Quigley, E.J., White, K.W., Pedowitz, R.A., Hargens, A.R.: Journal of Applied Physiology 101: 771-777, 2006.

- Assess cardiovascular responses to lower body positive pressure (LBPP) and to examine the effects of LBPP unloading on gait mechanics during treadmill ambulation.
- First such study to examine LBPP effects on cephalic and systemic cardiovascular parameters and to quantify the anti-gravity and gait effects of LBPP during upright standing, walking, and running.

- Findings pointed to lower body positive pressure exercise is effective at reducing ground reaction forces, while safely facilitating gait post-operatively.

### **Lower Body Positive-Pressure Exercise after Knee Surgery**

Eastlack, R.K., Hargens, A.R., Groppo, E.R., White, K.K., Pedowitz, R.A.: Clinical Orthopaedics & Related Research. 431:213-219, February 2005.

- Study of lower body positive pressure rehabilitation and impacts to gait mechanics and pain in post-operative arthroscopic meniscectomy or anterior cruciate ligament reconstruction patients.

# Cardiac

## Published

### **The Effect of Lower Body Weight Support on Arterial Wave Reflection in Healthy Adults**

Afzal, A., Galligan, S., Kral, J.G., Lazar, J., Saliccioli, L.: Journal of the American Society of Hypertension 8(6) (2014) 388–393.

- Studied cardiovascular responses to AlterG body weight support in 25 healthy males as a prelude to future studies in heart failure patients.
- Heart rate decreased, mean arterial pressure unchanged, systolic pressure unchanged, diastolic pressure slight but not significant decrease.

### **Feasibility and Safety of Exercise Stress Testing Using an Anti-Gravity Treadmill with Tc-99m Tetrofosmin Single-Photon Emission Computed Tomography (SPECT) Myocardial Perfusion Imaging: A Pilot Non-Randomized Controlled Study**

Daly, P., Kayse, R., Rudick, S., Robbins, N., Scheler, J., Harris, D., O'Donnell, R., Dwivedi, A.K., Gerson, M.C.: Journal of Nuclear Cardiology. 2017 Aug 31.

- Exercise is the AHA/ACC guideline-recommended stress modality for myocardial perfusion imaging.
- Many patients are unable to exercise to target heart rate on a conventional treadmill.

- 17 patients were able to reach target heart rate on the AlterG Anti-Gravity Treadmill, obviating the need for a pharmacologic stress agent.
- Stress testing using an Anti-Gravity Treadmill is feasible and may help some patients achieve target heart rate.

### **Cardiovascular Regulation During Body Unweighting by Lower Body Positive Pressure**

Evans, J.M., Knapp, C.F., Mohney, L., Wang, S.: Aviation Space and Environmental Medicine November 2013, 84:1140-1146.

- Investigated specific role of sympathetic control of cardiovascular function with lower body positive pressure.

### **Segmental Volume and Cardiovascular Responses to Changes in Body Position at Rest and During Walking Under Normal and Reduced Weight Conditions**

Evans, J., Shapiro, R., Moore, F.: Journal of Gravitational Physiology, 2011.

- Authors also measured pressure in mmHg at various body weight reductions for each subject.

- Pressure required will of course vary by subject's weight and body mass, but roughly 30-40mm Hg pressure is needed for a 20% reduction in body weight.
- Fluid shifts from the legs to the abdomen and thorax with lower body positive pressure support.
- Slight increase in systolic blood pressure, no change in diastolic blood pressure, slight decreases in heart rate, all of which can be expected with the fluid shift.
- The hypothesis in this large randomized study is that patients scheduled for pharmacologic testing may be able to perform exercise-based testing on the Anti-Gravity Treadmill, enabling the cardiologist to have a better measurement of cardiac risk.

## Current

### Cardiac Stress Testing

- In urban U.S., cardiac testing centers it is estimated that about 50% of individuals referred for testing are clinically obese, and a substantial portion of those patients are unable to perform standard modified Bruce protocol cardiac stress testing.
- Current methods call for those patients unable to do standard testing to go through pharmacologic testing, however, it is widely accepted that pharmacologic testing is not as accurate or reliable as exercise-based testing.

# Geriatric

## Published

### **Anti-Gravity Treadmill Can Promote Aerobic Exercise For Lower Limb Osteoarthritis Patients**

Kawae, T., Mikami, Y., Fukuhara, K., Kimura, H., Adachi N.: Journal of Physical Therapy Science 29:1444-1448, August 2017.

- Anti-Gravity Treadmill allows for lower extremity load to be adjusted, which is useful for those with lower limb OA.
- 20 subjects with lower limb OA walked eight minutes naturally, then eight minutes on the Anti-Gravity Treadmill.
- Pain after walking was significantly greater with walking on level ground versus in the Anti-Gravity Treadmill.
- Subjects were able to tolerate faster walking speeds in the Anti-Gravity Treadmill versus level ground walking.

### **Effect of Body Weight-Supported Exercise on Symptoms of Knee Osteoarthritis: A Follow-up Investigation**

Peeler, J, Leiter, J., MacDonald, P.: Clinical Journal of Sports Medicine, 2018, October.

- Study examines long-term effect of participation in a 12-week lower body positive pressure (LBPP)-supported low-load treadmill exercise regime on knee joint pain, physical function, and thigh muscle strength in patients with knee osteoarthritis.
- Knee pain, function, thigh muscle strength, and body anthropometry were reassessed six months after completion of the initial exercise regime and compared with results from baseline and post exercise evaluation.
- Data shows improvements in knee pain, joint function, and thigh muscle strength associated with participation in a 12-week LBPP-supported low-load exercise regime were maintained well after cessation of the program.

### **Cardiovascular Responses in Older Adults With Total Knee Arthroplasty at Rest and With Exercise on a Positive Pressure Treadmill**

Webber, S., Horvey, K., Yurach, M., Butcher, S.: European Journal of Applied Physiology 2014 114:653-662.

- Observational study of cardiovascular responses to Anti-Gravity Treadmill exercise after unilateral total knee arthroplasty (TKA).
- Demonstrated cardiovascular safety of Anti-Gravity Treadmill exercise in this population.

- Older adults with TKA demonstrated lower heart rate, systolic blood pressure, oxygen consumption and minute ventilation levels when walking under lower body positive pressure conditions.
- The Anti-Gravity Treadmill exercise enabled TKA patients to walk at faster speeds and/or to tolerate greater incline that may be important in the rehabilitation of these patients.

## Presented

### **Does Lower Body Positive Pressure Support (LBPPWS) Gait Training On The AlterG Affect Urinary Urgency?**

Tanza, S., Byl, N., Garcia, M., Presented at: Annual meeting of the California Chapter of the American Physical Therapy Association, September 21-24, 2011, Long beach, CA.

- 16 healthy individuals between ages 23-69 were studied using a VAS for urinary urgency during and exercise session on the AlterG.
- Body weight was incrementally decreased to 80%, and then increased back up to 100%.
- 100% of subjects experienced urinary urgency with weight support.
- 87.5% continued to have some urgency as weight support was removed.
- Researchers speculate that Anti-Gravity Treadmill training might be beneficial in training for better bladder control for individuals with a history of stress incontinence or urgency.

### **The Effects of Lower Body Positive Pressure Treadmill Training on Balance, Mobility and Lower Extremity Strength of Community Dwelling Older Adults**

Lazaro, R., Raymond, G., Chun, J., Spencer, B., Megazzi, A., Siegel, E., Schempp, A.: Presented at the Annual Meeting of the California Physical Therapy Association, Santa Clara, CA, Sept. 28-29, 2012.

- Ten healthy women, average age 70, participated in an eight week anti-gravity exercise study.
- All women in this series demonstrated improvements in balance, mobility, and lower extremity strength.
- This study provides the foundation for follow-on studies focused on specific physical impairments.

# Neurologic

## Published

### **Anti-Gravity Training Improves Walking Capacity and Postural Balance In Patients With Muscular Dystrophy**

Berthelsen, M.P., Husu, E., Christensen, S.B., Prahm, K.P., Vissing, J., Jensen, B.R.: Neuromuscular Disorder, 2014.

- Prospective training program for severely affected muscular dystrophy patients who are unable to do conventional exercise due to weakness.
- Improvements in walking distance and dynamic postural balance in all patients.
- Supported use of AlterG Anti-Gravity Treadmill as a safe and effective training modality for severely affected individuals with muscular dystrophy.

### **Effects of Lower Body Positive Pressure Treadmill Training on Dynamic Balance of Children with Cerebral Palsy**

Dadashi, F., Kharazi, M.R., Lotfian, M., Shahroki A., Mirbagheri, A., Mirbagheri, M.M.: Engineering in Medicine and Biology Society, 2018 Jul: 2487-2490.

- Study follows four CP children: two received Anti-Gravity Treadmill training three times a week for eight weeks and two received occupational therapy.

- Results showed that maximum velocity and acceleration of the COP and COM, the average variability (RMS) and peak to peak of the COM-COP separation, and RMS of velocity and acceleration of the COM and COP were all improved for both anti-gravity training patients (15-90%).
- There was a limited improvement of 0.2-24% in some features of the control patients.
- Results demonstrate that intensive sessions of the training program could have the potential to be used as a therapeutic tool that can produce dynamic balance improvements in CP children compared to that of typical occupational therapy.

### **Aerobic Anti-Gravity Exercise in Patients with Charcot-Marie Tooth Disease Types 1A and X: A Pilot Study**

Knak, K., Andersen, L.K., Vissing, J.: Brain and Behavior. November 2017 2; 7(12).

- Five adult patients with CMT performed moderate intensity aerobic exercise in the Anti-Gravity Treadmill three times per week for ten weeks.
- Significant positive difference in Berg balance scale and postural stability test.
- Walking distance in six-minute walk test increased.

- Study indicates that the Anti-Gravity Treadmill training of patient with CMT should be pursued in larger CMT cohorts.

### **Body Weight Supported Treadmill Training Improves the Regularity of the Stepping Pattern in Children with Cerebral Palsy**

Kurz, M., Stuberg, W., DeJong, S.L.: Developmental Neurorehabilitation, 2011; 14(2):87-93.

- The Anti-Gravity Treadmill improved the rhythmical control of the stepping kinematics, preferred walking speed, step length and gross motor function score.
- The improvements in the regularity of the stepping kinematics were strongly correlated with changes in the preferred walking speed, step length and gross motor function score.

### **Therapeutic Effects of Anti-Gravity Treadmill (AlterG) Training on Reflex Hyper-excitability, Corticospinal Tract Activities, and Muscle Stiffness in Children with Cerebral Palsy**

Parvin, S., Taghiloo, A., Irani, A., Mirbagheri, M.M., IEEE International Conference Rehabil Robot. 2017 Jul;2017:485-490

- The study aimed to understand the therapeutic effects of Anti-Gravity Treadmill training on reflex hyper-excitability, muscle stiffness, and

corticospinal tract (CST) function in children with spastic hemiplegic cerebral palsy (CP).

- Three children received Anti-Gravity Treadmill training 3 days per week for 8 weeks as experimental group.
- One child as control group received typical occupational therapy for the same amount of time.
- Findings from the study indicate that Anti-Gravity Treadmill training can improve reflexes, muscle stiffness, and CST activity in children with spastic hemiplegic CP and can be considered as a therapeutic tool to improve neuromuscular abnormalities occurring secondary to CP.

### **Evaluation of Lower Body Positive Pressure Supported Treadmill Training for Children with Cerebral Palsy**

Kurz, M., Corr, B., Stuberg, W., Volkman, K., Smith, N.: Pediatric Physical Therapy, 2011 Fall; 23(3): 232-9. PubMed PMID: 21829114.

- LBPPS (Lower Body Positive Pressure Supported) treadmill training resulted in significant changes in walking spatiotemporal kinematics and balance.

- After training, the children had a faster preferred walking speed, spent less time in double support, more time in single support, had improved overall balance, and improved walking balance.
- Furthermore, there was a trend for increased strength of the lower extremity anti-gravity musculature.
- LBPPS treadmill training utilizing the Anti-Gravity Treadmill is an effective treatment for improving the walking biomechanics and balance of children with CP.
- The Anti-Gravity Treadmill offered other advantages over conventionally used harness systems and was very well accepted by the children.

### **Neuromagnetic Activity of the Somatosensory Cortices Associated with Body Weight-Supported Treadmill Training in Children with Cerebral Palsy**

Kurz, M.J., Wilson, T.W., Corr B, Volkman, K.G.: Journal of Neurological Physical Therapy. 2012 Dec; 36(4):166-72.

- Neuromagnetic source amplitudes were attenuated after BWSTT and were accompanied by faster walking speeds and improved lower extremity strengths.

- BWSTT sensorimotor experience may result in neuroeconomical changes that reduce cortical processing demands in children with CP.
- Neuroplastic changes may be related to the parallel changes in the walking performance and lower extremity strength of children with CP.

### **Pressure-Controlled Treadmill Training in Chronic Stroke: A Case Study With AlterG**

Lathan, C., Myler, A., Bagwell, J., Powers, C.M., Fisher, and B.E.: Journal of Neurologic Physical Therapy, 2015 Apr; 39(2): 127–133.

- Case study of 81-year-old man, 14 months post stroke with poor ambulation and balance who trained four times per week for four weeks.
- Improved walking speed, stride length, walking kinematics, and reduced fall risk.
- Considerable variability in functional status for individuals post-acute or chronic stroke.
- The Anti-Gravity Treadmill has gained wide acceptance among neurologic therapists for its ability to allow ambulatory exercise in a secure fall-safe environment.

## **Aerobic Anti-Gravity Exercise in Patients with Charcot-Marie-Tooth Disease Types 1A and X: A Pilot Study**

Knack, K.L., Andersen, L.K., Vissing, J.: Brain Behavior, November 2017.

- Charcot-Marie-Tooth (CMT) disease is a hereditary neuropathy associated with impaired walking capacity because patients present with weak lower extremity muscles to walk at gravity with sufficient intensity or duration to gain benefit.
- Five adult patients performed moderate-intensity aerobic anti-gravity exercise three times per week for ten weeks, to understand the effect of aerobic anti-gravity exercise in weak patients with CMT 1A and X.
- There was a significant positive difference in Berg balance scale and postural stability test between test occasions, and walking distance in the Six-minute walk test trended to increase.

### **Presented**

## **The Impact of an Anti-Gravity Treadmill (AlterG) Training on Walking Capacity and Corticospinal Tract Structure in Children with Cerebral Palsy**

Azizi, S., Marzbani, H., Raminfard, S., Birgani, P.M., Rasooli, A.H., Mirbagheri, M.M.: Presented at 39th Annual International Conference of the IEEE, July 2017.

- Children with CP were given an AlterG training program for 45 min, three times per week for two months.
- Neuroplasticity of the corticospinal tract was evaluated using Diffusion Tensor Imaging (DTI).
- Outcome measures presented enhanced walking capacity of subjects.
- Improved walking capacity was concurrent with enhancement of corticospinal tract structure.
- AlterG training may be considered as a therapeutic tool for gait improvement in children with CP.

## **Can an Anti-Gravity Treadmill Improve Stability of Children with Cerebral Palsy?**

Birgani, P.M., Ashityani, M., Rasooli, A., Shahrokhnia, M., Mirbagheri, M.M., Engineering Biology Society, 2016 Aug;2016:5465-5468

- Study aimed to evaluate the effects of Anti-Gravity Treadmill training on balance and postural stability in children with Cerebral Palsy.
- Training was performed three days per week for eight weeks, with up to 45 minutes of training per session.

- Subjects were evaluated for balance and postural stability was evaluated based on the Romberg test that was performed by using a posturography device.
- Results indicated that balance features were improved substantially after training.
- The clinical implication is that the Anti-Gravity Treadmill has the potential to effectively improve postural stability in children with cerebral palsy.

### **Maintaining Safe Mobility in Patients with Parkinson's Disease: One-Year Outcomes of Dual Task Training Under Aerobic and Moderate Exercise**

Byl, N., Cox, L., Forte, A., Fedulow, I., Ide-Don, J.: Presented at International Movement Disorders, San Francisco, May 2010.

- Significant gains were made in mobility, bilateral lower extremity strength, fall reduction and depression.

### **Influence of Positive Air Pressure Body-Weight Support On Parkinsonian Gait**

Lander, J.J., Moran, M.F.: Presented at Gait and Clinical Movement Analysis Society, 2014.

- Single ten-minute training session for Parkinson's patients on the AlterG Anti-Gravity Treadmill.
- Performed as proof of concept prior to prospective training study.
- Improvements seen in step length, cadence and velocity.

## **Current**

### **Parkinson's Disease Randomized Clinical Trial – University of California, San Francisco**

- Does exercise on the AlterG improve functional indices, fall risk, and quality of life for patients with mild to moderate Parkinson's disease?
- Does exercise on the AlterG improve functional indices, fall risk, and quality of life for patients with acute and chronic stroke?
- Parkinson's Disease Randomized Clinical Trial – University of Copenhagen
- Denmark Muscular Dystrophy Training Study- University of Copenhagen, Denmark
- Multiple Sclerosis Randomized Clinical Trial- Tel Aviv, Israel

# Orthopedic

## Published

### **Use of an Anti-Gravity Treadmill for Early Postoperative Rehabilitation After Total Knee Replacement: A Pilot Study to Determine Safety and Feasibility**

Bugbee, W.D., Pulido, P.A., Goldberg, T., D'Lima, D.D.: American Journal of Orthopedics. 2016 May-Jun;45(4):E167-73.

- To determine the safety, feasibility, and effects of anti-gravity gait training on functional outcomes Knee Injury and Osteoarthritis Outcome Score (KOOS), the Timed Up and Go test (TUG), Numerical Rating Scale (NRS) for pain with the AlterG Anti-Gravity Treadmill device for Total Knee Arthroplasty (TKA) rehabilitation.
- For the Anti-Gravity Treadmill group, Sports/Recreation and Quality of Life subscales of the KOOS had the most improvement. At the end of physical therapy, TUG and NRS pain scores improved from 14 seconds to 8 seconds and from 2.8 to 1.1, respectively.
- This initial pilot study demonstrated that the Anti-Gravity Treadmill device was safe and feasible. While functional outcomes improved over time with use of the anti-gravity gait training, further studies are needed to define the role of this device as an alternative or adjunct to established rehabilitation protocols.

- The Anti-Gravity Treadmill is particularly effective after total knee replacement to reduce pain, improve exercise compliance, and improve early function (first three post op months).

### **Managing Knee Osteoarthritis: The Effects of Anti-Gravity Treadmill Exercise on Joint Pain and Physical Function**

Christian, M.: University of Manitoba Master's Thesis Dissertation, August 2012.

- 25 obese adults with moderate knee osteoarthritis pain participated in a 12-week Anti-Gravity Treadmill exercise program, twice a week for 25 minutes each session.
- A mean level of 17.9% LBPP (i.e. 16.1 kg) was effective in reducing knee joint pain during initial walking.
- Strength levels for the quadriceps and hamstring muscle groups increased significantly following the 12-week program.
- Significant improvements were found in all KOOS subscales, indicating a reduction in knee OA symptoms and improvement in functional abilities.
- Knee pain during walking significantly decreased, with some participants experiencing complete pain relief.

- Pain was reduced to a point where the addition of LBPP support was no longer required to reach minimal pain levels.

### **Body Weight Independently Affects Articular Cartilage Catabolism**

Denning, W.M., Winward, J.G., Pardo, M.B., Hopkins, J.T., Seeley, M.K.: Journal of Sports Science and Medicine (2015) 14, 290-296.

- Study measures serum cartilage oligomeric matrix protein (COMP) - a measure of cartilage catabolism.
- Participants were measured at their baseline unloaded condition, others were measured with a weighted vest adding 40% body weight, and others were measured on the Anti-Gravity Treadmill at -40% body weight.
- Cardiovascular responses were also measured through heart rate and perceived exertion and changes to COMP were noted immediately during exercise.
- Walking with unadjusted BW and increased BW resulted in measureable articular cartilage catabolism (via serum COMP); however, walking with decreased BW did not.

- The Anti-Gravity Treadmill body weight support for walking may potentially benefit individuals who wish to simultaneously minimize knee joint load and maintain cardiovascular response.

### **Return to Running Following Knee Osteochondral Repair Using an Anti-Gravity Treadmill: A Case Report**

Hambly, K., Poomsalood, S., Mundy, E.: Physical Therapy in Sport, Volume 26, July 2017 35-40.

- 39 year-old female endurance runner s/p arthroscopic microfracture surgery.
- The Anti-Gravity Treadmill was used to manipulate load during return to running progression over eight weeks.
- Program resulted in improved knee and rehabilitation self-efficacy and subjective knee function.
- Highlights potential role for the Anti-Gravity Treadmill in enhancing self-efficacy and subjective knee function in preparation for return to sport.

### **Use of Partial Body-Weight Support for Aggressive Return to Running After Lumbar Disk Herniation: A Case Report**

Moore, M.N., Vandenakker-Albanese, C., Hoffman, M.: Archives of Physical Medicine and Rehabilitation 2010;91:803-805.

- A highly motivated physician/runner successfully used AlterG training within one week of an acute lumbar disc herniation when he was experiencing considerable pain with unsupported walking and lower extremity weakness.
- He continued use until he adequately improved, allowing return to regular over-ground running program.
- Demonstrates how partial body-weight support can allow aggressive running training early after a lumbar disc injury when normal impact forces cannot be tolerated and when leg weakness is a limitation.

### **Antigravity Treadmills Are Effective In Reducing Knee Forces**

Patil, S., Steklov, N., Bugbee, W.D., Goldberg, T., Colwell Jr., C.W., D'Lima, D.: Journal of Orthopedic Research. 2012 Dec 13.

- Direct correlation between knee joint vertical reaction force as a function of the Anti-Gravity Treadmill body weight support, treadmill speed, and incline.
- Jogging at 4.5mph with 50% body weight support provides the same vertical knee joint reaction force as walking with full body weight.
- The Anti-Gravity Treadmill body weight supported activity is placed within the context of other daily and sports activities previously studied by the authors.

### **Managing Knee Osteoarthritis: The Effects of Body Weight Supported Physical Activity on Joint Pain, Function, and Thigh Muscle Strength**

Peeler, J., Christian, M., Cooper, J., Leiter, J., MacDonald, P.: Clinical Journal Sport Medicine 2015 Jan 30. Nov;25(6):518-23.

- 12 week prospective non-randomized clinical trial.
- Participants reported significant improvements in knee joint pain and function and demonstrated significant increases in thigh muscle strength.
- Significant reductions in acute knee pain during full weight bearing treadmill walking and required dramatically less LBPP support to walk pain free on the treadmill over time.
- LBPP-supported low-load exercise regimen can be used to significantly diminish knee pain, enhance joint function, and increase thigh muscle strength, while safely promoting pain-free walking exercise in overweight patients with knee OA.

## **The Effect of Low-Load Exercise on Joint Pain, Function, and Activities of Daily Living In Patients with Knee Osteoarthritis**

Peeler, J., Ripat, J.: The Knee, 2018 Jan 8.

- Knee Osteoarthritis has a lifetime risk of nearly one in two.
- Exercise is universally recognized as a critical component in management.
- Unsafe or ineffective exercise frequently leads to exacerbation of symptoms.
- Study showed that participation in a 12 week Lower Body Positive Pressure (LBPP) Treadmill walking exercise regimen significantly enhanced patient function and quality of life, and improved ability to perform ADL's.

## **Use of an Anti-Gravity Treadmill in the Rehabilitation of the Operated Achilles Tendon: A Pilot Study**

Saxena, A., Granot, A.: The Journal of Foot and Ankle Surgery. 2011 Sep-Oct;50(5):558-61.

- Individuals can perform closed chain walking and jogging early in the postoperative period after Achilles tendon repair, maintaining a training effect in spite of partial weight bearing.

- Authors proposed 85% BW as a benchmark to return patients to unsupported training.

## **Review Article titled “Strategies for Rehab After Achilles Tendon Surgery”**

Saxena, A.: Lower Extremity Review Online, September 2011.

- Study reviews Achilles tendon surgery for both acute ruptures and chronic tendinopathy with post-operative care including the Anti-Gravity Treadmill.
- In combination with regimens including soft tissue massage to the calf muscle and posterior ankle tendons; mobilization of the ankle and subtalar joints; gluteal/core strengthening; stationary biking without a boot; modalities such as therapeutic ultrasound and electrical stimulation, unilateral concentric strengthening of the lower leg at 50% to 70% of bodyweight using Anti-Gravity Treadmill and walking for 10 minutes at 50% to 70% of bodyweight.
- Pilot study found that use of the Anti-Gravity Treadmill resulted in faster return-to-activity for patients.

## **Effects of Unweighting and Speed on In-Shoe Regional Loading During Running on a Lower Body Positive Pressure Treadmill**

Smoliga, J.M., Wirfel, L.A., Paul, D., Doarnberger, M., Ford, K.R.: Journal of Biomechanics 48(2015)1950–1956, 2015 July.

- Observational biomechanics study evaluated specific loading across the foot using in-shoe sensors.
- Foot loading patterns were preserved at 80% to 100% body weight, but patterns shifted towards forefoot loading at increasing levels of body weight support.

### **Lower Body Positive Pressure: An Emerging Technology in The Battle Against Knee Osteoarthritis?**

Takacs, J., Leiter, J., Anderson, J.E., MacDonald, P.B., Peeler, J.D.: Clinical Interventions in Aging. 2013; 8: 983–991.

- Study evaluated pain responses to exercise for individuals with knee osteoarthritis on AlterG Anti-Gravity Treadmill.
- Pain relief consistently achieved, on average required 12% body weight support.

### **Use of an Antigravity Treadmill for Rehabilitation of a Pelvic Stress Injury**

Tenforde A.S., Wananabe, L.M., Moreno T.J., Fredericson, M.: Physical Medicine & Rehabilitation 2012 (4) 629-631.

- Published case report documents the training regimen for an elite level Division 1 runner with pelvic stress fracture.
- The runner was able to maintain running form and cardiovascular fitness while training at reduced body weight during the healing phase of her stress fracture.
- At ten weeks after injury onset, the runner was able to compete pain free in the NCAA 10k championships.
- Authors believe that Anti-Gravity Treadmill training allowed this runner to return to competition in a much faster fashion than she would have with conventional rehabilitation.

### **Recent Advances in the Rehabilitation of Anterior Cruciate Ligament Injuries**

Wilk, K.E., Macrina, L.C., Cain, L., Dugas, J.R., Andrews, J.R.: Journal of Orthopaedic and Sports Physical Therapy, 42(3):153-171, 2012.

- The Anti-Gravity Treadmill can be used very effectively in the early phases of rehabilitation to relieve pain, promote proper closed kinetic chain gait mechanics, improve motion, and promote independent activity.

## Rehabilitation Following Microfracture of the Knee

Wilk, K.E., Macrina, L.C., and Reinold, M.M.: Cartilage 1(2): 96-107, 2010.

- Microfracture surgery requires a period of non-weightbearing (NWB) or toe-touch weightbearing (TTWB) for several weeks, followed by progressive weightbearing.
- Phases are outlined in this rehabilitation protocol.
- Beginning in approximately week number four postoperative (termed the Transition Phase by the authors), and continuing on until full functional recovery, the Anti-Gravity Treadmill may be used to provide safe protected increases in weightbearing, which promotes improvements in muscle control and function.

### Presented

## Use of an Anti-Gravity Treadmill for Rehabilitation After Total Knee Arthroplasty

Bugbee, W.D., Colwell, C.C., D'Lima, D.D.: Presented at ISTA 2013.

- Prospective pilot study of 29 patients undergoing total knee arthroplasty.
- Demonstrated safety and efficacy, with improvements in KOOS, TUG, and pain scores.

- High level of compliance by patients with outstanding acceptance from physical therapists.

## Correlation of Body Weight Support to Pain Relief in Moderate Knee Osteoarthritis

Takacs, J., Presented on February 3, 2012 at the Ontario Medical Association Sports Medicine Conference.

- Patients with moderate (Grade 3) osteoarthritis and moderate obesity exercised on the AlterG Anti-Gravity Treadmill.
- Percentage of body weight support required to reliably produce pain relief was recorded.
- Patients required on average 12.3% body weight support to achieve pain relief.
- The amount of body weight support is used as a target for the patient's body weight reduction.

### Current

## Total Knee Arthroplasty

- A multicenter prospective randomized trial underway comparing AlterG rehabilitation with conventional therapy on approximately 360 patients.

## Predicting Tibial Stress Fracture

- Investigators are using surface mounted tibial accelerometers to measure tibial shock, a validated predictor of tibial stress fracture.
- The AlterG is used to modify tibial shock to safe levels and thus minimizing risk of stress fracture.

# Sports/Performance Training

## Published

### Physiological and Biomechanical Responses of Highly Trained Distance Runners to Lower-Body Positive Pressure Treadmill Running

Barnes, K.R., Janecke, J.N.: Sports Medicine Open. 2017 Nov 21; 3(1): 41.

- 15 highly trained distance runners completed running test of 4x9-min intervals from 0-30% Body Weight Support (BWS) in 10% increments.
- Expired gases, ventilation, breathing frequency, HR, RPE and stride characteristics measured during each running speed and BWS.
- Large attenuation of oxygen consumption ( $\text{VO}_2$ ) relative to BWS, while there were trivial-moderate reductions in respiratory exchange ratio, minute ventilation, and respiratory frequency.
- Biomechanical changes during LBPPT running all contributed to less metabolic cost and corresponding physiological changes.

### Alterations in the Rate of Limb Movement Using a Lower Body Positive Pressure Treadmill Do Not Influence Respiratory Rate or Phase III Ventilation

Buono, M.J., Burnsed-Torres, M., Hess, B., Lopez, K., Ortiz, C., Girodo, A., Lolli, K., Bloom, B., Bailey, D., Kolkhorst, F.W.: Biomed Research International 2015.

- Physiologic study of ventilation correlated to walking speed.

### Physiological Responses To Lower-body Positive-pressure Treadmill Running- A Systematic Review and Meta-Analysis

Farina, K.A., Wright, A.A., Ford, K.R., Wirfel, LA, Smoliga, J.M., Medical Science Sports Exercise. 2016 May;48 (5 Suppl 1):465.

### Physiological Responses to the AlterG Anti-Gravity Treadmill

Figuerola, M.A., Manning, J., Escamilla, P.: International Journal of Applied Science and Technology Vol. 1 No. 6; November 2011.

- Removal of up to 20% bodyweight did not alter metabolic responses ( $\text{VO}_2$ , HR, RER) during jogging.
- Prescribed cardiovascular training intensities can be achieved with a reduction in ground reaction forces in individuals who are overweight, obese or injured.

### **Validation of ACSM Metabolic Equations in an Anti-Gravity Environment: A Pilot Study**

Figueroa, M.A., Wicke, J., Manning J., Escamilla, P., Santillo, N., Wolkstein, J., Weis, M.: International Journal of Applied Science and Technology Vol. 2 No. 7; August 2012.

- The American College of Sports Medicine established equations used to predict  $\text{VO}_2$  for individuals walking or running at 100% body weight.
- The current study was designed to measure actual  $\text{VO}_2$  with body weight support on the AlterG at 100%, 90%, and 80% body weight.
- Measured  $\text{VO}_2$  with body weight support was significantly less than predicted for the 100% body weight condition, thus the ACSM equations cannot be used accurately on the Anti-Gravity Treadmill.

### **Maximal Physiologic Parameters During Partial Body-Weight Support Treadmill Testing**

Gojanovic, B., Cutti, P., Shultz, R., Matheson, G.O.: Medicine and Science in Sports and Exercise, 2012 Apr 24.

- $\text{VO}_2$  is maintained on the Anti-Gravity Treadmill at speeds relevant to the elite runner.

- Previous studies on other treadmills questioned whether the elite runner could maintain  $\text{VO}_2$  with body weight support.
- Overspeed running mechanics are maintained.
- The Anti-Gravity Treadmill offers the additional advantage over conventional training of reduced joint impact forces, theoretically preserving joint health over the long-term.

### **Overspeed HIIT in Lower Body Positive Pressure Treadmill Improves Running Performance**

Gojanovic, B., Shultz, R., Feihl, F., Matheson, G.: Medicine and Science in Sports and Exercise, 2015 May 15.

- The authors performed a four-week prospective high intensity interval-training (HIIT) program to assess improvements in running speed in trained high level runners.
- Participants were randomized to standard treadmill training versus 10% body weight support on the AlterG Treadmill.
- The four-week HIIT protocol improved field performance,  $\text{VO}_2$  max, and submaximal heart rate.
- The authors state that AlterG HIIT is an effective method to improve running performance while reducing potentially injurious joint loading seen in standard full body weight HIIT.

## **Metabolic and Biomechanical Effects of Velocity and Weight Support Using a Lower Body Positive Pressure Device During Walking**

Grabowski, A.: Archives of Physical Medicine and Rehabilitation, 91:951-957, 2010.

- Study uses similar methods to the running study by Dr. Grabowski referenced above but now focusing on individuals during walking.
- Proof of basic principles during walking is very important for the post-injury, post-operative, and other groups who would not be expected to run on the Anti-Gravity Treadmill.
- Many combinations of velocity and BW resulted in similar aerobic demands, yet walking faster with weight support lowered peak GRFs compared to normal weight walking.
- Manipulating velocity and weight support during walking with the AlterG may be a highly effective strategy for rehabilitation, recovery following surgery, and gait re-training.

## **Utility of Offloaded Running Gait Retraining in a Runner with Medial Knee Osteoarthritis and a Varus Thrust: A Case Report**

Hatimiya, N.S., Luke, A.C.: Medicine and Science in Sports and Exercise, May 2014, Vol. 46(5) and presented at SWACSM 2013.

- Case report of a 57-year-old male, experienced marathon runner with severe knee pain and varus thrust from medial knee osteoarthritis.
- He undertook a 14-week training program on the AlterG Anti-Gravity Treadmill.
- At conclusion of the training program, his pain was negligible when running at full body weight and 3-D gait analysis showed improvements in his varus thrust.
- He was successfully able to run a marathon without pain at four months after training on the AlterG Anti-Gravity Treadmill.

## **Exercise Responses During Partial Body-Weight Supported Treadmill Walking and Running in Healthy Individuals**

Hoffman, M., Donaghe, H.E.: Archives of Physical Medicine and Rehabilitation, 92(6):960-6 June 2011.

- For walking up to 3.5mph: a 25% reduction in body weight requires approximately a 0.5 mph increase in walking speed for the same  $VO_2$ .
- For running up to 9.0mph: a 25% reduction in body weight requires a 3mph increase in running speed for the same  $VO_2$ .

- Relationship between HR and  $\text{VO}_2$  is not changed with support, thus runners who use HR as an indicator of training intensity can continue to do so on the Anti-Gravity Treadmill with weight support.

### **Muscle Activation and Estimated Relative Joint Force During Running with Weight Support on a Lower-Body Positive-Pressure Treadmill**

Jensen, B.R., Hovgaard-Hansen, L., Cappelen, K.L.: Journal of Applied Biomechanics. 2016 Aug;32(4):335-41.

- Unweighting with LBPP reduced estimated joint force significantly although less than proportional to the degree of weight support (ankle).
- It was concluded that leg muscle activation adapted to the new biomechanical environment, and the effect of unweighting on estimated knee force was more pronounced than on ankle force.

### **Conversion Table for Running on Lower Body Positive Pressure Treadmills**

Kline, J.R., Raab, S., Coast, J.R., Bounds, R.G., McNeill, D.K., de Heer, H.D.: Journal of Strength Conditioning Research. 2015 Mar;29(3):854-62.

- Develop a user-friendly conversion table showing the speeds required on an LBPP treadmill to match the equivalent metabolic output on a regular, non-LBPP, treadmill across a range of body weight supports.
- 20 recreational runners (11 males, 9 females) ran multiple three-minute intervals on a regular treadmill and then on an LBPP treadmill at six different BWs (50–100%, 10% increments).
- Metabolic outputs were recorded and matched between the regular and LBPP treadmill sessions.
- Conversion table was successfully created for the speeds from 6.4 to 16.1  $\text{km}\cdot\text{h}^{-1}$  (4 to 10 mph) in 0.8  $\text{km}\cdot\text{h}^{-1}$  (0.5 mph) increments on the regular treadmill and BW proportions of 50%, 60%, 70%, 80%, 90%, and 100% on an LBPP treadmill.
- The table showed that a greater increase in speed on the LBPP treadmill was needed with more support ( $p < 0.001$ ) but that the proportion increase was smaller at higher speeds ( $p < 0.001$ ).
- Increased treadmill speed can compensate for the reduced metabolic load for runners wishing to maintain metabolic load on the Anti-Gravity Treadmill. Did not factor treadmill incline, which can also be used to increase metabolic loads with body weight support.

### **Cardiovascular Models of Simulated Moon and Mars Gravities: Head Up Tilt vs. Lower Body Unweighting**

Kostas, V.I., Evans, J.M., Stenger, M.B., Knapp, C.F., Shapiro, R, Wang, S., Diedrich, A.: Aviat Space Environ. Med 85(4) 414-419. 2014, April.

- Compared lower body positive pressure on Anti-Gravity Treadmill to head-up tilt for fluid volume shifts, cardiac output, blood pressure, heart rate.
- LBPP consistently shifts fluid from lower extremities to the thorax.
- Cardiac output maintained, systolic blood pressure increases, stroke volume decreases.
- LBPP advantageous over HIIT if dynamic activity is necessary.

### **Training Effects On A Lower Body Positive Pressure Treadmill At Different percentages of Body Weight**

Lee, D., Maltz, N., Becker, J., Cotter, J., Rozenek, R.: Medical Science Sports Exerc. 2016 May;48 (5 Suppl 1):497.

- This study examined the physiological adaptations resulting from an eight-week training program on a LBPP treadmill at three different levels of BW 50%, 75% and 100% in healthy subjects.

- While training on a lower body positive pressure treadmill (LBPP) has become a tool for injury rehabilitation, these devices are also used to train healthy individuals.
- The study concludes that in healthy subjects, running at 50% BW results in a slight reduction of aerobic capacity compared to running at 100% BW, while running at 75% BW does not result in any significant change. In order to maintain aerobic fitness, individuals should run with ~75% or more of their BW on LBPP treadmills at moderate intensities.

### **Physiological Responses During the Lower Body Positive Pressure Supported Treadmill Test**

Lee, K.Y., Han, J.Y., Kim, J.H., Kim, D.J., Choi, I.S.: Annals of Rehabilitation Medicine, 2016 Oct; 40(5): 915-923.

- Study measured changes in cardiopulmonary function using a lower body positive pressure supported (LBPPS) treadmill during the exercise tolerance test (ETT) in healthy subjects.
- Systolic BP increased as LBPPS level increased.
- PHR, RPE, METs, and VO<sub>2</sub> were negatively associated with LBPPS, though not always significant.

- Detection of the changes in physiological parameters during a submaximal ETT with the LBPPS system may be helpful for patients who cannot perform a standard ETT due to gait problems.

### **Accuracy of Unloading With the Anti-Gravity Treadmill**

McNeill, D., de Heer, H.D., Bounds, R.G., Coast, J.R.: Journal of Strength and Conditioning Research, 2015 Mar;29 (3):863-8.

- There is less than 5% difference between predicted and actual unloading with the most commonly used body weight unloading percentages from 90% to 40%.

### **Metabolic Accommodation to Running on a Body Weight-Supported Treadmill**

McNeill, D.K., de Heer, H.D., Williams, C.P., Coast, J.R.: European Journal of Applied Physiology, 2015 May;115(5):905-10.

- Study aimed at evaluating the existence and length of a metabolic accommodation period to running on a lower body positive pressure (LBPP) treadmill.
- An accommodation effect of running on a treadmill with LBPP was observed and reached after 60 minutes of running (four trials of 15 minutes).

- The accommodation effect was largest at the greatest level of body weight support pointing to the importance of an accommodation period for reliable measures of metabolic cost to be made.

### **Oxygen Consumption of Elite Distance Runners on an Anti-Gravity Treadmill**

McNeill, D., Kline, J.R., deHeer, H.D., Coast, J.R.: Journal of Sports Science and Medicine (2015) 14, 333-339.

- Measurement of  $\text{VO}_2$  in elite distance runners across a number of speeds and body weight support levels.
- Results consistent with prior research, which found that while running on an Anti-Gravity Treadmill:
  1. Metabolic cost significantly decreases with increasing levels of BWS.
  2. Metabolic cost significantly increases with increasing velocity.
  3. There is attenuation in the decrease in metabolic cost as BWS increases.

### **Muscle Activity While Running At 20% - 50% Of Normal Body Weight**

Res Sports Med October 2012.

- EMG activity of rectus femoris, biceps femoris, gastrocnemius, and tibialis anterior.

- Increased speed at any given body weight support level increased muscle activity for all groups.
- Increased body weight support at any given speed decreased muscle activity of the rectus, gastroc, and tibialis anterior but had no significant effect on the biceps femoris.

### **Effect of Body Weight Support on Spatiotemporal Running Mechanics**

Moran, M.F., Sullivan, A.B., Rickert, B.J.: Medical Science and Sports Exercise, 2012 (44:5) S572.

- Evaluated stride rate and stride length with varying levels of AlterG body weight support in experienced runners.
- With increasing support, stride rate decreases and stride length increases.
- Runners wishing to use Anti-Gravity Treadmill training to translate to over ground training may consider using a metronome on the Anti-Gravity Treadmill to maintain stride rate.

### **Tibial Acceleration and Spatiotemporal Mechanics in Distance Runners During Reduced Body Weight Conditions**

Moran, M.F., Rickert, B.J., Greer, B.K.: Journal of Sports Rehabilitation. 2016 Aug 24:1-17.

- Peak tibial acceleration and peak-to-peak tibial acceleration was measured via a uniaxial accelerometer attached to the tibia during a 37-minute continuous treadmill run that simulated reduced BW conditions.
- Trial began with a ten-minute run at 100% BW followed by nine three-min stages where BW was systematically reduced from 95% to 60% in 5% increments.
- There was no significant relationship between level of BW and either peak tibial acceleration or peak-to-peak tibial acceleration ( $p > .05$ ).
- Both heart rate and step rate were significantly reduced with each 5% reduction in BW level ( $p < .01$ ).
- Although ground reaction forces are reduced when running in reduced BW conditions on a DAP treadmill, tibial shock magnitudes are unchanged as an alteration in spatiotemporal running mechanics (e.g. reduced step rate) may nullify the unloading effect.

- Runners should aim to maintain step rate with body weight support on the Anti-Gravity Treadmill to achieve reductions in tibial shock magnitudes.

### **Effect of Body-Weight-Support Running on Lower-Limb Biomechanics**

Neal, M., Fleming, N., Eberman, L., Games, K., Vaughan, J.: Journal of Orthopedic Sports Physical Therapy, 2016 Sep; 46(9):784-93.

- To determine the effect of increasing BWS on lower-limb biomechanics during lower-body positive-pressure (LBPP) treadmill running.
- Running on an LBPP treadmill alters lower-limb kinematics, resulting in reduced ankle and knee joint range of motion. In addition, increased BWS alters stride characteristics, resulting in shorter GCT and longer flight time.

### **Effect of Plasma Osmolality and Baroreceptor Loading Status on Post Exercise Heat Loss Responses**

Paull, G., Dervis, S., Barrera-Ramirez, J., McGinn, R., Haqani, B., Flouris, A.D., Kenny, G.P.: The American Journal Physiology Regulatory, Integrative Comparative Physiology. 2016 March 15;310(6): R522-31.

- Examines the separate and combined effects of plasma osmolality and baroreceptor loading status on post exercise heat loss responses.

- Study follows nine young males in a 45-minute treadmill exercise protocol at  $58 \pm 2\%$   $\dot{V}O_{2\text{peak}}$  followed by a 60-minute recovery.

### **Study found that:**

- Hyperosmolality attenuates post exercise sweating heterogeneously among skin regions
- Baroreceptor loading modulates post exercise SkBF independently of changes in plasma osmolality without regional differences.

### **Muscle Metaboreceptors Modulate Post Exercise Sweating, but not Cutaneous Blood Flow, Independent of Baroreceptor Loading Status**

Paull, G., Dervis, S., McGinn, R., Haqani, B., Flouris, A.D., Kondo, N., Kenny, G.P.: The American Journal Physiology Regulatory, Integrative Comparative Physiology. 2015 Dec 1;309(11): R1415-24.

- Study examines whether sustained changes in baroreceptor loading status during prolonged post exercise recovery can alter the metaboreceptors' influence on heat loss.

- Thirteen young males performed a one-minute isometric handgrip exercise (IHG) at 60% maximal voluntary contraction followed by two-minutes of forearm ischemia (to activate metaboreceptors) before and 15-, 30-, 45- and 60-minutes after a 15-minute intense treadmill running exercise (>90% maximal heart rate) in the heat (35°C).

### **Running on a Lower-Body Positive Pressure Treadmill: VO<sub>2</sub>max, Respiratory Response, and Vertical Ground Reaction Force**

Raffalt, P.C., Hovgaard-Hansen, L., Jensen, B.R. Research Quarterly for Exercise and Sport, 84, 213–222, 2013.

- Possible to achieve VO<sub>2</sub>max with body weight unloading.
- Ground reaction forces reduced.
- Significant increase in time to exhaustion with Anti-Gravity Treadmill training.
- Improves running economy.

### **Influence of Short-Term Unweighting and Reloading on Running Kinetics and Muscle Activity**

Sainton, P., Nicol, C., Cabri, J., Barthelemy, J., Berton, E., Chavet, P.: European Journal Applied Physiology. 2015 May; 115 (5): 1135–1145.

- Confirmed results from other studies demonstrating maintenance of normal muscle firing patterns with body weight support, except for reduced activity during push-off phase.
- Also noted that muscle-firing patterns revert to pre-exercise within three minutes of full reloading.

### **Kinetics and Muscle Activity Patterns during Unweighting and Reloading Transition Phases in Running**

Sainton, P., Nicol, C., Cabri, J., Barthelemy, J., Berton, E., Chavet, P.: PLoS ONE. 2016; 11(12).

- This study focuses on runner's adjustments to LBPP-induced unweighting and reloading during running.
- Nine healthy males performed two running series of nine minutes at natural speed, with each series made of three sequences of three minutes at: 100% bodyweight (BW), 60% or 80% BW, and 100% BW.
- Study findings highlight both the rapidity and the complexity of the neuromechanical changes associated with LBPP-induced unweighting and reloading during running.

### **Effects of a Walking Program Using the AlterG Anti-Gravity Treadmill System on an Extremely Obese Female: A Case Study**

Simonson, S.R., Shimon, J.M., Long, E.M., Lester, B.: Clinical Kinesiology 65(2); Summer, 2011: 29-38.

- This case study examined the effects of a 14-week walking program on one extremely obese (BMI 69.2) Caucasian 44 year-old female utilizing the Anti-Gravity Treadmill.
- At the conclusion of the study, exercise tolerance time increased three-fold while caloric expenditure increased ten-fold without an increase in heart rate or perceived pain in her lower extremities.
- Participant demonstrated a 2.75% weight reduction, a decrease in upper body circumference measurements and lower extremity edema of her knees and ankles, and a 9.7% decrease in fasting blood glucose (102mg/dL).
- Overall, the Anti-Gravity Treadmill enabled the participant to exercise and walk pain-free at a distance, intensity level, and speed that she could not accomplish while walking on her own.

### **Effects of Unweighting and Speed on In-Shoe Regional Loading During Running on a Lower Body Positive Pressure Treadmill**

Smoliga, J.M., Wirfel, L.A., Paul, D., Doarnberger, M., Ford, K.R.: Journal of Biomechanics 48(10); 2015 Jul 16; 1950–1956.

- Observational biomechanics study evaluated specific loading across the foot using in-shoe sensors.
- Foot loading patterns were preserved at 80% to 100% body weight, but patterns shifted towards forefoot loading at increasing levels of body weight support.

### **Running Speed Increases Plantar Load More Than Percent Body Weight on an AlterG® Treadmill**

Thomson, A., Einarsson, E., Witvrouw, E., Whiteley, R.: Journal of Sports Sciences, 2016 March 21:1-6.

- The aim of this study was to quantify plantar loads borne by the athlete during rehabilitation.
- 20 trained male participants ran on the Anti-Gravity Treadmill in 36 conditions: all combinations of indicated BW (50–100%) paired with different walking and running speeds (range 6–16 km · hr<sup>-1</sup>) in a random order.

### **Cardiovascular Response of Running on a Normal and Lower Body Positive Pressure Treadmill**

Van Langen, D, Hokanson, J, Lind, E, True L. Medical Science and Sports Exercise. 2016 May;48(5 Suppl 1):429.

#### **Presented**

#### **Experiencing the Impact of Weight Loss on Work Capacity Prior to Initiation of a Weight Loss Program Enhances Success.**

- Greenwood, M., Mardock, M., et al: Presented at International Society for Sports Nutrition, Las Vegas, Nevada, June 2011.
- AlterG pre-training showed significant improvements over traditional exercise in weight loss, fat loss, free fat mass, and body fat.

#### **Physiological Responses to Simulated Anti-Gravity During Treadmill Running**

Pedlar, C., Burden, R.J., Hill, J.A., Whyte, G.: Presented at American College of Sports Medicine, Denver, CO, July 2011.

- Anti-Gravity Treadmill running with body weight support consistently showed longer times needed to achieve the same level of blood lactate level rise as with full body weight running.

### **Vertical Ground Reaction Force and Respiratory Response During Lower Body Positive Pressure Treadmill Running**

Raffalt, P.C., Hovgaard-Hansen, L., Jensen, B.R.: Presented at International Society for Biomechanics, Brussels, Belgium, July 2011.

#### **This study showed the following key points:**

- Experienced runners at high speeds can achieve  $\text{VO}_2$  max with reduced body weight by increasing incline.
- Body weight support was accompanied by reduced ground reaction force.
- The economy of running was significantly improved as shown by a large increase in time to exhaustion (642 seconds) compared to full body weight running (477 seconds).
- Authors conclude that AlterG training is a relevant tool for healthy runners to reduce joint loading while maintaining or even improving the aerobic stimulus.

## **Metabolic Study of Weight-Supported Treadmill Exercise in Young Caribbean-Black Obese Women in Brooklyn**

Yearwood, L., Kral, J.G.: Presented at The Obesity Society, 2013.

- Proof of concept study prior to prospective training study.
- Demonstrated high compliance with exercise regimen in a high-risk population.
- Evaluating metabolic effects of exercise in the obese.
- Improved fasting and two-hour plasma glucose after training sessions.
- The ability to "feel what their body is like at a lower weight" is highly motivational.
- Unweighting allows them to exercise in a pain free range.
- Metabolic demand can be maintained even with unweighting by increasing walking speed.
- Measuring metabolic markers of health: glucose tolerance, plasma lipids, liver fat, and muscle fat.

## **Current**

### **Obesity**

- The overweight individual must deal with a number of issues that make exercise very difficult, such as poor cardiovascular conditioning at baseline, and presence of painful lower extremity joints due to osteoarthritis.
- Modalities such as aquatic therapy, bicycle, and full body weight walking are commonly recommended, in addition to nutritional modification and lifestyle changes. It is believed that the Anti-Gravity Treadmill enables overweight individuals to exercise in ways they could not otherwise.