

Summary of Clinical Research Involving The AlterG Anti-Gravity Treadmill®

By Dev K. Mishra, M.D.
Chief Medical Officer, AlterG Inc.
June 1, 2014



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. Out of respect for the integrity of the scientific process, we will not cite specific authors or institutions until the studies have been published in peer-reviewed journals, presented at professional meetings, or until the author gives us permission. In the following sections, I will outline for you our new presentations or publications, previously published or presented research, present in aggregate format findings from studies already completed but not yet published, and a brief overview of planned studies and questions to be answered for the remainder of 2014. Additionally, I will outline the other available forms of clinical material, such as Case Reports, Case Series, Clinical Protocols, White Papers, and Clinical Guidelines.

Due to the large expansion of the number of installed AlterG machines 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.

WHAT'S NEW:

- New clinical research supporting safety and efficacy of the AlterG Anti-Gravity Treadmill in total knee arthroplasty rehab
- Independently produced athletic training studies showing positive effects of AlterG training to achieve VO₂max, improve running economy, increase time to exhaustion, and reduce tibial shock
- A preliminary study showing high compliance with exercise in a high-risk population of obese individuals, with improvements in oral glucose tolerance
- Published study demonstrating effectiveness of AlterG exercise in individuals with knee osteoarthritis; an average of 12% body weight support was required for pain relief
- Multiple prospective clinical studies are continuing data acquisition
- Clinical protocols were added for total knee replacement, high intensity interval training, lumbar disc herniation, and lower extremity stress fracture
- Additional user produced case studies were added to the website, bringing the total number of studies to 40.

Berthelsen, MP, Jensen, BR, et al: Anti-Gravity Training Improves Walking Capacity and Postural Balance In Patients With Muscular Dystrophy. *Neuromuscul Disord* (2014), <http://dx.doi.org/10.1016/j.nmd.2014.03.001>

- Prospective training program for severely affected muscular dystrophy patients who are unable to do conventional exercise due to weakness for severely affected individuals with muscular dystrophy
- 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

Bugbee, WD, Colwell, CC, D'Lima, DD, et al: Use of an Anti-Gravity Treadmill for Rehabilitation After Total Knee Arthroplasty. Presented at ISTA 2013, and In Press: The Knee.

- 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
- Foundation for large scale randomized clinical trial which is now underway

Evans, JM et al: Cardiovascular regulation during body unweighting by lower body positive pressure. *Aviat Space Environ. Med.* 2013, 84:1140-1146

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

Hatimiya, NS, Luke, AC: Utility of Offloaded Running Gait Retraining in a Runner with Medial Knee Osteoarthritis and a Varus Thrust: A Case Report. Presented at SWACSM 2013.

- Case report of a 57 y.o. male experienced marathon runner with severe knee pain and varus thrust from medial knee osteoarthritis

- Completed 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 4 months after training on the AlterG Anti-Gravity Treadmill

Raffalt, PC, Hovgaard-Hansen, L, Jensen, BR: Running on a Lower-Body Positive Pressure Treadmill: VO₂max, Respiratory Response, and Vertical Ground Reaction Force. *Research Quarterly for Exercise and Sport*, 84, 213-222, 2013

- Possible to achieve VO₂max with body weight unloading
- Ground reaction forces reduced
- Significant increase in time to exhaustion with AlterG Anti-Gravity Treadmill Training
- Improves running economy

Rickert, BJ, Moran, MF, Greer, BK: Effect of Weight Support on Tibial Accelerations During a Lower-Body Positive Pressure Treadmill Cadence-Controlled Run

- Presenting at ACSM 2014
- Tibial shock reduces with each 10% reduction in body weight while running on the AlterG Anti-Gravity Treadmill
- AlterG Anti-Gravity Treadmill can be a useful modality for runners recovering from tibial stress fracture

Takacs, J, Leiter, J: Lower body positive pressure: an emerging technology in the battle against knee osteoarthritis? *Clin Interv 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

Yearwood, L, Kral, JG: Metabolic study of weight-supported treadmill exercise in young Caribbean-Black obese women in Brooklyn

- 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 2-hour plasma glucose after training sessions

Zhang, Q., Evans, JM et al: Simulations of gravitational stress on normo- and hypovolemic men and women. *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

Published Studies:

Early studies provide the foundation for the biomechanics of running and walking on the AlterG. They also show that for each individual a “metabolic prescription” can be achieved, thus maintaining metabolic load while reducing the ground reaction forces. More recent studies have focused on clinical rehabilitation topics. The principles shown here can be applied to a wide variety of medical and athletic rehabilitation settings. Here are summary findings:

- Jogging at 4.5mph with 50% body weight support produces the same knee joint reaction force as walking with full body weight
- For any given walking or running speed, weight support reduced metabolic demand by the individual
- For any given amount of weight support, metabolic demand can be increased by increasing walking or running speed

- Ground reaction forces are reduced at all levels of weight support
- Surface EMG electrode activity shows that muscle firing patterns and gait mechanics are maintained for all levels of weight support and speeds.
- Anti-gravity muscles show reduced activation with weight support
- Weight support causes a slight increase in Heart Rate and Systolic Blood Pressure, but Diastolic Blood Pressure and Mean Blood Pressure are not changed
- Individuals who use Heart Rate to create exercise regimens can continue to do so on the AlterG and they should expect a similar metabolic demand from body weight support as with unsupported exercise
- Dramatic improvements in gait mechanics are seen in children with cerebral palsy who use the AlterG for exercise
- AlterG exercise is very well tolerated by individuals with knee osteoarthritis, and results in a reduction in knee pain when ambulating off the AlterG. An average of 12% body weight support is needed to produce pain relief.
- Gait and functional improvements are seen in several adult neurologic conditions such as Parkinson’s Disease and muscular dystrophy

Berthelsen, MP, Jensen, BR, et al: Anti-Gravity Training Improves Walking Capacity and Postural Balance In Patients With Muscular Dystrophy. *Neuromuscul Disord* (2014), <http://dx.doi.org/10.1016/j.nmd.2014.03.001>

- 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

Christian M: Managing knee osteoarthritis: the effects of Anti-Gravity Treadmill exercise on joint pain and physical function. University of Manitoba Master's Thesis Dissertation. <http://mspace.lib.umanitoba.ca/handle/1993/8580>

- 25 obese adults with moderate knee osteoarthritis pain participated in a 12 week AlterG 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
- This thesis is being prepared for publication in a peer-reviewed journal

Evans, JM et al: Cardiovascular regulation during body unweighting by lower body positive pressure. *Aviat Space Environ. Med.* 2013, 84:1140-1146

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

Evans, J., Shapiro, R., Moore, F.: Segmental Volume and Cardiovascular Responses to Changes in Body Position at Rest and During Walking Under Normal and Reduced Weight Conditions *J 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. There was a slight increase in systolic blood pressure, no change in diastolic blood pressure, slight decrease in heart rate, all of which can be expected with the fluid shift.

Figuroa, M.A., Manning, J., Escamilla, P.: Physiological Responses to the AlterG Anti-Gravity Treadmill. *International Journal of Applied Science and Technology Vol. 1 No. 6; November 2011*

- Removal of up to 20% bodyweight did not alter metabolic responses (V02, 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.

Figuroa, MA, Wicke J, Manning J, Escamilla P, Santillo N, Wolkstein J, Weis M: Validation of ACSM Metabolic Equations in an Anti-Gravity Environment: A Pilot Study. *International Journal of Applied Science and Technology Vol. 2 No. 7; August 2012*

- The American College of Sports Medicine established equations used to predict V02 for individuals walking or running at 100% body weight
- The current study was designed to measure actual V02 with body weight support on the AlterG at 100%, 90%, and 80% body weight
- Measured V02 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 AlterG

Gojanovic B, Cutti P, Shultz R, Matheson GO: Maximal physiologic parameters during partial body-weight support treadmill testing. *Med Sci Sports Exerc* 2012 Apr 24.

- V02 is maintained on the AlterG at speeds relevant to the elite runner. Previous studies on other treadmills questioned whether the elite runner could maintain V02 with body weight support.
- Overspeed running mechanics are maintained
- The AlterG offers the additional advantage over conventional training of reduced joint impact forces, theoretically preserving joint health over the long-term

Grabowski, Alena: Metabolic and Biomechanical Effects of Velocity and Weight Support Using a Lower Body Positive Pressure Device During Walking. *Archives of Physical Medicine and Rehabilitation*, 91:951-957, 2010.

This 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 AlterG.

- 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.

Hoffman, M.D., Donaghe, H.E.: Exercise responses during partial body-weight supported treadmill walking and running in healthy individuals. *Arch Phys Med & Rehab*, 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 V02.
- For running up to 9.0mph: a 25% reduction in body weight requires a 3mph increase in running speed for the same V02.
- Relationship between HR and V02 is not changed with support, thus runners who use HR as an indicator of training intensity can continue to do so on AlterG with weight support.

Kostas, VI, Evans, JM et al: Cardiovascular models of simulated moon and Mars gravities: Head up tilt vs lower body unweighting. *Aviat Space Environ. Med* 85(4) 414-419. 2014

- Compared lower body positive pressure on AlterG 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 HIT if dynamic activity is necessary

Kurz, M., Corr, B., Stuberg, W., Volkman, K., Smith, N.: Evaluation of Lower Body Positive Pressure Supported Treadmill Training for Children with Cerebral Palsy *Pediatr Phys Ther*. 2011 Fall;23(3):232-9. *PubMed PMID: 21829114*.

- LBPPS treadmill training resulted in significant changes in the 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 AlterG is an effective treatment for improving the walking biomechanics and balance of children with CP. The AlterG offered other advantages over conventionally used harness systems and was very well accepted by the children.

Kurz MJ, Stuberg W, DeJong SL (2011). Body weight supported treadmill training improves the regularity of the stepping pattern in children with cerebral palsy. *Developmental Neurorehabilitation*, 2011; 14(2):87-93.

- AlterG 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.

Lazaro R, Raymond G, Chun J, Spencer B, Megazzi A, Siegel E, Schempp A: The effects of lower body positive pressure treadmill training on balance, mobility and lower extremity strength of community dwelling older adults. *Presented at the Annual Meeting of the California Physical Therapy Association, Santa Clara, CA, Sept. 28-29, 2012.*

- 10 healthy women, average age 70, participated in an 8 week AlterG 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

Liebenberg, J., Scharf, J., Forrest, D., Dufek, J., Masumoto, K., Mercer, J.A.: Determination of Muscle Activity During Running at Reduced Body Weight *J Sports Sciences 29(2): 207-214, 2011*

- The purpose of this study is to investigate how lower extremity muscles are influenced by body weight (BW) support during running at different speeds. Reducing BW leads to a reduction in muscle activity with no changes in muscle activity patterns.

Mercer, JA, Applequist, B, Masumoto, K: Muscle activity during running with different body weight support mechanisms: Aquatic environment versus body weight support treadmill. In Press, *J Sport Rehab 2014.*

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

Mercer, JA: 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

Mercer, JA, Applequist, B, Masumoto, K: Muscle Activity During Running With Different Body Weight Support Mechanisms. *Med Sci Sports Exerc 2012 (44:5) S572*

- Compared EMG activity of lower extremity muscles with deep water running and AlterG body weight support, as well as different running styles
- Showed no significant differences in rectus femoris and biceps femoris activity as long as stride frequency was equalized using cross country running style
- Showed increased rectus femoris activity in high knee running style in deep water running

Moran MF, Sullivan AB, Rickert BJ: Effect of Body Weight Support on Spatiotemporal Running Mechanics. *Med Sci Sports Exerc 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 AlterG training to translate to overground training may consider using a metronome on the AlterG to maintain stride rate

Patil, S., Steklov, N., Bugbee, W.D., Goldberg, T., Colwell, C.W., D'Lima, D.: Antigravity treadmills are effective in reducing knee forces. *J Orthop Res. 2012 Dec 13. doi: 10.1002/jor.22272. [Epub ahead of print] PMID: 23239580 [PubMed - as supplied by publisher]*

- The e-Knee study from Scripps Clinic La Jolla shows a direct correlation between knee joint vertical reaction force as a function of AlterG body weight support, treadmill speed, and incline. An equation relating these variables is provided by the authors

- Jogging at 4.5mph with 50% body weight support provides the same vertical knee joint reaction force as walking with full body weight.
- AlterG body weight supported activity is placed within the context of other daily and sports activities previously studied by the authors.

Raffalt, PC, Hovgaard-Hansen, L, Jensen, BR: Running on a Lower-Body Positive Pressure Treadmill: VO2max, Respiratory Response, and Vertical Ground Reaction Force. *Research Quarterly for Exercise and Sport*, 84, 213–222, 2013

- Possible to achieve VO2max with body weight unloading
- Ground reaction forces reduced
- Significant increase in time to exhaustion with AlterG training
- Improves running economy

Saxena, A., Granot, A.: Use of an Anti-Gravity Treadmill in the Rehabilitation of the Operated Achilles Tendon: A Pilot Study *J Foot Ankle Surg.* 2011 Sep-Oct;50(5):558-61.

- Individuals are able to perform closed chain walking and jogging early on 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

Saxena, Amol:

Review Article titled “Strategies for Rehab After Achilles Tendon Surgery” was published in Lower Extremity Review Online, September, 2011: <http://www.lowerextremityreview.com/article/strategies-for-rehab-after-achilles-tendon-surgery>

Takacs, J, Leiter, J: Lower body positive pressure: an emerging technology in the battle against knee osteoarthritis? *Clin Interv 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

Zhang, Q., Evans, JM et al: Simulations of gravitational stress on normo- and hypovolemic men and women. *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

Premarketing Studies and Technology Validation Prove Safety and Effectiveness of the AlterG Anti-Gravity Treadmill

The concept of using advanced differential air pressure technology for weight support was originally conceived by Dr. Robert Whalen and Dr. Alan Hargens while they were studying the biomechanics of exercise in space as part of an effort to design effective exercise regimens for NASA’s astronauts. These early studies specifically using patented AlterG technology show that the machine is:

- Capable of accurate and precise unweighting across a variety of body types
- Comfortable and safe for most individuals, including those with stable cardiac, vascular, and respiratory disorders
- Able to reduce ground reaction force for walking and running in proportion to the amount of unweighting
- Effective in reducing pain in individuals whose lower extremity pain is related to full weight bearing ambulation or exercise

- Bugar, C.G., Schwandt, D., Anderson, J., Whalen, R., Breit, G.: Differential Walking Assist: an inflatable walking support *Rehabilitation R&D Center Progress Report, 1994.*
- Buckley, E.L., Bugar, C.G., Cao, Y., Schwandt, D.F.: Partial Body Weight Support Using Air Pressure: Safety and Unloading *Second National Department of Veterans Affairs Rehabilitation Research and Development Conference Proceedings, 2000.*
- Eastlack, R.K., Hargens, A.R., Groppo, E.R., Steinbach, G.C., White, K.K., Pedowitz, R.A.: Lower Body Positive-Pressure Exercise after Knee Surgery. *Clinical Orthopaedics & Related Research. 431:213-219, February 2005.*
- Cutuk, A.A., Groppo, E.R., Quigley, E.J., White, K.W., Pedowitz, R.A., Hargens, A.R.: Ambulation in Simulated Fractional Gravity Using Lower Body Positive Pressure: Cardiovascular Safety and Gait Analyses. *J Appl Physiol 101: 771-777, 2006*

Submitted Studies Under Editorial Review:

Bugbee, WD, Colwell, CC, D'Lima, DD, et al: Use of an Antigravity Treadmill for Rehabilitation After Total Knee Arthroplasty. Presented at ISTA 2013, and In Press: The Knee.

- Prospective pilot study of 29 patients undergoing total knee arthroplasty
- Demonstrated safety and efficacy, with improvements in KOOS, TUG, and pain scores
- Foundation for large scale randomized clinical trial which is now underway

Gojanovic, B., Cutti, P., Matheson, G.: High intensity interval training program with body weight supported treadmill training in elite distance runners. *Medicine And Science In Sports And Exercise, in press.*

- A high intensity interval training protocol that results in faster 2 mile times, V02 max, and Time Limit at V02 max.

Kurz MJ, Wilson TW, Corr B, Volkman KG. Body weight supported treadmill training influences the neuromagnetic activity of the somatosensory cortices in children with cerebral palsy. *Journal of Neurologic Physical Therapy, in press.* Kurz, M., Deffeyes, J.E., Karst, G.M., Stuberg, W.A.: Influence of Lower Body Pressure Support on the Walking Patterns of Healthy Children and Adults. Accepted for publication to *Journal of Applied Biomechanics, In Press*

- The lower extremity joint angles and activity of the lower extremity anti-gravity muscles of children did not differ from those of adults
- Lower body positive pressure support resulted in reduced activation of the anti-gravity musculature, and reduced range of motion of the knee and ankle joints
- The magnitude of the changes in the lower extremity joint motion and 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.

Deffeyes, J., Stuberg, W., Karst, G., Kurz, M.: Coactivation of Lower Leg Muscles During Body Weight Supported Treadmill Walking Decreases With Age In Adolescents *Accepted for publication to Human Movement Science, In Press*

- It unknown how use of a body weight supported treadmill device affects coactivation, which is important as these devices are commonly used for therapy and rehabilitation of individuals with musculoskeletal or neurological disorders.
 - Coactivation was found to be higher in adolescents than in adults, but only for the lower leg muscles. These results show the importance of using age-matched controls in adolescent studies of pathologic agonist/antagonist coactivation of lower leg muscles during walking.
-

Published Review On Knee Microfracture Postoperative Rehabilitation Shows Clinical Effectiveness Of The AlterG Anti-Gravity Treadmill:

- Wilk, Kevin E., Macrina, Leonard C., and Reinold, Michael M.; Rehabilitation Following Microfracture of the Knee. *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 4 postoperative (termed the Transition Phase by the authors), and continuing on until full functional recovery, the AlterG may be used to provide safe protected increases in weightbearing which promotes improvements in muscle control and function. This is an outstanding review of the science behind microfracture rehabilitation.

Published Review Of Current Anterior Cruciate Ligament Reconstruction Rehabilitation Principles Includes The AlterG Anti-Gravity Treadmill:

Wilk, K.E., Macrina, L.C., Cain L., Dugas, J.R., Andrews, J.R.: Recent Advances in the Rehabilitation of Anterior Cruciate Ligament Injuries *JOSPT* 42(3):153-171, 2012.

The authors present state-of-the-art techniques in rehabilitation after anterior cruciate ligament reconstruction. AlterG 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.

Presentations at National or International Meetings:

Athletic Performance

Raffalt, P.C., Hovgaard-Hansen, L., Jensen, B.R.: Vertical ground reaction force and respiratory response during lower body positive pressure treadmill running. Presented at International Society for Biomechanics, Brussels, Belgium, July 2011.

Pedlar, C., Burden, R.J., Hill, J.A., Whyte, G.: Physiological responses to simulated anti-gravity during treadmill running. *Presented at American College of Sports Medicine, Denver, CO, July 2011*

- AlterG 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

Rickert, BJ, Moran, MF, Greer, BK: Effect of Weight Support on Tibial Accelerations During a Lower-Body Positive Pressure Treadmill Cadence-Controlled Run

- Presenting at ACSM 2014
- Tibial shock reduces with each 10% reduction in body weight while running on the AlterG Anti-Gravity Treadmill
- AlterG Anti-Gravity Treadmill can be a useful modality for runners recovering from tibial stress fracture

Basic Science: Cardiovascular

Yates, J.W., Mohny, L.E., Abel, M.G., Shapiro, R.: Effect of unweighting using the AlterG Trainer on VO₂, heart rate, and perceived exertion. *Presented at American College of Sports Medicine, Denver, CO, July 2011.*

Basic Science: Biomechanics

Donaghe, H.E., Hoffman, M.D.: Exercise Responses During Partial Body-Weight Supported Treadmill Walking and Running in Healthy Individuals. *Presented at ACSM annual meeting, June 2010, Baltimore, Maryland Med Sci Sport Ex 42(5) Supplement S445, 2010*

- This study has been accepted for publication, see "Hoffman, M.D. and Donaghe, H.E.: Exercise responses during partial body-weight supported treadmill walking and running in healthy individuals. *Arch Phys Med & Rehab*, 2011

Jensen, B.R., Hovgaard-Hansen, L., Cappelen, K.L.: Effects of Lower Body Positive Pressure on Muscle Activity and Joint Loads. (University of Copenhagen, Denmark) *Presented at The International Society of Biomechanics meeting, South Africa, July 2009*

- This study showed that maintained horizontal ground reaction forces are most likely responsible for the normal gait patterns seen with all levels of weight support.
- 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
- 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

Forrest, Dana M., Dufek, J.S., Masumoto, K., Mercer, J.A.: Muscle Activity During Running at Reduced Body Weight (University of Nevada, Las Vegas) *Presented at American College of Sports Medicine Annual Meeting, Indianapolis, Indiana, May 2008.*

Applequist, B., Mercer, J.A.: The Effect of Simulated Anti-Gravity on Muscle Activity (University of Nevada, Las Vegas) *Presented at Southwest Meeting of ACSM, San Diego, October 2009*

Liebenberg, J., Scharf, J., Forrest, D., Dufek, J., Mercer, J.A.: Muscle Activity During Running at Reduced Body Weight (University of Nevada, Las Vegas) *Presented at Southwest Meeting of ACSM, San Diego, October 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
- M 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

Mercer, J.A. and Masumoto, K.: Muscle activity during different body weight support mechanisms. *Presented at ACSM Annual Meeting, San Francisco, 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

Moran, M.: Effect of Body Weight Support on Spatiotemporal Running Mechanics. *Presented at ACSM Annual Meeting, San Francisco, May 2012.*

- Body weight support causes runners to increase stride length and decrease stride frequency. Author suggests that runners in training consider using a metronome to maintain appropriate cadence as support increases.

Neurologic: Parkinson's Disease

Byl, N., Cox, L., Forte, A., Fedulow, I., Ide-Don, J.: Maintaining safe mobility in patients with Parkinson's disease: one year outcomes of dual task training under aerobic and moderate exercise. *Presented at International Movement Disorders, San Francisco, May 2010.*

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

Lander, JJ, Moran, MF: Influence of Positive Air Pressure Body-Weight Support On Parkinsonian Gait.

- Presenting at Gait and Clinical Movement Analysis Society 2014
- Single 10 minute training session for Parkinson's patients on AlterG treadmill
- Performed as proof of concept prior to prospective training study
- Improvements seen in step length, cadence, and velocity

Orthopaedics: Achilles Tendon

Saxena, A., Granot, A.: Use of an Anti-Gravity Treadmill in the Rehabilitation of the Operated Achilles Tendon: A Pilot Study *Presented at American College of Foot and Ankle Surgeons Annual Conference, Las Vegas, Nevada, February 2010*

- Individuals are able to perform closed chain walking and jogging early on 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

Orthopaedics: Total Knee Arthroplasty Rehabilitation

Bugbee, WD, Colwell, CC, D'Lima, DD, et al: Use of an Antigravity Treadmill for Rehabilitation After Total Knee Arthroplasty. Presented at ISTA 2013, and In Press: *The Knee*.

- Prospective pilot study of 29 patients undergoing total knee arthroplasty
- Demonstrated safety and efficacy, with improvements in KOOS, TUG, and pain scores
- Foundation for large scale randomized clinical trial which is now underway

Overweight/Obesity:

Christian M: Managing knee osteoarthritis: the effects of anti-gravity treadmill exercise on joint pain and physical function. University of Manitoba Master's Thesis Dissertation. <http://mspace.lib.umanitoba.ca/handle/1993/8580>

- 25 obese adults with moderate knee osteoarthritis pain participated in a 12 week AlterG 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
- This thesis is being prepared for publication in a peer-reviewed journal

Greenwood, M., Mardock, M., et al: Experiencing the Impact of Weight Loss on Work Capacity Prior to Initiation of a Weight Loss Program Enhances Success *Presented at International Society for Sports Nutrition, Las Vegas, Nevada, June 2011, and Published in: J Int Soc Sports Nutr. 2011; 8 (Suppl 1): P2*

- AlterG pretraining showed significant improvements over traditional exercise in weightloss, fat loss, free fat mass, and body fat
- There is an overall significant effect for weight loss and fat loss irrespective of diet

Takacs, Judit and Leiter, Jeff: Correlation of body weight support to pain relief in moderate knee osteoarthritis. *Presented on February 3, 2012 at the Ontario Medical Association Sports Medicine Conference. <http://mspace.lib.umanitoba.ca/handle/1993/4742>*

Greenwood, M., Mardock, M., et al: Experiencing the Impact of Weight Loss on Work Capacity Prior to Initiation of a Weight Loss Program Enhances Success Presented at International Society for Sports Nutrition, Las Vegas, Nevada, June 2011, and Published in: *J Int Soc Sports Nutr.* 2011; 8 (Suppl 1): P2

- AlterG pretraining showed significant improvements over traditional exercise in weightloss, fat loss, free fat mass, and body fat
- There is an overall significant effect for weight loss and fat loss irrespective of diet

Takacs, Judit and Leiter, Jeff: Correlation of body weight support to pain relief in moderate knee osteoarthritis. Presented on February 3, 2012 at the Ontario Medical Association Sports Medicine Conference. <http://mspace.lib.umanitoba.ca/handle/1993/4742>

- 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.

Urology:

Tanza, Sara; Byl, Nancy; Garcia, Maurice: Does Lower Body Positive Pressure Support (LBPPWS) Gait Training On The AlterG Affect Urinary Urgency? 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.

- 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

Conclusions:

- Authors recommend that all individuals void prior to using the AlterG
- Individuals with a history of bladder incontinence should exercise with a pad or diaper
- Authors speculate that AlterG training might be beneficial in training for better bladder control for individuals with a history of stress incontinence or urgency

Ongoing Studies:

Orthopaedics: ACL Reconstruction

- A procedure in which the patient can be "weight bearing as tolerated" immediately after surgery, but typically chooses to use crutches for several weeks due to pain, stiffness, disuse atrophy, and muscle weakness is an opportunity in which the AlterG can be used very early. It is hypothesized that very early postoperative use will lead to improved near term functional outcomes, the ability for the patient to gain an early cardiovascular training effect, and faster return of running activity in a manner that is safe for the ACL graft. A randomized prospective clinical trial is concluding in Q3 2014.

Orthopaedics: Total Knee Arthroplasty

- A multicenter prospective randomized trial is commencing comparing AlterG rehabilitation with conventional therapy. This trial will enroll approximately 360 patients and will continue enrollment and data collection through the end of 2014.

Orthopaedics: Lumbar Microdiscectomy

- A 120 patient Level 1 randomized clinical trial is underway comparing conventional physical therapy vs. combination conventional physical therapy + AlterG following lumbar microdiscectomy and fusion. This study is enrolling and is scheduled to run through 2014.

Orthopaedics: Usage of Tibial Shock as a Predictor of 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.

Orthopaedics/Sports Medicine: Modulation of Cartilage Oligomeric Matrix Protein Turnover

- Cartilage oligomeric matrix protein (COMP) is a marker of articular cartilage degradation. A comparison of running with and without AlterG is underway in Germany, with the hypothesis that body weight support will lessen the amount of COMP turnover with running.

Orthopaedics / Sports Medicine: Recovery of Muscle Function and Blood Lactate

- Blood lactate levels are a marker of muscle injury in high-intensity running training. The AlterG is proposed as a method to improve the speed and quality of recovery after intense running. A study is underway in Germany examining this question.

Orthopaedics: Arthritis

- Arthritis Gait Pain and Exercise Study
- The effect of treadmill walking exercise with a partial reduction of body weight on knee osteoarthritis disease progression
- Nonsurgical management of knee osteoarthritis using the AlterG
- What is the effect of the AlterG on perceived pain levels during exercise for patients with knee osteoarthritis?

- Will patients with knee osteoarthritis choose to exercise more on the AlterG compared to other forms of exercise?
- What are the quality of life improvements for exercise on the AlterG?

Geriatric Conditioning: Effects of AlterG Treadmill Training on Balance, Mobility, and Lower Extremity Strength of Physically Impaired Community-Dwelling Adults

- Certain geriatric conditions result in a loss of independent ambulation, loss of strength, and increased fall risk. The second part of a planned multi-part investigation is a pilot study of strength and functional gains in older adults with specific physical impairments.

Neurologic

- 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

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 AlterG enables overweight individuals to exercise in ways they could not otherwise.

- o The ability to "feel what their body is like at a lower weight" is highly motivational
- o Unweighting allows them to exercise in a pain free range
- o Metabolic demand can be maintained even with unweighting by increasing walking speed
- o Measuring metabolic markers of health: glucose tolerance, plasma lipids, liver fat, muscle fat

Athletic Performance

- Overspeed training
- Strength and speed gains in healthy runners
- Rehabilitation of chronic tendonopathies
- Effect of Reduced Body Weight Running on Footstrike Haemolysis

Prospective Studies Proposed (In Early Planning):

Cardiovascular: Cardiac Rehabilitation

- Planned prospective study at Johns Hopkins University to use the AlterG Anti-Gravity Treadmill as an exercise modality during cardiac rehabilitation

Cardiovascular: Cardiac Stress Testing In Obese Individuals

- Planned prospective study at University of Cincinnati
- Use of the AlterG Anti-Gravity Treadmill as an alternative to pharmacologic stress testing for obese patients who are otherwise unable to do conventional treadmill stress testing

Orthopaedics: "Prehabilitation" for Weight Reduction Prior to Total Knee Arthroplasty

- Orthopaedists traditionally recommend presurgical weight reduction for overweight individuals scheduled for total knee arthroplasty. However, most patients are unable to achieve meaningful weight reduction due to the fact that exercise leads to knee pain.
- The study authors propose that weight reduction can be achieved on the AlterG with a combination of pain relief and exercise

Fully-Referenced Case Reports:

Hatimiya, NS, Luke, AC: Utility of Offloaded Running Gait Retraining in a Runner with Medial Knee Osteoarthritis and a Varus Thrust: A Case Report. Presented at SWACSM 2013.

- A 57 y.o. male presented with persistent right medial knee pain. An active runner since 13 y.o., he was running 60 miles per week and 3 marathons annually. The patient could not run without severe pain, despite avoiding impact activity for 2 months with NSAIDs and traditional physical therapy. The patient underwent a 14 week training program on the AlterG Anti-Gravity Treadmill beginning at 30% body weight and progressing to full body weight. After training the patient's pain was negligible, with results maintained to the follow up conclusion at 4 months. He successfully completed a marathon at 4 months after training.

Moore MN, Vandenakker-Albanese C, Hoffman MD. Use of partial body-weight support for aggressive return to running after lumbar disk herniation: a case report. *Arch Phys Med Rehabil* 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 its use until he adequately improved to allow return to his regular over-ground running program. This case 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.

Simonson, S.R., Shimon, J.M., Long, E.M., Lester, B: Effects of a Walking Program Using the AlterG Anti-Gravity Treadmill System on an Extremely Obese Female: A Case Study. *Clinical Kinesiology* 65(2); Summer, 2011: 29-38.

- This case study examined the effects of a 14 wk walking program on one extremely obese (BMI 69.2) Caucasian 44 year-old female utilizing the AlterG Anti-Gravity Treadmill. At the conclusion of the study, exercise tolerance time increased 3-fold while caloric expenditure increased 10-fold without an increase in heart rate or perceived pain in her lower extremities. The 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 AlterG 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.

Tenforde AS, Wananabe, LM, Moreno TJ, Fredericson, M: Use of an Antigravity Treadmill for Rehabilitation of a Pelvic Stress Injury. *PM&R* 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 on AlterG during the healing phase of her stress fracture
- At 10 weeks after injury onset the runner was able to compete pain free in the NCAA 10k championships.
- Authors believe that AlterG training allowed this runner to return to competition in a much faster fashion than she would have with conventional rehabilitation

Case Studies From Physical Therapist and Clinician Users:

- Hip: labrum repair, microfracture, total hip arthroplasty, arthroscopy for femoro-acetabular impingement, bilateral hip resurfacing, slipped capital femoral epiphysis, bilateral hip arthroplasty, femoral neck stress fracture
- Knee: acl reconstruction, microfracture, nonsurgical rehabilitation after acl tear, partial meniscectomy, unicompartmental knee replacement, total knee replacement, patellofemoral pain syndrome, tibial plateau fracture
- Ankle: lateral ligament reconstruction, open reduction and internal fixation of ankle fracture
- Foot: plantar fascia tear, metatarsal stress fracture in elite runners
- Leg: bilateral compartment syndrome release, fibula stress fracture, tibia stress fracture, tibia fracture intramedullary rod
- Femur/Thigh: femur fracture intramedullary rod
- Neurologic: chronic stroke rehabilitation, transient ischemic attack
- Cardiovascular: postural orthostatic tachycardia syndrome
- Geriatrics: general conditioning for severe functional decline