AlterG®
Differential Air Pressure (DAP) Technology for Assisted Exercise

Differential Air Pressure (DAP) Technology for body weight support to assist standing and exercise.

The concept of using advanced differential air pressure (DAP) technology for weight support was originally conceived by Dr. Robert Whalen while he was studying the biomechanics of exercise in space as part of an effort to design effective exercise regimens for NASA's astronauts. AlterG® has developed this concept into a technology for use in training and rehabilitation and developed a user friendly platform with ergonomics and adjustability that suit an extraordinarily wide range of users.

Figure 1a is a photograph of our current commercial model the AlterG Anti-Gravity Treadmill® a computer-controlled integrated body-weight-support treadmill system, which uses DAP technology to support the user comfortably while he or she stands, walks or runs on the treadmill. Figure 1b is a simplified sketch that illustrates how Alter-G uses the principle of a difference in air pressure ($\Delta P = P_2 - P_1$) between the lower body (elevated pressure P_2) and the upper body (atmospheric pressure P_1) to generate a resultant vertical upward force (F_{air}). The upward force (F_{air}) acts directly opposite to the force of gravity and therefore subtracts from body weight (BW) to provide partial body-weight-support that is proportional to (ΔP) the air pressure difference.

There are several key points that clearly distinguish the Anti-Gravity Treadmill® from other forms of weight supported exercise:

1) The elevated air pressure, and therefore the support force, is uniformly distributed against the lower body which makes it almost imperceptible just as lying on a comfortable sofa or mattress can be. A large percentage of body weight can be supported without an appreciable sense of pressure. This is distinctly different from harness systems that have distinct concentrated points of contact pressure.
2) The support force acts very near the center of mass and this contributes to balanced or neutral support which maintains normal biomechanics even at high levels of support (low body weight). This is distinctly different from harnesses which apply torques at the periphery of the body and pool systems in which the magnitude and focus of the support force changes with water level.
3) Body weight not mass or viscous drag is affected, therefore the natural forces associated with the acceleration and deceleration of limbs is not affected. This maintains the neuromuscular patterns of movement while impact is reduced. Water based systems have very large drag components that substantially alter muscle activation patterns.
4) The support force is proportional to the air pressure which can be easily and rapidly regulated. This makes possible: a wide range of body support, very rapid control of support (even controlling the support during a single stride) and highly accurate support that can be reproduced both within and between uses.

Figure 1a

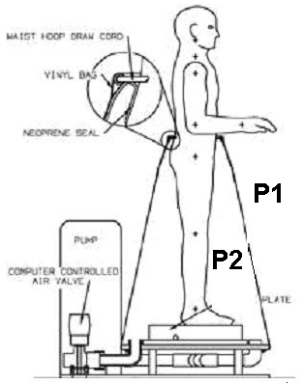

Figure 1b

How much pressure does it take to completely support a person with air pressure alone? Surprisingly little. The ratio, (BW/ $A_{waist\ x\text{-}section}$), is such that it takes *approximately* 2 pounds per square inch (2 psi) to lift a person, regardless of body weight. A person with reasonable lung power can produce, for example in blowing up a very stiff balloon, a pressure on the order of 2-3 psi. Thus, in principle, a person could lift one's self with his or her own breath pressure.

Interactive Effects of Running Speed and Weight Support on Metabolic Power and Ground Reaction Forces

The mechanics of walking and running gait are controlled primarily by gravity (*g*) acting at the center of gravity of the body, which during gait is at or near the center of the waist. Using air pressure to support the body works so well because the support force, , acts at or very near this same point, regardless of the amount of body weight support. Thus, for example, walking or running at 50% body-weight-support in the Anti-Gravity Treadmill® is a good simulation for walking and running in a reduced gravitational field equal to 1/2 Earth's gravity—gait mechanics are maintained with an appropriate reduction in the external ground reaction forces (GRFs) and internal musculoskeletal forces.

Research carried out By Drs. Alena Grabowski and Rodger Kram at the University of Colorado, Boulder on healthy runners confirm the physics we have stated and illuminates additional functionality of the Alter G Anti-Gravity Treadmill®. (http://www.asbweb.org/conferences/2007/pdf/161.pdf).

The highlights of their research include:

1) Ground reaction forces (GRF) can be effectively reduced and precisely regulated by controlling differential air pressure.
2) By running at faster speeds with weight support, runners can have the same aerobic stimulus with reduced peak vertical GRFs.
3) The decrease in active peak GRF may additionally benefit runners by reducing the potential risk of over-use injury.
4) The Anti-Gravity Treadmill® allows runners to run at very high, sustainable speeds with weight support. It is generally believed that training at high speeds can positively affect running performance by enhancing cardiovascular and neuromuscular function (Costill, 1979; Daniels, 2005).
5) The Anti-Gravity Treadmill® can provide assistive horizontal and lateral forces (important in low mobility or "at risk" populations) when the user leans or looses balance.
6) The comfort of the Anti-Gravity Treadmill® allows workouts of 1-2 hours duration if desired.
7) Peak active GRFs of a person running at 50% body weight are similar to walking however step frequency and length are substantially greater.

This last point is particularly exciting for lower mobility populations who are currently rehabilitating or have long ago given up running because of limiting factors such as muscle strength, ground reaction support, joint pain, and insecurity of falling.

In Figure 2a, active peak vertical GRF at 50% body weight is approximately 1.15 BW, equivalent to walking at about 1.3 m/s. Step frequency and step length for the runner are considerably greater than walking however. In addition, muscle activation patterns for the runner are similar to full body weight running, not walking. With the Anti-Gravity

Treadmill® providing a secure environment for the user, this becomes an attractive exercise method which could restore fast twitch muscle activation patterns and strength both of which are considered important in fast corrective steps used to regain balance and prevent falling(ref). Additionally the presence of this sort of muscle activity is very likely adequate for reducing or preventing atrophy and muscle enzymatic changes that begin in the early post-surgical rehabilitation period.

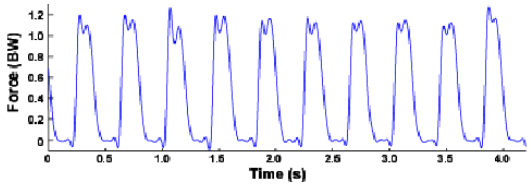

Figure 2a

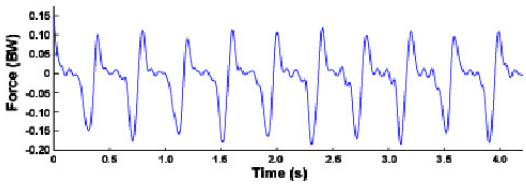

Figure 2b

Figures 2a and 2b: Subject running 3.0 m/s at 50% body-weight-support in the Anti-Gravity Treadmill®. Vertical (2a) and horizontal (2b) ground reaction forces (GRF). (With permission from Grabowski and Kram)

The research also showed an interesting effect of running speed on metabolic rate. As speed increases the total metabolic demand is increasingly dominated by the energy required to support the rapid shortening of muscle fibers required to stiffen the leg. Conversely, the energy necessary to actually support the body becomes relatively smaller. In other words by running increasingly fast with increasing weight support one can increasingly escape the normal impact forces associated with running while maximizing the stimulus for aerobic conditioning and leg power development. This could very well define a new operational envelope for speed training in both aerobic and anaerobic realms as well as new paradigms for interrupting loss of mobility or initiating the restoration of gait in the disabled. The fact that the rigid bag structure of the Anti-Gravity Treadmill® serves to stabilize the user and prevent falling only strengthens its use in mobility impaired individuals who must limit their efforts in order to avoid potentially falling. Grabowski and Kram summarized the interaction of speed and weight on gross metabolic power with the following equation:

MP = 6.11BW + 2.29v – 2.65 (R2 = 0.49)

Where MP is in units of watts per kilogram, v is in units of meters per second, and BW is a decimal fraction of body weight. (http://www.asbweb.org/conferences/2007/pdf/161.pdf).

Cardiovascular Effects of Lower Body Pressure

Positive pressure applied to the lower part of the body decreases blood pooling in the veins of the lower limbs. The body and cardiovascular system respond to this much the same as they do to a transition from upright to lying posture. This has several important implications regarding use of the Anti-Gravity Treadmill®:

1) Application of modest pressures such as those used in the Anti-Gravity Treadmill® (0-50mmHg) enhances venous return and reduce presyncopal or syncopal events. This may be useful in individuals at risk for fainting and fall including those with impaired mobility, spinal cord injury, neuropathies or those returning to upright posture after surgery or extended bed rest.

2) Lower body positive pressure applied in conjunction with aerobic exercise does not significantly alter the relationship between heart rate and workload. Athletes, trainers and therapists working with individuals that have normal cardiovascular health can build comparable workouts based on heart rate indexes of workload.

3) The positive pressure can serve as a therapeutic modality to discourage: the pooling of blood in the legs, swelling, and edema. This may be beneficial following workouts, for active recovery, and to enhance circulation or to reduce the occurrence of inflammation.

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