Published in final edited form as:
J Strength Cond Res. 2021 October 01; 35(10): 2910–2914. doi:10.1519/JSC.0000000000003223.

The AlterG® Anti-Gravity Treadmill accuracy of unloading is affected by support frame height

Hendrik D de Heer[1], **Alex Kaufman**[2], **Chris P Repka**[1], **Katia Rojas**[2], **Brenda Charley**[1], **Roger Bounds**[1]

[1]Northern Arizona University, Department of Health Sciences.

[2]Northern Arizona University, Department of Biological Sciences

Abstract

The AlterG® Anti-Gravity Treadmill™ uses air pressure to provide partial Body Weight Support (BWS), lowering impact forces and metabolic demand of walking and running. Users wear specialized shorts that zip onto a bag supported by a metal bar frame covering the treadmill. The frame is placed at hip height in positions numbered 1–9, adjusted up or down based on preference. Machine accuracy in providing body weight support is important to achieve desired training effects, but it is unknown whether frame placement impacts accuracy. Twenty participants (10 males/females) were weighed in 10% increments from 0% to 60% BWS with the frame at hip height (iliac crest), the 'neutral' position, and re-weighed with the frame placed up to 3 numbers above or below hip height. While the machine displayed the same proportion BWS, placing the frame *higher* than the neutral position resulted in significantly *more* support, whereas placing the frame *lower* led to less support. At 10% BWS, placing the frame 3 positions higher resulted in 3% more support compared to the neutral position (13.1% BWS, p<.001), and 3 positions lower in 4.7% less support (5.3% BWS, p<.001). Deviances were greater with more BWS. At 60% BWS, 3 positions higher than neutral resulted in 71.2% BWS (11.2% more than expected, p<.001), and 3 below 48.1% BWS (12.9% below expected, p<.001), total 24.1% difference. These findings suggest that the position of the support frame significantly impacts the AlterG® accuracy in providing body weight support, with placement higher than hip height resulting in more support than displayed by the machine, and lower placement resulting in less support.

Keywords

Running; body weight support; bar height; support structure; precision; lower body positive pressure

INTRODUCTION

The AlterG® Anti-Gravity Treadmill™ is a device that uses air pressure to allow people to walk or run with partially supported body weight (1). Users wear specialized shorts that zip onto a bag, which is in turn supported by a metal frame bar that covers the treadmill.

Corresponding author: Hendrik 'Dirk' de Heer, PhD, MPH. Northern Arizona University, Department of Health Sciences. Address: 1100 S Beaver Street, PO Box 15095, Flagstaff, AZ, 86011. dirk.deheer@nau.edu. Phone: 928-523-1499. Fax: 928-523-0148.

This setup creates a sealed positive pressure environment (Figure 1). Running or walking on the treadmill with partially supported body weight has been found to reduce the impact forces and metabolic demand of running or walking (3,4,7,8,10,15) The machine has been used in a range of performance and rehabilitation settings and included world-class distance runners (2), people recovering from Achilles tendon surgery (16), pelvic stress fracture (17) and people with neurological conditions such as cerebral palsy (11).

The accuracy of the machine in providing body weight support is important to achieve the desired training effects and to implement systematic rehabilitation protocols. Prior research (13) has shown that the machine is highly accurate between 10% to 40% Body Weight Support (BWS). However, what this study did not assess was whether the placement of the metal bar frame support structure impacted the accuracy of the AlterG® in providing BWS. The frame bar is recommended to be placed at the iliac crest and locked into a position numbered 1 through 9, which can be adjusted up or down based on preference, as specified in the operations manual: "*Set the support frame at a height that places the zipper at your iliac crest…This is a starting point. For additional trunk support the frame can be set higher. For more freedom, the frame may be set lower. With use, you will discover the best height for you. (AlterG® operations manual, p.13)"*

However, it is not mentioned whether moving the frame impacts the actual body weight support provided by the machine, and no published studies have tested whether this is the case. Therefore, this technical study aimed to assess whether the placement of the bar frame height impacted the accuracy of unloading. Since the operations manual suggested the frame can be moved up for *additional trunk support,* we hypothesized that moving the bar up would lead to more support compared to the neutral setting (hip height), possibly be due to a higher air volume when the frame is moved up (all else being equal). We hypothesized the opposite would be true if the frame bar was moved down.

METHODS

Experimental Approach to the problem

To test whether the frame height impacted the AlterG® accuracy, we weighed every participant on the machine with the bar frame in the recommended position with the zipper just below the iliac crest ('neutral'). This weight was then compared to measurements with the bar frame placed up to 3 positions and below the neutral position. Participants were weighed in 10% increments between 40% of their original body weight and 100% body weight as displayed by the machine.

Subjects

All study procedures were approved by the Institutional Review Board (protocol #929347) and all participants signed an institutionally approved informed consent form prior to the study outlining the study risks and benefits. Participants were recruited through word of mouth from the University population. A total of 20 healthy adults were recruited, 10 males and 10 females.

Procedures

After being provided with written and verbal informed consent, anthropometric measurements (height, weight, hip height and waist circumference) were measured and recorded. Hip height was measured barefoot from the ground to the top of the anterior superior iliac spine. Waist circumference was measured with a tape measure below the rib cage and above the pelvis at the umbilicus. Height and weight were measured and recorded before the participant entered the AlterG®, Model P200 (AlterG® Inc., Fremont, CA). All participants were measured twice, with the average taken as the final value.

After completion of anthropometric measurements, subjects entered the AlterG®, calibrated their weight and had their standing body weight measured with a Tanita BF679 portable scale, which we compared and found to be within 0.1kg (99.8%−99.9% agreement) of a professional grade Tanita WB Medical Scale. Participants were weighed at 0% BWS, 10%, 20%, 30%, 40%, 50%, 60% BWS (as indicated by the AlterG®). At each level of BWS, participants were weighed with the frame bar in 7 different positions: first with the frame bar set according to the directions in the user manual (with the zipper just below the iliac crest while standing on the scale), called the 'neutral' position. Then, they were weighed with the frame 1,2 and 3 positions above and below the recommended (neutral) setting, all while standing on the scale. Thus, participants were weighed at 7 different BWS increments (0% through 60% BWS) and at 7 settings (neutral and 1,2,3 above/below), or 49 unique settings. At each setting, participants were measured twice to avoid errors and the value averaged.

Data were collected in a single measurement time, taking approximately 45 minutes per individual. Data were manually recorded on a data collection sheet and entered into a spreadsheet. This spreadsheet data were then imported to SPSS version 24.0 (SPSS Inc, Chicago, IL) for analyses.

Statistical Power

Assessing statistical power was challenging due to the relative lack of research guiding our estimated effect size. A medium effect size was used in part based on one relevant article (9), which documented a wide range in magnitude of effects, but medium size effects of 2–7% deviation from expected at the lower end of unloading. For a medium effect size, a power analysis using GPower version 3.1.9.2 for repeated measures' ANOVA within factors effect, one group, 49 total measures and an average correlation of 0.8 between measures showed an N=16 to result in estimated power over 0.80. After 20 participants were recruited, further recruitment was stopped as only very small changes (less than 0.25%) were observed in our primary outcomes with the addition of each new participant.

Statistical Analyses

Participant demographic and anthropometric characteristics were summarized using frequency distributions and descriptive statistics. To test whether the frame bar height impacted extent of unloading, repeated measures Analyses of Variance were used. The neutral position was used as Time 1 (the reference), with the higher or lower frame height positions as the comparisons. First, overall effects were tested. Second, one ANOVA was conducted for each of the proportions BWS support (seven total, 0% support through

60% support in 10% increments). Pairwise comparisons were used to test for significant differences between each setting and the neutral setting. A Bonferroni confidence interval adjustment was used to correct for multiple comparisons. All analyses were conducted using SPSS 24.0 (SPSS Inc, Chicago, IL).

RESULTS

Participant characteristics

Participant characteristics are summarized in Table 1. Participants were on average 27.45 ±6.76 years old, average height (175.10± 10.33 centimeters tall). Participants Body Mass Index (BMI) was in the healthy range with 22.27 ±2.52 kg/m^2 and none of the participants were obese (BMI ≥ 30kg/m^2). Average waist circumference also indicated that participants were not obese, with an average of 86.76 ±8.90cm.

Accuracy of Body Weight Support

First, the accuracy of the AlterG® treadmill in providing BWS was assessed in the recommended ‘neutral’ setting of the frame bar height, comparing observed to expected proportion body weight support. In the ‘neutral’ setting (at hip height), the AlterG® was the most accurate between 10% and 40% BWS (90% and 60% of full body weight), with less than 1% deviation from the expected proportion support. At the lower end of the scale, the deviation was larger, although practically modest (3.5% less support than expected at 40% BWS). At 0% BWS, the machine still provided approximately 6% support. These findings closely mirrored findings from prior research (9).

The most accurate setting for each respective BWS (the closest to the expected BWS) was aligned with these findings. At 0% BWS, the most accurate setting was actually the lowest setting (3 slots below), whereas from 10% BWS to 40% BWS, the neutral setting was the most accurate. For 50% and 60% BWS, the setting 1 above the neutral setting was the most accurate.

Next, we assessed our primary study question by first testing for a main effect for frame height using a repeated measures’ ANOVA with level of support and frame height. There was a significant main effect for frame height (F(df=6)=166.04, p<.001), indicating that there were overall differences in BWS for frame position (neutral and 1,2,3 above/below). There was also a significant interaction, indicating the effect of bar height was different across levels of support (F(df=36)=83.83, p<.001).

Next, we compared the amount of deviation caused by moving the bar up or down 3 slots from the neutral setting. The proportion of deviation from the expected BWS is shown in Table 3. At each level, moving the bar from the neutral setting had a substantial impact on the accuracy of unloading. At 10% BWS, the lowest setting (3 below neutral) resulted in only 5% BWS, and the highest setting (3 above neutral) resulted in 13% support, a difference of 8%. This difference became larger with more BWS. At 60% BWS, the lowest setting (3 below neutral) provided only 43.43% support, and the highest (3 above neutral) 67.49%, a difference of 24% in BWS.

Using repeated measures' ANOVA with Bonferroni adjustment, we tested whether each setting was significantly different from the neutral setting. Almost all settings were significantly different from the neutral setting, with the exception of 0% and 10% BWS at 1 setting below and above. Linear trends (p<.001) were observed for each proportion BWS. These findings are graphically summarized in Figure 1.

DISCUSSION

This study aimed to test the impact of the height of the AlterG® treadmill metal bar frame support structure on the accuracy of the body weight support provided by the machine. The owners' manual indicates the bar should be placed at hip height, but can be moved up or down through the 9 spaces ('slots') depending on user preference for greater trunk support or more freedom of movement. However, we found that moving the bar from the neutral setting (at hip height) impacts the actual proportion of support provided by the AlterG® treadmill, despite showing the same proportion of unloading on the machines' display. We found that mostly, placing the bar at hip height was indeed the most accurate setting, with the greatest accuracy between 10% BWS and 40% BWS and overall accuracy consistent with prior research (13). Moving the bar up resulted in significantly more body weight support, and moving the bar down reduced the support. These findings were largely consistent with our a priori hypotheses, which stated that when the bar is moved up, the BWS would be higher (or lower when moved down), all other factors being constant.

Effects were found to be greater at the higher proportions of support. For example, when running with at least 30% BWS, moving the bar just 1 slot up or down from neutral impacted the amount of BWS by between 4 and 8%, with somewhat stronger effects for moving the bar down. This may be particularly important when for people who use the AlterG® for initial weight-bearing after serious injury, people who may be in early rehabilitation stages, or people with conditions that require substantial BWS (>30% BWS). Several clinical case studies and clinical protocols show rehabilitation starting with at least 50% BWS is common. For example, case studies documented aggressive return following lumbar disk herniation starting at 50% and progressing to 15% BWS in 23 days (11), progression from 50% BWS to 5% BWS for a runner with pelvic stress fracture in 5 weeks (15) and progression from 70% to 20% BWS in 7 weeks following knee osteochondral repair (5). Similarly, clinical protocols published by AlterG® suggest rehabilitation from fibular stress fracture from 45% to 15% BWS in 6 weeks (6) and following Achilles tendon repair from 70% to 10% BWS in 7 weeks starting 9 weeks post- surgery (9).

As can be seen, these protocols typically start at around 50% BWS, and progress systematically between 5% and 10% per week. This would suggest that the 4 to 8% deviation documented by moving the frame bar by only 1 slot could be meaningful, with larger effects if the frame height is moved by more than 1 slot. In addition, research has documented that with more than 30% BWS, changes in running mechanics are observed (8). In other words: deviation from what the machine displays due to the bar height could also impact running mechanics.

Further, the AlterG® has been used for some of the most common running injuries and can be used for a wide range of conditions, suggesting this information may be relevant for a wide range of practitioners and users. For example, a systematic review found that the most common running injury was medial tibial stress syndrome with an incidence ranging from 13.6% to 20.0% (12). If a runner with medial tibial stress syndrome started low-speed running on the AlterG® with half their body weight supported (50% BWS), and preferred to have more freedom of movement and lowered the bar several slots, this could have actually resulted in them running with close to 35% BWS. This difference could result in greater impact forces than intended. The reverse could occur and lead to undertraining.

This study had several limitations. First, it was challenging to conduct a power analysis due to limited effect size estimates in the literature. Second, we used a specific AlterG® model, the P200 performance model. Although it would be assumed that the system of unloading is similar in all models, this will have to be tested. Further, we only tested the range from 0% BWS through 60% BWS, as these were the most commonly used settings for athletic and rehabilitation purposes. However, the higher-pressure settings (the machine can provide as much as 80% BWS) were not included. In addition, the top of participants' iliac crest while standing on the scale was used to estimate the initial frame bar placement (neutral). Although participants stood on the scale for every measurement, the impact of the height of the scale itself deserves further study. Also, while the patterns of deviance found in this study were consistent, we have not tested the impact on frame height on metabolic demand or impact forces. Also, our population included healthy weight adults with non-obese waist circumference. Finally, while we have proposed a working hypothesis to explain these effects, we did not conduct further tests to gain insight into the likelihood of specific mechanism behind the observed deviance.

PRACTICAL APPLICATION

Users, coaches, physical therapists, athletic trainers and others who instruct people on the AlterG® need to know that moving the AlterG® frame height frame impacts the extent of unloading provided by the machine. The machine will show the same proportion of unloading, but if the user adjusts the frame upwards, they are now walking or running with greater support. If the user lowers the frame, they are now walking or running with less support. Placing the frame bar at hip height is generally the most accurate setting, particularly at 10% through 40% support. The more the frame bar is moved from the recommended hip height, the greater the deviation in support provided.

The effects are largest with more body weight support, and thus particularly meaningful for people walking or running with a lot of BWS, such as people who are in the initial stages of recovery. For example, if a therapist wants a user who is recovering from a fracture to walk with a high proportion BWS (for example, with 60% BWS or at 40% of their full body weight), and lowers the frame bar 3 positions for additional freedom of movement, they are actually decreasing the BWS by up to 13%. These findings demonstrate that moving the frame bar may lead to more impact than intended, or less impact resulting in a lighter workload than intended, and should be taken into account when using the machine.

Acknowledgements

The current study was made possible by funding from the Technology Research Initiative Fund (TRIF) and National Institute of General Medical Sciences of the National Institutes of Health under award number 1R25GM127199–01. The authors declare no conflict of interest. The results of the present study do not constitute endorsement of the AlterG® treadmill by the authors or the NSCA.

REFERENCES

1. AlterG® Inc. Operation Manual AlterG® AntiGravity TreadmillTM P200, 2011. Fremont, CA. Available at: https://www.AlterG®.com/wp-content/themes/AlterG®-child/PDFs/Manuals/AlterG®-P200-Operations-Manual-2011.pdf
2. de Heer HD, Raab S, Kline JR, Bounds R. AlterG® Anti-gravity Treadmill Training To Facilitate Return From Injury Of A World-class Marathon Runner. J Orthop Sp Phys Ther44(1):A189, 2014.
3. Gojanovic B, Cutti P, Shultz R, Matheson GO. Maximal Physiological Parameters during Partial Body-Weight Support Treadmill Testing. Med Sci Sports Exerc44(10):1935–941, 2012. [PubMed: 22543742]
4. Grabowski AM. Metabolic and Biomechanical Effects of Velocity and Weight Support Using a Lower-Body Positive Pressure Device During Walking. Arch Phys Med Rehab91(6):951–57, 2010.
5. Hambly K, Poomsalood S, Mundy E. Return to running following knee osteochondral repair using an anti-gravity treadmill: A case report. Phys Ther in Sport226:35–40, 2017.
6. Hashimoto JK. AlterG Clinical Protocol Lower Extremity Stress Fracture. Available at: https://www.alterg.com/wp-content/themes/alterg-child/PDFs/Clinical-Protocols/Lower-Extremity-Stress-Fracture.pdf
7. Hoffman MD, Donaghe HE. Physiological Responses to Body Weight–Supported Treadmill Exercise in Healthy Adults. Arch Phys Med Rehab92(6): 960–66, 2011.
8. Farina KA, Wright AA, Ford KR, Wirfel LA, Smoliga JM. Physiological and biomechanical responses to running on lower body positive pressure treadmills in healthy populations. Sp Med47(2):261–75, 2017.
9. Granot AAlterG Clinical Protocol Achilles Tendon Repair. Available at: https://www.alterg.com/wp-content/themes/alterg-child/PDFs/Clinical-Protocols/Achilles-Tendon-Repair.pdf
10. Kline JR, Raab S, Coast JR, Bounds RG, McNeill DK, De Heer HD. Conversion table for running on lower body positive pressure treadmills. J Strength Cond Res29(3):854–62, 2015. [PubMed: 25162650]
11. Kurz MJ, Corr B, Stuberg W, Volkman KG, Smith N. Evaluation of lower body positive pressure supported treadmill training for children with cerebral palsy. Pediatr Phys Ther23(3):232–9, 2011. [PubMed: 21829114]
12. Lopes AD, Hespanhol LC, Yeung SS, Costa LO. What are the main running-related musculoskeletal injuries?Sports Med42(10):891–905, 2012. [PubMed: 22827721]
13. McNeill DK, De Heer HD, Bounds RG, Coast JR. Accuracy of unloading with the anti-gravity treadmill. J Strength Cond Res29(3):863–8, 2015. [PubMed: 25226319]
14. 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 Rehab91(5):803–5, 2010.
15. Patil S, Steklov N, Bugbee WD, Goldberg T, Colwell CW Jr, D'lima DD. Anti-gravity treadmills are effective in reducing knee forces. J Orthop Res31(5):672–9, 2013. [PubMed: 23239580]
16. Saxena A, Granot A. Use of an anti-gravity treadmill in the rehabilitation of the operated achilles tendon: a pilot study. The journal of foot and ankle surgery50(5):558–61, 2011. [PubMed: 21703879]
17. Tenforde AS, Watanabe LM, Moreno TJ, Fredericson M. Use of an Antigravity Treadmill for Rehabilitation of a Pelvic Stress Injury. Am Acad Phys Med Rehab4(8): 629–31, 2012.

Figure 1:
The AlterG® P200 treadmill (www.AlterG®.com)

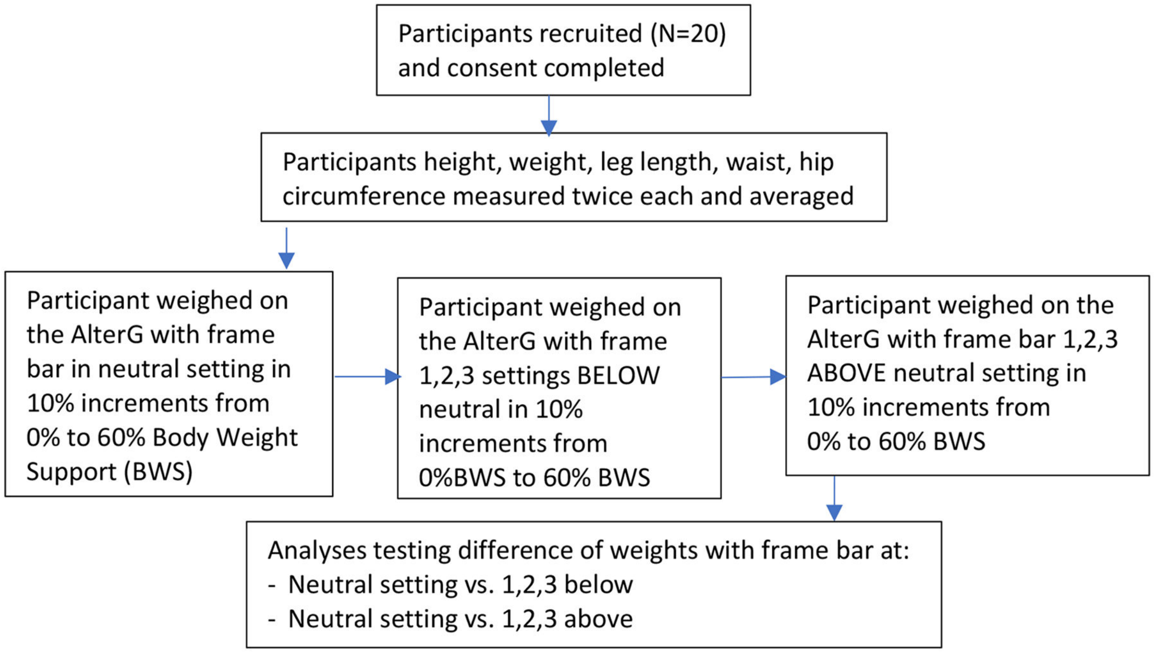

Figure 2:
Study flowchart

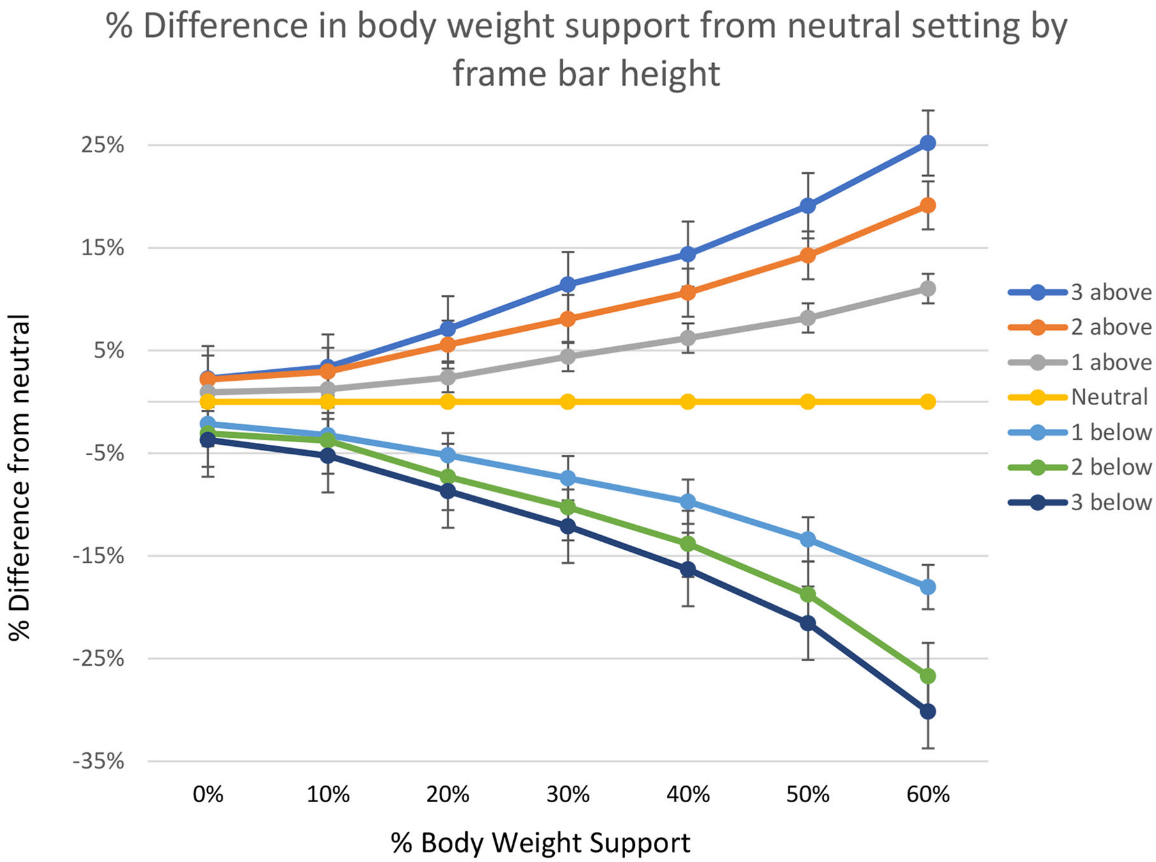

Figure 3:
Proportion difference in Body Weight Support from neutral setting by frame height

Table 1:

Participant demographic and anthropometric characteristics.

Variable	Average value (Standard Deviation)
% Male	50%
Age (years)	27.45 (6.76)
Weight (kg)	68.13 (8.28)
Height (cm)	175.10 (10.33)
Body Mass Index	22.27 (2.52)
Waist circumference (cm)	86.76 (8.90)
Hip Height (cm)	89.94 (5.81)

Table 2:

Expected and observed Body Weight Support provided by the AlterG® in the neutral setting

Expected support	0%	10%	20%	30%	40%	50%	60%
Observed support (%, SD †) with							
frame bar in neutral setting *	5.92 (2.49)	10.06 (2.56)	19.78 (3.42)	29.21 (4.31)	38.47 (4.45)	47.63 (5.64)	56.54 (6.48)
Most accurate setting	3 Below	Neutral	Neutral	Neutral	Neutral	1 Above	1 Above

*Neutral setting refers to frame bar placed at hip height as recommended in the user manual;

†SD= Standard Deviation.

Table 3

: Observed Body Weight Support by frame height setting on the AlterG® Treadmill

(%) BWS displayed	0% (95% CI†)	10%	20%	30%	40%	50%	60%
3 below	2.41** (1.86, 2.97)	5.34** (4.68, 5.99)	12.81** (11.80, 13.83)	20.63** (19.21, 22.04)	28.43** (26.62, 30.24)	36.34** (34.13, 38.55)	43.43** (40.91, 45.95)
2 below	3.01** (2.29, 3.73)	6.67** (5.35, 7.98)	13.92** (12.86, 14.97)	21.94** (20.47, 23.41)	29.96** (28.07, 31.85)	37.81** (35.56, 40.06)	48.70** (46.16, 51.24)
1 below	3.89 (3.09, 4.74)	7.14 (5.52, 8.76)	15.61* (14.18, 17.04)	23.94** (22.14, 25.75)	32.49** (30.48, 34.50)	40.61** (38.37, 42.86)	48.70** (46.16, 51.24)
0 (Neutral)	**5.92** (4.76, 7.09)	**10.06** (8.86, 11.26)	**19.78** (18.18, 21.39)	**29.21** (27.19, 31.23)	**38.47** (36.39, 44.56)	**47.63** (44.99, 50.27)	**56.54** (53.51, 59.57)
1 above	6.79 (5.70, 7.88)	11.16 (10.07, 12.25)	21.68** (19.91, 23.46)	32.33** (30.31, 34.35)	42.29** (39.73, 44.85)	51.91** (49.03, 54.78)	61.33** (58.18, 64.48)
2 above	7.96** (6.79, 9.13)	12.70** (11.41, 13.98)	24.25** (22.29, 26.21)	34.92** (32.55, 37.28)	45.01** (42.39, 47.63)	55.10** (51.84, 58.35)	64.86** (61.34, 68.37)
3 above	8.06** (6.78, 9.34)	13.10** (11.80, 14.40)	25.49** (23.26, 27.72)	37.30** (34.24, 40.37)	47.32** (44.21, 50.43)	57.63** (54.20, 61.06)	67.49** (64.16, 70.82)
Model Partial $\acute{\eta}^2$	.816	.740	.865	.868	.878	.892	.917

* = significantly different from neutral at p<.01,

** = significantly different from neutral at p<.001.

† 95% Confidence Interval with Bonferroni adjustment for multiple comparisons. Analyses included repeated measures' ANOVA with neutral as reference condition, and pairwise comparisons with Bonferroni confidence interval adjustment. BWS=Body Weight Support. Neutral setting indicates frame bar is placed at hip height.