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GAIT INTERVENTION FOR IMPROVEMENTS IN HUMAN TOP SPEED RUNNING

By

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Professional Paper

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Gait Intervention for Improvements in Human Top Speed Running

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Between individuals faster sprinting speeds are achieved by applying greater stance average forces against the running surface. Recent evidence further indicates that elite level performers also strike the ground with leg kinematics that differ from those of non-elites and that these leg movements act to enhance the force transients occurring in the milliseconds following foot-ground impact. I investigated whether sprint performance could be enhanced through a short term gait intervention, consisting of 3 laboratory training sessions wherein subjects ($n = 6$) completed 5 high-speed runs on an instrumented force treadmill at 90% of their measured top sprint. The subjects received immediate visual feedback of the previous bout of sprinting by reviewing the video record obtained from a laterally positioned camera with a frame rate of 1000 Hz. The subjects also received verbal cues throughout their participation, which were focused on encouraging leg postures more suitable for applying greater vertical forces into the ground. Incremental tests to top speed were administered on the force treadmill prior to and following the gait intervention. Paired sample t-tests were used to analyze the pre- vs. post-intervention variables which included; ground contact time, aerial time, swing time, stride time, and step length. Following the gait intervention top speeds increased by 6.7% [SD 1.3] and ground reaction forces increased by $0.03 \times W_b$. 3D video analysis revealed that the velocity of the ankle and foot immediately before touchdown also increased by 7.3%. This permitted the leg to use a posture better able to apply the high vertical forces needed in the first half of stance. These data indicate that an acute training intervention can augment sprinting performance within a time frame that is too brief for the improvement to be attributed to changes within the musculature of the individual subjects. I conclude that running speed can be taught by providing knowledgeable cues that focus on the mechanics of the foot-ground impact.

Table of Contents

Chapter 1: Introduction	4
Chapter 2: Methods	8
Human Subjects	8
Treadmill Protocol	8
Gait Kinetics	9
Gait Kinematics	10
Chapter 3: Results	11
Gait Kinetics	11
Gait Kinematics	12
Chapter 4: Discussion	14
Perspectives & Significances	16
Concluding Remarks	16
Acknowledgements	18
References	19
Tables	21-22
Figure Captions	23
Figures	24-30

Chapter 1 -- Introduction

Human runners use a gait cycle that consists of alternating periods of foot ground contact and aerial phases in which force is applied by the leg during the stance phase and very little muscle force is generated during the aerial phase (Fig. 1). As individuals run faster, they apply greater forces against the ground and do so in decreasing periods of foot-ground contact. This increase in the requirement for force application, primarily for weight support, is due largely to the need to provide sufficient aerial time to return the leg for the next stance phase because faster locomotion frequencies are achieved by a reduction in the stance as opposed to the aerial phase (Robert *et al.*, 1998; Weyand *et al.*, 2000). Thus, the application of force against the ground is the critical element to faster running speeds.

Muscles hydrolyze ATP when they generate force, and during sprint running the forces applied against the ground can exceed five times the body's weight. Thus the leg muscles of terrestrial runners consume tremendous quantities of ATP in order to generate the ground forces needed during locomotion (Taylor & Heglund, 1982). Cursorial animals reduce the demand for energy by storing and releasing elastic energy within the muscles and tendons of the leg. (Cavagna *et al.*, 1977). This storage and release of elastic energy is known as the spring-mass model of bouncing gaits (McMahon *et al.*, 1987) and involves the lengthening of muscle-tendon units as the spring is loaded in the first portion of stance and subsequently released during the second half (Dickinson *et al.*, 2000; Taylor 1994; Taylor & Heglund, 1982). It is the movements at the center of mass that create the compression and extension of the leg necessary for spring to function.

Recently, Clark and colleagues (2014) recognized that the spring mass model does not describe the motion of the body's center of mass during sprint running. Accordingly, these authors modified the existing quantitative understanding to more accurately reflect the realities of high speed running. The main addition to the spring mass model is the inclusion of a collisional term that affects the shape of the ground reaction force in the milliseconds following the beginning of stance. This effect is harnessed by elite sprinters to enhance their foot-ground collision when compared to recreational runners. By increasing the lower limb's velocity prior to touchdown and reducing deceleration time during impact, elites increase the collisional impulse and total ground reaction forces that are needed to attain faster speeds.

Experienced sprinters tend to contact the ground when the foot is placed below the center of gravity (Mann & Herman, 1985). With this limb geometry, it is likely that the foot ground collision will avoid unwanted horizontal force. These kinematic positions are typically referred to as back-side and front-side sprinting mechanics and are widely considered in applied settings as contributing factors to top speed running. At the instant of touchdown, the swing knee should be equal with or in front of the stance knee (Mann, 2008). This is considered ideal front side mechanics. Thus, both the scientific and this instructional coaching framework highlight the importance of the lower leg and ankle at the instant of touchdown (Mann, 2008). Because sprinters spend most of the stance period on the toes (Mann & Hagy, 1980), this position dramatically increases the torque acting at the joint, in addition to the important role played in weight support by the rest of the extensors. Finally, because sprinters typically strike the ground with the ball of their foot, the torques and forces necessary at the ankle increase substantially. Because the opposing torque needed to stabilize the joint is the product of muscle force and the

essentially constant distance between the center of the ankle and the Achilles tendon, large torques require huge muscle forces (Weyand *et al.*, 2010).

To achieve elite sprinting speeds, fast muscle tension development is needed, yet the faster muscle fibers and motor units present in the legs of these runners do not allow the legs to be repositioned noticeably faster (Weyand *et al.*, 2000). Although swing times at top speeds do not vary among different individuals or their levels of experience, the aerial phase is important to prepare for the next foot-ground contact. Passive energy transfer is thought to be necessary to reposition the swing leg instead of active muscular power contribution (Weyand *et al.*, 2010). Being able to quickly reposition the limb into the correct position is crucial to achieving the augmented collision that is characteristic of elite sprinting performance. This provides the preparation for the next impact and is thought to be most effectively done by using a high knee lift, wherein the shank of the swing leg is able to be driven rapidly into the ground (Clark & Weyand, 2014).

Improved collisions result in a more rapid rise of the ground reaction force, consequently greater forces are the result. Elite sprinters apply more force in the first half of ground contact ($2.65 \times W_b$) than recreational sprinters ($2.21 \times W_b$), which is what separates the level of experience (Clark *et al.*, 2014). Moreover, this is essentially the only difference, since the forces applied in the second half of stance are virtually identical between these groups. Thus, at every speed, sprinters apply more force than recreational runners, which explains their long-observed poor economy, differing by only body weight, but they do so only in the first half of stance.

We initiated this study to determine whether the sprinting performances of human runners could be improved with a short gait intervention. The properties that confer elite sprinting performance are neuromuscular and the mechanics of gait. Here, the brevity of this

intervention targets the gait mechanics as a source of performance enhancement. Properties used during sprinting are under the control of either muscle physiology or the mechanics of gait. It is important to recognize that previous interventions that alter the gait of runners have been found to have negative performance effects. For instance, McMahon and colleagues (1987) studied the effectiveness of altering vertical leg stiffness on performance when running. They found that when vertical stiffness was reduced and knees were in a flexed position, less force was applied to the ground and oxygen consumption increased by as much as 50% (McMahon *et al.*, 1987). In addition, these investigators discovered that when the mass strikes the ground with less velocity, gravity is relatively unimportant in determining the vertical force during the collision (McMahon *et al.*, 1987). A second gait intervention aimed at changing the stride frequencies used by runners found that with either higher or lower frequencies, the spring-mass model became less effective and the storage and recovery of elastic energy use was reduced and oxygen costs were increased (Farley *et al.*, 1991).

We therefore asked whether or not it is possible to teach speed or if a training-induced muscle physiological response is the only avenue to augment speed? We hypothesized that a short training program, targeting the swing mechanics of sprinters to augment the effectiveness of their foot ground collision would improve the measured speeds. Finally, we asked if we can enhance the foot-ground collision of the subjects, will it make them faster? It suggests that sprinting ability is a learned activity rather than a natural occurrence.

Chapter 2 -- Methods

Human Subjects

Four women and four men ages 19-23 provided written, informed consent, in accordance with the guidelines of the University of Montana Institutional Review Board before participating in this study. The subjects were recruited and participated voluntarily. Measures of body weight were taken before and after the intervention. Six of the subjects were collegiate athletes accustomed to short duration sprinting exercise. The other two participants were recreational runners. One collegiate male and one recreational male withdrew prior to the study completion, one due to a viral illness unrelated to the testing procedure and the other experienced soreness.

Treadmill Protocol

Subjects participated in a minimum of six sessions (Fig. 2). Day one was a treadmill acclimation day. For all testing, subjects wore an upper-body harness to prevent injury in the event of a fall. They then performed their individual warm-up. On the second day, participants performed a speed incremented test to top speed, increasing in increments of 0.2 m s^{-1} . At each speed, subjects lowered themselves onto the treadmill by transferring their weight from the handrails while initiating the leg movements necessary to begin running on the moving treadmill belt. A minimum of eight steps were needed at each speed interval with no backwards drift to count the trial as successful. While the subjects ran on the treadmill the forces they applied to the running surface were measured using a high-speed instrumented treadmill (Bundle *et al.*, 2015).

Days three through five consisted of a gait intervention which included five sprinting trials on the treadmill at 90% of the measured top speed. The intervention also consisted of three

drills chosen to maximize ankle stiffness at touch down and rapid knee drive (Gary Winckler, *pers. comm.*). They were collected and modified from the coaching styles of Gary Winckler and the USATF. Each drill was performed 3 times over a distance of 22 meters each time. The first drill was a double leg quick hop, drill two a skip with a pause, and drill three was a rapid single leg high knee. After the interventions, participants performed the five treadmill sprints at 90% of top speed and received video feedback following sprints 1, 3, and 5. Feedback consisted of verbal communication to the subjects to apply as much force as possible when sprinting and to drive the knee as high as possible while watching 1000Hz high speed video. Day six was a post-test to top speed. Top speed was determined if the subjects could not physically maintain form while sprinting on the treadmill or there was considerable backwards drifting before the 8 steps were achieved.

Gait kinetics

Stance-average forces: The average vertical ground reaction force applied during the contact period was determined from the time during which the vertical force signal exceeded a threshold of 50 N. Forces expressed as multiples of the body's weight ($\times W_b$) were determined by dividing the force recorded during each trial by the weight of the subject recorded on a platform scale immediately before treadmill testing (Weyand *et al.*, 2010).

Contact times: The times of foot-ground contacts were determined from the continuous periods during which the vertical treadmill reaction force exceeded 45 N.

Aerial times: Aerial times were determined from the time elapsing between the end of the one period of foot-ground contact and the beginning of the subsequent period.

Step times: Step times were determined from the time taken to complete consecutive foot-ground contact and aerial periods.

Swing Times: Swing time was the time that a given foot was not in contact with the ground and was determined by subtracting the contact time from the total stride time.

Stride times: Stride time was defined as Cavagna and colleagues (1977) described as the time between consecutive footfalls of the same foot.

Step length: Step length, or the distance the belt traveled between consecutive periods of foot-ground contact, was determined by dividing the treadmill speed by step frequency.

Step frequency: Step frequency, the number of steps taken per second, was determined from the inverse of step time.

The interventions were performed over an in-ground force plate pit along the length of 22 meters in which the first 3 meters of the drill ground forces were recorded. Pre- vs. post-intervention measures were analyzed using paired sample t-tests and study means.

Gait kinematics

Three-dimensional video was captured using two Fastec cameras at a rate of 1,000 frames per second. One camera faced the lateral aspect of the body and a second camera faced to the back right half of the subject's body. A 3-dimensional calibration cube was used to digitize the 62 points of interest using MATLAB per Hedrick (2008). The images were re-calibrated using the calibration cube to calculate the DLT lens coefficients. Joint axes of rotation of the hip, knee, ankle, forefoot, and hind-foot were identified by palpation and marked with reflective tape

to acquire position data from the video record. Limb kinematics were taken from the right limb during the trials (Weyand *et al.*, 2010).

Chapter 3 -- Results

Gait kinetics

Top Speed Performance: Each of the 6 subjects attained faster top speeds during the post- versus pre-intervention testing. The average increase in speed was 0.57 [SD 0.14] m s^{-1} , representing an average individual improvement of 6.7 [SD 1.3] % (Table 1 & Fig. 3).

Stance-average forces: At top speed the mean stance average vertical force, measured from 8 consecutive steps, did not differ between the pre- and post-intervention testing, and was 2.21 [SD 0.15] $\times W_b$ during the pre-intervention testing compared to the post-test value of 2.23 [SD 0.20] $\times W_b$. The highest observed stance average vertical force was $2.46 \times W_b$ for subject #1, at a top speed of 9.0 m s^{-1} . The lowest observed stance average force was $1.88 \times W_b$ from subject #6, at a top speed of 7.2 m s^{-1} (Fig. 4).

Contact times (T_c): The pre- vs post- measures of foot-ground contact durations were similar, and occurred in 0.111 [SD 0.008] s and 0.108 [SD 0.009] s, respectively. The longest post-intervention, top speed contact time was 0.121 s for subject #6, the briefest was observed from subject #5; 0.097 s at his top speed of 10.2 m s^{-1} (Table 2 & Fig. 4)).

Aerial times (T_{aer}): Following the intervention the subjects used flight, or aerial, times that were 5 ms briefer than those prior to the intervention, and were 0.136 [SD 0.014] s vs. 0.131 [SD 0.013] s, respectively during the top speed tests. The longest observed top speed aerial time was 0.146 s at a top speed of 9.0 m s^{-1} ; whereas, the briefest aerial time was 0.107 s at a top speed of 7.2 m s^{-1} (Table 2 & Fig. 4).

Step times (T_{step}): The step durations were statistically similar but were generally 7 ms briefer following the intervention, with pre- vs post step times of 0.246 [SD 0.010] s and 0.239

[SD 0.009] s, respectively. The maximum observed step time at top speed was 0.250 s for Subject #1, and the minimum was 0.227 s for Subject #6 (Table 2).

Swing times (T_{swing}): The duration necessary to replace the limb in readiness for the next foot contact, or the swing time, was 0.383 [SD 0.022] s compared to 0.371 [SD 0.021] s in the pre- vs. post-intervention, respectively. This is a 12 millisecond reduction in the leg repositioning time. On an individual basis the maximum measured swing time from the post intervention testing was 0.398 s from subject #1 and the minimum observed was 0.335 s from subject #6 (Table 2).

Stride times (T_{stride}): Following the intervention the stride times were generally 15 milliseconds more brief and were 0.493 [SD 0.020] vs. 0.478 [SD 0.018] in the pre- and post-testing respectively. The longest step time was 0.501 s from subject #1 and the briefest was 0.455 s measured from subject #6 at a top speed of 7.2 m s^{-1} (Table 2). These stride times correspond to stride frequencies of 2.03 [SD 0.08] Hz and 2.09 [SD 0.08] Hz at tops speed in the pre- vs post-testing.

Step length (T_{step}): The step lengths, or the distance traveled by the body during the contact phase, were 5 cm longer following the intervention and were 0.92 [SD 0.07] m and 0.97 [SD 0.07] m, respectively for the pre- and post-intervention testing. The greatest extent of center of mass travel was 1.09 m from subject #3 while the shortest steps were taken by subject #6 and were 0.87 m.

Gait kinematics

We analyzed the joint kinematics (Fig. 6) to determine the velocity of the ankle in the instant before touchdown to determine whether the intervention resulted in the greater shank velocities

necessary to engage the elite force augmentation strategy of interest. Following the intervention the vertical velocities of the ankle increased from 2.18 [SD 0.41] m s⁻¹ to 2.34 [SD 0.34] m s⁻¹ and the overall ankle velocity in the YZ-plane increased from 4.65 [SD 0.78] m s⁻¹ to 4.99 [SD 1.09] m s⁻¹ (Fig. 7).

Chapter 4 -- Discussion

The purpose of this study was to determine whether it is possible to beneficially alter the gait dynamics of human runners. Here, we used the recent discoveries of Clark and Weyand (2014) who have found that elite sprinters apply more vertical forces to the ground during the first half of foot-ground contact than non-elites. Thus our gait intervention targeted the events occurring in the first half of the stance phase, here we found this phase to last 0.054 [SD 0.005] s. As an indication of how rapid this event is, the 0.054 s interval is only slightly longer than the minimum period of roughly 0.033 s needed for the fastest afferent signals to reach the spinal cord following the foot strike (Mense, 2010). Thus virtually all of the adjustment in stance dynamics must occur in the absence of neural feedback and are likely determined prior to the foot ground contact. After the gait intervention was complete, subjects had a combined average increase in top speed of 6.7[SD 1.3] %. This is a considerable improvement for such a short intervention of time. The brevity of the intervention suggests that the performance improvement was achieved in the absence of altered muscle physiology, because the typical length of time to achieve muscle adaptation is roughly 12 weeks when using resistance exercise (Raue *et al.*, 2012). Moreover, because most of the subjects were accomplished sprint performers it is unlikely that the intervention elicited the motor control response that is typical of novice performers and accounts for their rapid strength gains following the introduction to a novel task (Sampson *et al.*, 2012). Thus, the performance improvements realized through this study are likely attributable to altered gait mechanics.

The gait intervention consisted of 3 drills that aimed at maintaining dorsiflexion and generating a rapid and high knee drive in order to generate as much vertical force as possible. The improvements in speed ranged from 0.4 m s⁻¹ to 0.7 m s⁻¹, although virtually nothing is

known about how individual performers alter their gait in response to training programs, when considered between performers a 1 millisecond reduction in stance duration leads to 0.10 m s^{-1} improvement in sprint speed (Clark & Weyand, 2014). If this rule of thumb is applied to our 0.6 m s^{-1} improvement result, we would expect to observe a reduction in foot contact durations of 6 milliseconds, twice as large as 3 millisecond reduction we observed. Further, the increased running speeds would be expected to require an increase in ground reaction forces applied, however the average ground reaction forces following the intervention were only increased by about $0.03 \times W_b$ (Fig. 5).

Our results are consistent with the focus on the first half of stance as the portion of the gait cycle in which elite sprinters apply greater vertical forces while the second half of foot-ground contact is similar between runners of different experience levels. We did observe a slight increase of about $1.2 \times W_b$ ($P=0.5048$) in vertical forces applied to the ground in the first half of foot-ground contact post-intervention (Fig. 5). Although the stance average forces comparing the first half of stance with the second half of stance pre- to post-intervention were not significant with a $P=0.5048$ for the first half of stance and a $P=0.8128$ comparing the second half of stance. This is likely due to the considerable variance present in the capabilities of the subjects rather than the lack of effect. A recognition, likely responsible for the many comparisons in this study, *a priori* level of statistical significance was not achieved despite a considerable percentage change following the intervention. From our data it is not possible to determine whether the improved performance may be attributed to the intervention drills, or the 3D gait kinematic subject feedback, or a combination of these methods.

Nonetheless, following the intervention subjects reduced their aerial phases by 5 milliseconds and similarly reduced their stride durations 15 milliseconds. The greater emphasis

on leg position during swing allowed the subjects to collide with the ground with ankle velocities that were 0.34 m s^{-1} more rapid, an improvement of 7.3%. A response that is necessary to achieve the greater forces in the instant following impact that is common to elite sprinters. Finally we note that the runners increased their step lengths by roughly 5 cm, although this measure doesn't explain how the performance was achieved, Weyand and Bundle (2009) have previously suggested that step length increases translate to 1.0 m s^{-1} of top speed for every 10 cm of increase, a ratio that is supported by these results.

Perspectives and Significances

Future work includes a control group ideally with a homogenous subject pool. Do these results transfer to other mediums? Speed and force work should be done over ground.

Concluding Remarks

After conducting this study, it is concluded that it is possible to beneficially alter gait despite predictions and results that have been previously published (McMahon *et al.*, 1987). The most effective part of this intervention study was the video feedback that allowed subjects to see their gait and then instantaneously try to alter these movements in accordance with the verbal feedback during the very next bout of treadmill sprinting. This warrants further study with a control group, possibly with homogeneous subjects. This would reduce the performance difference seen with the current study and allow for significant comparisons in the pre- vs post-tests.

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References

- Bundle, M. W., Powell, M. O., & Ryan, L. J. (2015). Design and testing of a high-speed treadmill to measure ground reaction forces at the limit of human gait. *MedEng & Physics; In press*.
- Cavagna, G. A., Heglund, N. C., & Taylor, C. R. (1977). Mechanical work in terrestrial locomotion: two basic mechanisms for minimizing energy expenditure. *American Journal of Physiology*, 233(5): 243-261.
- Clark, K. P., & Weyand, P. G. (2014). Are running speeds maximized with simple-spring stance mechanics? *J Appl Physiol*, 117(6): 604-615.
- Clark, K. P., Ryan, L. J., & Weyand, P. G. (2014). Foot speed, foot-strike and footwear: linking gait mechanics and running ground reaction forces. *The Journal of Experimental Biology*, 217(Pt 12): 2037-2040.
- Dickinson, M. H., Farley, C. T., Full, R. J., Koehl, M. A., Kram, R., & Lehman, S. (2000). How Animals Move: An Integrative View. *Science*, 288(5463): 100-106.
- Farley, C. T., Blickhan, R., Saito, J., & Taylor, C. R. (1991). Hopping frequency in humans: a test of how springs set stride frequency in bouncing gaits. *J Appl Physiol*, 71(6): 2127-2132.
- Hedrick, T. L. (2008). Software techniques for two- and three-dimensional kinematic measurements of biological and biomimetic systems. *Bioinspiration & Biomimetics*, 3(3): 1-6.
- Mann, R. *The Mechanics of Sprinting and Hurdling*. Las Vegas: Compusport, 2008, 1-226.
- Mann, R. A., & Hagy, J. (1980). Biomechanics of walking, running, and sprinting. *Am J Sports Med*, 8(5): 345-350.
- Mann, R., & Herman, J. (1985). Kinematic Analysis of Olympic Sprint Performance: Men's 200 Meters. *International Journal of Sport Biomechanics*, 1: 151-162.
- McMahon, T. A., Valiant, G., & Frederick, E. C. (1987). Groucho Running. *J Appl Physiol*, 62(6): 2326-2337.
- Mense S (2010). Functional anatomy of muscle: muscle, nociceptors and afferent fibers. In S Mense & RD Gerwin (eds.), *Muscle Pain: Understanding the Mechanisms* (17-48). Springer Berlin Heidelberg, Germany.
- Raue, U., Trappe, T. A., Estrem, S. T., Qian, H.-R., Helvering, L. M., Smith, R. C., & Trappe, S. (2012). Transcriptome signature of resistance exercise adaptations: mixed muscle and fiber type specific profiles in young and old adults. *J Appl Physiol*, 1625-1636.
- Roberts, T. J., Kram, R., Weyand, P. G., & Taylor, C. R. (1998). Energetics of bipedal running-metabolic cost of generating force. *J Exp Biol*, 201(Pt 19): 2745-2751.
- Sampson, J. A., McAndrew, D., Donohoe, A., Jenkins, A., & Groeller, H. (2012). The effect of a familiarisation period on subsequent strength gain. *J Sports Sci*, 31(2): 204-211.
- Taylor, C. R. (1994). Relating Mechanics and Energetics during Exercise. *Advances in Veterinary Medicine*, 38A: 181-215.

- Taylor, C. R., & Heglund, N. C. (1982). Energetics and Mechanics of Terrestrial Locomotion. *Ann. Rev. Physiol.*, 44: 97-107.
- Weyand PG, Bundle MW. (2009) Artificial limbs do make artificially fast running speeds possible. *J Appl Physiol* 108(4): 1011-1012
- Weyand, P. G., Sandell, R. F., Prime, D. N., & Bundle, M. W. (2010). The biological limits to running speed are imposed from the ground up. *J Appl Physiol*, 108(4): 950-961.
- Weyand, P. G., Sternlight, D. B., Bellizzi, M. J., & Wright, S. (2000). Faster top running speeds are achieved with greater ground forces not more rapid leg movements. *J Appl Physiol*, 89(5): 1991-1999.

Table 1

Subject	Gender	Pre-test Top Speed (m/s)	Post-test Top Speed (m/s)	Percent Change
1	F	8.4	9.0	+7.1%
2	F	8.0	8.4	+5.0%
3	M	10.0	10.6	+6.0%
4	F	7.9	8.6	+8.8%
5	M	9.5	10.2	+7.3%
6	F	6.8	7.2	+5.9%
			Average Increase	6.7% [SD = 1.3]

Table 1: Pre- and post-test top speeds (m s^{-1}) of the 6 subjects with percent change.

Table 2

	Pre-	Post-
Tc	0.111	0.108
Taer	0.136	0.131
Tstep	0.246	0.239
Tswing	0.383	0.371
Tstride	0.493	0.478
Step length	0.92	0.97

Table 2: Study means of the variables compared pre- vs post-intervention in s.

Figure Captions

Figure 1: The phases of the running gait over time (s). Stance phase is when one leg is in contact with the ground producing vertical and horizontal forces (N). Aerial phase is when the body is in flight and no force is being applied. Leg swing is the leg cycle moving through two aerial phases and a stance phase of the contralateral leg. *Figure 2:* Flow chart of experimental understanding; Day 1 pre-test to top speed, Days 3, 4, 5 gait intervention and treadmill sprints, and Day 6 post-test to top speed. *Figure 3:* Change in top speeds (m s^{-1}) comparing the pre- vs post-intervention. *Figure 4:* Data from subject #1 displaying contact time (s), aerial time (s), and reaction forces ($\times W_b$). As speed increased, contact times decreased slightly (1 millisecond), aerial times stayed the same, and ground reaction forces increased ($1.2 \times W_b$). *Figure 5:*

Average vertical forces ($\times W_b$) are greater in the first half of foot-ground contact compared to the second half. Post-intervention, average vertical forces in the first half of foot-ground contact increased ($2.23 \times W_b$). Figure 5A is a waveform of the average of 8 steps. *Figure*

6: Axis joint (mm) positions pre- (black dotted line) vs post- (red line) intervention.

Subjects were able to better reposition the limbs for a more effective foot-ground contact.

Figure 7: Vertical ankle velocity (m s^{-1}) just before touchdown pre- vs post- intervention.

Overall change in velocity of the YZ plane of 0.34 m s^{-1} .

Figure 1

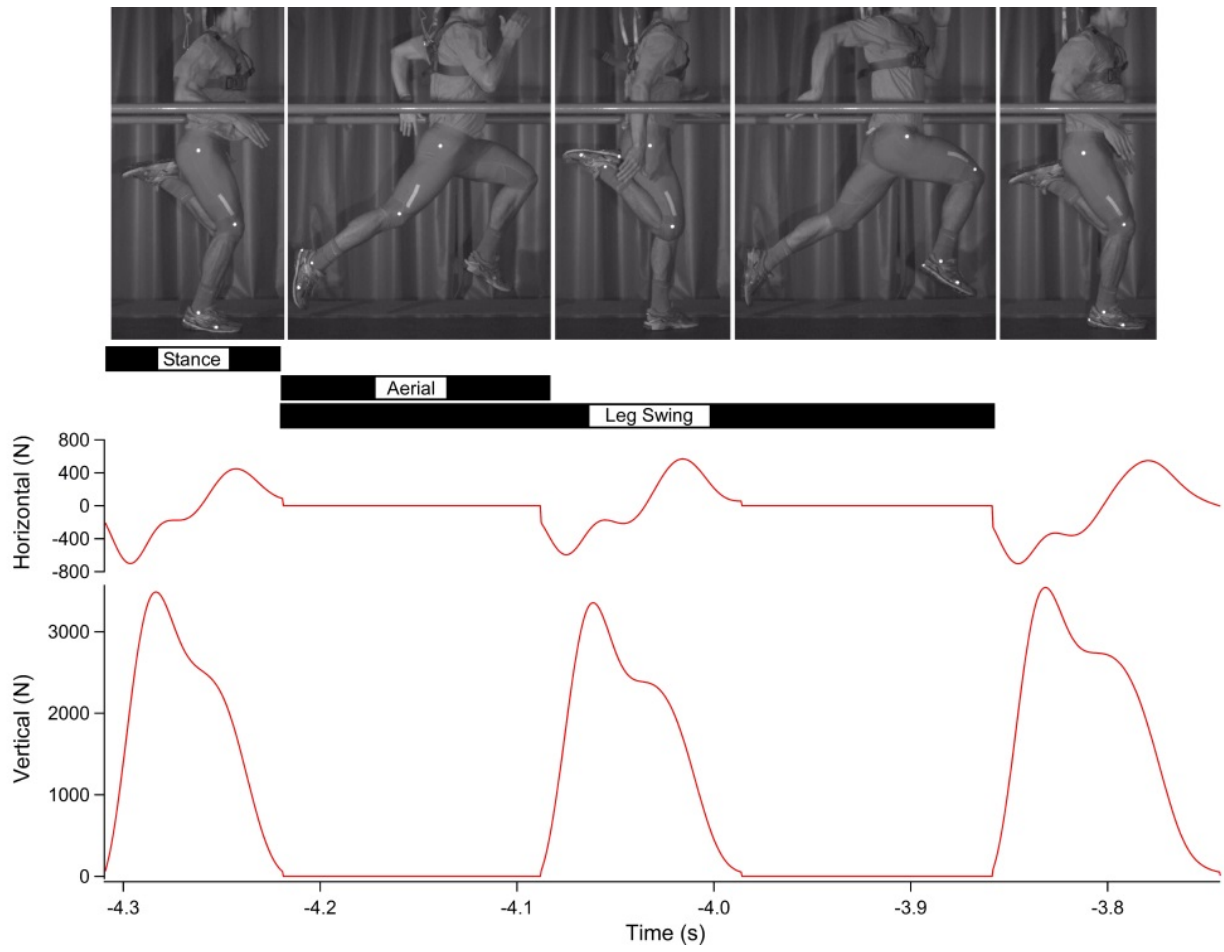


Figure 2

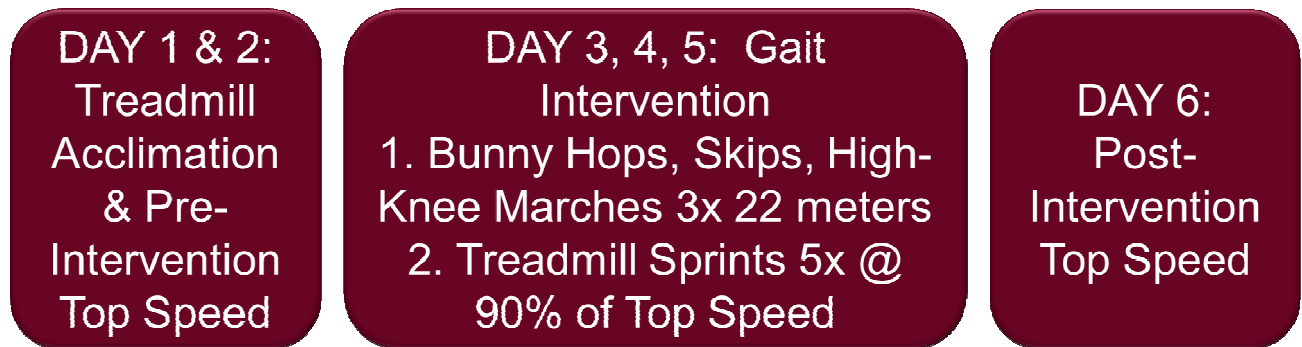


Figure 3

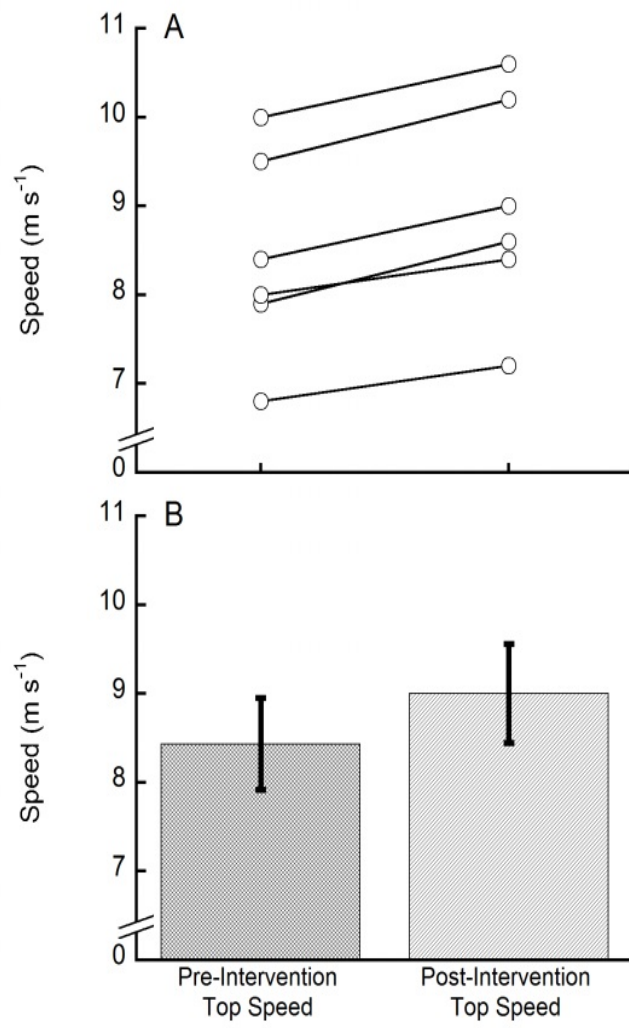


Figure 4

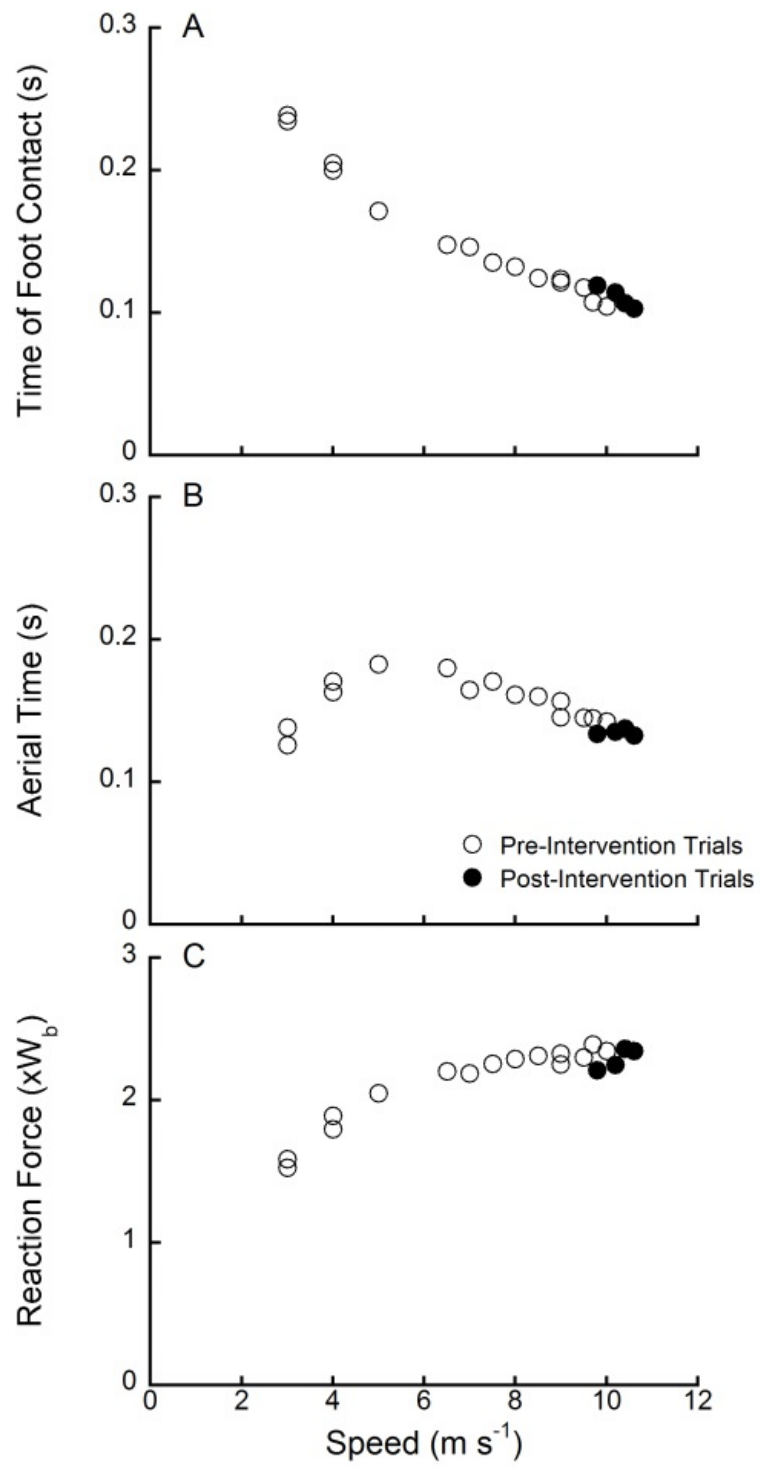


Figure 5

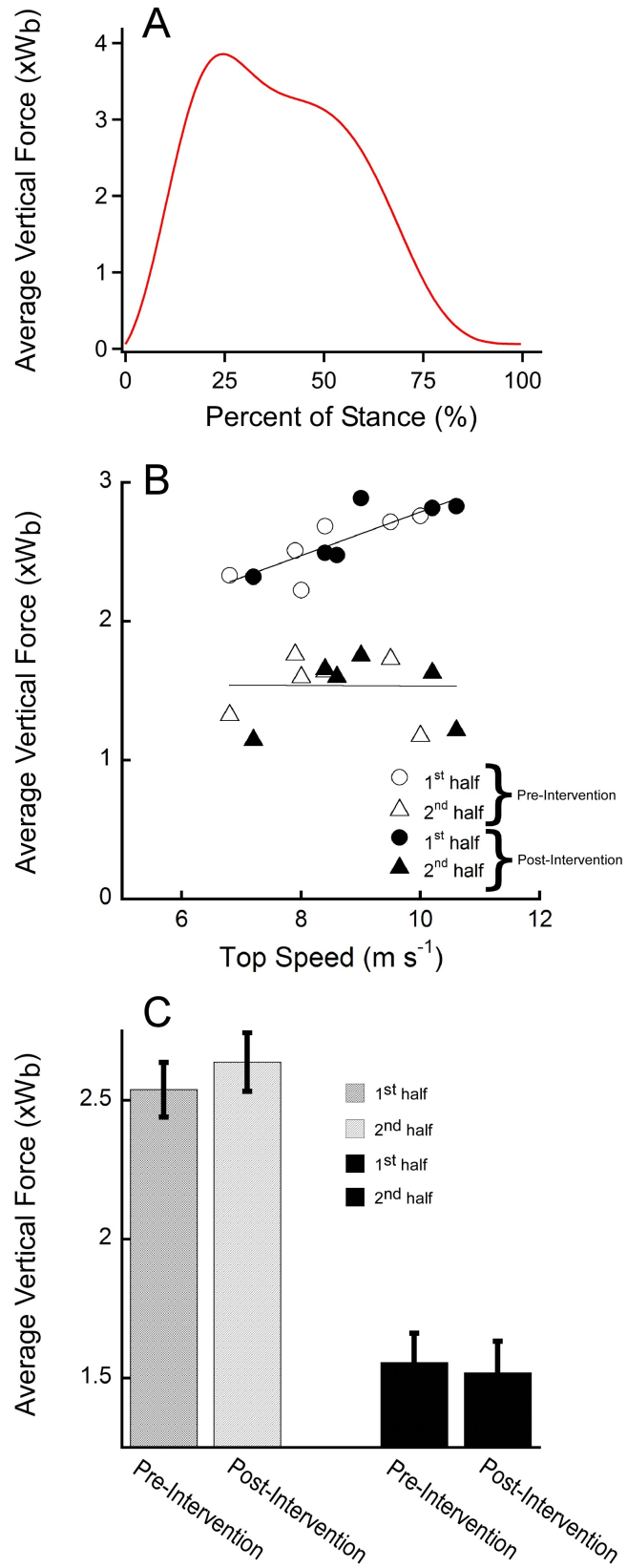


Figure 6

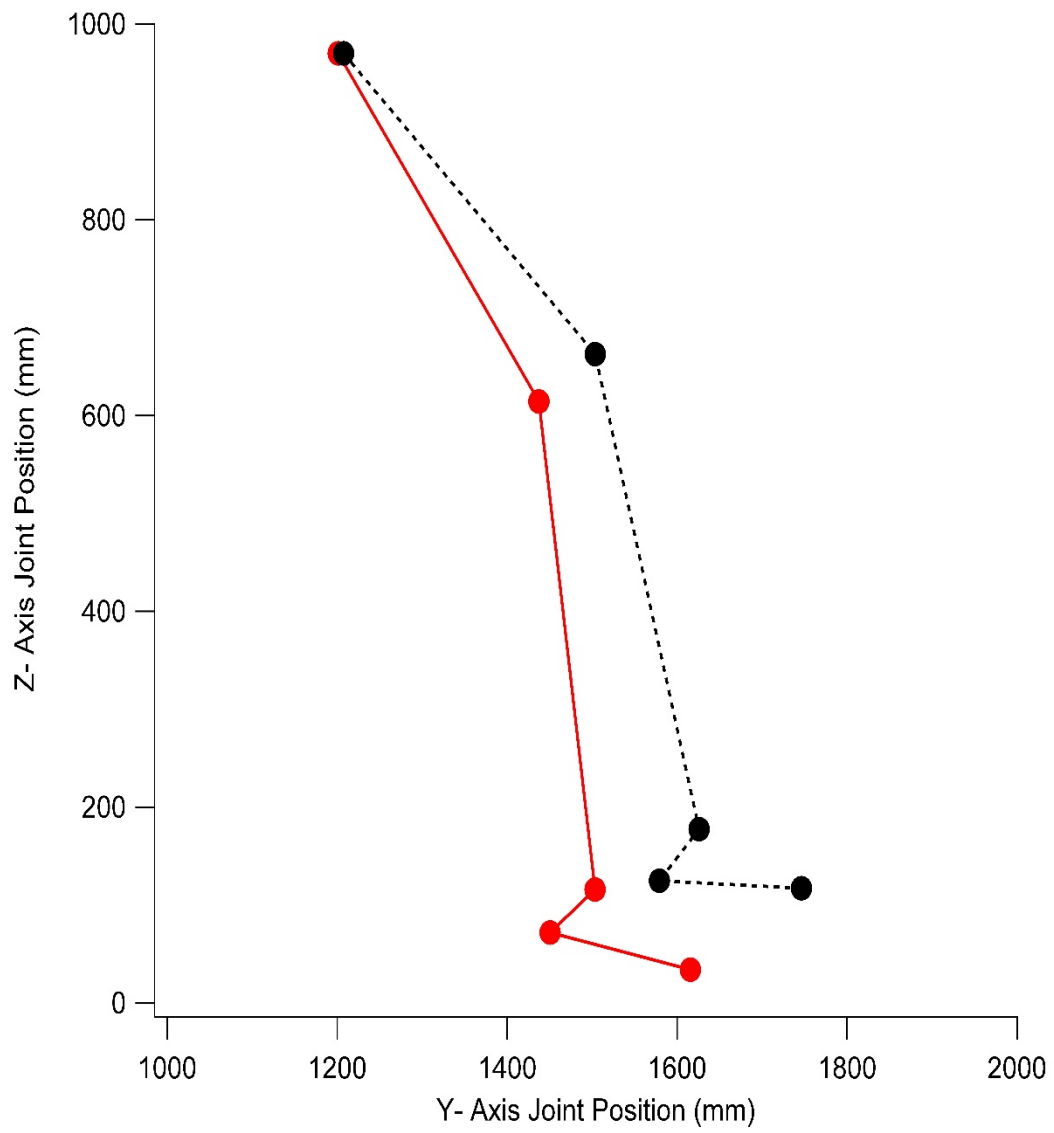


Figure 7

