# Integrating High-Speed Treadmills Into a Traditional Strength and Conditioning Program for Speed and Power Sports

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## SUMMARY

HIGH-SPEED TREADMILLS HAVE BECOME VALUABLE TOOLS FOR INCREASING SPEED AND SPORTS PERFORMANCE OVER THE PAST 2 DECADES. TRADITIONALLY, THEY HAVE BEEN PART OF NARROWLY FOCUSED CLINIC-BASED PROGRAMS DESIGNED TO INCREASE SPEED SOLELY WITH THE USE OF TECHNOLOGY. THIS HAS LED TO QUESTIONS ABOUT SURFACE TRANSFER, HIGH INJURY RATES, AND HOW THIS TECHNOLOGY FITS INTO A COMPREHENSIVE STRENGTH AND CONDITIONING PROGRAM. HERE, WE WILL NOT ONLY ADDRESS THESE ISSUES BUT ALSO DEMONSTRATE THAT WHEN PROPERLY INTEGRATED, HIGH-SPEED TREADMILLS ARE EXCEPTIONAL TOOLS THAT CAN BE USED IN A VARIETY OF SETTINGS TO IMPROVE PERFORMANCE FOR THE SPEED AND POWER ATHLETES WHILE ALL BUT ELIMINATING SPRINT-RELATED INJURIES.

## INTRODUCTION

High-speed treadmill training has seen a steady increase in popularity over recent years as a means of sports performance enhancement for speed and power sports. This is evidenced by the increase in treadmill companies producing units capable of high speeds and/or elevations. The concept dates back to the late 1980s when Frappier first began implementing overspeed training and incline running with professional football players in Fargo, ND, on large treadmills, which were capable of speeds of 28 miles per hour (mph) and elevations reaching 40% grade. Traditionally, many programs that use high-speed treadmills (treadmills that are capable of 20+ mph and 25%+ grade) have been designed as intense 6-week programs narrowly focused on speed development by way of the treadmill, with little thought into the integration of the treadmill modality into a more traditional strength and conditioning program to develop the well-rounded athlete. Such a narrow mentality can lead to questions about the transfer from one running surface to another (4,26,37,55,68,69), concerns of injury rates, and leaves us wondering about integrating these short intense cycles into a larger strength and conditioning program.

In this article, emphasis will be placed on using high-speed treadmill programs as a valuable training tool within a more traditional strength and conditioning model to improve linear speed, acceleration, and sport-specific power for athletes participating in speed and power sports (i.e., football, basketball, soccer, baseball, softball, and so on). Obviously, coaches and athletes should embrace and use new technologies as they become available. However, one should use caution because it is tempting to use every new item or technology that becomes available. But, as many new trends fade over time, such a mind-set can lead to long-term frustration for both the coach and athlete. This article will also highlight supportive research for the use of high-speed treadmill programming as an effective long-term training modality.

## BACKGROUND

Speed can be defined as stride frequency × stride length. To increase speed performance, we must improve 1 or both of these 2 variables. Although it can be difficult to improve both stride length and stride frequency

**KEY WORDS:**
high-speed treadmill; speed training; periodization; metabolic training; sprint mechanics

simultaneously, this article will provide evidence to support the enhancement of both variables concurrently when an athlete is placed into a quality, individualized, comprehensive, and periodized program.

As part of the speed discussion, the running gait cycle should be reviewed. It is defined as the basic unit of measurement when analyzing the gait (38). The cycle begins as one foot comes in contact with the ground (initial contact) and ends when the same foot returns back to the ground again.

The cycle can be divided into 2 distinct components: stance and recovery (38). For the purposes of this article, stance is the portion of the running cycle when the foot is in contact with the ground. It begins with initial contact and ends at toe off. Toe off then initiates the recovery (or flight) phase and ends back at initial contact. As running speed increases, less time is spent in stance, thus causing periods where neither foot is in contact with the ground (38).

### INCREASED STRIDE LENGTH

Increasing stride length is achieved by increasing speed strength, which is defined as "the explosiveness produced by the muscles during athletic events" (2). Simply put, one must increase the power output and explosiveness of the lower body if they hope to increase stride length. Mann and Hagy (29) support the need for increased power output during sprinting by demonstrating that with a magnification of gait speed, the body showed an increase in muscle activity in the quads, hamstrings, and posterior muscles of the calf; all of which are considered primary accelerators of body mass (10). A good number of other research validates this concept, showing that increased power development in the lower extremities and force production improve running speed (5,13,22,24,32, 34,40,57,70). This increase in activity can be accomplished by using a variety of techniques.

Uphill running at high speeds has been shown to increase muscle activation and power output within the gluteal muscles, quadriceps, gastrocnemius/soleus complex, and hip flexors on both electromyogram (EMG) and magnetic resonance imaging (39,44,57, 64,67,71). Similar results have been revealed within research involving varied speeds of locomotion while on an uphill slope (27,34,56,57). This greater activation of motor units, coupled with increased efficiency in intramuscular coordination, leads to improved propelling forces, while teaching decreased braking forces during the act of running (5,7,13,25,34,60). Gottschall and Kram (17) actually demonstrated an increase in propulsive peak force rates by as much as 75% while running at 9 degrees of elevation. They also observed that this occurred with little to no vertical impact forces through the leg. Others have also shown favorable differences in impact forces and joint torques while running uphill as compared with flat ground running (4,71). Such differences may be advantageous for the long-term health of the athlete.

In the initial 2–5 weeks of training, the changes in propelling forces are primarily neurological in nature, but following the early adaptation period, more permanent muscular changes become present (25,31). The research is not clear as to exactly what muscular changes (i.e., hypertrophy) are taking place after the initial adaptation period during sprinting movements (35). It is likely individualized to each athlete based on factors such as strength, body type, muscle fiber type, neurological efficiency, and so on.

The most traditional method used for developing speed strength is tow training (i.e., sled and parachute). This can also be effective, but caution should be used with these techniques because some research has shown a likelihood of an athlete using poor running mechanics when towing an object, especially under high loads (1,28).

### INCREASED STRIDE FREQUENCY

Increasing stride frequency is performed by moving the ground leg through the same range of motion faster than normal (6), the basis of overspeed training. Historically, overspeed training has been performed by downhill running or being towed (47).

Again, initial improvements with overspeed training have been shown to be largely neurological, increasing the rate of muscle firing responsible for moving the legs through the running cycle more quickly. The focus with regards to improving stride frequency shifts to the efficiency and strength of the hip flexors because they are primarily responsible for decreasing the amount of time spent in the recovery phase of the running cycle (38). As with power development, after the initial adaptation of the nervous system, more permanent muscular changes will take affect (18,35).

As stated, the traditional means of overspeed training includes tow training and/or downhill running. Downhill running is effective when performed at the right elevation under supervision (12). Unfortunately, most athletes have an unusual running gait and tend to heel strike unnaturally, increasing braking forces when performing the downhill task (3,43,47). Additionally, athletes tend to experience delayed onset muscle soreness (DOMS) after downhill workouts because of its eccentric nature. Several researchers recommend a recovery period of 2–5 days after DOMS because of the decrease in running efficiency and power output (3,11,59), wasting valuable training time.

Unfortunately, tow training does not offer much of an alternative because research shows a decrease in running kinematics while being towed (8,31). For the sake of running economy and injury prevention, good-quality running mechanics should be a priority (38).

The high-speed treadmill is a tool that solves a great deal of the above concerns. With trained spotting techniques (Figure 1) and the proper running mechanics, an athlete can be placed into a safe and an appropriate environment for overspeed training, including, but not limited to, maintaining pelvic neutral and good knee drive, while allowing the athlete to run at speeds that are slightly higher than the athlete is accustomed to. This is especially true of spotting an athlete while running at elevation.

Swanson and Caldwell confirmed the impact treadmill training has on stride frequency by showing that while running on a treadmill at high elevation, the athlete tends to spend a greater time in the stance phase of the leg cycle than when running on flat ground. This forces the legs to move through the recovery phase at a higher rate than normal (63), developing neuromuscular adaptations within the muscles primarily responsible for accelerating the lower extremity through the recovery phase of the leg cycle.

Clinical experience demonstrates that the most effective and safe means of attaining the overspeed effect is through a combination of running at elevation with speeds that are taxing to the athlete (9–13 mph at 15–35% elevation). Spotting the athlete by lightly supporting them with a hand at the base of their sacrum when they fatigue, will help them extend the duration of a run while maintaining normal running mechanics and invoking the overspeed training effect. Using a spotting technique (Figure 1) in the manner described seems to be more effective and safer than running at very high speeds (20+ mph) with little to no elevation for short bursts with the aid of a harness system, which can lead to poor mechanics and exposure to injury.

### IMPROVED TECHNIQUE

The treadmill makes motion analysis and motor learning simple because of the controlled environment that the athlete is placed in. In most cases, it eliminates the need for video analysis because the athlete is running, cycle after cycle, in one spot. This also allows closeness for ease in cuing the athlete during the act of sprinting, rather than watching the athlete run and then trying to make corrections during a moment of recovery within their running workout.

Another advantage of treadmill training is that running uphill (at elevation) is a “self-limiting exercise.” That is, if the athlete cannot perform the activity correctly, they will not be able to perform it at all. As the athlete runs uphill, even at slow speeds, they will have a tendency to improve their final recovery position with very little coaching because the body attempts to avoid stumbling while climbing the hill. The elevation forces the “knee up, heel up, toe up” position at the end of the recovery phase of the cycle (27,56,71). This triple flexion position is the most explosive position for the lower body because of the stored energy and prestretch placed on the musculotendinous junction of the gluteal group, quadriceps, and gastrocnemius/soleus complex (38).

Although sprinting on a treadmill at elevation will have a tendency to improve running mechanics, this may not always occur with every athlete. A good coach with knowledge of sprint technique is still needed to identify and fix problem areas within an athlete’s mechanics. The most likely area of concern for athletes running at elevation is their postural positioning (43). Many athletes have a tendency to lean forward while running uphill, causing an anterior tilt of the pelvis. An anterior tilt will effectively shorten their stride length by limiting their ability to reach maximal hip extension at the terminal phase of stance (14,54). Core strength, flexibility, and neuromuscular education are all items to consider when addressing this issue.

### METABOLIC FACTORS

Metabolic markers such as maximum oxygen consumption, anaerobic threshold (AT), and rate of recovery are also differentiating factors for today’s speed and power athletes (16,49). Research reveals that there are a number of advantages to training anaerobically on a treadmill. Pyne et al. (48) demonstrated an increase in oxygen uptake and lactate levels with interval uphill running as compared with running on a near level surface. Roberts and Belliveau (50) theorized that this increase in mechanical work is because of the heightened activation of the hip and leg musculature responsible for propelling the body under the load of the hill. Several others have shown an increase in lactate production with running at elevation (3,21). Increased lactate production has been correlated to anaerobic capacity (closely related to AT) (21).

Olesen demonstrated that as elevation increased during treadmill running (up to 20%), so did cumulative oxygen deficit, largely because of the increase in the muscle mass involved in the running process. He further explains that cumulative oxygen deficit (the difference between his mathematically determined estimate of energy demand and the actual oxygen consumption during running) can be used as a marker for anaerobic capacity, and it can be improved over time with training while running at elevation (41).

With this in mind, high-speed running with varying degrees of elevation is an excellent avenue to achieving new levels of sport-specific conditioning for the speed and power athletes. By introducing varying levels of lactate and increasing aerobic and anaerobic fitness, the body will develop an increased buffering capacity to lactate, which will improve the rate of movement of lactate out of muscle cell tissue via the lactate shuttle. This will thereby restore intracellular pH and prevent fatigue (7,15,30,42,61,65,66). In summary, athletes trained at high speeds while running uphill will likely find themselves possessing the ability to compete at higher levels of intensity for longer durations with less recovery time between intense bouts of exercise.

## PROGRAM DESIGN

### INDIVIDUALIZED PROGRAM

Individualization is an important feature of a good strength and conditioning program (49). Using a shotgun approach to training, hoping to hit the majority of your athlete’s needs is insufficient when developing talent and getting the most out of every athlete that enters your door.

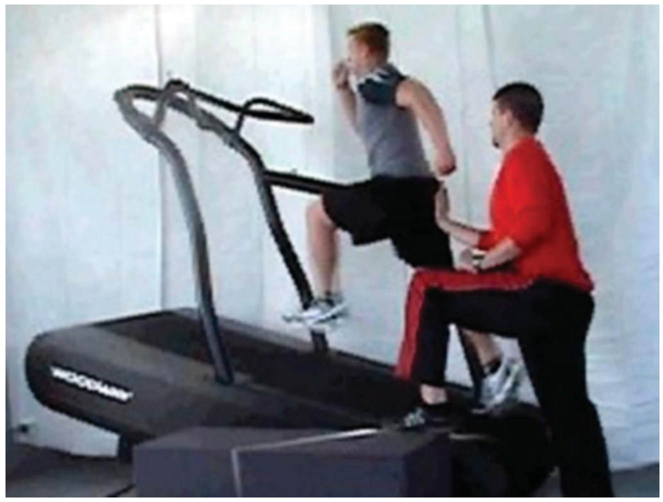


Figure 1. Run with a spot.

Whatever your program, it should have an appropriate screening tool to not only assess performance but also functional movement skills and biomechanics. Understanding basic movement patterns will not only reduce the athlete's likelihood of injury, but it will give you valuable information to plan exercise prescription. Without first understanding an athlete's needs, a coach will have difficulty prescribing the quality of program an athlete needs to reach their full potential. Also understand that if an athlete is not biomechanically and functionally sound, they should not be permitted to train on a high-speed treadmill unit.

One of the keys to individualizing a treadmill speed program is using a quality pretest to ensure that the athlete is initially placed in an appropriate program for them. This test should take into account an athlete's demographics (age, maturity level, sport, position, and so on) and running performance. The running performance is determined with a 2-part evaluation tool that consists of the treadmill pretest and the metabolic test.

### TREADMILL PRETEST

The pretest starts at 0% elevation and relatively slow speeds. From there, the athlete progresses to increasingly more intense runs for a relatively constant time frame. As the athlete successfully completes runs without a spot, they progress through the workout to more intense runs. If, at any point, the athlete requires a spot, they will then be classified into a program based on treadmill running performance. From there, several runs can be performed after the spotted run in an effort to achieve the desired volume and intensity of the initial workout to appropriately overload the lactate system as needed for the athlete as prescribed using the coach's best judgment.

### METABOLIC TEST

The second component of the initial evaluation is the metabolic test. The metabolic test defines the volume used in the training program, as well as the recovery rate that will be used between runs. Metabolic markers can be obtained using any one of a host of metabolic units commercially available (Metabolic Cart, iMETT by MicroMed, New Leaf, and like). Traditionally, accurate numbers on metabolic markers have only been available by means of expensive and time-consuming metabolic carts, but in recent years, technology has evolved to allow us to collect numbers with smaller relatively inexpensive equipment, which is fast and user friendly. Each piece of equipment has their own recommendations and protocols for arriving at the most accurate data set using their equipment. The important thing is that the coach is able to determine an accurate maximum heart rate (HR), HR at AT, and a 2-minute recovery HR while walking.

Running volume for later workouts is based on the ratio of AT HR to maximum HR achieved. The recovery HR to be used between treadmill runs within each running workout is a product of the athlete's 2-minute recovery HR as compared with their AT HR.

An example of an athlete who has completed their initial treadmill session is shown in Figure 2. With this information, the athlete can be placed into an appropriate program for the athlete based on the coach's experience, taking into account speed, elevation, volume, and recovery factors. By classifying the athlete by treadmill running performance, volume, and HR recovery, you can truly individualize each program while training in a group setting. The training sessions should be challenging but tolerable. Keep in mind that the mark of a quality program and trainer is the constant ability to evaluate the athlete's progress and adapt it accordingly to fit their ever-changing needs (i.e., recovery status, nutrition needs, rapidly improving fitness levels, and so on).

| Treadmill Pretest | | | | |
|---|---|---|---|---|
| # Runs | Incline | Speed | Time | Complete |
| 2 | 0 | 7.5 | :20 | X X |
| 1 | 15 | 7.5 | :20 | X |
| 1 | 25 | 8.7 | (hold) :15 | X |
| 1 | 25 | 10.0 | (hold) :15 | X |
| 1 | 15 | 10.0 | :12 | X |
| 1 | 20 | 10.0 | :10 | X |
| (Move to **Developmental Program** if spot is needed to finish workout) | | | | |
| 1 | 22 | 10.0 | :10 | X |
| (Move to **Reduced Speed Program** if spot is needed to finish workout) | | | | |
| 1 | 25 | 10.5 | :10 | X (Needed Spot) |
| (Move to **Standard Program** if spot is needed to finish workout) | | | | |
| 2 | 25 | 9.5 | :08/:08/:08 (run/hold/run) | |
| **(Advanced Program if no spot is needed)** | | | | |
| **Developmental Program** | | | | |
| 1 | 17.5 | 10.0 | :08 | |
| 1 | 17.5 | 9.0 | :08/:08/:08 (run/hold/run) | |
| **Reduced Speed Program** | | | | |
| 1 | 22 | 8.7 | :08/:08/:08 (run/hold/run) | |
| **Standard Program** | | | | |
| 2 | 22 | 9.5 | :08/:08/:08 (run/hold/run) | X X |

X = Run Completed

| Metabolic Test | | | |
|---|---|---|---|
| **Volume** | | **Recovery** | |
| A.T. HR | 178 | 2 min. Recovery HR | 152 |
| Max HR | 187 | A.T. HR | 178 |
| A.T./Max % | 95.2% | Recovery/A.T. % | 80.8% |
| **Program (based on AT/Max %)** | | **Program (based on Recovery/A.T.%)** | |
| If Less than 88% | ↑ LA | If Less than 85% use - | 82% of AT |
| If 88% to 94% | Standard Metabolic | If 85% to 92% use - | 80% of AT |
| If 94% and up | Low Metabolic | If 92% and up use - | 77% of AT |
| *Red denotes items computed from metabolic test | | Workout HR Recovery between runs | 146 |

| Program Prescription Based on Pre-Test |
|---|
| Standard Speed Program (Athlete possesses average speed) |
| Low Metabolic Program (Athlete possess good aerobic fitness in needed of less conditioning) |
| Recover to 146 BPM between Runs (Multiply AT of 178 BPM by 82%) |

Figure 2. Sample pretest.

The sample pretest (Figure 2) shows both the treadmill and metabolic portions of the pretest. The sample pretest can be confusing, but keep in mind that for the purposes of this article, understanding the concept of a pretest procedure is more important than the details. Equipped with the concepts and ability to individualize, you can then begin to work on the details of a training pretest, which fits the needs and demands of your athletes.

## PERIODIZATION

Based on clinical experience, it is appropriate for most athletes to incorporate 2–3 treadmill mesocycles (8–10 weeks long each) within a yearly macrocycle. It is most effective to have one mesocycle as a preseason preparation period, occurring approximately 8–12 weeks before preseason practice. The remaining speed training cycles would then take place in the athlete's off-season for general athletic performance enhancement. It is rare that an athlete would necessitate more than 3 programs within a yearly macrocycle (Figure 3). It may be counterproductive to perform more than 3 mesocycles during a training year because it may not allow for proper recovery and will make it very difficult for them to continually respond to the treadmill training stimulus. As discussed earlier, new stimulus is needed on a consistent basis to promote neurological adaptations (18). To further promote desirable training adaptations, each mesocycle is

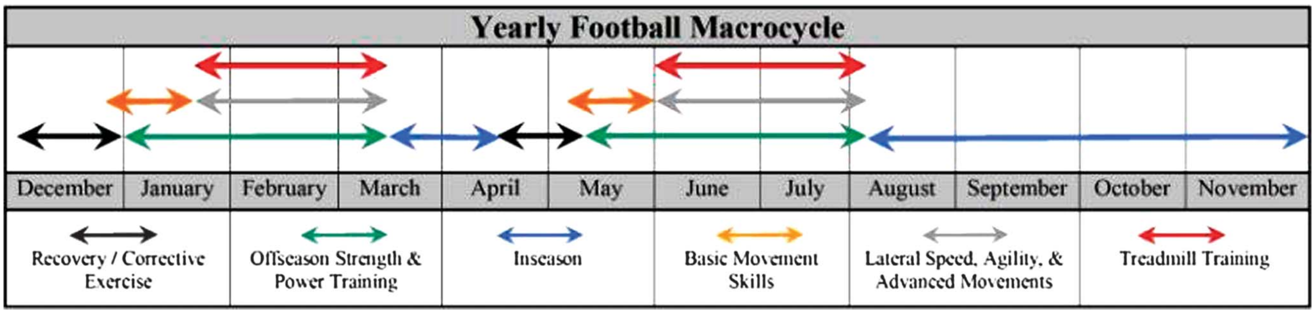


Figure 3. Yearly macrocycle for a football athlete.

designed using a nonlinear periodization model (33) containing 3 microcylces, allowing for 3 distinct peaks of increasing intensity throughout the 8- to 10-week program (Figure 4).

Within the 8-week mesocycle, athletes typically train their movement skills 3 days per week to enhance linear speed, nonlinear speed, and vertical power development. Day 1 should be a traditional ground-based workout, and day 2 should include plyometrics and agility training, with the third day focusing on the use of the treadmill to improve linear speed and power.

### EXERCISE SELECTION

*Drills.* Basic speed drills should be performed with every workout to consistently reinforce proper running mechanics. These should include typical sprint drills such as A skips, B skips, high knee running, hamstring kicks, and single leg cycles. Other drills (i.e., A march, arm swings, ankling, lunge to run, harness running, acceleration technique, and like) can be integrated as needed on an individual basis.

*Ground-based speed workout.* The entry level speed training technique of choice should be in a traditional ground-based setting. It is important to integrate ground-based training with treadmill training. This provides an excellent opportunity for the athlete to apply skills learned on the ground to treadmill training and vise versa.

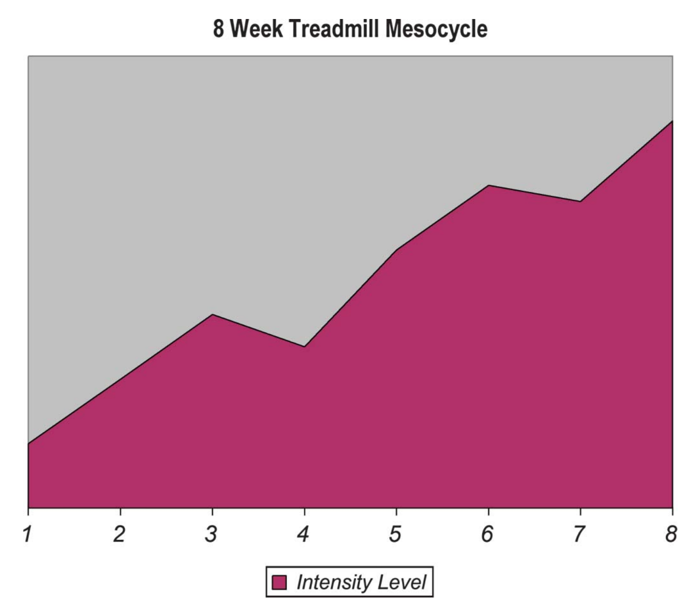


Figure 4. Intensity level variation during an 8-week treadmill mesocycle.

The integration of treadmill and ground-based training is important for improving sprint performance (36,51) and, although not yet researched, is likely a key to decreasing the rate of hamstring strains for those athletes performing treadmill training at high speeds and elevations.

While running at elevation, athletes may have a tendency to develop an increased rate of hamstring strains as compared with those training on a flat surface. This is likely because of the decreased activation of the hamstrings during an uphill run (56,57) and a combination of differing hill running kinematics and reciprocal inhibition.

When running on level surfaces, EMG demonstrates that the hamstrings experience the highest activation during the final 20% of the swing phase of recovery to decelerate the lower leg just before the beginning of the stance phase of the leg cycle (64). While running at elevation, an athlete will experience a decreased shin angle as compared with running flat (44), and thus the hamstrings do not likely experience the same stretch. This infers that while running uphill, the hamstring group does not experience the same activation because of the decreased stretch placed upon them and thus the decreased demand for work.

The concept of reciprocal inhibition states that as one muscle contracts (agonist), the opposing muscle relaxes (antagonist) (9,23,46). In the situation of uphill running, it has been discussed previously that uphill running causes a heighted activation of the quadriceps muscles, and thus because of reciprocal inhibition, there is a propensity to get a relaxation and deactivation of the hamstring group.

Because the hamstrings are used at a lower rate while running uphill, they may have a tendency to become less efficient while running. If this training stimuli persists and the neurological adaptations shift toward more permanent muscular changes (as discussed previously), then the hamstrings may develop difficulties with firing sequences when running on flat ground. Clinically, this is best solved with quality drill work, followed by ground-based speed development 1–2 days per week to ensure that the hamstrings maintain efficiency during the last 20% of the swing phase of the running cycle.

Ground-based sprint workouts are an opportunity to use traditional speed development techniques. Short sprints (less than 100 yd) should be used in conjunction with acceleration and starting drills. This period should be very technically oriented and allow for proper recovery to encourage motor learning. Conditioning should take place after strength training and should not be performed while training speed development.

*Treadmill workout.* Treadmill training sessions usually contain 8–15 runs of varying intensities and durations. These 8–15 runs typically take a total of 20–35 minutes to complete, not including the warm-up and running drills. The duration will vary, depending upon the individual needs of the athlete, recovery times, where the workout is in the training cycle, and what the coach is attempting to achieve with that athlete. Shorter workouts can make it difficult for proper motor learning to take place and energy system development but may allow an athlete to spend more time training other areas of need within their total regime. Longer workouts can provide greater opportunity for energy system development and neurological adaptations, but they may fatigue the body to the extent that neuromuscular development will become increasingly more difficult as the workout progresses (62).

Most runs are between 4 and 20 seconds in length, and each athlete is allowed to recover to their target recovery HR (determined with the metabolic testing information at the initiation of the program) before initiating the next run. Volumes can be very difficult to judge because there are so many variables with treadmill training (elevation, speed, duration, and overspeed). Intensity is a much better term for quantifying workouts because a 15-second run at 15% elevation and 10 mph is less difficult than an 8-second run at 30% elevation and 9 mph. Unfortunately, as it is today, there is no accurate way to objectively quantify sprinting intensity while on a treadmill at elevation with or without a spot. With experience, it becomes easier to judge the intensity of an overall workout.

A simple tool to use while in the learning process of developing programs is the use of rating of perceived exertion (RPE). This is not always reliable and can be individually specific, but RPE can show trends within your workouts. Refer to the nonlinear periodization model described earlier as a guideline for varying the intensities of the workouts over the course of a mesocycle (Figure 4).

A variety of speeds, elevations, and techniques should be incorporated into each training session. Typically, the first several runs should be of somewhat light intensity to allow the athlete to refamiliarize themselves with the transition on and off of the belt while it is moving and provide ample opportunities for technique corrections at lower intensities while the nervous system is fresh. Following that, medium-to-high intensity runs can be performed depending on what the training goals are for that specific session (Figure 5).

Longer runs (10–20 seconds) with slower speed (8–10 mph) and lower elevation (10–20%) are a useful tool for increasing a general fitness base for the athlete. The slower speeds and low elevations will allow the athlete to tolerate the intensity well enough to complete the full duration without a spot. Using holds (athlete running while holding onto the bar) allows the athlete to tolerate runs of greater intensity for longer durations as well


Figure 5. Medium-intensity run at elevation.

(Figure 6). Holds will also allow the trainer to teach proper hip position and core stability with the assistance of the bar in front of the athlete.

Medium-intensity runs (6–10 seconds; 9–11 mph; 20–27.5%) should comprise the bulk of the workout. Runs of this intensity level allow the trainer to push the envelope of the athlete's fitness capacity; incorporate proper mechanics at speeds that are intense but tolerable; and spur motor unit activation, thus increasing power output.

High-intensity runs (4–6 seconds; 10–13 mph; 27.5–35%) must also be a major component of the training program. These runs are intended to be very difficult and require a spot for part of the run to stay on the treadmill with good running mechanics. These runs are important for incorporating an overspeed training effect. Spotting is performed by standing to the rear of the treadmill and supporting the pelvis of the athlete as they drift backward because of fatigue or high speeds that they are not accustom to running (Figure 1). Safety can be a concern because the athlete must rely on the trainer's expertise to help them stay on the treadmill unit with a neutral pelvic position and good overall posture. If the pelvis is not kept neutral, the athlete is placed at risk for a hamstring strain because they may rock their pelvis anteriorly and elongate the hamstrings (19). To better understand the treadmill workouts, see Table 1 for a sample workout.

*Metabolic component.* While many times overlooked, the metabolic component of a strength and conditioning program is very important. Simply running to "get into shape" does very little to appropriately propel the body's energy systems to new levels. Athletes of almost all levels of fitness will struggle to improve their conditioning if they are continuously training the same energy system at the same intensity. The body adapts and learns to perform an activity with the least energy expenditure possible. Just as we periodize sets and repetitions for lifting, we should consider altering intensities and loads for the body's energy systems.

A comprehensive understanding of energy system development is beyond the scope of this article. The important take home here is that variation of training intensity and duration is the key to improving fitness because it relates to treadmill training.

In the 3-day split example (Table 2), each workweek contains a low-level workout (agility day), a moderate-intensity workout (ground-based speed day), and the high-intensity workout (treadmill day). Specific volumes and recovery rates are dictated by evaluating the athlete's metabolic test at the onset of training. Using the nonlinear periodization model discussed earlier, overall intensity levels of the treadmill workouts will vary during the 8-week mesocycle, but because of the variables involved in treadmill training, the treadmill workout will frequently be the most intense workout of the weekly microcycle. Other training variables (i.e., strength training, Olympic lifting, and so on) should be adjusted to accommodate these training sessions (Table 2).

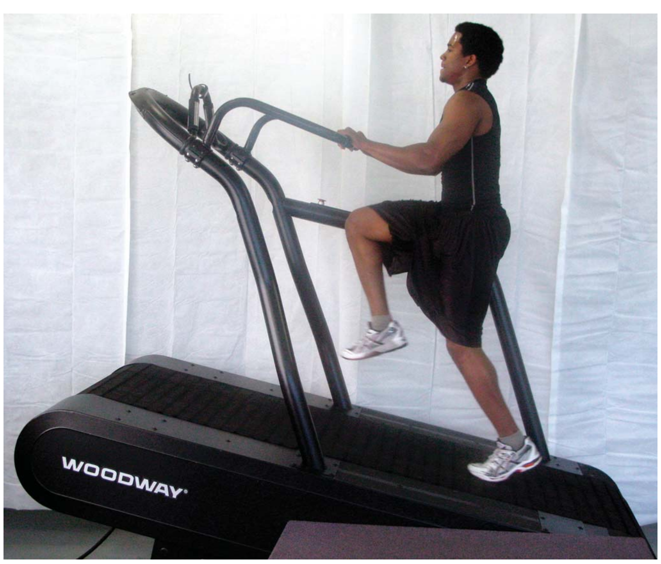


Figure 6. Run with a hold.

An indication of aerobic capacity is an athlete's $\dot{V}O_2$max, AT, and HR recovery (49). Clinical experience demonstrates that an easy means of determining aerobic fitness is by comparing the AT HR with the maximum HR achieved during their metabolic test. An athlete with a low AT/maximum HR will likely possess a decreased aerobic capacity and thus necessitate large amounts of anaerobic conditioning to improve their AT and consequently their aerobic capacity. Conversely, an athlete who demonstrates a very good aerobic capacity will be able to focus more time and attention to other deficiencies in their athleticism (strength, agility, and so on). Several runs within a workout can easily be modified to address these variations between athletes for a custom workout while staying within a group setting. Recommendations for these variations are shown in the "volume" portion of the "metabolic test" at the bottom of Figure 2.

As an example, most athletes perform a "standard" metabolic program, but with a variation of just 2–4 runs in a workout, you can easily create a version to train lactate tolerance for those needing more fitness. You can also create a low metabolic variation for those who need to spend less time on fitness and more time in other areas of their training (strength, flexibility, power, and like). All 3 versions are

**Table 1**
**Sample treadmill running workout**

| Standard Speed/Low Metabolic Program | | | | |
|---|---|---|---|---|
| **Workout #5** | | | | |
| **# Runs** | **Incline** | **Speed** | | **Time** |
| **1** | **20** | **9.5** | | **:10** |
| **2** | **22.5** | **10.0** | | **:08** |
| **2** | **25** | **10.0** | | **:08** |
| **1** | **27.5** | **10.0** | | **:04/:04/:04** (run/hold/run) |
| **3** | **25** | **11.0** | | (hold)**:08** |
| **4** | **25** | **10.5** | | **:06** |
| **Speed work** | | | | |
| | | **Male** | **Female** | |
| **1** | **0** | **13.0** | **12.0** | **:08** |
| **1** | **0** | **14.0** | **13.0** | **:08** |
| **1** | **0** | **15.0** | **14.0** | **:08** |
| **1** | **0** | **16.0** | **15.0** | (hold) **:08** |

similar, but with the minor modification of intensity and duration of several runs, a coach can provide individual attention within a group setting. Recommendations for these variations are shown in the "volume" portion of the "metabolic test" at the bottom Figure 2. The example shown presents an athlete with an AT to maximum HR ratio of 94%, which indicates that this athlete has a good aerobic capacity and a decreased need for extensive fitness training.

Recommended recovery rates are determined by looking at the athlete's ability to actively recover for 2 minutes after a maximal effort. The lower the athlete's HR at 2 minutes after maximum effort, the better they will tolerate decreases in recovery time between running bouts. Within the treadmill training workouts, HR recovery is established with the ratio of 2-minute recovery HR to AT HR. A lower ratio indicates improved recovery, thus better fitness. As the athlete's fitness improves, their recovery HR will have a tendency to improve as well (49).

Recommendations based on clinical experience are presented in the "recovery" section at the bottom of Figure 2. An athlete with a good HR recovery (less than 85% of AT) will need less time between runs to recover. Thus, their personal HR recovery is established at 82% of their AT. If, during an athlete's initial metabolic test, their recovery HR to AT HR ratio is higher, it is unlikely that they will be able to tolerate the work loads because of the fatigue created by increased lactate

**Table 2**
**Three- and four-day split workout recommendations**

| | **3 Day Split Work Week** | | |
|---|---|---|---|
| | **Day 1** | **Day 2** | **Day 3** |
| Movement | Linear Ground-Based Speed | Lateral Speed & Agility | Treadmill |
| Overall Movement Intensity | Moderate | Low | High |
| **Lifting Exercises:** | | | |
| Overall Lifting Intensity | Moderate | High | Low |
| Plyometrics | Moderate | High | Low |
| Weightlifting | Moderate | High | Low |
| Lower Extremity Strength Training | Moderate | High | Low |
| Upper Extremity Strength Training | Moderate | Low | High |
| Core | Moderate | Moderate | High |

| | **4 Day Split Work Week** | | | |
|---|---|---|---|---|
| | **Day 1** | **Day 2** | **Day 3** | **Day 4** |
| Movement | Lateral Speed & Agility | Linear Ground-Based Speed | Lateral Speed & Agility | Treadmill |
| Overall Movement Intensity | Moderate | Moderate | Low | High |
| **Lifting Exercises:** | | | | |
| Overall Lifting Intensity | High | Moderate | Moderate | Low |
| Plyometrics | High | Moderate | Moderate | Low |
| Weightlifting | High | Low | Moderate | Low |
| Lower Extremity Strength Training | High | Low | Moderate | Low |
| Upper Extremity Strength Training | Low | Moderate | Moderate | High |
| Core | Low | Moderate | Moderate | High |

levels (20,52,53) and/or neuromuscular fatigue (62). Depending on how high the recovery HR to AT HR ratio is, an athlete will need to recover to either 80% or 77% of AT HR between runs during their treadmill training session.

Using testing results and HR monitors will allow you to individualize training for your athletes, monitor recovery, and ensure that your athletes are getting the energy system development that they need.

*Strength training.* Although we work in a setting in which speed and agility have become the dominant factors between average and elite athletes, we must keep in mind that strength is the fundamental basis for all athletic movement. If an athlete is not strong, they will not be fast.

Strength training should be performed in collaboration with treadmill training. Performing closed-chain lower extremity and core stability exercises will tend to activate similar muscles as shown with treadmill training at elevation. This will likely allow an athlete to continue to reinforce the neurological adaptation that they are establishing within their speed training workouts.

The volume of the strength training workout during a treadmill mesocycle should be reduced by approximately 10–20% while keeping intensities fairly high to maintain and/or improve strength and power. This is especially true of the lifting workout, which is performed on the same day as a treadmill workout. The most intense lifting workout should be performed on the plyometrics/agility training day because the movement portion of this workout is typically less intense than its linear speed counterparts (see Table 2 for explanation of weekly workouts). Judgment should be used if the intensity of the lower extremity lift causes muscle soreness, which may impact the athlete's performance on the treadmill. If soreness is present, the coach can determine if modifications are warranted on an individual basis.

## CONCLUSION

Conflicting research exists as to whether the mechanics of movement while on a treadmill matches the mechanics of ground-based running or walking (4,26,37,45,55,68,69). Many have been quick to dismiss high-speed treadmill training because of the lack of scientific consensus on this issue. Although it is difficult to study, it could be argued that a bench press does not necessarily produce the same neurologic responses that a football lineman experiences during a blocking maneuver. Yet, the bench press is a staple exercise within American football training. In this scenario, the bench press is typically used as a tool to produce loads in excess of what they may be able to experience otherwise, in a controlled environment in hopes of creating neurological adaptations, which are deemed as advantageous for the football athlete. Similarly, high-speed treadmills can provide a good-quality tool to increase speed and power output under conditions not seen in other environments. Results are typically best when the treadmill programs are properly integrated into the individualized strength and conditioning program using a variety of tools to simultaneously improve stride frequency and stride length.

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