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The Truth on Fitness: **Is Treadmill Running The Equivalent Of Running Over Ground?**

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When running on a treadmill, "the belt pulls your leg through, resulting in a relatively passive extension of the hip. Passive [hip] extension would then minimize the contribution of the primary hip extensors. Running over ground, on the other hand, requires that you pull your leg through, therefore involving active hip extension."

These were the comments of one author on a recent sports performance forum entitled, The Myth of Speed Training – Part 2 (Reynolds, 2010). This particular line of debate actually focused on whether high speed treadmills were effective training aids, but the underlying message was clear; treadmills don't work. In fact, the author goes on to claim that "you are never going to improve speed of extension or the force generation capacity of that extension when you utilize an activity that minimizes the contributions of the primary hip extensors." In other words, if a treadmill fails to actively work the hip extensors, then it will fail to induce the necessary force generation from those muscles, and in the end, it will fail to produce a training effect.

Another contributor to that particular chat string went on to state that "it's well known by anyone that has any background in anatomy and human performance [that] there is [a] higher incidence of hamstring pulls by athletes who transition from the treadmill to ground based running programs." Thus, not only are treadmills ineffective, but they are potentially harmful as well.

The genesis of these arguments is the opinion that there are tangible differences between a moving center of gravity over a stable base, and a relatively stable center of gravity over a moving base. The latter, it is suggested, will result in deviations in movement patterns, muscle activity, force production, and ultimately, training outcomes. But are these assumptions correct? Do treadmills deliver an inferior training experience, or is it the equivalent of running over ground?

Interestingly, even a cursory review of the literature indicates that there is no shortage of research on this topic. Treadmill and over ground comparisons have been made under conditions of walking, running, sprinting, and even sprinting up significant grades. While most studies reveal fairly consistent findings, there seem to be some differences in the outcomes of kinematic analyses.

For example, White and colleagues (1998) discovered that walking on a treadmill at slow, normal, and fast paces, involved the same cadence, stride length, and stride time, as walking at similar speeds over ground. On the other hand, Wank, Frick, and Schmidtbleicher (1998) reported reduced step lengths and higher step frequencies on a treadmill as compared with over ground running. One might conclude then, that treadmills do induce changes in movement patterns, at least at gait velocities greater than walking paces.

There are, however, some very curious facts embedded in their data, which might explain the differences in the kinematics they reported. In their study, video data were recorded for five seconds while subjects ran on the treadmill at 4.0 m/s (9 mph) or 6.0 m/s (13 mph). For over ground trials, subjects were instructed to run at 3.95 to 4.05 m/s for the 9 mph pace, and 5.95 – 6.05 m/s for the 13 mph pace. Motion was captured as they passed through a recording zone measuring 10 meters in length. From these events, five steps were extracted for the purpose of data analysis.

It's noteworthy, that for the over ground condition, subjects were given a range of speeds at which to run, owing to the fact that for those trials, speed was self-regulated. This implies that there is a natural variability in running speed. After all, humans are not perfectly regulated, so variations in pacing would not be unusual. Indeed, the authors noted that "not all attempts were within the acceptable range of the target speed, and on average, subjects required between five and eight trials per speed level in order to produce data sets for analysis." This inconsistency in running speed over ground is further confirmed by a recorded horizontal speed variance of up to 1.89 m/s (4.2 mph) for the 4.0 m/s condition.

So, here is a situation in which running over ground produced one set of kinematic characteristics with greater speed variability, while running on a treadmill evoked a different set of kinematic characteristics at a more consistent speed.

What does this mean? Consider first that in over ground running, any deviation in speed will be accompanied by a concomitant change in the velocity of the ground, relative to the runner. This, in contrast, does not arise in treadmill running, during which the belt moves at a consistent pace, despite any variability in human kinematics. Perhaps, the kinematic variability seen in treadmill running is simply the behavior of a relatively variable human system coping with a highly regular moving condition. Yet, despite this inherent variability, there is little difference in muscle activation between treadmill and over ground running.

Schwab, et al (1983), for example, examined lower extremity muscle activity, using electromyography (EMG), and found no differences between treadmill running and running over ground. Even Wank and colleagues (1998), who demonstrated kinematic variances between running modalities, were unable to detect any differences in EMG activity in key muscle groups, including the hip extensors. Despite differences in step length and frequency, muscle activity was similar across modalities.

These findings are consistent amongst biomechanical analyses as well. According to Van Ingen Schenau (1980), "the amount of kinetic energy required to keep up with the moving belt is the same as over ground." This assumes that the belt moves at a constant speed, which it does, according to Wank, et al.

In their examination of treadmill and overground walking, White and associates noticed only insignificant differences in ground reaction forces (GRF), and identical force distribution patterns. These results are mirrored by Kram, et al (1998), who evaluated GRF in treadmill and over ground running at 3 m/s, or 6.7 mph. The authors not only revealed that there were no differences between the ground and treadmills, but also, that the ground reaction force of 2.46 times body weight for treadmill gait is consistent with the vast body of literature demonstrating GRF magnitudes of 2.0 – 3.0 percent body weight for running over ground.

Treadmills, in fact, create the same force requirements as running over a stationary surface. The same can be said for metabolic activity. In keeping with the findings of Van Ingen Schenau, a 1985 study by Bassett and others, revealed that oxygen consumption of subjects in level running, or up a 5.7% grade, was the same, regardless of whether on treadmill or ground. These findings were consistent for slow and fast paces as well.

One exception does exist, however, in cases of high speed running. According to Bassett, at velocities of 358 m/min (13.3 mph) or higher, oxygen demands increase because of added wind resistance. The author suggests that energy demands may rise 8% due to wind, while Van Ingen Schenau calculated a 13% increase in energy demands owing to the wind.

In this regard, level treadmill running is at somewhat of a disadvantage. On the other hand, to compensate for this deficit, runners may choose to set treadmills on an incline, as indicated by Swanson and Caldwell (2000). They noted that subjects exhibited muscle power and net muscle work that was 345% and 219% greater, respectively, while running up a 30% incline, as compared to level treadmill running. Admittedly, 30% is a steep hill to climb, but based on their numbers, it wouldn't require a substantial grade to overcome a mere 13% increase in energy demand. Besides, while instances of runners ascending steep treadmill inclines are rare, so are those cases of running in excess of 13 mph. All in all, the net effect of drag due to wind, is incidental.

The potential differences between the ground and treadmills can be examined in many different ways. Ultimately, however, the question is, "so what? Arguably, people use equal muscle energy, produce similar forces, and consume equivalent amounts of oxygen on either modality. From a general fitness perspective, this makes treadmills and outdoor running equally valuable.

But one question that hasn't been addressed is whether training on treadmills will induce performance gains, or deficits, in subjects measured over solid ground. Elliott (1974), for example, had subjects train on treadmills four times per week, for four weeks, with no recorded changes in support duration, stride length, or stride rate, when measured over the ground. They recorded a 5.4% decrease in steady state heart rate and a 3.0 ml/kg increase in steady state oxygen consumption, both considered improvements, as a consequence of their treadmill regimes.

Top end speed does not always increase as a result of treadmill training (Elliott et al, 1974), but sprint start speed has been shown to increase in treadmill-trained subjects. Myer and colleagues (2007) measured 10-meter sprint times in subjects who trained for 6 weeks using either a resisted ground-based paradigm, or treadmill sprints inclined to match the loading characteristics of the ground-based trials.

According to the authors, both groups experienced significant improvements in starting sprint speed, with no differences between groups. Thus, it could be argued that treadmill training results in positive adaptations that carry over to ground based running.

Lastly, there's the claim that anyone with a background in anatomy recognizes that runners are more susceptible to hamstring injury when transitioning from treadmills to ground. Unfortunately, a fairly rigorous review of literature failed to uncover specific studies which could support that claim.

One study (Taunton, et al, 2003) did examine injury rates amongst 844 recreational runners, correlating a multitude of variables, including demographic factors, body composition and morphology, training habits, footwear characteristics, and running surfaces. The investigators did find injury correlates with age, body mass index, training frequency, and shoe age. There was no correlation between injury rates and treadmill use.

Another study compared the potential for tibial stress fractures in treadmill users and ground-based runners (Milgrom and associates, 2003), and determined that tibial strain levels were actually 48% – 285% higher in runners who ran over ground. Treadmills, unless designed very poorly, are apparently not the catalyst for running injuries.

The truth is that treadmills are quite effective training tools which are capable of delivering results that are commensurate with an individual's level of effort. The concerns of the author who prompted this discussion – the effects of a moving or stable base – are generally unfounded. What he failed to recognize was the concept of relative motion. To wit, whether it's a moving center of gravity over a stable base, or a stable center of gravity over a moving base, the reality is that one is in motion relative to the other, amounting to identical conditions.

Can treadmills do everything? No, clearly not. As one blogger points out, one can't learn to change direction on a treadmill. But realistically, all training implements have their limitations as well as their advantages. Wouldn't we be better off focusing on what these devices can do, instead of worrying about what they can't?

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