Effectiveness of treadmill vs ground-based repeated sprint training on sprint time and high-intensity running ability in youth female soccer players

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Abstract

In Canadian youth soccer, the pre-season period prior to the outdoor season typically comprises 6 - 8 weeks, beginning in mid-to-late March and ending in mid-to-late May. Repeated sprint training is a commonly used training method during the soccer pre-season. The aim of this study was to examine the efficacy of a treadmill-based training (TT) versus an on-field ground-based training (GBT) protocol on repeated sprint training by measuring differences in speed over short distances and high intensity running ability.

19 elite female soccer players (aged 14 – 17) from a Toronto-based youth soccer club were randomly assigned to either TT or GBT groups using a simple computer-generated randomization. 9 players participated in the TT Group, and 10 players participated in the GBT group. Both groups performed a 6-week, 2 sessions per week repeated sprint training protocol, comprising of 15 repetitions of a 6-second maximal effort, separated by 60 seconds of passive recovery. Sprint times over 10-, 20- and 35-m distances as well as high-intensity running ability, measured using the Yo-Yo Intermittent Recovery Test (YYIRT), were performed prior to and after the training program. Following 6 weeks of training, there were significant ($p<0.05$) improvements in player performances in the TT and GBT groups for all tests post-training (10-m, 20-m, 35-m sprint and YYIRT). However, the differences in improvement between pre- and post- training sprint performances were greater in the TT group than in the GBT group (10m TT vs GBT, $p<0.0001$, 20m TT vs GBT, $p<0.0001$, 35m TT vs GBT, $p=0.01$). There were no significant differences in distance covered pre- and post- training between TT and GBT in the Yo-Yo Intermittent Recovery Test (YYIRT TT v GBT, $p=0.35$).

Results of the study indicate that treadmill-based repeated sprint training produced a significantly greater increase in running speed, with a small – but also greater – increase in high intensity running ability, than a traditional on-field training protocol.

Introduction:

In Canada, youth outdoor soccer seasons follow a calendar in which there is a 6-8 week pre-season, which starts in the middle of March, and finishes with the start of the competitive season in the middle of May. Typically, training during this pre-season period is focused on improving the aerobic and anaerobic energy systems, which may have been neglected over the course of the off-season. While certain players may be involved in playing indoor soccer during the off-season, the majority of such games are played in 5v5 or 6v6 format, with frequent and unlimited substitutions, resulting in training which is not as conducive to maintaining soccer-specific fitness levels when compared to playing outdoor soccer (Gorostiaga *et. al.,* 2009). Cold temperatures in the Canadian winter (which average -10 degrees Celsius from December to March) and a lack of large indoor soccer fields with the capacity for 11v11 games, also contribute to this problem. Because the middle of March is typically a time when temperatures rise, and training and playing on outdoor soccer fields becomes possible, more intense physical preparation for the Canadian outdoor soccer season typically begins during this time period.

In soccer, short-duration sprints (5-10 seconds), interspersed with brief periods of recovery (60-120 seconds) are common, and are referred to as "repeated sprint sequences" (RSS). Buchheit *et. al*. (2010) found that youth players averaged 2.7 repeated sprint sequences per game. Another study by Vescovi (2012) reported that the average distance of sprints made in elite female soccer was 15.8 metres and the average time of these sprints was 2.3 seconds). Buchheit *et al*. (2010) also determined that the average distance of sprints in RSS in youth soccer was 9.6 metres; and the average speed of youth players' sprints was above or equal to 60% of their individual peak velocity. The ability to perform short distance sprints is especially important in soccer in general, and female soccer specifically, because they occur during many critical moments in matches, including when players are attacking and/or defending (Granda *et. al*., 2008). Further, several studies have shown RSS to be a cause of short-term fatigue in soccer (Mohr *et. al*., 2004, Buchheit *et al*., 2010, Girard *et. al*., 2011).

Repeated sprint ability (RSA) is the ability to perform RSS. RSA is a unique physical ability that encompasses contributions from both the aerobic and anaerobic energy systems (Coutts *et. al*., 2009). Aerobic fitness (measured using the YYIRT) and anaerobic fitness (running speed, and RSA) have both been shown to be good predictors of match performance in soccer (Castagna *et al*., 2010). Repeated sprint training, consisting of 10 or more repetitions of high/maximal intensity runs/sprints, is one commonly used method of soccer pre-season fitness training (Bishop *et. al*., 2011). The reason for this is that repeated sprint combines high speed running with relatively low work-to-rest ratios (typically a 1:5 to 1:10 ratio), which creates a training stimulus to both the anaerobic (speed/high speed running) and aerobic (recovery) energy systems (Buchheit *et. al*., 2012). Repeated sprint training has been shown to produce improvements in RSA, as well as improvements in sprint speed, and endurance, measured as VO_2max (Bishop *et. al*., 2011). Therefore, by implementing an effective RSA training programme soccer players can achieve improvements in both their aerobic and anaerobic fitness levels in a relatively short amount of time (6-8 weeks), prior to the start of the competitive season.

Several different studies have demonstrated the effectiveness of running training, or "ground based training" (GBT) on improving RSA, speed, and high intensity running ability. Buchheit *et al*. (2010)

showed improved repeated sprint performance and improved maximal running speed in elite level adolescent male soccer players following a 10-week, 1 training session per week repeated "shuttle-sprint" training (comprising 2-3 sets of 5-6 trials of a 15-20-m sprint)[i]. Shalfawi *et al*. (2013) demonstrated significant improvements in RSA, running speed, jump height, and high intensity running ability (measured using the YYIRT-Level 1) in elite professional female soccer players, following an 8-week, 1 training session per-week repeated sprint training protocol (comprising of 2x (5-9) x 40-m sprints, with 1.5 minutes rest between sprints, and 10 minutes rest between sets).

Treadmill training (TT), which is used as an alternative training method to GBT, utilizes high speed and/or high incline running treadmills (Myer *et. al*., 2007). As compared to GBT, high speed and/or high incline treadmill training is advantageous in that the workloads, such as speed and incline percentage, can be more closely controlled (Myer *et. al*., 2007). The addition of a spotter, during TT also provides a further advantage over GBT, as they can help the athlete perform higher speed runs than they could normally complete by spotting/pushing on the athlete's lower pelvis. However, very limited evidence is available on the effectiveness of using high speed and/or high incline TT with athletes. In one study performed using elite level distance runners, high intensity interval training using high incline treadmill running (2 days per week for 6 weeks) was shown to improve running economy, but had no significant effect on muscle power as compared to level-ground treadmill running (Ferly *et. al*., 2013). Myer *et. al*. (2007) were able to demonstrate a similar significant improvement in sprint start speed (9.1 metre sprint test) using high speed and/or high incline TT, as compared to resistive GBT sprint training. In this particular study, 67% of the variance in sprint start time was predicted/controlled for by stride length and stride frequency in the TT group, while total vertical pelvic displacement and stride length predicted 62% of the variance in sprint start time for the GBT group (Myer *et. al*., 2007). Further research into the biomechanical effects of incline treadmill running demonstrated that incline treadmill running provided enhanced muscular loading of key mono-articular (*gastrocnemius, soleus,* and *vastus lateralis*) and b-articular (*rectus femoris,* and *gluteus maximus*) lower body muscles during both stance and swing phases of running as compared to level-ground running (Swanson *et. al*., 2000). Thus, while the exact mechanisms of improvement are not yet clear, TT has been shown to elicit improvements in running economy, as well as increased activation of key lower body muscles in athletes. As a result, TT can be seen to be an effective method of high intensity interval and/or repeated sprint training in athletes.

To date, there have not been any studies comparing a ground-based versus a treadmill-based protocol for repeated sprint training on youth soccer players. The aim of this study was to examine the differences in speed and high intensity running ability following a 6-week, 2 days per week repeated sprint protocol of ground-based versus treadmill based repeated sprint training.

Methods:

Subjects participating in this study were elite female soccer players, aged 14-17 years old, from a local Toronto area youth soccer club. Subjects (n=19) were randomly assigned to the Treadmill Training (TT) or the On-Field Ground-based Training (GBT) group using simple computer-generated randomization. 9 players in total participated in the TT Group, and 10 players in total participated in the GBT Group. All participants gave informed and written consent through their parent and/or legal guardian to participate in the study.

Performance Assessments:

Prior to, and following the training intervention, both groups participated in performance assessments including the linear running speed test and aerobic fitness test. The linear running speed test consisted of a player running a linear 35-metre length. Photo-cell timing gates (Brower Timing System, TC System, Utah, United States) were set up at the start, and at 10-, 20-, and 35-metre intervals along the running course, with a 15-metre distance to decelerate at the end of the course. Players performed 3 sprint trials, and the fastest individual running times were selected. All three linear running speed tests were measured in the same running trial.

The aerobic fitness of the participants was measured using the YYIRT-Level 1. This test has been shown to be an effective, reliable, and valid tool to measure high intensity running ability in soccer players, as well as specifically in female soccer players (Bangsbo *et al*., 2008). The test comprises a repeated, progressive 2 x 20-metre shuttle run, with 10 seconds of passive recovery between each 2 x 20-metre shuttle runs. Players start on or behind the middle line, and begin running 20 m when instructed by the audio signal “beep”. Players then turn and return to the starting point when signaled by the second recorded “beep”. There is a 10-second active recovery period interjected between every 2 x 20 metre (out and back) shuttle, during which the players must walk or jog around another cone and return to the starting point. A warning is given when a player does not complete a successful out and back shuttle in the allocated time; the player is removed the next time they do not complete a successful shuttle.

Repeated Sprint Training Programme:

To evaluate the effectiveness and compare the differences in speed and high intensity running ability performances between TT and GBT, a standardized protocol was used. The repeated sprint protocol implemented in this study consisted of 15 repetitions of a 6-second maximal effort, with 60-seconds of passive recovery in between. The protocol used in this study was based on a protocol presented in a recent study by Mohr *et. al*. (2007.). The protocol involving a 6-second running time was chosen because of the authors’ experience administering speed tests with female players. Most of the female youth players we have tested have been able to run 35-m in a time ranging between 5- and 6-seconds, therefore the 6-second running time was thought to provide the optimal time to allow the players in this study to reach their maximal running speed. Participants in both groups trained for a total of 6-weeks, with 2 training sessions per week; training frequency and training volume was also the same as that presented in Mohr *et. al*. (2007). The players performed a standardized 10-minute warm-up prior to the repeated sprint training sessions. After the repeated sprints, both groups performed a strength training circuit (Figure 1), followed by a standardized 5-minute cool-down. All other team training and matches were carried out by all the team members, thus the specific repeated sprint training intervention was the only different variable amongst the 2 groups over the 6-week training period.

Players performed the following circuit 3 times, with no rest between repetitions:

1. Glute Bridge Hold (2 legs x 10 seconds, 1 leg each x 10 seconds)
2. Push-Ups (x 10)
3. Front Plank Hold (2 legs x 10 seconds, 1 leg each x 10 seconds)
4. Side Plank Hold (2 legs x 10 seconds, 1 leg x 10 seconds – both sides)

Figure 1: Strength Training Circuit. List and description of the 4-exercie, 3-set strength training circuit performed by all participants, following completion of each repeated sprint training session)

GBT training sessions were conducted on a 30-metre long indoor soccer turf field (Terra Sport Complex, Vaughan, Canada). Players performed a 6-second sprint, running forwards from end-line to end-line, turning around and running to the ½ line in the opposite direction with 60 seconds of passive recovery; during which they walked back to their starting position on the end-line. The TT training sessions were conducted at the Soccer Fitness Training Centre (Vaughan, Canada) using a Woodway Pro-XL high speed running treadmill (National Fitness Products, Inc., Toronto, Canada). Treadmill workload was set with an incline of 25%. Treadmill speed was individualized for each player, based on and calculated at 80% of their maximal running distance as determined by the pre-training linear running speed assessment. Players trained in groups of 4-5 players per session, so that the rest period between each 6-second sprint was exactly 60 seconds. All athletes in the TT group performed one practice training session, where they were taught the safe and correct method of getting on and off the treadmill. Players used a safety clip, and a Soccer Fitness Training Centre Certified Trainer was on-hand to spot the players during every run.

Participants' rating of perceived exertion (RPE – a subjective measurement of intensity) during TT and GBT training sessions was assessed using the Borg CR-10 Scale, which has become a standard method for evaluating perceived exertion in exercise testing, training, and rehabilitation and has been validated against objective markers of exercise intensity (Borg *et al*., 1985) (see Figure 2 for a description of the Borg CR-10 scale).

Repeated measures *student's t-tes*t statistical analyses of pre- and post-training sprint performance and high-intensity running ability (YYIRT total distance) were performed using IBM SPSS Statistics Version 22.0 (IBM Corp., Amrock, New York, United States). Differences in pre- and post-training results between TT and GBT group were statistically analyzed by performing the student t-test using IBM SPSS Statistics Version 22.0.

Figure 2: Borg CR-10 Scale

Rating	Descriptor
0	Rest
1	Very Easy
2	Easy
3	Moderate
4	Sort of Hard
5	Hard
6	
7	Very Hard
8	Very, Very Hard
9	Near Maximal
10	Maximal

<u>Results:</u>

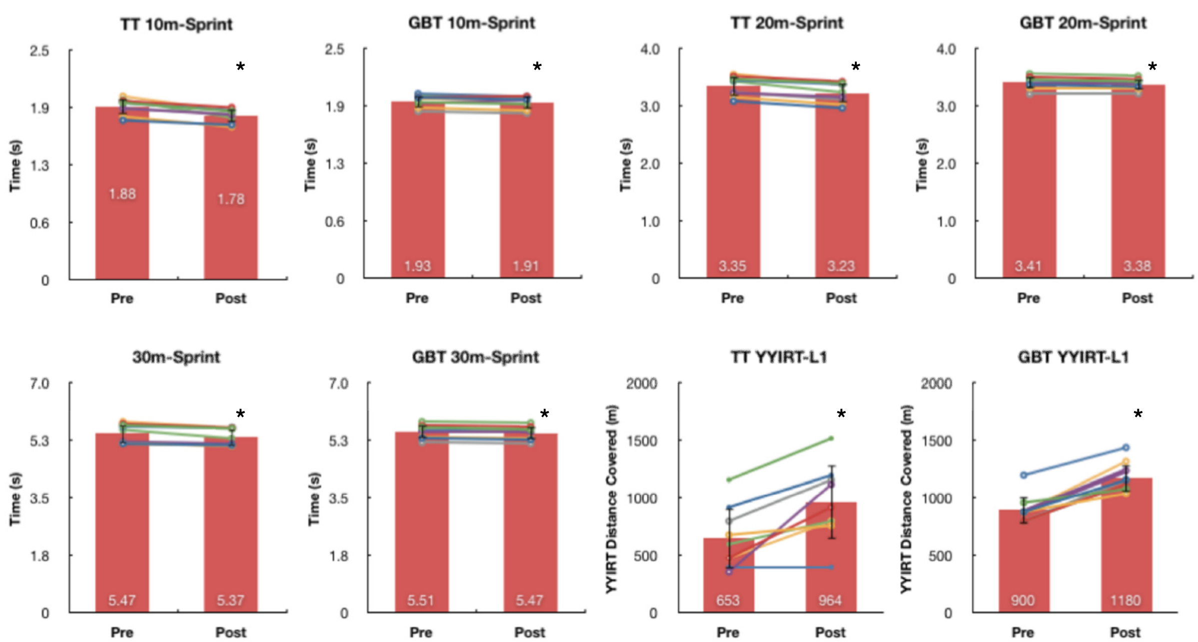

Figure 3: Pre- and Post-training test results for TT (n=9) and GBT (n=10) sprint performance and high intensity running ability. Both TT and GBT resulted in significant improvements in the 10m (TT, p=0.0003; GBT, 0.043), 20m (TT, p<0.0001; GBT, GBT, p=0.002), and 35msprint (TT, p=0.0031; GBT, p<0.0001) sprint performance post-training. There was also a significant improvement in the total YYIRT distance following both TT (p=0.003) and GBT (p<0.0001). * indicates a significant difference (p<0.05).

Both TT and GBT resulted in significant improvements in the 10m (Pre-TT, 1.88s ± 0.09, Post-TT, 1.78s ± 0.07, p=0.0003; Pre-GBT, 1.93s ± 0.07, Post-GBT, 1.91s ± 0.07, p=0.043), 20m (Pre-TT, 3.35s ± 0.17, Post-TT, 3.23s ± 0.17, p<0.0001; Pre-GBT, 3.41s ± 0.11, Post-GBT, 3.38s ± 0.2, p=0.002), and 35m (Pre-TT, 5.47s ± 0.29, Post-TT, 5.37s ± 0.26, p=0.0031; Pre-GBT, 5.51s ± 0.2, Post-GBT, 5.47s ± 0.20, p<0.0001) sprint performances. Similarly, there were significant improvements in the high intensity running ability of the players following both TT (Pre-, 653m ± 265; Post-, 964m ± 325; p=0.003) and GBT (Pre-, 900m ± 118; Post-, 1180m ±121; p<0.001) (Figure 3). However, there was a slightly greater, but not significant difference (p=0.345), in the total distance covered pre- and post-test following TT (311m ± 220) compared to GBT (280m ± 100) in the YYIRT (Table 1).

Table 1: Differences in sprint times (seconds, 10-m, 20-m, and 35-m sprint) and distances covered (metres, YYIRT) between pre- and post- test for TT and GBT groups

	10m-Sprint (s)		20m- Sprint (s)		35m-Sprint (s)		YYIRT-Distance (m)	
	TT	GBT	TT	GBT	TT	GBT	TT	GBT
	-0.05	-0.02	-0.12	-0.03	-0.05	-0.05	280	280
	-0.09	-0.02	-0.07	-0.03	-0.09	-0.06	360	120
	-0.11	-0.03	-0.13	-0.02	-0.08	-0.04	80	160
	-0.07	0.01	-0.09	-0.04	-0.12	-0.03	440	320
	-0.07	0.03	-0.07	-0.01	-0.06	-0.02	760	360
	-0.06	-0.02	-0.12	0.01	-0.07	-0.03	360	360
	-0.08	-0.03	-0.07	-0.03	-0.02	-0.04	0	240
	-0.19	-0.03	-0.19	-0.04	-0.26	-0.03	200	320
	-0.16	-0.01	-0.19	-0.07	-0.18	-0.03	320	440
		-0.03		-0.05		-0.04		200
Mean	-0.098	-0.015	-0.12	-0.03	-0.10	-0.04	311	280
Stdev	0.048	0.020	0.05	0.02	0.07	0.01	220	100
p-value		<0.0001		<0.0001		0.01		0.35

Table 2 : **Mean RPE scores for participants in TT and GBT groups**

	RPE (0-10 Borg CR 10 Scale)	
	TT	GBT
	3.1	4.3
	3.9	3.8
	3.1	3.6
	3.3	4.1
	3.1	3.7
	3.1	4.2
	3.1	4.3
	3.1	4.2
	3.8	3.9
	3.3	4.5
		4.2
		3.8
		4.1
Mean	3.3	4.1
Stdev	0.3	0.3
p-value	<0.0001	

RPE responses were significantly (p=<0.0001) lower following TT compared to GBT. Mean player RPE values are presented. Significance value was set at p<0.05.

When evaluating program effectiveness, TT produced a significantly higher difference in improved player 10-m (p<0.001), 20-m (p<0.001), and 35-m (p=0.006) sprint performance when compared to GBT. There was however no significant difference between the TT and GBT in post-training tests for the YYIRT

(Table 1). Furthermore, player RPE responses following each training session also demonstrates that TT (3.3) was significantly ($p<0.0001$) lower significantly lower than GBT (4.1).

Discussion:

Aerobic fitness (including high intensity running ability) and anaerobic fitness (including speed, and repeated sprint ability) are both key components of general performance in soccer. In female soccer the ability to perform many short duration, high intensity runs and sprints is a predictor of performance; differentiating between higher and lower levels of play in the sport (Krustrup *et. al*., 2007). Repeated sprint training is a unique training method that has been shown to be effective at improving both aerobic fitness and anaerobic fitness in soccer players and other athletes (Bishop *et. al*., 2011). Repeated sprint training (RST) can be implemented using two different types of training methods including on-field ground based training (GBT) and treadmill training (TT). While GBT has been shown to be effective at improving speed, repeated sprint ability (RSA) and high intensity running ability (Bishop *et. al*., 2011), limited research has been done on the effectiveness of TT at improving these qualities (Myer *et. al*., 2007). In this respect, the aim of our study was to investigate and compare the effectiveness of ground based repeated sprint training, and treadmill repeated sprint training, on speed and high intensity running ability of elite youth female soccer players. While there has been limited research demonstrating the importance of RSS in soccer, it is clear that RSS does occur in soccer and that they may be a cause of fatigue in soccer. RSA, then, can be seen to be a critical component of physical performance ability in soccer. The fitness assessment protocol selected was chosen to give an accurate representation of a player's soccer-specific speed and high intensity running ability. The 10-metre linear running speed test is useful in determining an athletes' ability to accelerate, which is a key physical ability in female soccer due to the high number of short sprints performed in the sport (Krustrup *et. al*., 2005). The 20-metre linear running speed test determines players' speed over a longer distance, taking into account both the acceleration phase (0-10m) and progression towards maximal running speed. As reported by Buchheit *et. al*. (2010), the average distance of sprints in youth soccer players is close to 20 metres (15.8 metres). The 35-metre linear running speed test is a measurement of a soccer players' maximal running speed. Kollath & Quade (1993) originally suggested the use of a 35-metre sprint test to measure maximal running speed because most soccer players are able to reach their maximal running speed at or before this distance.

Although repeated sprint training has been shown to improve RSA, there is also evidence that this method of training can be effective in improving running speed, and running economy in athletes, including soccer players (Bishop *et. al*., 2011). The great majority of the repeated sprint training interventions used in studies showing improvements in physical ability have involved GBT protocols. Nevertheless, there is a small body of evidence demonstrating high speed and/or high incline TT can also be effective in improving running speed and endurance in athletes (Myer *et. al*., 2007). Intensity and workloads, including running speeds and percentage of incline, can be much more effectively and accurately controlled using TT than they can with GBT. If TT could be shown to be as effective, if not more effective, in improving physical performance in female soccer as GBT, then TT may be a preferable method of repeated sprint training during pre-season for female soccer players.

Based on the results of our study, both TT and GBT have been shown to elicit significant improvements in speed and high intensity running ability in a 6-week, 2 days per week training protocol (both training programs were effective in this regard). Results of the study indicated that TT produced a significantly greater increase in running speed, with a small – but also greater – increase in high intensity running ability, when compared to GBT. However, the exact mechanisms responsible for the improvements in performance as a result of repeated sprint training are not clear. It is possible that improvements in high intensity running ability came about through physiological changes leading to a more efficient use of oxygen in running muscles, such as increased capillary density, myoglobin concentration, increased size and density of mitochondria, and greater activity of oxidative enzymes within mitochondria (Reilly *et. al*., 2009). Alternatively, it is also possible that improvements in speed and high intensity running ability occurred as a result of improved neuromuscular function, better coordination of motor units and muscle groups (Folland & Williams, 2007). Despite not having investigated the specific mechanisms underpinning improved RSA in this study, previous research has demonstrated that RSA is a complex physical ability that requires both a strong neuromuscular and anaerobic components, such as speed and power, as well as strong metabolic components, including oxidative capacity, creatine phosphate replenishment, and H^+-ion buffering capacity (Chaoachi *et al*., 2010). Thus, repeated sprint training will place a great demand on the athletes' anaerobic and aerobic energy systems. As such, this method of training can lead to improvements in both speed and high intensity running ability, as were demonstrated in our study. Due to the observation that TT was shown to elicit a greater improvement in sprint times over the 35-m sprint interval distances (10-, 20-, and 35-m), it is possible that TT may be more effective at training and improving the neurological component of RSA. Perhaps, further research using a TT repeated sprint training protocol with additional assessments, including measurements of running economy such as stride length, stride frequency, and pelvic displacement, as was done in the study by Myer *et. al*. (2007), could determine whether or not the improvements seen in 10-m, 20-m, and 35-m sprint times from TT were due to improved ability in these markers of running economy.

There were certain additional limitations in our study that may have affected the results. Firstly, although the time duration of the repeated sprint bouts in GBT and TT were the same (6-seconds), the intensity of runs carried out by each individual player may not have been consistent. Reasons for this may be due to the onset of fatigue, fitness levels of individual players, and motivation (Krustrup *et. al.,* 2005, Mohr *et. al.,* 2005, Reilly *et. al.,* 2009). With the TT protocol, treadmill incline was kept at 25% grade but running speed was individualized at 80% of each player's maximal running speed. The 80% threshold was selected because we believed it to be the highest running speed the athletes would be able to maintain while running for 6 seconds at a high incline. By comparison, in the GBT protocol, players performed their sprints on a turf soccer field (level ground with no incline), and players were encouraged to run as fast as they could for all 15 repetitions. The total distance covered in each repetition was maintained at 45-metres in total; however, the workloads were not individualized for players, as they all were required to cover the same distance, regardless of their speed and/or fitness level despite players in the GBT being instructed to perform each run "as fast as they can".

The differences in workloads in our study could have affected the results in two ways. First, it is possible that the increased improvements in the neuromuscular fitness (10-m, 20-m, and 35-m linear running speed) in the TT group occurred simply because the sprints were done at an incline, rather than on level ground as was the case with the GBT group. Second, and perhaps more importantly, the greater short distance speed improvements in the TT group could have occurred because the running speeds were higher relative to the individuals' maximal running speed (80% of maximal running speed). Due to the fact that running speeds in the GBT group were not customized, several players may not have been challenged enough with each sprint to substantially push themselves and run "as fast as they can". It is possible that further research, comparing a similar TT repeated sprint training protocol with a GBT repeated sprint protocol conducted on a hill of similar % grade would elicit greater improvements in short distance running speed in the GBT group. Furthermore, it is also possible that a study using individualized and/or customized running speeds in level-ground GBT repeated sprint training could also elicit greater improvements in short distance running speed.

In future research, some additional and alternative methods could be used. For example, training intensity could be monitored during TT and GBT using heart rate monitors in addition to RPE, as opposed to just RPE. In our study, RPE for both groups was not as high as we expected (average – using the 0-10 Borg CR10 scale – of 3.3 – "moderate" - for TT, and 4.1 – "sort of hard" – for GBT). As such, players may not have reached volition exhaustion, and the use of heart rate monitors would help to clarify the intensity of the training sessions. While the training load (speed, and % incline) was controlled for in the TT group, in the GBT group the speed of the runs was not measured. In future, the use of electronic timing gates during GBT would help to ensure that specific targets (running speeds) are met in the GBT group.

In conclusion, the results of this study indicated that treadmill training produced a significantly greater increase in running speed, with a small – but also greater – increase in high intensity running ability, than on-field ground-based training. When considering the results of this study, as well as the other aforementioned benefits of Treadmill Training, it appears that Treadmill Training is at least as effective, if not more effective, as a method of pre-season repeated sprint training, than on-Field Training. More research, involving larger sample sizes, may also be required before definitive conclusions can be made.

References:

Bangsbo, J., Iaia, F.M., Krustrup, P. (2008). The yo-yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. *Sports Medicine*, 38(1): 37-51.

Bishop, D., Girard, O., Mendez-Villanueva, A. (2011). Repeated sprint ability – part II – recommendations for training. *Sports Medicine*, 41(9): 741-756.

Borg, G. (1985). *An introduction to Borg's RPE scale*. Movement publications, Ithica, New York.

Buchheit, M., Bishop, D., Olivier, G. (2012). Should we be recommending repeated sprints to improve repeated sprint performance? *Sports Medicine*, 42 (2): 169-173.

Buchheit, M., Mendez-Villanueva, A., Delhomel, G., Brughelli, M., Ahmaidi, S. (2010). Improving repeated sprint ability in young elite soccer players: repeated shuttle sprints vs. explosive strength training. Journal of Strength and Conditioning Research, 24(10): 2715-22.

Buchheit, M., Mendez-Villanueva, A., Simpson, B.M., Bourdon, P.C. (2010). Repeated sprint sequences during youth soccer matches. *International Journal of Sports Medicine*, 31(10): 709-16.

Castagna C, Manzi, V., Impellizzeri, F., Weston, M., Barbero Alvarez, J.C. (2010). Relationship between endurance field tests and match performance in young soccer players. *Journal of Strength and Conditioning Research*, 24(12): 3227-33.

Chaouachi, A., Manzi, V., Wong, P., Chaalali, A., Laurencelle, L., Chamari, K., Castagna, C. (2010). Intermittent endurance and repeated sprint ability in soccer players. *Journal of Strength and Conditioning Research*, (10): 2663-9.

Coutts, A., Morelli, A., Rampinini, E., Sassi, A., Mazzoni, S., Fanchini, M. (2009). Repeated sprint ability in professional and amateur soccer players. *Applied Physiology, Nutrition, and Metabolism*, 34(6).

Ferly, D.D., Osborn, R.W., Vukovic, M.D. (2013). The effects of incline and level-grade treadmill running on running economy and muscle power in well-trained distance runners. Journal of Strength and Conditioning Research, 28(5): 1298-1309.

Folland, J. P., & Williams, A. G. (2007). The adaptations to strength training: morphological and neurological contributions to increased muscle strength. *Sports Medicine*, 37: 145–168.

Girard, O., Mendez-Villanueva, A., Bishop, D. (2011). Repeated sprint ability – part I – factors contributing to fatigue. *Sports Medicine*, 41(8): 673-94.

Gorostiaga, E.M., Llodio, I., Ibanez, J., Granados, C., Navarro, I., Ruesta, M., Bonnabau, H., Izquierdo, M. (2009). Differences in physical fitness among indoor and outdoor elite male soccer players. *European Journal of Applied Physiology*, 106: 483–491.

Granda, J., Barbero-Álvarez, V., Gómez-López, M., Barbero-Álvarez, J.C., Castagna, C. (2008). Heart rate and activity profile for young female soccer. *Journal of Human Sport and Exercise*, Volume 3, No.2.

Kollath, F., & Quade, K. (1993). Measurement of sprinting speed of professional and amateur soccer players. In Reilly, T. Clarys, J. & Stibbe, A., *Science and soccer II,* 31 – 36. London: E & FN Spon.

Krustrup, P., Mohr, M., Ellingsgaard, H., Bangsbo, J. (2005). Physical demands during an elite female soccer game: Importance of training status. *Medicine and Science in Sports and Exercise*, 10(12): 1242-48.

Mohr, M., Krustrup, P., Bangsbo, J. (2005). Fatigue in soccer: a brief review. *Journal of Sports Sciences*, June 2005, 23(6): 593 – 599.

Mohr, M., Krustrup, P., Nielsen, J.J. (2007). Reply to Bishop and Schneiker (letter). *American Journal of Physiology, Regulatory Integrated, and Comparative Physiology*, 293: R1460.

Myer, G.D., Ford, K.R., Brent, J.L., Divine, J.G., Hewett, T.E. (2007). Predictors of sprint start speed: the effects of resistive ground-based vs. inclined treadmill training. *Journal of Strength and Conditioning Research*, 21(3): 831-6.

Reilly, T., Morris, T., Whyte, G. (2009). The specificity of training prescription and physiological assessment: A review. *Journal of Sports Sciences*, 27(6): 575-589.

Shalfawi, S.A.I., Young, M., Tonnessen, E., Haugen, T.A., Enoksen, E. (2013). The effect of repeated agility training versus repeated sprint training on elite female soccer players' physical performance. *Kinesiologia Slovenica*, 19(3): 29–42.

Swanson, S.C., Caldwell, G.E. (2000). An integrated biomechanical analysis of high speed incline and level treadmill running. *Medicine in Science, Sports and Exercise*. 32(6): 1146-55.

Vescovi, J. D. (2012). Sprint profile of professional female soccer players during competitive matches: Female Athletes in Motion (FAiM) study. *Journal of Sports Sciences*, 30(12): 1259-1265.