



When I invented the VK Insole for the USA Olympic Bobsled Team, I had two objectives: 1) Help athletes perform to the best of their abilities, and 2) Better protect them from injuries. The scientific study by the Human Performance Lab at SCSU confirms what I have heard repeatedly – *athletes feel more explosive with VK Insoles.*

As a Certified Pedorthist, I was aware that flat, rigid plates have been used for decades to treat athlete injuries. Extensive research has been performed on this product proving athletic performance improvements as well. The major problem – typical foot stabilizing plates are uncomfortable and intended to be worn *after* an injury.

My mission was to develop a product which combined performance, protection and comfort enabling an athlete to wear *before* an injury takes place. Patented VK Insoles are unique in the following ways:

- Innovative insole curvature to increase midsole support, shock absorption and energy return.
- Variable product stiffness across the foot to ensure comfort and retain injury protection benefits.
- VK Insoles come in 5 degrees of flexibility (PRO 3-7) to correspond to an athlete’s weight and sport.

As confirmed by the SCSU study, customized insole stiffness for the athlete is important in achieving performance benefits. When the optimal PRO level was selected for the athlete, performance showed the greatest improvement. VKTRY Gear’s proprietary algorithm selects the proper level for the athlete based on shoe size, weight and sport.

Shown in this as well as prior studies is the inherent variability of athletic performance testing. Technique, weight, muscle size, conditioning, and countless other variables can influence test results. Since only so many variables can be controlled, SCSU’s approach to address this was to also record biomechanical variables associated with the ground force an athlete can generate (using force plates), because this data is not only consistent and reliable but it also is the greatest single determinant of performance outcome.

	Variable	All Participants		Top 30%	
		Delta	Percent	Delta	Percent
Vertical	Vertical Jump Height (Take Off V)	+1.1”	4%	+2.54”	11%
	Rate of Force Development	BW/s	8%	BW/s	15%
	Average Power	139W	4%	318 W	9%
Sprint	0 - 10 Yard Split Time	0.02 sec	2%	0.07 sec	4%
	20 - 40 Yard Split Time	0.03 sec	1%	0.08 sec	3%
	Max Force (Back Foot)	BW	8%	BW	22%
	Rate of Force Development (Back Foot)	BW/s	9%	BW/s	51%

I am extremely pleased that the professors at SCSU who have studied VK Insoles over the last 12 months have determined that the performance benefits are statistically significant. And because all athletes are unique, I encourage you to try VKs for yourself.

Sincerely,

Matt Arciuolo
Founder, VKTRY Gear



**Technical Report:
The Effects of a Carbon Fiber Shoe Insert
on Athletic Performance in Collegiate Athletes**

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INTRODUCTION

An athlete has three major strategies available to improve the work-energy balance during training and competition: 1) maximize energy storage and return, 2) minimize the loss of energy, and 3) optimize muscle functions (Nigg, Stefanyshyn, & Denoth, 2000; Nigg, 2010). Athletes often select equipment, such as running shoes, that is designed to maximize energy storage and return. Indeed, manufacturers of athletic footwear such as Adidas and Nike often highlight the enhanced energy storage and return provided by their footwear as compared to competing brands. However, athletic footwear is typically characterized by poor energy storage and return (~1-2%) as a result of current technological limitations in the design of and material properties used in shoe midsole construction (Nigg, Stefanyshyn, & Denoth, 2000; Nigg, 2010). As a result, most of the energy (~98-99%) that is stored in a shoe midsole when the foot contacts the ground is lost through heat, friction, and vibrations and, thus, decreases the efficiency of the athlete.

While the effectiveness of foot orthoses/shoe inserts for the treatment and prevention of lower limb injuries has been studied extensively (e.g., Hume, Hopkins, Rome, et al., 2008; MacLean, Davis, & Hamill, 2006; Nigg, Nurse, & Stefanyshyn, 1999), there is limited research to date that has addressed the role of foot orthoses/shoe inserts on performance improvement via enhanced energy storage and return. Stefanyshyn & Nigg (2000) demonstrated that increasing the stiffness of shoes (via the use of carbon fiber plates inserted into the shoe midsole) resulted in a 1.7 cm increase in vertical jump height for a group of 25 subjects. The stiff shoes with the carbon fiber plates did not increase the amount of energy stored and reused; however, they reduced the amount of energy lost at the metatarsophalangeal joint and resulted in a corresponding improvement in performance. The influence on shoe bending stiffness on sprint performance was examined by Stefanyshyn & Fusco (2004). Thirty-four athletes were tested

using four different shoe conditions – a standard condition consisting of their currently used footwear and three conditions where the bending stiffness was increased systematically (via carbon fiber plates inserted under the shoe sock liner). On average, increasing the shoe bending stiffness increased sprint performance; it should be noted that the stiffness each athlete required for his or her maximal performance was subject specific. Finally, Roy & Stefanyshyn (2006) examined the influence of shoe midsole stiffness on running economy. Carbon fiber plates were inserted into running shoe midsoles and running economy, joint energy, and electromyographic data were collected on 13 subjects. Approximately a 1% metabolic energy savings was observed when subjects ran in a stiff midsole relative to the control midsole, but this improvement was not attributed to any specific underlying mechanism. While all three of these studies demonstrated improvements in performance when using carbon fiber shoe inserts or plates embedded in shoe midsoles, these studies used a flat carbon fiber plate design with a uniform stiffness distribution and limited optimization for the athletes.

VKTRY Gear (formerly ROAR Performance; Milford, CT) has developed the VK (formerly XG4) carbon fiber shoe insert that is designed to overcome the current limitations in athletic footwear design and construction and allow for increased energy storage and return. Anecdotal evidence suggests that athletes can run faster and jump higher when using the VK shoe insert. However, there was no published data available to support these claims. Therefore, the purpose of this study is to examine the effects of a carbon fiber (CF) shoe insert on athletic performance. The specific parameters related to athletic performance that were assessed in this study were speed and power. It is hypothesized that the use of the CF shoe insert will result in increased linear speed (assessed by a 40-yard sprint) and lower-body muscular power (assessed by a vertical jump).

METHODS

Participants

Twenty-eight male collegiate athletes (NCAA Division II skill-position football players) participated in this study. These participants had a mean age of 19.4 (SD 1.1) yr, a mean height of 178.7 (SD 4.5) cm, and a mean mass of 85.9 (SD 6.9) kg. All participants provided informed consent according to the policies and procedures of the Institutional Review Board at Southern Connecticut State University.

Instruments

In this study, speed was assessed using a 40-yard sprint and power was assessed using a vertical jump. During the 40-yard sprint, time was measured using a laser timing system (PowerDash 3×, Zybek Sports; Broomfield, CO) and start kinetics were measured using two (one for the front foot and one for the back foot) multi-component force plates (Type 9260AA; Kistler Instrument Corp.; Winterthur, SUI). During the vertical jump, height was measured using a Vertec Vertical Jump Training Measurement System (Jump USA; Sunnyvale, CA) and jump kinetics were measured using a portable Quattro Jump force plate (Type 9290CD; Kistler Instrument Corp.; Winterthur, SUI).

Procedures

Potential participants were invited to a study orientation/familiarization session during which all study procedures and test protocols were explained. An informed consent form was then provided to the potential participants. If an individual agreed to participate in the study, he provided written informed consent (via signing an informed consent form) in the presence of either the principal investigator or one of the co-investigators.

After providing informed consent, each participant completed a physical activity readiness questionnaire to determine if he was at an elevated risk for suffering an adverse event during the study. If a participant had a pre-existing history of (or possessed current risk factors for) heart/pulmonary disease or musculoskeletal injuries, he was be excluded from participating in the study. Height, weight, and arterial blood pressure of all participants were measured following the completion of the physical activity readiness questionnaire. Height and weight were measured using a standard physician beam scale with height rod. Blood pressure was measured using auscultation at the antecubital space (elbow joint) using a standard laboratory sphygmomanometer. In addition, after completing the physical activity readiness questionnaire, participants were fitted in the footwear (Visaro Control TF; New Balance Athletics, Inc.; Boston, MA) to be used during the sprint and vertical jump testing. All participants used the same footwear to avoid the potential confounding effects of wearing footwear with different bending stiffnesses.

Within one week after providing informed consent and completing the physical activity readiness questionnaire, participants reported to the Human Performance Laboratory/Moore Field House on the campus of Southern Connecticut State University for vertical jump testing in groups of 2-4 participants. Following the completion of the vertical jump testing, the participants returned to the Human Performance Laboratory/Moore Field House exactly one week (seven days) later for sprint testing in groups of 2-4 participants. At the time of the sprint and vertical jump testing, all participants had just completed the football team's off-season strength and conditioning program and were very familiar with the 40-yard sprint and Vertec vertical jump tests. Before both the vertical jump and sprint test sessions, all participants performed a standardized 15-20 minute dynamic warm-up designed by the National Strength and

Conditioning Association. The warm-up consisted of the following exercises: 1) walking knee to chest (1 × 10 yards); 2) forward lunge with elbow to instep (1 × 5 each side); 3) side lunge (1 × 5 each side); 4) toy soldier (1 × 10 yards); 5) high knees (2 × 10 yards); 6) heel ups (2 × 10 yards); 7) carioca (2 × 10 yards); and, 8) sprints (3 × 30 yards with intensity increasing from 50-100%).

The following procedures endorsed by the National Strength and Conditioning Association (Haff & Triplett, 2016) were used to conduct the vertical jump test:

1. The tester adjusted the height of the stack of movable color-coded horizontal plastic vanes to be within the athlete's standing reach height. The highest vane that could be reached and pushed forward with the dominant hand while the athlete stood flat-footed determined the standing touch height.
2. The vane stack was then raised by a measured distance (marked on the shaft holding the vanes) so that the athlete would not jump higher or lower than the set of vanes. This required a rough estimate of how high the particular athlete would jump, but a correction could be made on the second attempt if necessary.
3. Without a preparatory or stutter step, the athlete performed a countermovement by quickly flexing the knees and hips, moving the trunk forward and downward, and swinging the arms backward (Figure 1a). During the jump, the dominant arm reached upward while the nondominant arm moved downward relative to the body.
4. At the highest point in the jump, the athlete tapped the highest possible vane with the fingers of the dominant hand (Figure 1b). The score was the vertical distance between the height of the highest vane tapped during the standing vertical reach and the vane tapped at the highest point of the jump.

5. The best of three trials was recorded to the nearest 0.5 inches or 1 cm (the distance between adjacent vanes). NOTE: the Vertec was used as a visual target for the athlete; the actual jump height was measured using the take-off velocity obtained using the Quattro Jump force plate.



Figure 1. (a) Starting position and (b) maximum height of the vertical jump.

The participants completed a vertical jump test for the control condition and three different carbon fiber (CF) shoe insert stiffnesses: medium (VK 4 flex; 4F), stiff (VK 5 flex; 5F), and extra stiff (VK 6 flex; 6F). The four different shoe insert conditions were tested in random order. Participants were provided with 5-7 minutes of rest between the vertical jump test conditions to avoid fatigue.

The following procedures endorsed by the National Strength and Conditioning Association (Haff & Triplett, 2016) were used to conduct the 40-yard sprint test:

1. The athlete warmed up and dynamically stretched for 15-20 minutes.

2. The athlete was allowed three practice runs at submaximal speed.
3. The athlete assumed a starting position using a four-point stance.
4. On an auditory signal, the athlete sprinted the specified 40-yard distance at maximal speed.
5. The best 10-, 20-, and 40-yard split times of two trials were recorded to the nearest 0.01 second (Figure 2).
6. At least 2 minutes of active recovery or rest between trials were allowed.

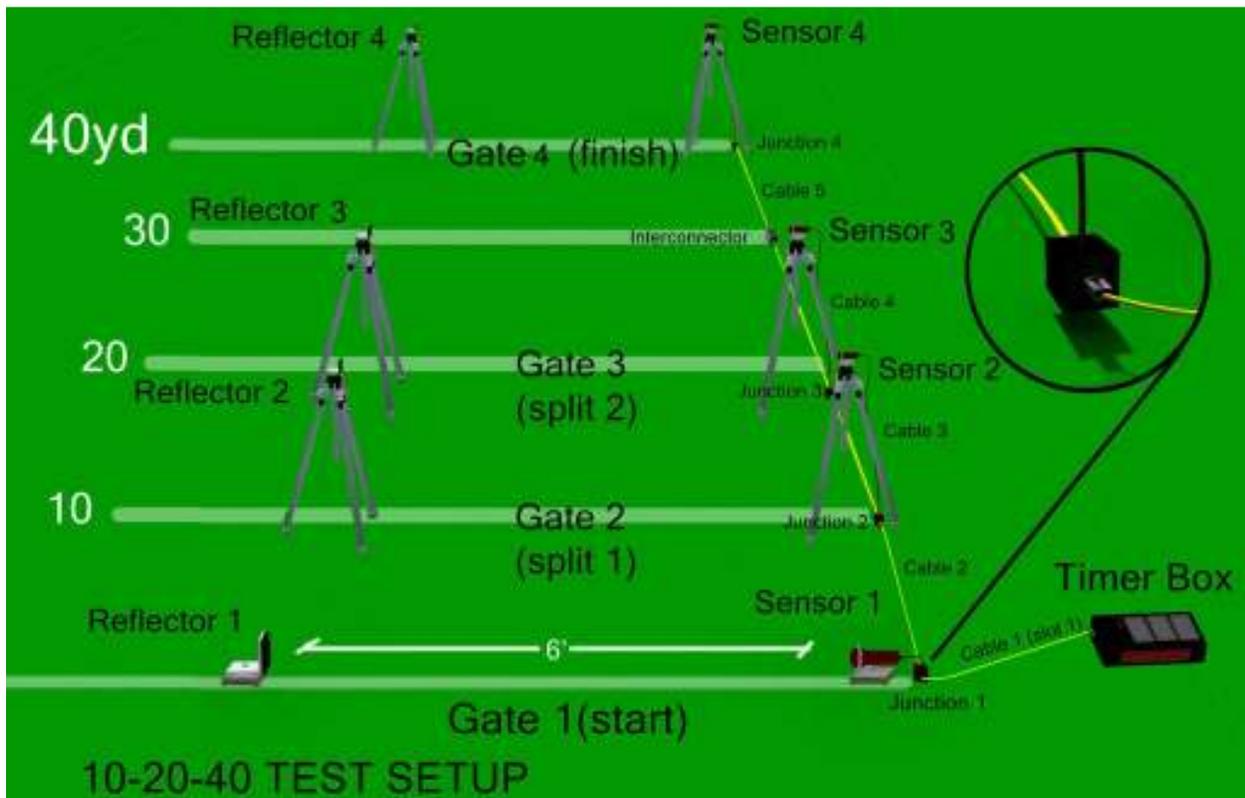


Figure 2. Timing setup for the 40-yard sprint.

The participants completed a sprint test for the control condition and two different carbon fiber (CF) shoe insert stiffnesses: medium (VK 4 flex; 4F) and extra stiff (VK 6 flex; 6F). The three different shoe insert conditions were tested in random order. Participants were provided with 5-7 minutes of rest between the sprint test conditions to avoid fatigue.

Design and Analysis

Performance and biomechanical data were measured during both the vertical jump and sprint tests. During the vertical jump test, the following dependent variables were measured: 1) jump height, 2) peak force (both absolute and relative), 3) impulse (both absolute and relative), 4) rate of force development (both absolute and relative), 5) total work, 6) average power, and 7) peak power. During the 40-yard sprint test, the following dependent variables were measured: 1) 10-yard split time, 2) 20-40 yard split time, 3) 40-yard total time, 4) peak propulsive force (both absolute and relative for front and back feet), 5) rate of propulsive force development (both absolute and relative for both front and back feet), and 6) peak propulsive power (both absolute and relative). The biomechanical variables characterizing the sprint start (peak force and rate of force development) were analyzed separately for the front and rear feet due to the sequential timing ground reaction force patterns during the sprint start; force production by the rear foot and front foot dominates the first half and second half of the sprint start, respectively (Mero, Komi, & Gregory, 1992; Čoh, Jošt, Škof, Tomažin, & Dolenc, 1998; Slawinski, Bonnefoy, Levêque, Ontanon, Riquet, Dumas, & Chèze, 2010).

The kinetic analyses for both tests (vertical jump and 40-yard sprint) started when the propulsive ground reaction force exceeded the weight force of the participant by 10 N; the kinetic analysis ended when the force platform(s) no longer measured a propulsive ground reaction force acting on the participant. The peak force was calculated as the maximum force achieved over the force-time curve during the propulsive phase of the jump or sprint start. The impulse was calculated by trapezoidal integration of the area under the force-time curve during the propulsive phase of the trial. The rate of force development was calculated as the peak force divided by the time required to reach peak force. The velocity that was calculated from the

integration of the force-time curve was multiplied by the vertical or horizontal force throughout the propulsive phase of the vertical jump or sprint start, respectively, to yield power. The propulsive force-time data for both the vertical jump and 40-yard sprint tests were sampled at a rate of 1,000 Hz and filtered using a fourth-order Butterworth low-pass filter with a cutoff frequency of 25 Hz (Yu, Gabriel, Noble, & An, 1999; Winter, 2009).

To determine whether CF shoe inserts improved athletic performance, all dependent variables were analyzed using a repeated measures analysis of variance (ANOVA) to compare the four different shoe insert conditions (control vs. 4F/5F/6F CF shoe inserts) for the vertical jump test and the three different shoe insert conditions (control vs. 4F/6F CF shoe inserts) for the 40-yard sprint test. In addition, a dependent t-test was used to compare the optimal CF shoe insert condition to the control condition for all dependent variables. Analysis was performed using Excel software (Office Professional 2016; Microsoft Corp.; Redmond, WA). The level of significance was set at $p < 0.10$ because the consequence of incorrectly accepting a false result (slightly increased expenses for athletes and shoe/equipment manufacturers) are minor in comparison to the benefits of a positive effect (improved performance).

RESULTS

Vertical Jump

Jump Height

There was no difference in vertical jump height (as calculated from takeoff velocity) when a comparison was performed across the four different shoe insert conditions (see Figure 3).

However, when comparing the control condition versus the optimal CF flex condition for each individual participant, there was a significant ($p < 0.0005$) increase in vertical jump height from 62.8 ± 9.4 cm to 65.4 ± 13.0 cm (a 4.1% increase).

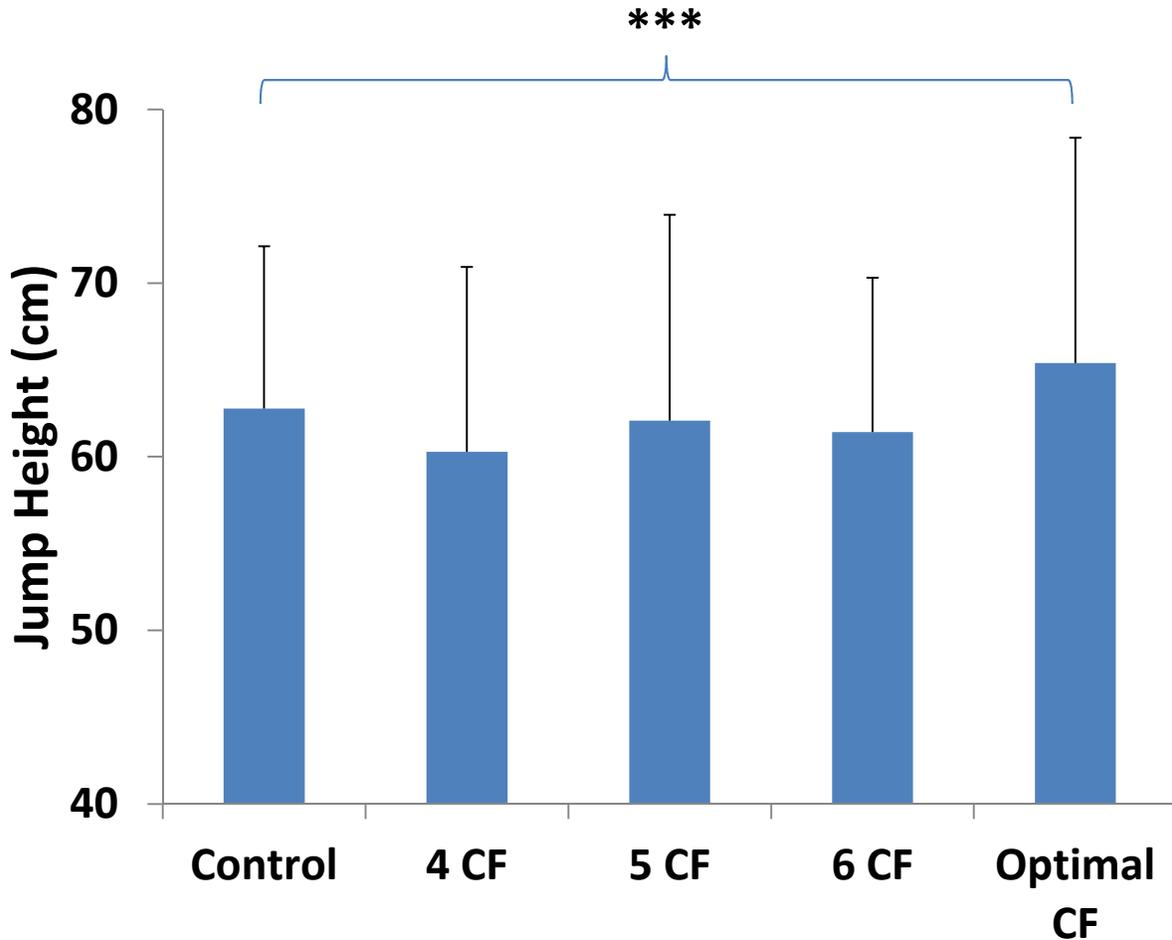


Figure 3. Mean (\pm standard deviation) jump heights for the four different shoe insert conditions tested and the optimal flex CF shoe insert.

Maximal Force

The relative peak force was significantly greater ($p < 0.05$) in the control and 5F conditions than the 4F and 6F conditions when a comparison was performed across the four different shoe insert conditions (see Figure 4). When comparing the control condition versus the optimal CF flex condition for each individual participant, there was a significant ($p < 0.05$) increase in peak force from 3.12 ± 0.37 BW to 3.20 ± 0.40 BW (a 2.6% increase).

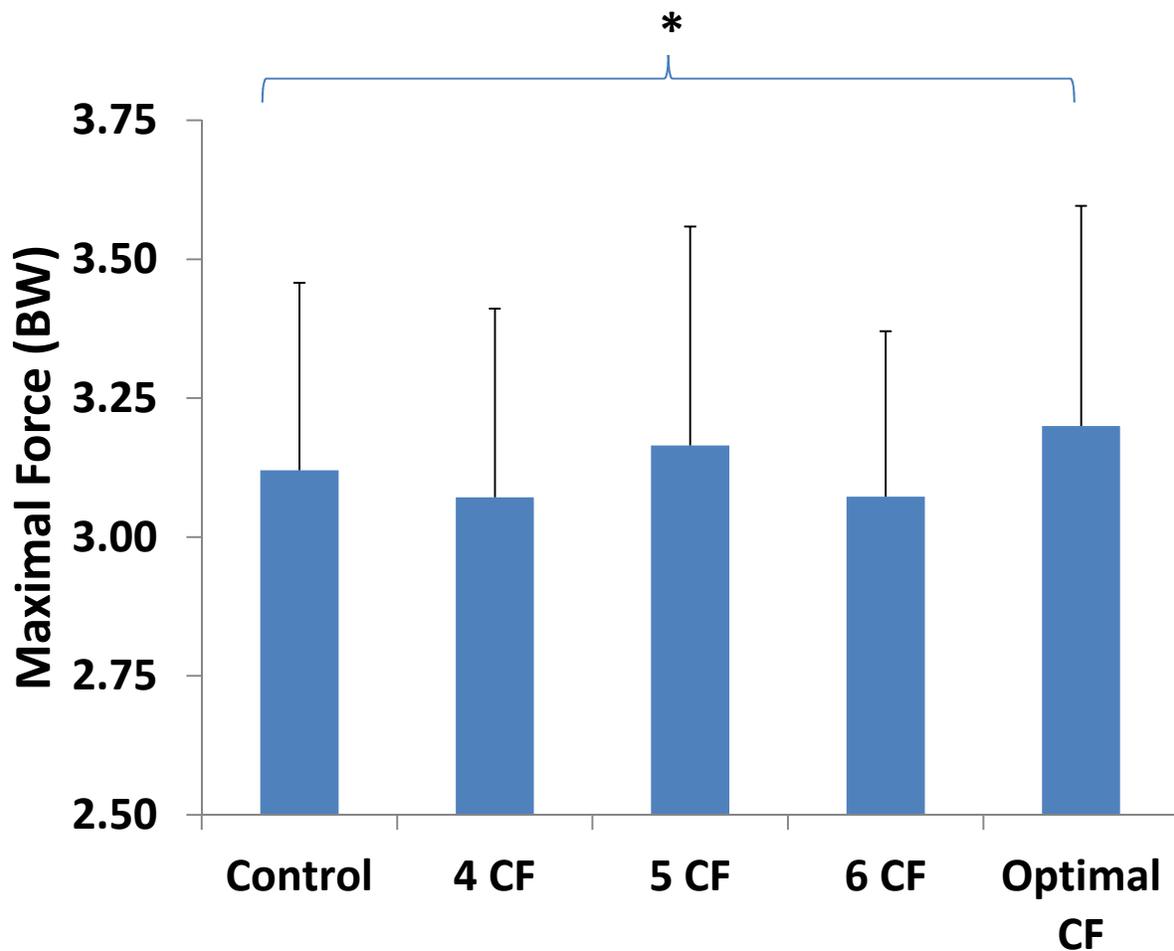


Figure 4. Mean (\pm standard deviation) peak force (relative to % body weight) for the four different shoe insert conditions tested and the optimal flex CF shoe insert.

Impulse

There was no difference in relative impulse when a comparison was performed across the four different shoe insert conditions (see Figure 5). However, when comparing the control condition versus the optimal CF flex condition for each individual participant, there was a significant ($p < 0.05$) increase in relative impulse from 0.355 ± 0.027 BW·s to 0.362 ± 0.034 BW·s (a 2.0% increase).

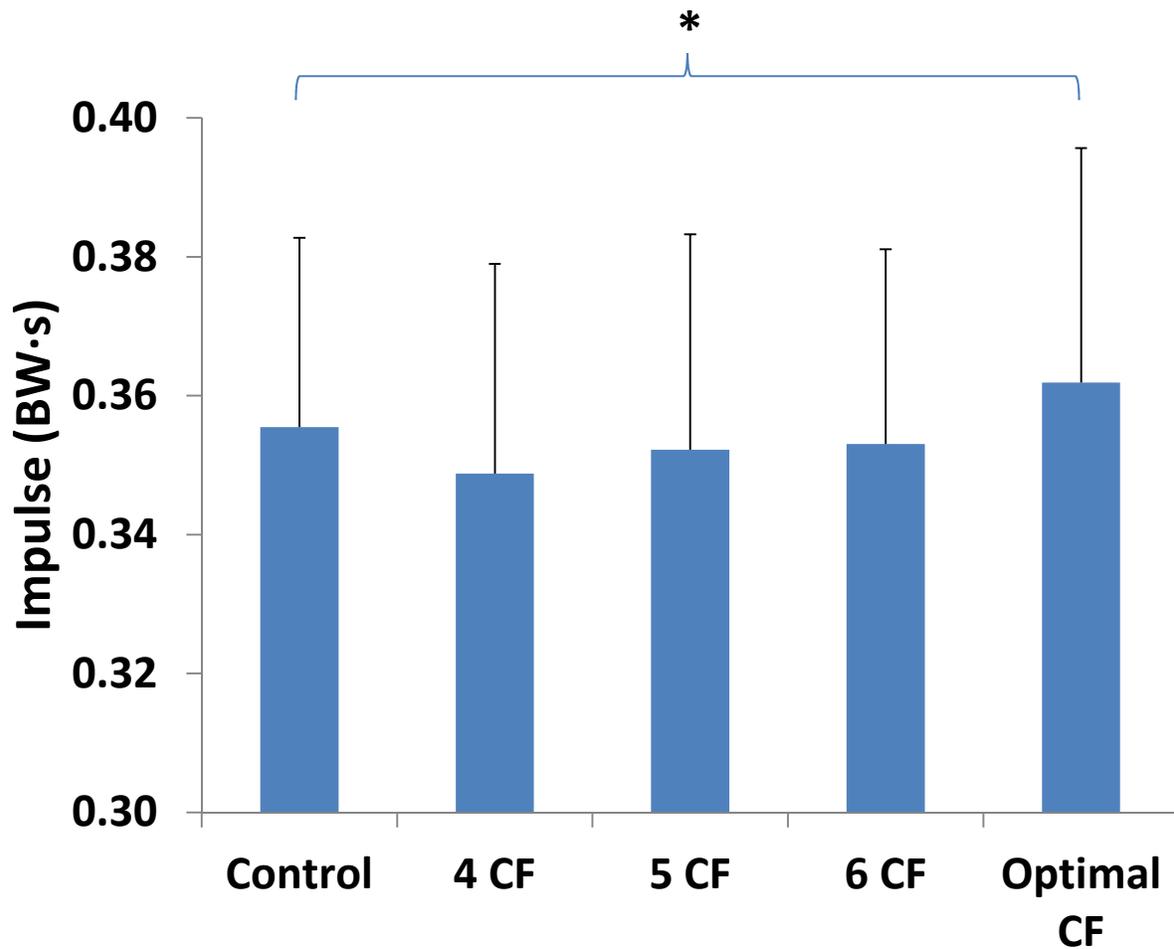


Figure 5. Mean (\pm standard deviation) impulse (relative to % body weight) for the four different shoe insert conditions tested and the optimal flex CF shoe insert.

Rate of Force Development

There was no difference in relative rate of force development when a comparison was performed across the four different shoe insert conditions (see Figure 6). However, when comparing the control condition versus the optimal CF flex condition for each individual participant, there was a significant ($p < 0.005$) increase in relative rate of force development from 23.6 ± 4.5 BW/s to 25.4 ± 5.7 BW/s (a 7.6% increase).

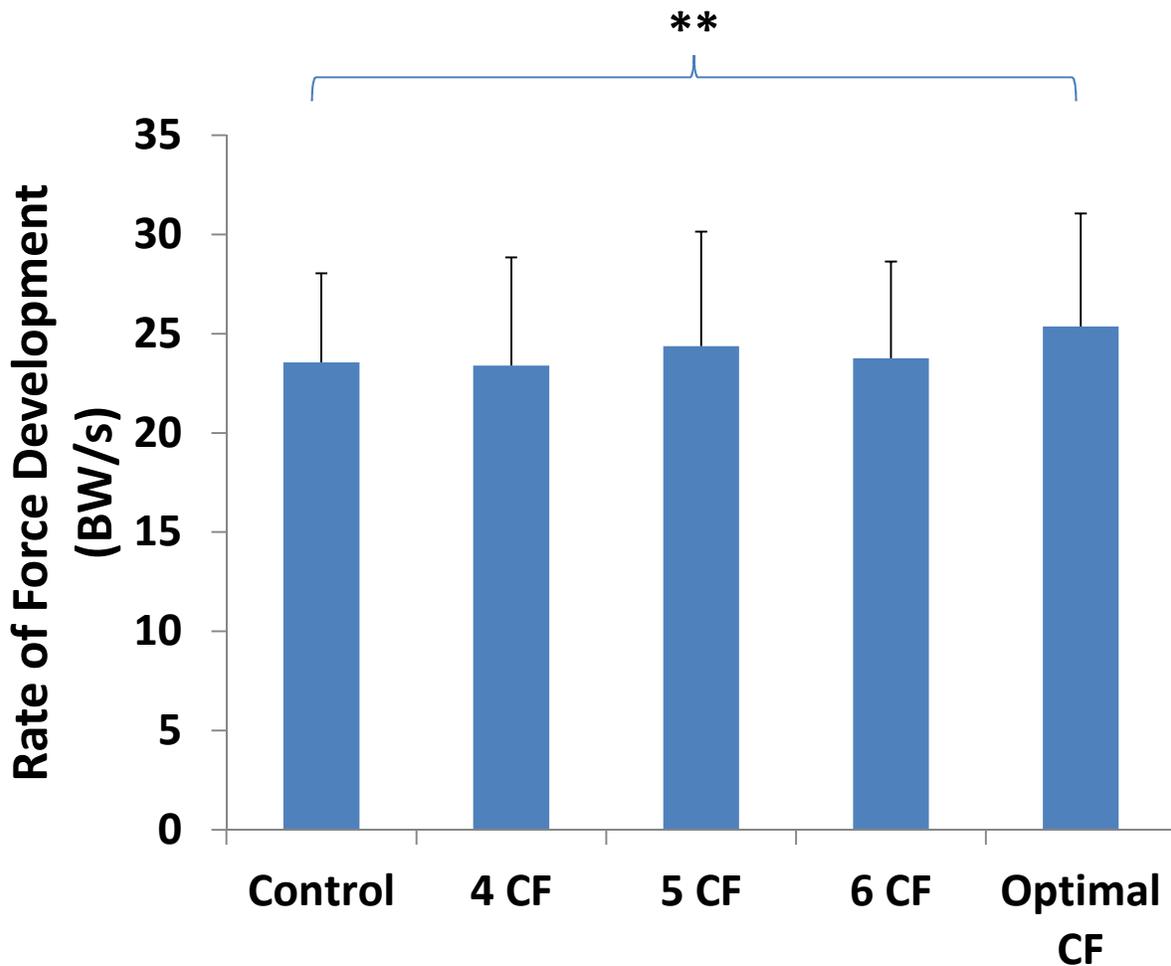


Figure 6. Mean (\pm standard deviation) rate of force development (relative to % body weight) for the four different shoe insert conditions tested and the optimal flex CF shoe insert.

Total Work

There was no difference in relative total work when a comparison was performed across the four different shoe insert conditions (see Figure 7). However, when comparing the control condition versus the optimal CF flex condition for each individual participant, there was a significant ($p < 0.05$) increase in relative total work from 11.3 ± 1.2 J/kg to 11.7 ± 1.6 J/kg (a 3.8% increase).

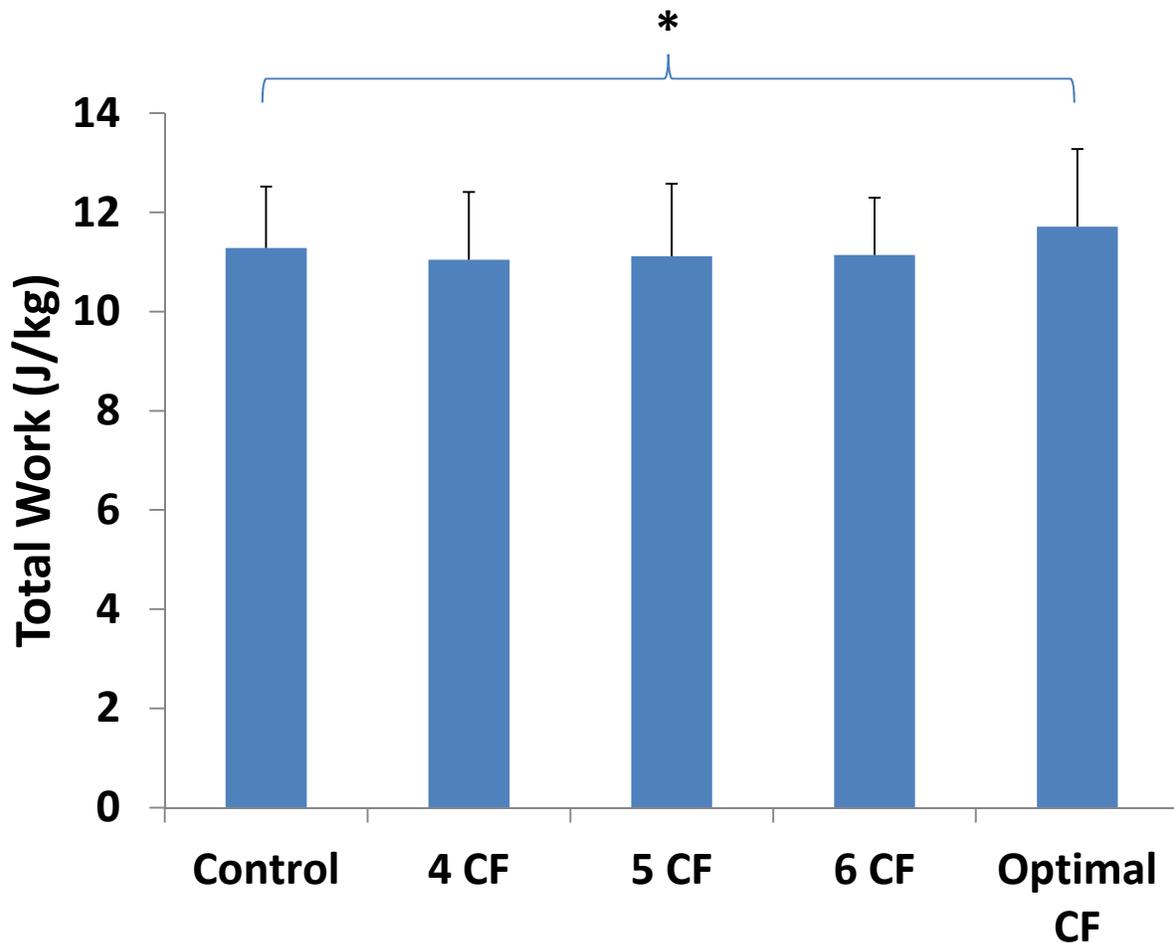


Figure 7. Mean (\pm standard deviation) work (relative to body mass) for the four different shoe insert conditions tested and the optimal flex CF shoe insert.

Average Power

There was no difference in average power when a comparison was performed across the four different shoe insert conditions (see Figure 8). However, when comparing the control condition versus the optimal CF flex condition for each individual participant, there was a significant ($p < 0.01$) increase in average power from $3,656.8 \pm 531.5$ W to $3,795.4 \pm 626.4$ W (a 3.8% increase).

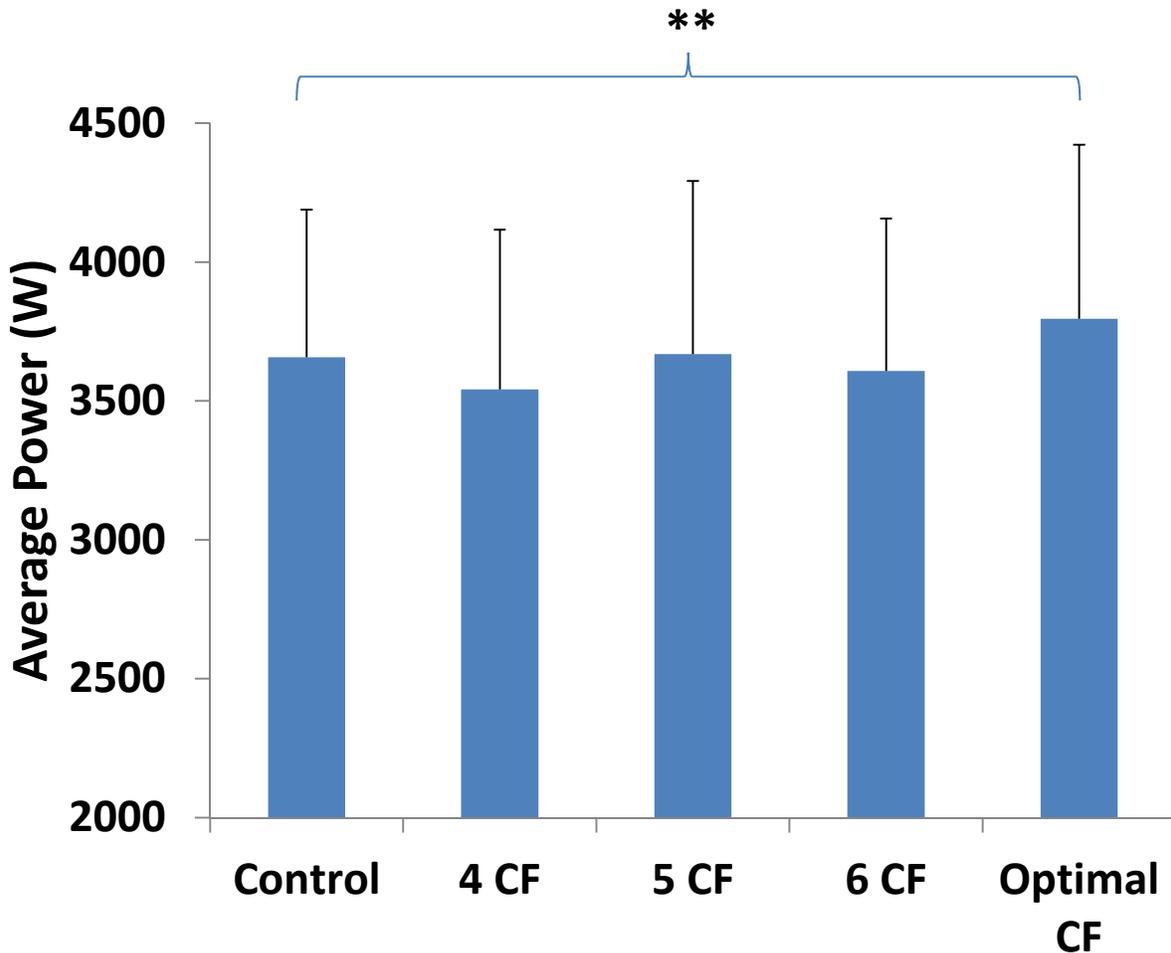


Figure 8. Mean (\pm standard deviation) average power for the four different shoe insert conditions tested and the optimal flex CF shoe insert.

Maximal Power

There was no difference in relative peak power when a comparison was performed across the four different shoe insert conditions (see Figure 9). However, when comparing the control condition versus the optimal CF flex condition for each individual participant, there was a significant ($p < 0.005$) increase in relative peak power from 85.7 ± 12.1 W/kg to 89.6 ± 14.8 W/kg (a 4.6% increase).

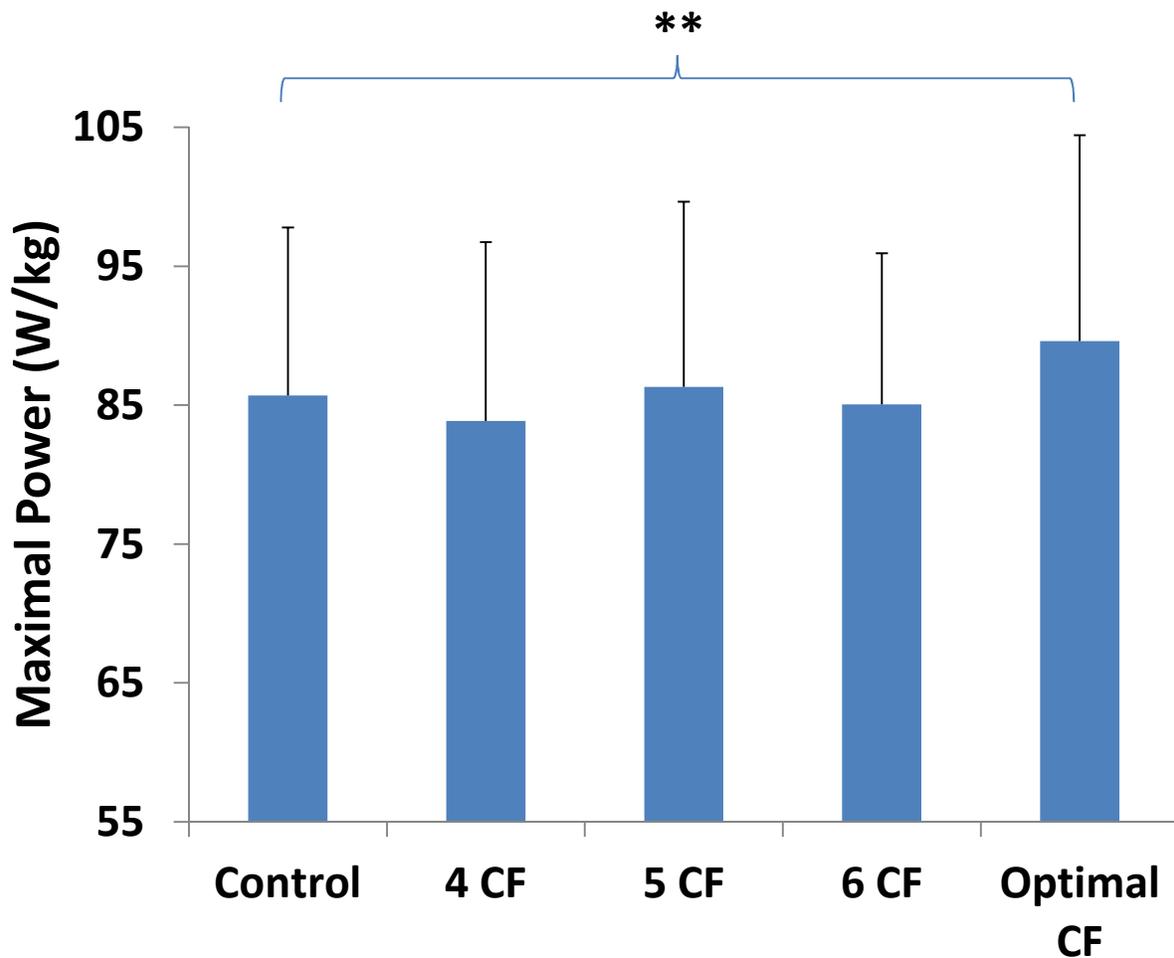


Figure 9. Mean (\pm standard deviation) peak power (relative to body mass) for the four different shoe insert conditions tested and the optimal flex CF shoe insert.

40-Yard Sprint

0-10 Yard Split Time

There was no difference in 0-10 yard split time when a comparison was performed across the three different shoe insert conditions (see Figure 10). However, when comparing the control condition versus the optimal CF flex condition for each individual participant, there was a significant ($p < 0.05$) improvement in 0-10 yard split time from 1.72 ± 0.07 s to 1.69 ± 0.6 s (a 1.6% decrease).

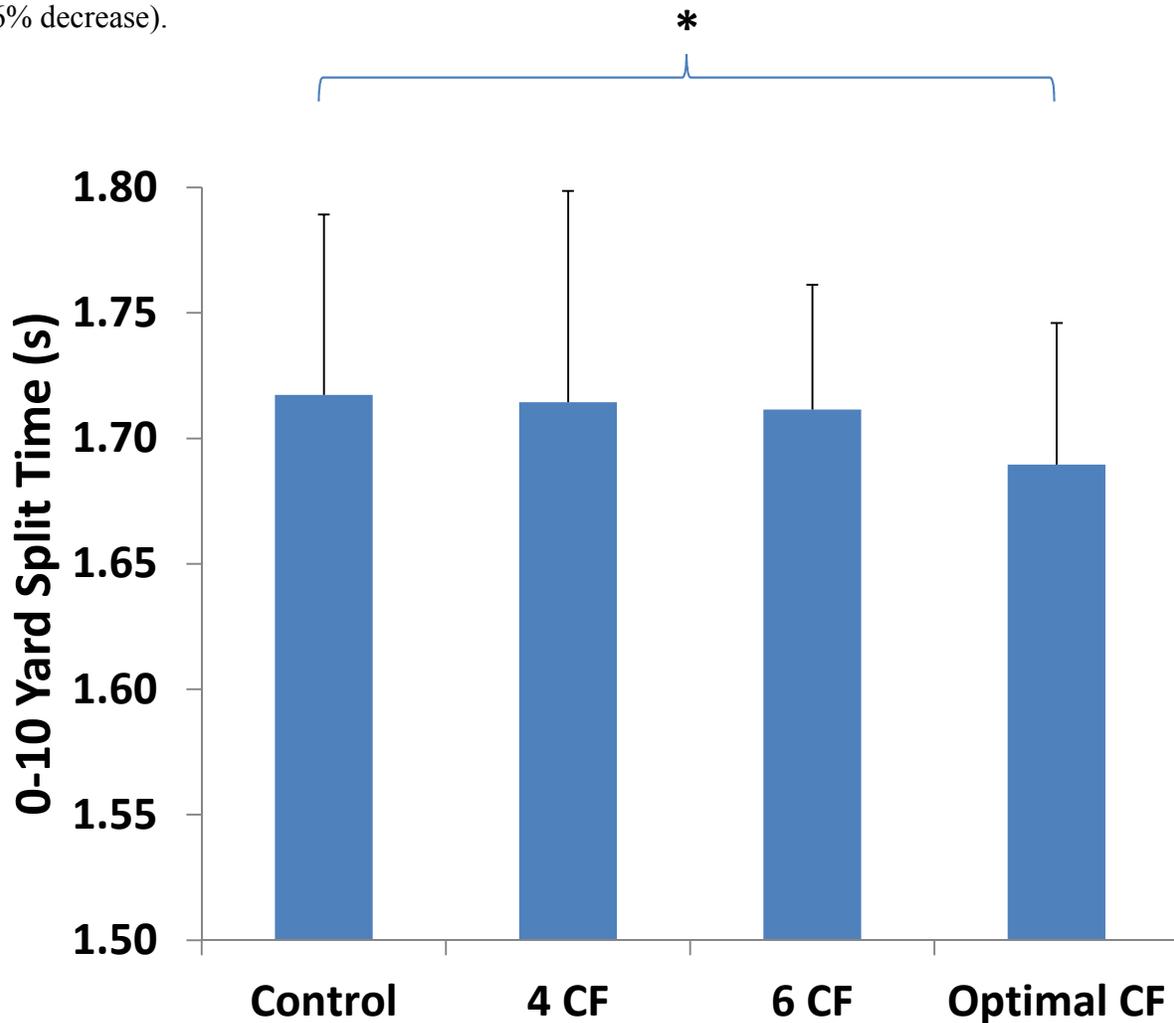


Figure 10. Mean (\pm standard deviation) 0-10 yard split time for the three different shoe insert conditions tested and the optimal flex CF shoe insert.

40-Yard Sprint Time

There was no difference in 40-yard sprint time when a comparison was performed across the three different shoe insert conditions (see Figure 11). Even though there was an improvement in 40-yard split time from 5.06 ± 0.12 s to 5.05 ± 0.12 s when comparing the control condition versus the optimal CF flex condition for each individual participant, this difference was not statistically significant ($p = 0.26$).

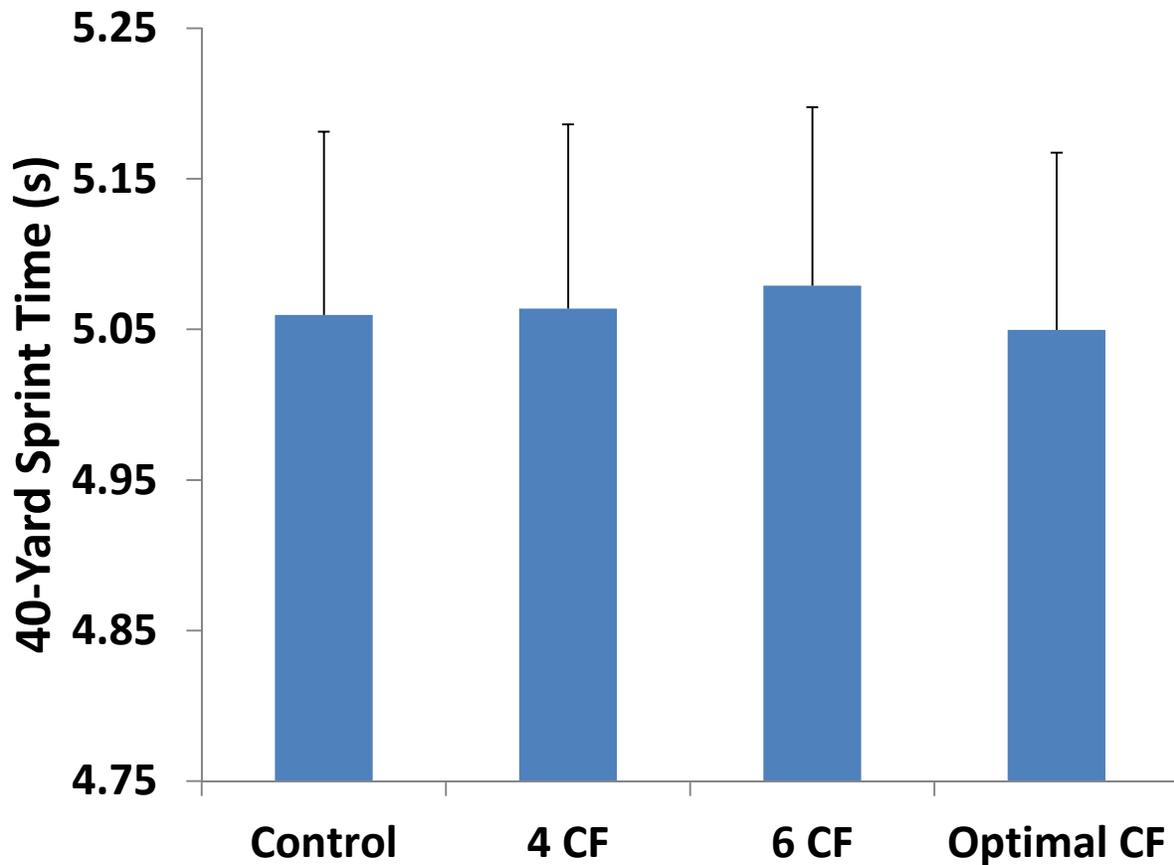


Figure 11. Mean (\pm standard deviation) 40-yard sprint time for the three different shoe insert conditions tested and the optimal flex CF shoe insert.

20-40 Yard Split Time

In addition to the analysis of the 40-yard sprint time and the 0-10 yard split time associated with that time, a separate analysis of the best 20-40 yard split time was also conducted to compare the results of this study with that of Stefanyshyn & Fusco (2004). There was no difference in 20-40 yard split time when a comparison was performed across the three different shoe insert conditions (see Figure 12). However, when comparing the control condition versus the optimal CF flex condition for each individual participant, there was a significant ($p < 0.10$) improvement in 20-40 yard split time from 2.18 ± 0.08 s to 2.15 ± 0.12 s (a 1.3% decrease).

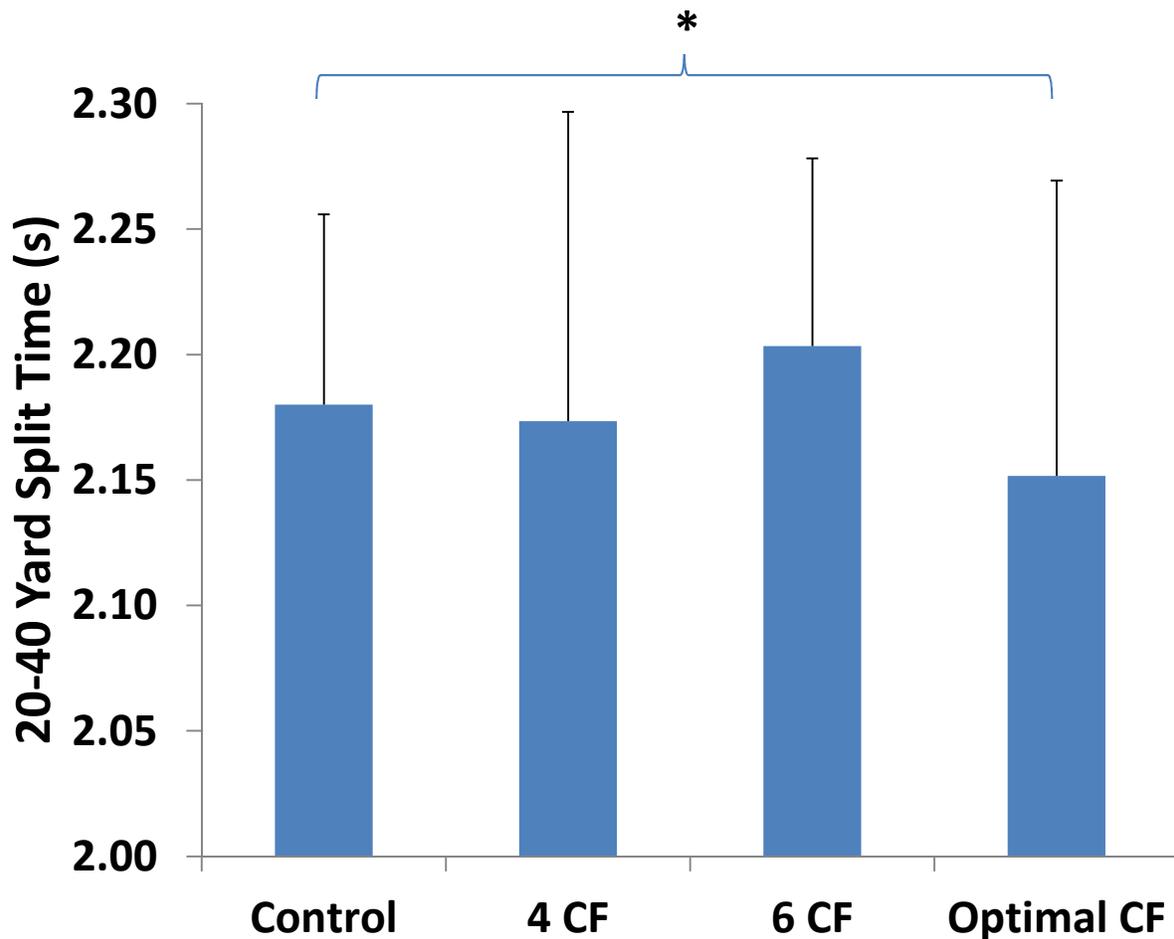


Figure 12. Mean (\pm standard deviation) 20-40 yard split time for the three different shoe insert conditions tested and the optimal flex CF shoe insert.

Maximal Force

Front Foot:

There was no difference in front foot relative peak force when a comparison was performed across the three different shoe insert conditions (see Figure 13). However, when comparing the control condition versus the optimal CF flex condition for each individual participant, there was a strong trend ($p = 0.11$) for an increase in front foot peak force from 1.03 ± 0.09 BW to 1.05 ± 0.13 BW (a 1.6% increase).

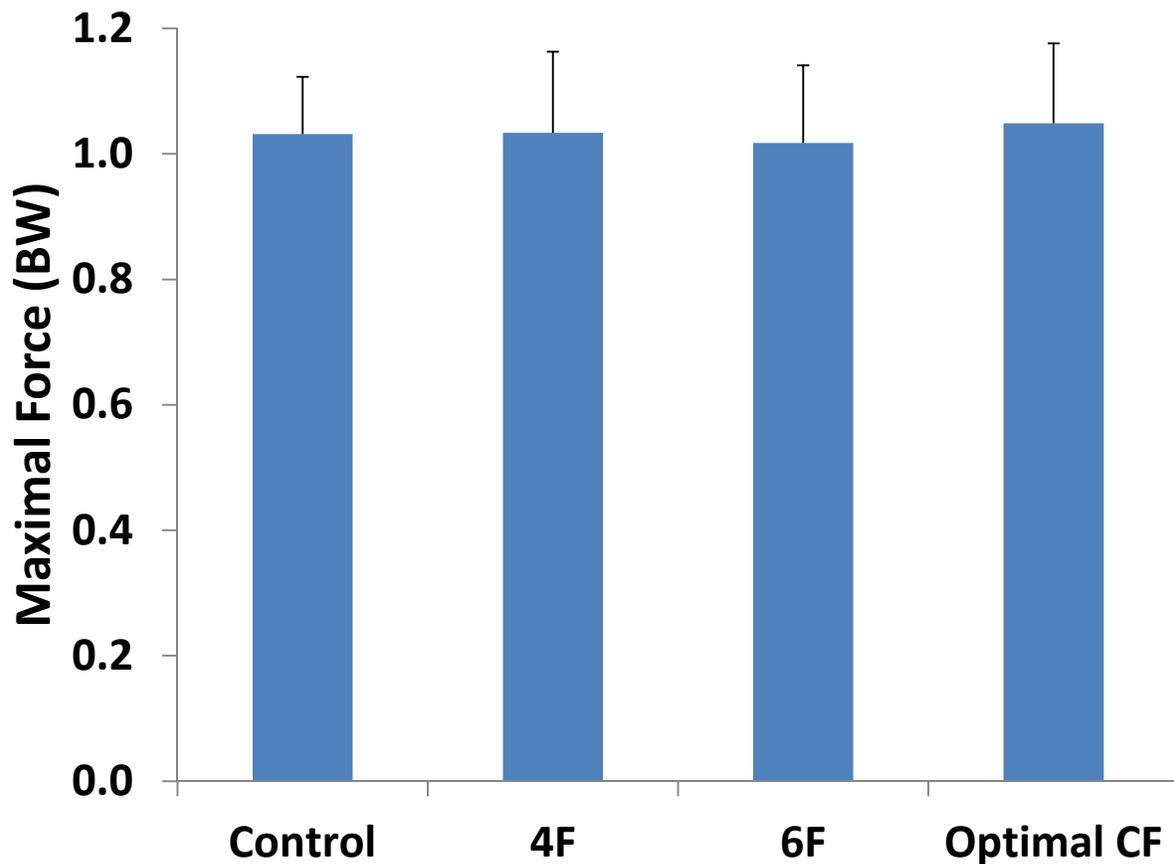


Figure 13. Mean (\pm standard deviation) front foot peak force (relative to % body weight) for the three different shoe insert conditions tested and the optimal flex CF shoe insert.

Rear Foot:

There was no difference in rear foot relative peak force when a comparison was performed across the three different shoe insert conditions (see Figure 14). However, when comparing the control condition versus the optimal CF flex condition for each individual participant, there was a significant ($p < 0.05$) increase in maximal force from 0.762 ± 0.186 BW to 0.824 ± 0.149 BW (an 8.1% increase).

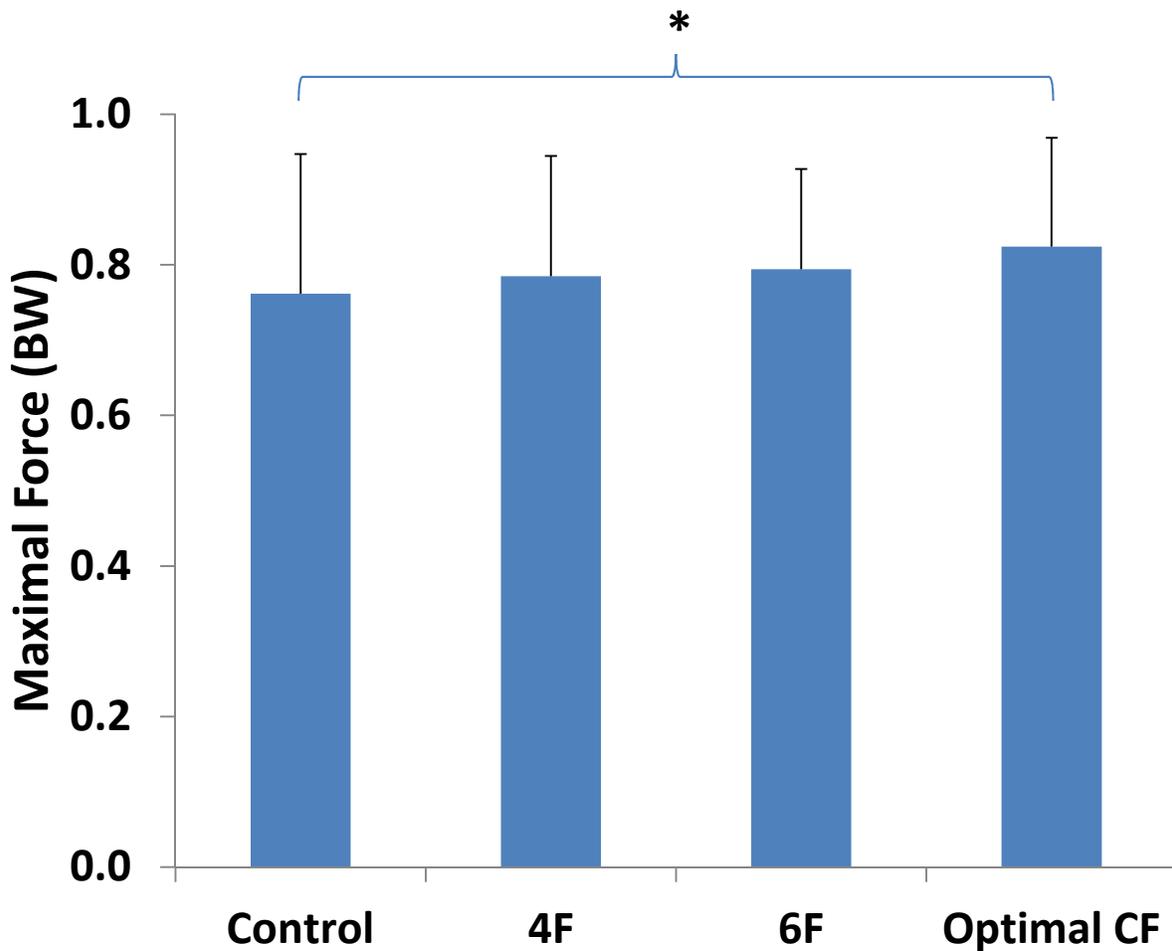


Figure 14. Mean (\pm standard deviation) rear foot peak force (relative to % body weight) for the three different shoe insert conditions tested and the optimal flex CF shoe insert.

Rate of Force Development

Front Foot:

There was no difference in front foot relative rate of force development when a comparison was performed across the three different shoe insert conditions (see Figure 15). However, when comparing the control condition versus the optimal CF flex condition for each individual participant, there was a significant ($p < 0.05$) increase in front foot relative rate of force development from 11.1 ± 4.2 BW/s to 12.1 ± 3.8 BW/s (an 8.9% increase).

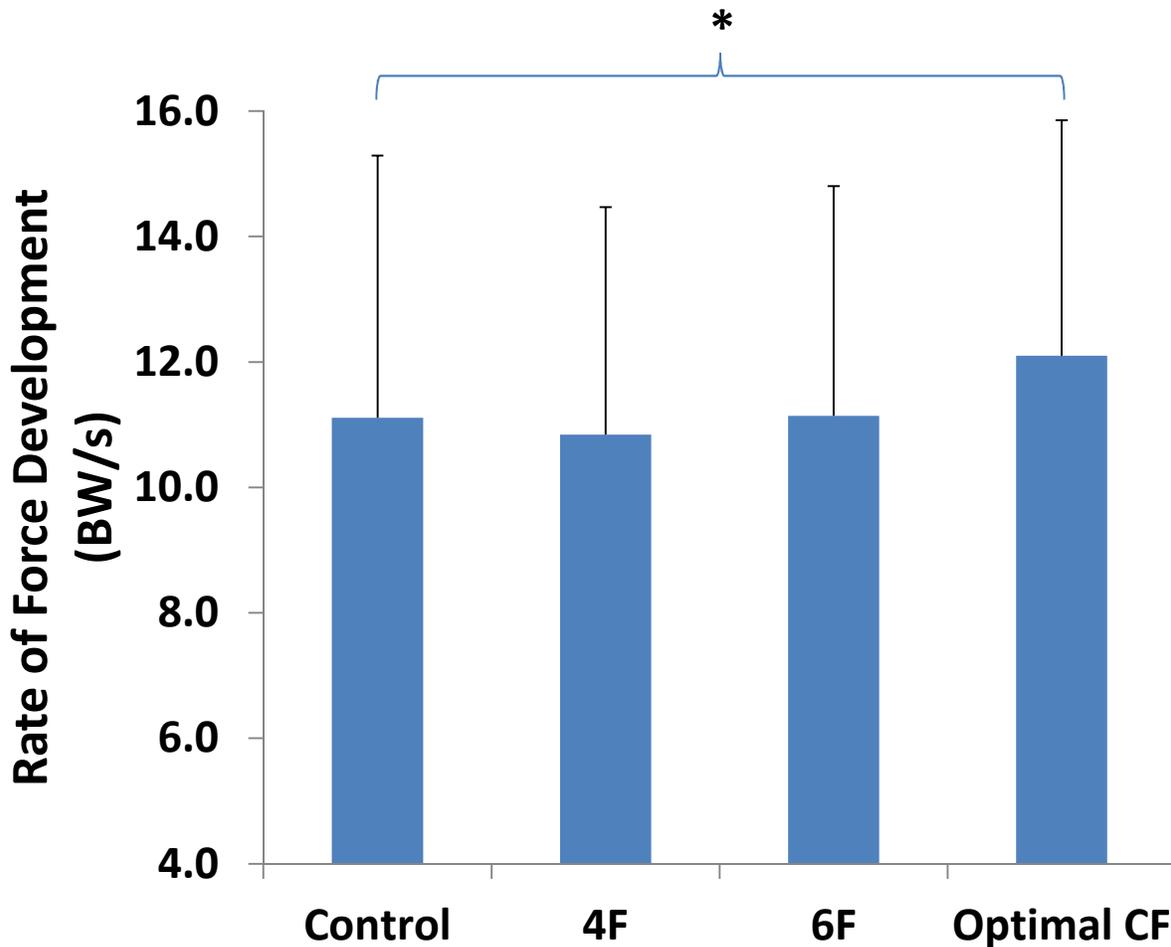


Figure 15. Mean (\pm standard deviation) front foot rate of force development (relative to % body weight) for the three different shoe insert conditions tested and the optimal flex CF shoe insert.

Rear Foot:

There was no difference in rear foot relative rate of force development when a comparison was performed across the three different shoe insert conditions (see Figure 16). However, when comparing the control condition versus the optimal CF flex condition for each individual participant, there was a significant ($p < 0.10$) increase in front foot relative rate of force development from 12.2 ± 3.6 BW/s to 13.3 ± 4.4 BW/s (a 9.3% increase).

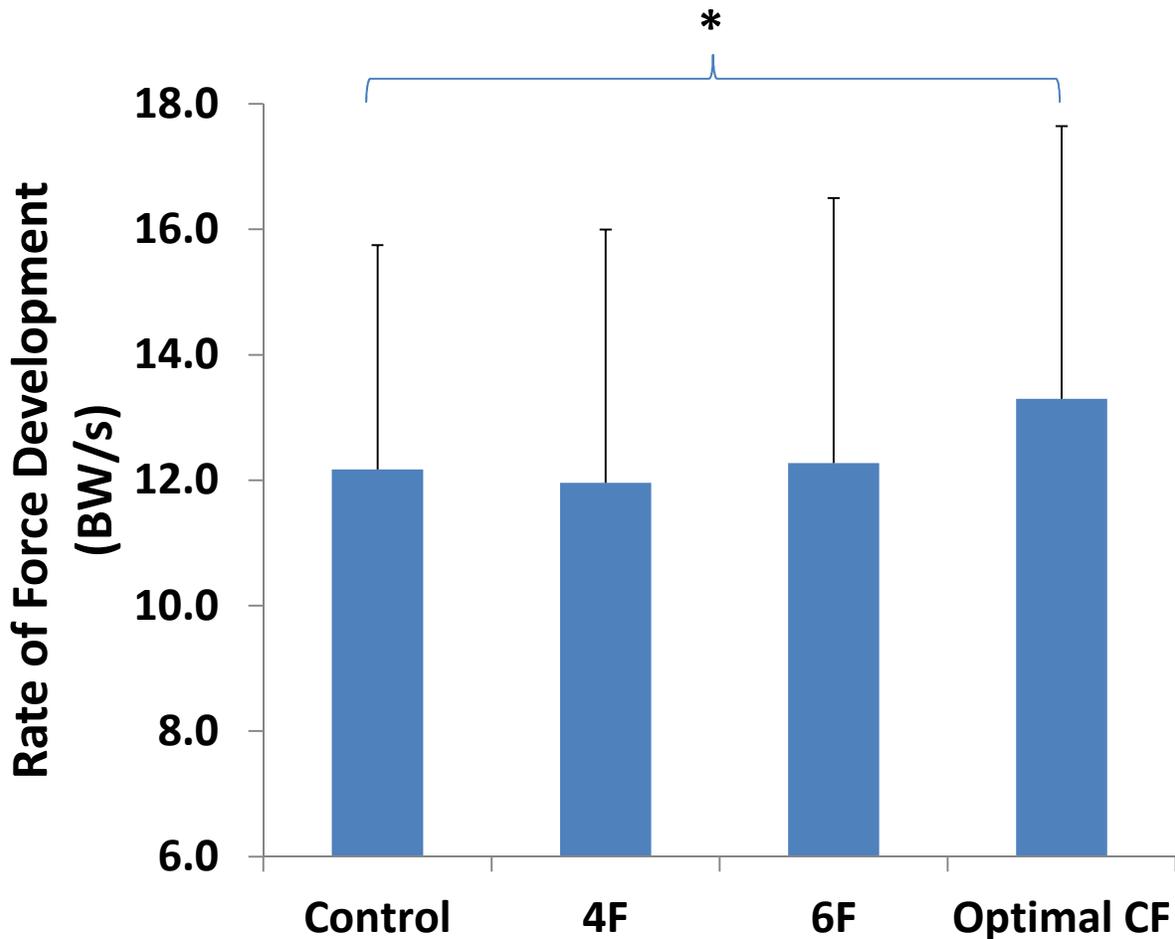


Figure 16. Mean (\pm standard deviation) rear foot rate of force development (relative to % body weight) for the three different shoe insert conditions tested and the optimal flex CF shoe insert.

Maximal Power

There was no difference in relative peak power when a comparison was performed across the three different shoe insert conditions (see Figure 17). However, when comparing the control condition versus the optimal CF flex condition for each individual participant, there was a significant ($p < 0.10$) increase in relative peak power from 25.1 ± 10.4 W/kg to 27.2 ± 11.3 W/kg (an 8.1% increase).

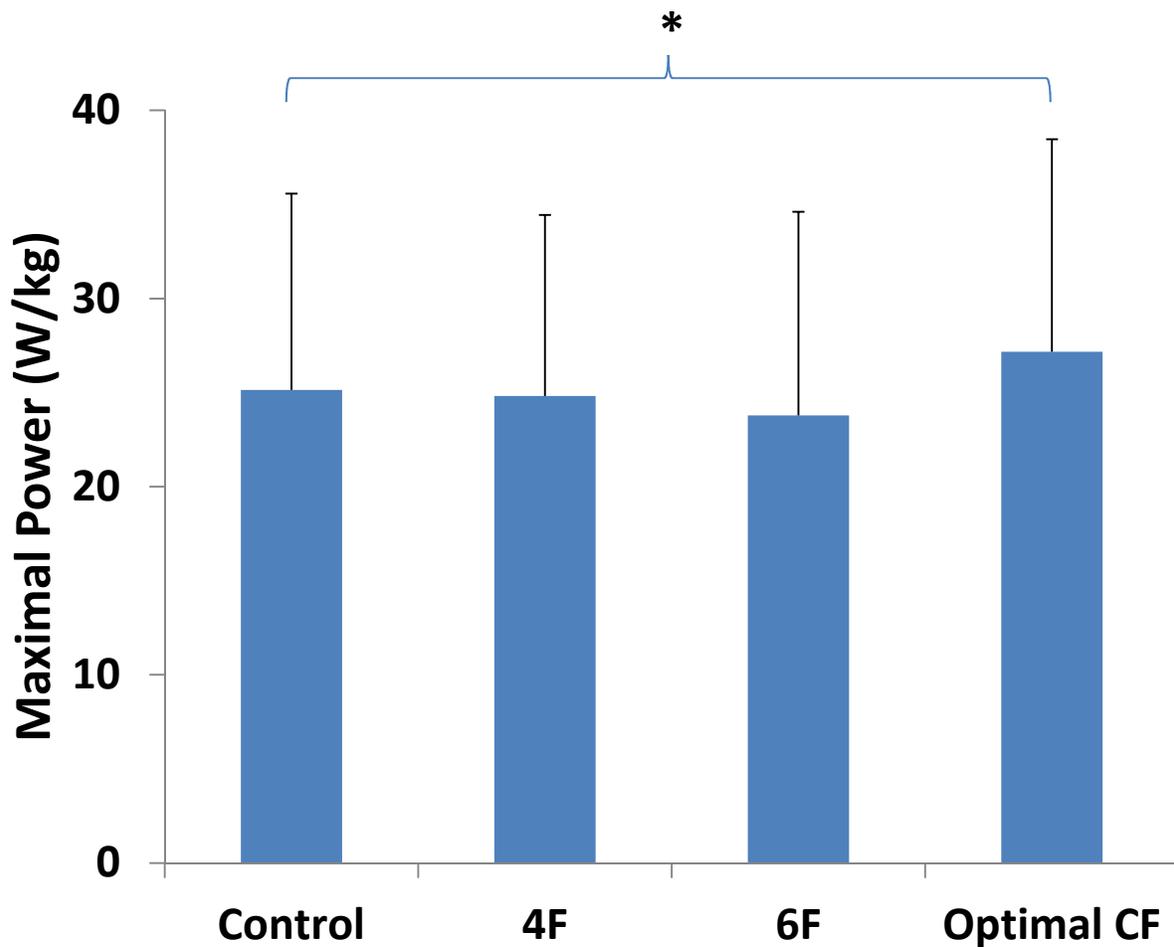


Figure 17. Mean (\pm standard deviation) peak power (relative to body mass) for the three different shoe insert conditions tested and the optimal flex CF shoe insert.

SUMMARY

The use of a carbon fiber shoe insert can improve performance in the 40-yard sprint and vertical jump. In the vertical jump, jump height increased by 2.6 cm (4.1%) in a group of 28 participants. These results are similar to those found by Stefanyshyn & Nigg (2000) when using carbon fiber plates inserted into shoe midsoles. In addition, all of the biomechanical variables measured during the vertical jump (maximal force, impulse, rate of force development, total work, average power, and maximal power) increased between 2.0-7.6% when using a CF shoe insert compared to a standard shoe insert. However, it should be noted that these increases were observed in the optimal CF shoe insert condition for each individual. When analyzing the performance of the 40-yard sprint, the 0-10 yard and 20-40 yard split times both improved by 1.6% and 1.3%, respectively. These performance improvements are similar to the 1.2% improvement in 20-40 yard split times observed by Stefanyshyn & Fusco (2004) in a group of 34 male and female sprinters. In addition, all of the biomechanical variables measured during the 40-yard sprint (maximal force, rate of force development, and maximal power) increased between 1.6-9.3% when using a CF shoe insert compared to a standard shoe insert.

It is imperative that an athlete choose the correct CF shoe insert flex to benefit from these improvements in performance. An athlete cannot use a carbon fiber shoe insert of random stiffness and expect to experience performance improvement; instead, the athlete must choose the correct flex that matches his/her body weight and movement biomechanics. Similar to the conclusions of Stefanyshyn & Fusco (2004), it is speculated that individual differences in technique as well as the length-tension and force-velocity relationships of the calf musculature may influence the appropriate CF shoe insert stiffness for each athlete to obtain their maximal performance.

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