Effects of Static Stretching on Foot Velocity During the Instep Soccer Kick

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EFFECTS OF STATIC STRETCHING ON FOOT VELOCITY

DURING THE INSTEP SOCCER KICK

by

Craig D. Workman

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Health, Physical Education and Recreation

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UTAH STATE UNIVERSITY
Logan, Utah

2010

ABSTRACT

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The purpose of this study was to assess the acute effects of static stretching on foot velocity at impact with a soccer ball. Eighteen Division I female soccer athletes underwent two test conditions separated by 48 hr. Each condition was randomly assigned and began by placing four retro-reflective markers on bony landmarks of the ankle (total of eight markers, four on each ankle). One condition was the no-stretch condition, in which each participant performed a self-paced jog for 5 min as a warm-up, and then sat quietly for 6 min before performing three maximal instep kicks into a net. The second condition was the stretch condition, which was identical to the no-stretch condition, except the participants performed a series of six randomly ordered stretches instead of sitting quietly for 6 min. Three-dimensional motion analysis was used to quantify the resultant velocity of the head of the 5^{th} metatarsal immediately prior to foot impact with a soccer ball. The results of a dependent *t* test indicated that there was no significant difference between the no-stretch (18.34 ± 1.29 m/s) and stretch conditions (17.96 ± 1.55

m/s; p = .102, d = .3) Based on these findings, acute stretching performed one time for 30 s before maximal instep soccer kicking has no effect on the resultant foot velocity of Division 1A university female soccer players. Pre-event stretching performed in a like manner may best be prescribed at the discretion of the athlete.

(64 pages)

ACKNOWLEDGMENTS

I would like to thank my family for sticking with me through all of my life's decisions. To my brother Richard, who patiently and willingly provided for me through my time at school and who has always been one of my best friends. To my dear companion Aubrey, who has comforted me and assured me in my academic endeavors and still continues to support my career goals. And finally to my parents (all four of them), for encouraging me and supporting me in all of my whims and fancies, believing all of the time that I could do it.

I especially thank Dr. Eadric Bressel, who has always maintained a positive outlook on my projects and goals and who worked industriously with me by providing suggestions, support, and advice in both academic and life endeavors. Thanks to my committee for their patience with me as it has been a long journey through this process and for their insights and enthusiasm about my thesis.

I offer my sincerest thanks and appreciation to my fellow graduate colleagues for the friendships we have and the hilarious office times we shared. I also thank all of my professors at Utah State University for being personable and kind to me during my 8-year span in the department and who have become experts at writing letters of recommendation for me.

My final thanks go to Bill Bauer of USU's Campus Recreation. For being my boss for 5 years, through thick, thin, and mediocre and for trusting me the way few people ever did to that point of my life.

Craig D. Workman

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CHAPTER I

INTRODUCTION

Much research is currently being performed on the effects of stretching on human performance. The bulk of the research has focused on laboratory experiments that are weakly applicable to real-life settings. The current study has several unique aspects that may provide useful insight into the applicability of results of previous stretching research to athletic settings. The outline for this thesis will be (a) an introduction in which a case for the study will be made; (b) a review of literature regarding acute stretching and its effects on performance; and (c) a discussion of the methods, results, discussion, and conclusion for the current study.

Clinicians, coaches, and athletic trainers have previously prescribed stretching as a method of preparing the muscles for the impending performance and reducing the possibility of injury. Contrary to this traditional thinking, some researchers have reported that stretching before a performance may actually decrease strength, power, and performance (Behm, Bambury, Cahill, & Power 2004; Kokkonen, Nelson, & Cornwell, 1998; Young & Behm, 2003). In the literature available on acute effects of stretching, several researchers have measured outcomes that are not directly related to sport performance. The most common outcome measures were isokinetic peak torque (Cramer et al., 2004; Zakas, Galazoulas, Doganis, & Zakas, 2006) and jump performance (Church, Wiggins, Moode, & Crist, 2001; Cornwell, Nelson, Heise, & Sidaway, 2001; Young & Behm, 2003), which are single-joint and non-sport specific measures of performance, respectively; although several sports include jumping, vertical jump performance is not specific to any one sport and may not be a primary performance indicator.

Additionally, previous researchers have used stretching times and regimens that are not applicable to sport environments. Kokkonen et al. (1998), for example, performed five different stretches on the knee. Each stretch was held for 15 s and performed six times (a total of approximately 20 min of stretching), which is excessive for one joint in sport situations. Therefore, these findings must be cautiously applied to athletic settings.

In an effort to study a complex, multi-joint performance, Young, Clothier, Otago, Bruce, and Liddell (2004) studied the effects of stretching on the soccer dropkick, as measured by foot velocity at impact with the ball. Sixteen participants underwent two conditions (control & stretch). The control condition consisted of a 5-min run at 10 km/h, followed by seven practice kicks performed at 50, 60, 70, 80, 90, 95, and 100% of perceived maximum effort. After a flexibility assessment, the participants then performed six maximum effort kicks. The stretch condition included a stretching protocol of three stretches consisting of three 30-s stretch intervals executed on the hip flexors and quadriceps muscle groups, performed between the jogging warm-up and the practice kicking. The study results indicated no significant differences between the control (20.6 ± 0.9 m/s) and the stretch (20.7 ± 0.8) conditions on either post-stretch ROM or foot impact velocity (*p* value not reported). However, the stretching regimen only focused on hip flexors and knee extensors and they included practice kicks. Because practice kicking is a form of dynamic warm-up and may have increased muscle temperature, the effects of the stretching regimen may have been influenced by the practice kicks. This may be assumed because increasing muscle temperature has been shown to increase performance (Mohr, Krustrup, Nybo, Nielson, & Bangsbo, 2004). Additionally, the complexity of the soccer kick is such that three major joints of the lower extremity (hip, knee, and ankle) contribute to kick performance, not just the hip and knee.

Although the ankle joint has not been shown to directly contribute to ball velocity as a part of the kinetic link (Robertson & Mosher, 1985), diminished stiffness of the ankle joint (i.e., as a result of stretching) has been shown to affect resultant ball velocity (Dörge, Anderson, Sørensen, & Simonsen, 2002). Specifically, Asai, Akatsuka, and Kaga (1995) observed that increased deformation of the metatarsalphalangeal joints, compared to the talotibial joint, resulted in decreased soccer ball velocity. From this latter study, it may be inferred that increasing ankle joint compliance, which would increase the deformability of the ankle joint, through stretching of the ankle dorsi flexors and ankle plantar flexors may result in a decreased amount of force transferred to the ball, which would result in decreased ball velocities.

In light of previous research, questions remain regarding how stretching influences soccer kick performance. Particularly, how does stretching of the hip, knee, and ankle influence multi-joint performances when they are performed in accordance with stretching times and regimens typically used in athletic settings? Therefore, the purpose of this study was to assess the effects of acute static stretching of the hip, knee, and ankle joints on resultant foot impact velocity during the instep soccer kick. It was hypothesized that static stretching will have a negative influence on kick performance as measured by a decrease in foot velocity at impact. The specific focus of this study on the instep soccer kick could provide additional evidence of performance effects observed by other authors of non-sport specific studies. If a negative effect is found, then the inclusion of a stretching routine during the pre-event warm-up may not be warranted from a performance perspective. The effects of stretching on injury prevention are unclear (Fields, Burnworth, & Delaney, 2007) and not addressed in this study.

Definition of Terms

It is important to operationally define several terms for an accurate discussion of stretching and soccer biomechanics. For the purposes of this study, the term *warm-up* will be used exclusively to mean increasing core or muscle temperature (Enoka, 2002, p. 363); this differs from *stretching,* which means increasing the length of a tissue (Enoka, 2002, p. 298). The phrase *static stretching* for this study will mean moving to the end of joint rang of motion (ROM) slowly and then statically holding that position for 30 s (Hall, 2007, p. 132). The term *velocity* is defined as the rate of change in position, or how fast an object moved from point A to point B along a straight path (Hall, 2007, p. 321). Another term, *impact velocity*, will mean the velocity of the foot immediately prior to impact with the ball (Apriantono, Nunome, Ikegami, & Sano, 2006). The term *plant leg* or *plant foot* will mean the non-kicking leg or foot that provides stability during the kicking motion.

Finally, *digitization* is defined as the assigning of x, y, and z coordinates to joint centers and other key bony landmarks so that real-life, or analog, motions can be measured in a digital format or computer environment by using a Cartesian coordinate system to describe an analog signal. The process of digitization involves: (a) the creation of link-segment models, (b) scaling of real-world units (i.e., m, in.) to digital units (i.e., pixels), and (c) assigning coordinates to the marked points of interest on a computer to create a link-segment model. In order to properly digitize, markers are placed on the participant at the center of rotation for all involved joints or on other landmarks that are needed to digitally describe the motion of a joint or boney landmark. For example, in this study, a marker was placed over the head of the 5th metatarsal and the conclusions that were made were based on the motion of this marker. Once this scaled model was created, the researcher or the researcher's computer program assigned each marker point a coordinate location by placing digital markers over the analog markers on the captured motion. A motion analysis program was used to calculate various measures, such as linear velocity [$V_i = (s_{i+1} - s_{i-1}) / 2\Delta t$], using finite difference equations (Robertson, Caldwell, Hamill, Kamen, & Whittlesey, 2004, p. 21). Based on these and other calculations researchers assessed the effects of an intervention or the coordination between certain joints during a movement.

Purpose Statement and Significance

The purpose of this study was to assess the acute effects of static stretching of the hip, knee, and ankle joints on instep kick foot velocity. Specifically, the resultant linear velocity of the foot immediately prior to impact with the ball was examined. This study is important because of the possible contribution the results may make to the recently expanding literature of the effects of static stretching on sport performance. The defining quality of this study was its applicability to sport settings, because the generalizability of previous research is weak due to the use of excessive stretching regimens and outcomes that are not representative of sport performance. The unique contributions of this study could give further evidence to the current trend of performance decrements that have been reported in previous research. For example, to prepare for competition, many teams employ a general warm-up, such as jogging. This is typically followed by a series of stretches and then completed by performing practice kicks. If stretching has a negative effect on this warm-up, as was suggested by Young and Behm (2003), then the exclusion of stretching in the pre-performance warm-up could be advantageous to athletes allowing them to perform better at the onset of the match.

Limitations

In order to gain a full appreciation for the results of this study, the study limitations should be considered. One limitation of this study was the number of cameras used to gather data. In order for the Nexus software of the Vicon system (Vicon, Centennial, CO, USA) to recognize a marker, at least two cameras need to see the marker at all times. Six cameras were placed in a circular fashion in the present study, which means that it was relatively easy for a marker to not be seen by at least two cameras as a result of being blocked by the body or by the goal into which the ball was kicked. Having more cameras would have increased the ability of the system to see and recognize the various markers and their positions, which would increase the validity and reliability of the study results.

The stretching method may also be a limitation. Because stretching was based on the perception of discomfort without pain by each participant individually, it may be possible that some participants were stretched to a greater degree than others based on personal pain tolerance. Another limitation was marker movement over bony landmarks after placement. Because human skin moves over bony landmarks, the true motion of the skeletal system may not be accurately represented by surface markers.

CHAPTER II

LITERATURE REVIEW

In the past, clinicians, coaches, and athletic trainers have prescribed stretching as a method of reducing the possibility of injury and increasing the readiness of the muscles for the impending performance. Typically, stretching has been part of the warm-up routine. It has recently been suggested, however, that pre-event stretching (increasing tissue length) and warming up (increasing core & muscle temperature) need to be separated (Claxton, Cronin, & Bressel, 2005). This is important to consider because much of the previous research on the topic of stretching has included stretching in conjunction with warming up. This lack of distinction in previous research may be partly responsible for conflicting findings in the literature since increasing muscle and core temperature, independent of stretching, has been shown to improve performance and reduce musculoskeletal injury (Fields et al., 2007; Mohr et al., 2004).

Several researchers that have studied performance outcomes after a bout of stretching have typically used stretching times and regimens that were not applicable to sport settings (Cramer et al., 2004; Fowles, Sale, & MacDougall, 2000; Knudson, Bennett, Corn, Leick, & Smith, 2001; Kokkonen et al., 1998; Nelson, Guillory, Cornwell, & Kokkonen, 2001; Unick, Kieffer, Chessman, & Feeney, 2005). Additionally, there is a lack of research on the effects of stretching on complex or multi-joint performances, such as the instep kick in soccer. The bulk of previous research on stretching has mainly focused on the effects of acute, pre-event static stretching on injury prevention, performance, and the adaptations that occur during a stretch. This literature review will focus only on the performance effects of stretching. There have been several researchers who have performed various studies assessing the effects of different kinds of stretching on myriad varieties of performance. Many studies may not be included in this literature review, but those discussed are adequate to illuminate the ongoing debate. The format for this review will be research findings that stretching decreases performance and research findings that stretching has no effect on performance.

Decreases in Performance

Church et al. (2001) studied the effects three types of pre-performance preparation activities on the vertical jump performance of 40 Division I female athletes. The three conditions studied were (a) a general warm-up only, (b) a warm-up in conjunction with static stretching (focusing primarily on the hamstrings and quadriceps muscle groups), and (c) a warm-up in conjunction with proprioceptive neuromuscular facilitation (PNF) using the contract-relax agonist-contract (CRAC) form to stretch the hamstring and quadriceps muscle groups. The results of the study indicated that PNF stretching yielded significantly lower jump performances compared to pre-stretch measures. Additionally Cornwell et al. (2001) studied the effects of three passive stretches on two vertical jump types (static jump and counter movement jump). All stretches were employed on the quadriceps muscle group and were performed three times for 30 s. The results of the study showed significant decreases in jump performance for both the static and counter movement jumps.

The following three studies assessed the effects of stretching on isokinetic peak torque. Cramer et al. (2004) investigated the effects of static stretching on peak torque in women and found that one active and three passive stretches of the dominant leg of the participant decreased peak torque in both legs (the stretched and the non-stretched legs) and at both velocities measured (60 & 240°/s) compared to pre-stretch values. Zakas et al. (2006) studied the effects of static stretching durations on 15 professional soccer players and found that a routine stretch of the dominant leg performed four times for 15 s for a total stretch time of 1 min of the quadriceps muscle group yielded no significant differences, but when the same protocol was performed in conjunction with a second protocol of 28 stretch bouts performed for 15 s each for a total stretch time of 8 min, significant decreases in peak torque were found. Nelson et al. (2001) assessed the effect of velocity on peak torque pre- and post-stretching. The 15 participants underwent a series of four stretches held for 30 s with a 20-s rest interval, performed four times on the dominant leg. The participants underwent a testing procedure in which a baseline peak torque was assessed at gradually increasing angular velocities, followed by the stretching protocol (15 min), and then the same procedure as the baseline was then administered as a post-stretch value. The researchers found that significant decreases in peak torque were only evident at the first two, slowest velocities while the other velocities were not significant.

In a study on the effects of passive stretching on the plantarflexors, Fowles et al. (2000) performed cyclical passive dorsiflexion stretches on the ankle joint for 30 min (13 stretches of 135 s each over 33 min) and found (among many other things) a 28% significant strength loss post stretch which lasted for at least 60 min, with 80% of the strength loss recovered after 5 min and up to 9% still not recovered after 60 min. Furthermore, Kokkonen et al. (1998) studied the effects of static stretching of the hip, thigh, and calf muscle groups on the one repetition maximum (1RM) of 30 college students. Five different stretches designed to stretch all of the muscles involved in knee flexion and extension were performed six times (three unassisted and three assisted) for 15 s each, with a 15 s recovery period between stretches. The results of the study indicated that 1RM was significantly decreased for both the knee flexion and knee extension exercises.

In an effort to study the effects of running, static stretching, and practice jumps on explosive force and jump performance, Young and Behm (2003) studied 16 participants who underwent five randomly ordered protocols. The protocols were (a) control, in which participants walked at a comfortable pace for 3 min and then performed five non-weighted squats and heel raises; (b) run, in which the participants ran indoors for 4 min at a pace that would allow them to induce sweating; (c) stretch, in which participants performed two quadriceps and two ankle plantar flexors stretches performed on both legs twice for 30 s; (d) run + stretch, which combined the run and stretch protocols; and (e) run + stretch + jumps, which combined the run and stretch protocols immediately followed by four practice jumps. The results of the study indicated that wherever running and practice jumps were included, performance increased, but wherever stretching was included, performance was decreased. For example, the run protocol was significantly different from the control, while the run + stretch protocol was similar to the control and not significantly different. However, the run + stretch + jumps protocol, however, was significantly different from the control group.

Behm et al. (2004) studied the effects of static stretching on force, balance, reaction time, and movement time. The stretching protocol included a 5-min cycle warm-up followed by four stretches (quadriceps, hamstrings, ankle dorsiflexors, & ankle plantarflexors) of 45 s with a 15 s recovery period, repeated three times each. The results of the study showed significant decreases in balance, reaction time, and movement time compared to control values, while differences in force production were non-significant.

In order to assess the effects of static stretching on sprint performance, Fletcher and Jones (2004) randomly assigned 97 males to four different groups. The groups were (a) passive static stretch, (b) active dynamic stretch, (c) active static stretch, and (d) static dynamic stretch. Each protocol stretched the gluteals, hamstrings, quadriceps, adductors, hip flexors, ankle plantarflexors, and ankle dorsiflexors. The static stretches were performed one time for 20 s per muscle group. Dynamic exercises were performed at a jogging pace with 20 repetitions performed on each leg for each exercise. The results of the study indicated that dynamic stretching significantly improved sprint time, while static stretching significantly decreased sprint time, compared to baseline values.

When the results of the previous studies are compared together, acute bouts of stretching appear to have negative effects on subsequent performances. Although a variety of stretching times and regimens were used, the same outcome of a negative effect on performance resulted. The following section contains research in which no performance effects resulted from stretching.

No Effect on Performance

In contrast to the above studies, there have been a number of studies that have found no stretching effects on performance. Among the research discussed above, it can be noted that not all of the outcomes measured had significant differences. In fact, several studies (Behm et al., 2004; Church et al., 2001; Nelson et al., 2001; Young & Behm, 2003; Zakas et al.2006) had at least one outcome that was not significant. Aside from those studies already discussed above, there are others that have not shown significant differences.

Knudson et al. (2001) investigated if the effects of stretching were evident in vertical jump kinematics on 20 participants. The two protocols used in this study were a control, in which the participants sat and rested for 10 min after undergoing a 3-min cycle warm-up and three practice jumps, and a stretch protocol, in which the participants performed the same warm-up as the control but performed three sets of three 15-s stretches of the hamstrings, quadriceps, and ankle plantarflexors. The differences between the stretch and the control conditions were nonsignificant, nor were the differences evident in the kinematic data.

Little and Williams (2006) studied the effects of stretching, dynamic stretching, and no stretching on four outcomes (counter movement jump, stationary 10 m sprint, flying 20 m sprint, and agility) on 18 professional soccer players. The three protocols consisted of performing warm-up exercises for 4 min, followed by static or dynamic stretching for 6.20 min (when included in the protocol), followed by more warm-up exercise for 4 min, and then completed by a 2-min rest. The results of the study showed that static stretching did not appear to negatively influence the high-speed performances measured. Interestingly, dynamic stretching significantly improved all conditions except for the counter movement jump.

Unick et al. (2005) assessed the effects of static and ballistic stretching on the jump performance of 16 actively trained women. Three conditions (control, static stretch, and ballistic stretch) were performed by all participants. All conditions included a 5-min self-paced jog as a warm-up, followed by a 30-s rest interval. Immediately after the rest interval, a stretching regimen was performed. For the static stretching condition, the participants performed four stretches (hamstring, quadriceps, ankle plantarflexors, & ankle dorsiflexors) three times and held each stretch for 15 s. The ballistic stretch condition followed the static stretch condition except the participants were asked to bob up and down at the end range of motion at a rate of 1 bob/s and each bob being approximately 2-5°. There was a 20-s rest interval between all stretches. The results of the study showed that there were no significant differences across all conditions.

In an effort to study a complex, multi-joint performance, Young et al. (2004) studied the effects of stretching on the soccer dropkick. Sixteen participants underwent two conditions (control and stretch). The control condition consisted of a 5-min run at 10 km/h, followed by seven practice kicks performed at 50, 60, 70, 80, 90, 95, and 100% of perceived maximum. After a flexibility assessment, the participants then performed six maximum effort kicks. The stretch condition included a stretching protocol of three stretches consisting of three 30-s stretch intervals executed on the hip flexors and quadriceps muscle groups, performed between the jogging warm-up and the practice kicking. The results of the study showed no significant differences between the control and the stretch conditions on either post-stretch ROM or foot velocity upon impact with the ball.

In a review article, Shrier (2004) summarized several of the available articles dealing with stretching and performance. The author found that of the 23 studies on an acute bout of static stretching, 22 showed no benefits for isometric force, isokinetic torque, or jump height, while the remaining one found increased running economy. The results of four articles on running speed were inconsistent, with one showing benefits, one detriments, and the other two no difference. Interestingly, of nine studies on regular stretching programs performed away from the exercise activity, seven had benefits and the other two found no detriments to performance. In a recent review of the literature, Fields et al. (2007) suggested that stretching has no evidence of improving performance, preventing injuries, or reducing delayed onset muscle soreness. These authors further noted that flexibility may be beneficial for some sports in which range of motion is advantageous, such as gymnastics, and detrimental for others in which it may predispose to injury or inhibit performance, such as football linemen and distance runners, respectively. In support of the latter conclusion, Jones (2002) found that, for trained distance runners, the stiffer runners had better running economy than their more compliant counterparts.

Summary

The literature discussed above was divided into two categories; decreases in performance and no effect on performance. Many of the studies that did have significant performance decrements also had some performance measures that were not affected by the stretching protocol. The possible reasons for this apparent disparity could be many, but some may be that some the researchers did not randomize the order of their performance measures. For example, Nelson et al. (2001) did not randomize the order of the angular velocities that were performed. Such randomization could have diminished any order effects of the performance regimen.

Several of the studies discussed above focused only on the quadriceps and hamstrings muscle groups. Although these groups are the major muscle groups of the lower extremity and are the primary movers in the activities studied, there may be a piece that is lost by the exclusion of other muscles that move the lower extremity. Although the total stretch time of some of the studies may not appear to be excessive, the muscles stretched must be considered. For example, stretching one or two muscle groups for 5 min would have a greater effect than stretching 4 muscle groups in the same amount of time.

Conclusion

Based on the previous research discussed in this literature review, it is impossible to formulate a concrete standard for all athletes and other physically active individuals. As can be seen from the above studies, much research is still needed on the subject of stretching and its effects on performance. Small, but important, consistencies in research, such as the distinction of warm-up from stretching, will make future research more valid and increase the degree to which future results may generalize to a more extensive population

CHAPTER III

METHODS

Twenty-one female Division I soccer players (age: 19.4 ± 1.7 years; height: 1.7 ± 0.07 m; mass: 63.5 ± 8.6 kg) were recruited. The participants were free of any injuries to the hip, knee, or ankle joints that hindered a maximal effort. Participants who had previous injuries but were cleared to play by the medical and coaching staff were also asked to participate in the study. The University's Review Board approved the research and all subjects read and signed an informed consent form before participation.

Equipment

The kicking trials were captured using the Vicon motion analysis system via six MX T-Series cameras (Vicon, Centennial, CO, USA) operating at 200 Hz (Young et al., 2004). The trials were automatically digitized using the Nexus motion analysis software version 1.4.112. Cameras were dynamically calibrated using a five marker L-wand calibration tool, with typical calibration errors below .25 pixels. Although the beginning point of digitization was the instant the plant foot contacted the ground and the ending point was the instant the kicking foot reached its apex or disappeared from view, data were captured from the standing position until the ball was clearly in the net.

Procedures

Participants attended two randomly ordered test sessions, with at least 48 hr and no more than 72 hr between sessions. The participants were asked to refrain from stretching and fatiguing activity other than those they were already performing at team practice and exercise sessions. Additionally, sessions were performed at the same time of day and the participants were asked to be consistent in their pre-experiment activities on those days. Upon arrival to the motion analysis laboratory, markers required for digitization were placed on the participant. The markers were placed on (a) the lateral malleolus (Figure 1), (b) the medial malleolus (used for calibration only, not shown), (c) the head of the 5th metatarsal (Figure 1), and (d) the lateral-posterior aspect of the calcaneus (Figure 1).

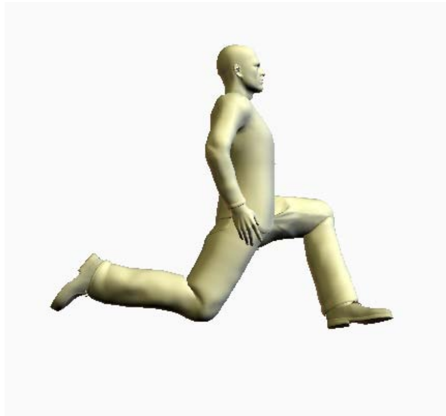
Figure 1. Lateral view of ankle markers. Medial ankle marker not shown.

Markers were placed on both ankles for all sessions. Additionally, reflective tape was placed on the soccer ball and aimed at a camera so that the moment of ball contact could be visualized. The ball used was a Nike 90 soccer ball, inflated to 12 psi. A lacrosse goal and net was used to catch the soccer ball after kicking. The ball was placed 0.5 m from the center of the goal in order to ensure the safety of the cameras.

One session (no stretch) required the participants to undergo a 5-min, self-paced jog as a warm-up, and then sit quietly for 6 min before performing three maximal-instep kicks without stretching. Only three kicks were performed to avoid a dynamic warm-up and negate the stretching regimen. The other session (stretch) was the same as the baseline session except the participants performed a stretching regimen of randomly ordered stretches that focused on three major joints of the lower extremity instead of sitting quietly for 6 min. The time between stretching/sitting quietly and kicking was less than 30 s for each participant. The stretches in this regimen were chosen because they are commonly used in athletic settings and are performed without assistance.

The following stretches were performed (Figure 2). The first was the one-leg static lunge stretch, in which the participant stepped forward with one leg and allowed the knee of the opposite leg to make contact with the ground. Once this was accomplished, the participant pushed the hips forward over the knee on the ground in order to stretch the hip flexors. The second was the one-leg knee huggers stretch, which were accomplished by having the participant lie supine and bring one knee to the chest and hug the shank towards the chest and chin. When needed, the participant was allowed to hook the hands under the foot and pull the knee towards the chin to further stretch the hip extensors.

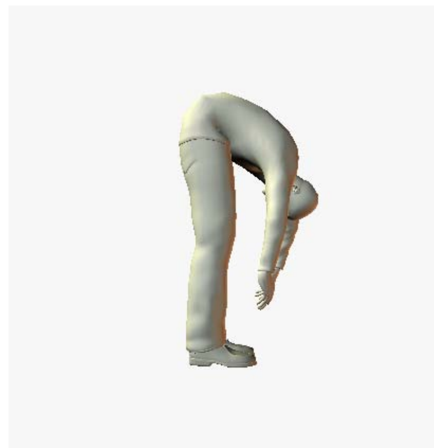
A.



B.

C.

D.



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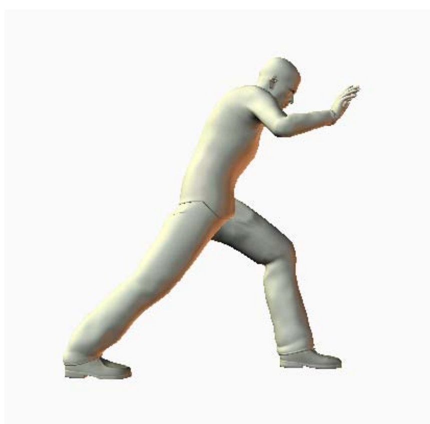


F.

Figure 2. A. One-leg static lunge stretch; B. One-leg knee huggers stretch; C. One-leg standing hurdler stretch; D. Bent-over hang stretch; E. One-leg wall leans stretch; F. Heel sits stretch.

The third was the standing one-leg hurdler stretch, in which the participant flexed the knee and brought one foot towards the buttocks and grasped the foot with the ipsilateral hand, while placing the other hand on a wall for stability. The participant pulled the heel of the foot towards the buttocks to stretch the quadriceps muscle group.

The fourth was the bent-over hang stretch, which required the participant to stand with the feet together, the knees extended but not locked, and bend forward at the hip joint and reach the hands toward the floor. If the participant required further stretching, the posterior shank was grasped and the chest pulled closer to the knees in order to stretch the hamstring muscle group.

The fifth was the one-leg wall leans stretch that required the participant to face a wall and step forward with one leg, leaving the other hip hyper-extended with the heel on the floor. The stretch occurred as the participant kept the heel on the floor with the knee straight and leaned toward the wall, with the hands placed on the wall for stability. This stretched the ankle plantarflexors.

The sixth was the heel sits stretch, in which the participant knelt on the floor with the knees and ankles together. The participant sat on the heels and allowed the ankles to plantar flex. When needed, the participant was allowed to lean backwards to achieve the appropriate amount of stretch of the ankle dorsiflexors.

The four one-leg stretches were performed on each leg. Each stretch was executed one time for 30 s, as per Bandy, Irion, and Briggler (1997), and was pulled to the pain threshold (maximum stretch without pain) as described by Young and Behm (2003). Total stretch time was about 6 min (8 one-leg stretches x 30 s + 2 two-leg stretches x 30 s + 1 min total to switch between stretches = 6 min). A researcher explained each stretch beforehand, provided visual demonstrations, and then timed the stretches with a stopwatch as the participants performed them. The same researcher supervised the participants as they stretched to ensure the stretches were being performed as specified.

Data Analysis

Each participant was calibrated individually using the Nexus program, and a researcher manually indicated, with a computer mouse, marker names based on a template created in the Nexus program. Raw coordinate data were smoothed using a Woltring filter to remove noise in the data (Molloy, Salazar-Torres, Kerr, McDowell, & Cosgrove, 2008). Gaps in the data were minimal, but those missing were filled automatically using the Nexus program. Only the data contained in the region of the motion of interest (i.e., between the instant of plant foot contact with the ground until the kicking foot reached its peak height or was lost from view) were filtered and gap-filled. After the data were filtered and gap-filled, a researcher visually examined the 3D data and renamed markers that had lost names during data collection. Velocity at impact was calculated at the instant before the marker on the soccer ball visually moved. The raw x, y, and z position data of the marker on the head of the 5^{th} metatarsal of the kicking foot were used in the following equation, as an extension of the general velocity equation $v_i = (s_{i+1} - s_{i-1}) / 2\Delta t$ (Robertson et al., 2004), to calculate the resultant velocity

$$v_i = \frac{\sqrt{(x_{i+1} - x_{i-1})^2 + (y_{i+1} - y_{i-1})^2 + (z_{i+1} - z_{i-1})^2}}{(t_{i+1} - t_{i-1})}$$

The trial containing the fastest foot velocity was retained for statistical analysis (Young et al., 2004). A peak trial was used instead of a mean because the participants were outdoor athletes and it was anticipated that some would not make all of the adjustments needed to maximally kick indoors for all kicks. Using a peak trial allowed the participants to have less consistent data overall and still contribute meaningfully to the purpose of the study.

Statistical Analysis

A within-subjects design was employed where the pre-event condition (no stretch and stretch) was the independent variable and linear resultant velocity of the foot was the dependent variable. Mean and *SD* were calculated to gain an appreciation for the centrality and spread of the data. A paired *t*-test was performed on the dependent measure and an effect size calculation (Cohen's *d*; (high mean – low mean) / high mean *SD*) was performed in order to assess the stretching effect. An alpha level of .05 was used to determine significance. A researcher who was blind to the conditions performed the statistical analysis.

CHAPTER IV

RESULTS

Three of the 21 participants recruited did not complete the conditions as scheduled due to the wearing of improper equipment combined with rescheduling conflicts. The peak values of the participants, the difference between the peak values, and the mean and *SD* of the combined velocities for the different conditions are expressed in Table 1. The results of the *t* test indicated no significant difference between the no-stretch and the stretch conditions ($p = .102$, $d = .3$).

Figure 8 depicts the no-stretch and stretch condition foot velocities of Participant 18 (all trials) (*SD* = .24 m/s and .27 m/s, no-stretch and stretch conditions, respectively); this figure is representative of the majority of the other participants. Similarly, Figure 9 depicts the foot velocities of Participant 8 (all trials), whose data were the most variable (*SD* = 1.43 m/s and 0.67 m/s, no-stretch and stretch conditions, respectively). In addition to being the most variable, Participant 8 also had the greatest velocity difference between the no stretch and stretch conditions (3.07 m/s).

The mean *SD* of the participants was greater for the no stretch condition compared to the stretch condition (no-stretch mean *SD* = .60 m/s, stretch mean *SD* = .38 m/s; $p = .003$). Even if the velocities for Participant 8 were removed from the no stretch condition (as an outlier), the mean *SD* is still greater than the stretch condition mean *SD* (no-stretch mean SD = .55 m/s, stretch mean SD = .36 m/s; $p = .007$).

Table 1

Peak Impact Velocities (m/s; mean ± SD) for Each Participant

Participant	No Stretch	Stretch	Difference
1	16.40 ± .70	17.15 ± .86	-0.75
2	18.47 ± .51	18.48 ± .27	-0.01
3	18.74 ± .27	19.70 ± .29	-0.96
4	18.77 ± .38	18.66 ± .43	0.11
5	15.74 ± .49	15.58 ± .17	0.16
6	18.13 ± .33	17.73 ± .34	0.40
7	18.90 ± .70	17.17 ± .08	1.73
8	17.15 ± 1.43	14.08 ± .67	3.07
9	17.71 ± .87	17.94 ± .36	-0.23
10	17.67 ± .54	18.20 ± .60	-0.53
11	20.96 ± .69	20.81 ± .38	0.15
12	19.72 ± .64	18.45 ± .11	1.27
13	19.90 ± .63	19.23 ± .33	0.67
14	19.86 ± .87	19.39 ± .58	0.47
15	17.27 ± .45	16.39 ± .16	0.88
16	18.17 ± .60	18.50 ± .80	-0.33
17	18.07 ± .52	17.75 ± .10	0.32
18	18.57 ± .24	18.03 ± .27	0.54
Mean	18.34 ± 1.29	17.96 ± 1.55	0.39

Note. Difference column is the no stretch value minus the stretch value. *SD* for each participant is across three trials. *SD* for the mean is across the participants.

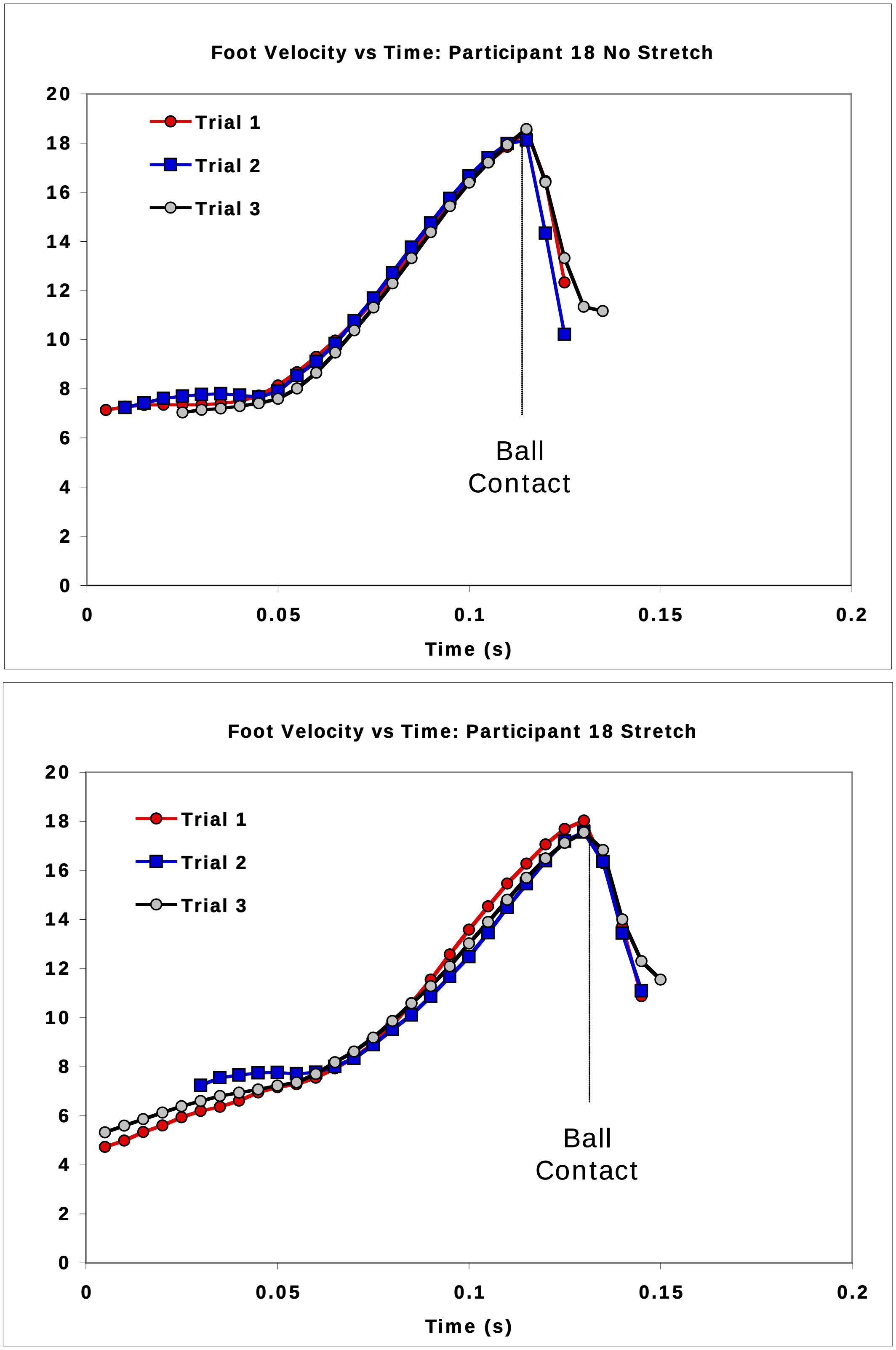
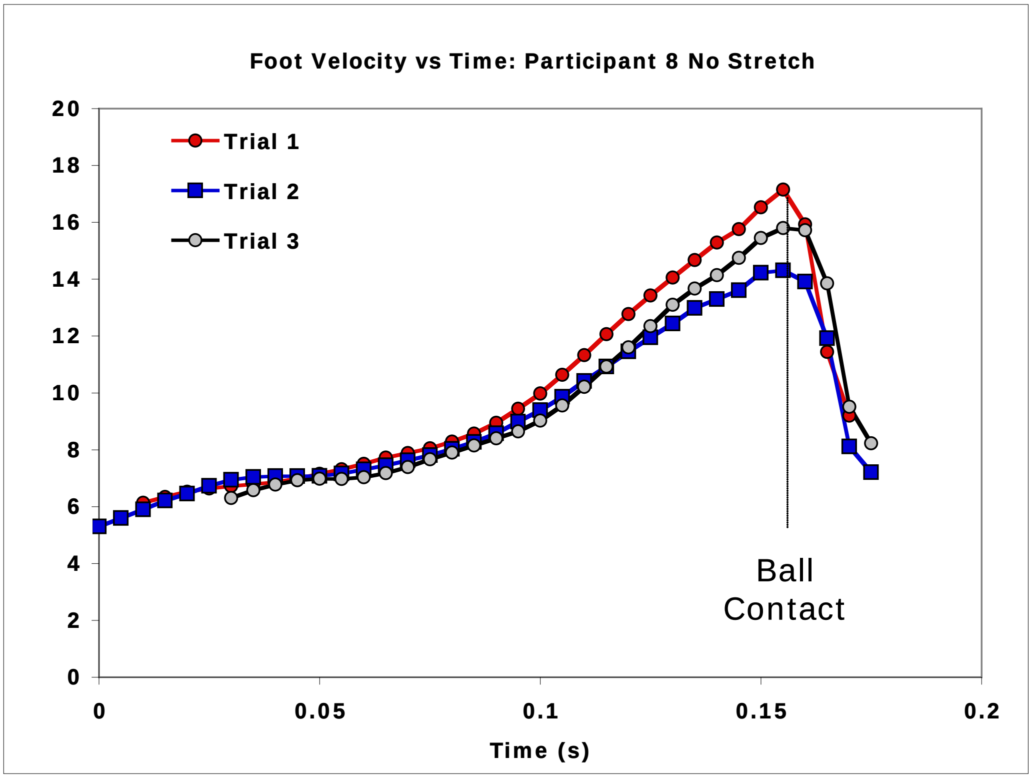


Figure 3. Foot velocity versus time, no stretch and stretch conditions (Participant 18).



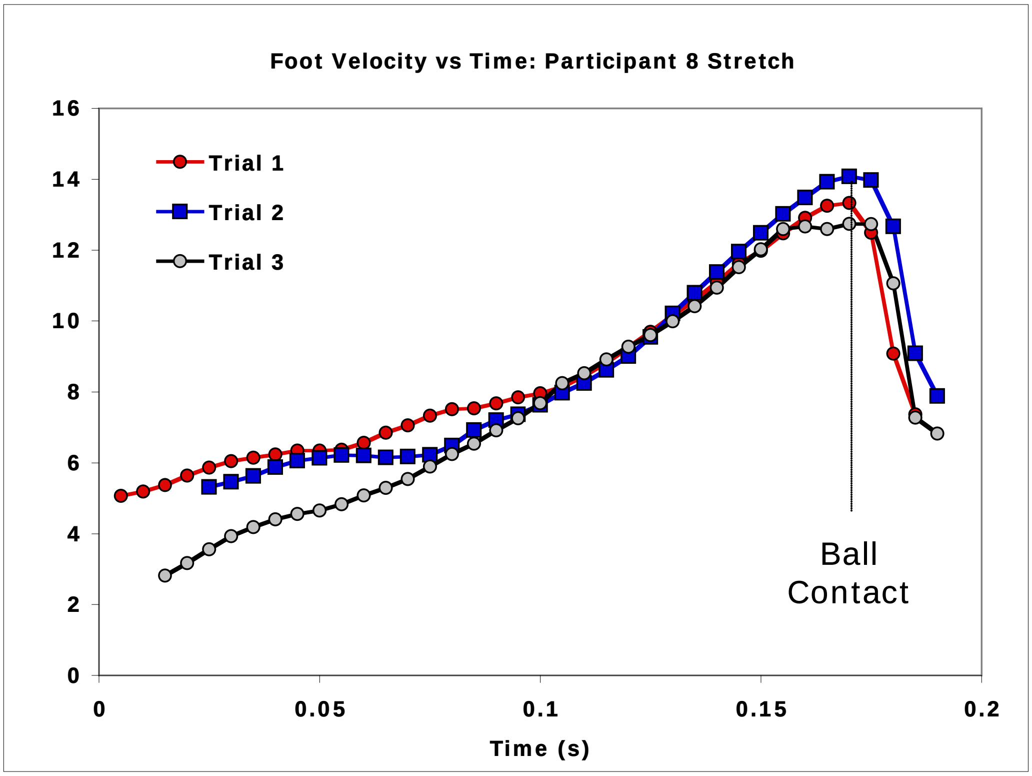


Figure 4. Foot velocity versus time, no stretch and stretch conditions (Participant 8).

CHAPTER V

DISCUSSION

The purpose of this study was to assess the effects of a routine static stretching regimen, as may be performed before a soccer match, on the velocity of the kicking foot during an instep kick. The results indicated that there were no statistical differences between the conditions, which are in agreement with the results of Young et al. (2004) who reported no differences in foot velocity after stretching. Additionally, the mean velocities of the participants in the current study (18.34 ± 1.29 to 17.96 ± 1.55 m/s) are comparable to those of Young et al., in which the male participants exhibited mean velocities of 20.6 ± 0.9 to 20.7 ± 0.8 m/s; the velocity differences between the Young et al. study and the current study may be attributed to gender differences.

Although changes in ROM are often anecdotally attributed to performance increases, confirming research in this area is scarce (Liebesman & Cafarelli, 1994). The stretching regimen utilized in this study may not have been sufficient to cause changes in ROM. This is important because the intention of the stretching regimen used in this study was to mimic pre-match preparation activities (i.e., general warm-up, stretch, perform).

It is possible that stretching may have other kicking effects that were not assessed in this study. Resultant ball velocity and kick accuracy are also important factors to consider in soccer kicking. Specifically, stretching of the ankle may increase the compliance of the ankle joint (Asai et al., 1995) and because rigid objects attenuate less force upon impact, and are therefore capable of imparting more force on impact, it can be assumed that a less rigid (more compliant) object would be less effective at imparting force (Dörge et al., 2002). That means if compliance of the ankle joint increased (i.e., as a result of a stretching), the foot-ankle complex would be less effective at transferring momentum, or imparting force, to the ball. Therefore, increased compliance could result in less accurate kicking or decreased resultant ball velocity.

Furthermore, acute static stretching has previously resulted in statistical differences in balance, movement time, and reaction time (Behm et al., 2004). Although Behm et al. did not find any significant force differences between conditions, the complexity of the soccer kick is such that negative effects in any of the other areas discussed above could hinder overall kick performance (i.e., kick accuracy) and should be considered in future research.

ROM was not included as an assessment in this study because the focus was the effect of a routine stretching regimen on the instep soccer kick. As such, it is unknown if ROM changed after stretching. This may be a moot point, however, because participants do not achieve maximum ROM during the soccer kick (Young et al., 2004).

There are also few velocity results that are noteworthy. Twelve of the 18 participants had greater no stretch velocities compared to stretch velocities (see difference column in Table 1). Although this group is just more than half of the total sample of participants, the tendency of the positive values of the difference column to be greater (mean of positive values = .81 m/s; mean of negative values = .46 m/s) may indicate that not stretching before performance for more than half of the participants could be recommended. Of these differences, the greatest was 3.07 m/s, exhibited by Participant 8 and could be beneficial to that participant.

However, the greater mean *SD* of the no stretch condition (.62 m/s) compared to the mean *SD* of the stretch condition (.38 m/s) also needs to be considered. The greater *SD* in the no stretch condition means that the participants had less consistent data during the no stretch trials. This could have a negative effect on performance because the goal of many athletes is not only to perform well, but also consistently. Therefore, any recommendations the velocity data may seem to suggest, as discussed above, should be carefully considered in light of data consistency. When these two ideas are juxtaposed, it appears that the recommendation of stretching may best be at the discretion of the participant.

Research on the application of previous research findings to athletic settings is still necessary. A more vigorous or lengthy stretching regimen may show performance decreases similar to those reported by others (Nelson et al., 2001; Young & Behm, 2003) and could be another topic for further research. Furthermore, research on the effects of dynamic warm-up activities that closely mimic sport performances could provide valuable insights into pre-performance preparation techniques.

CHAPTER VI

SUMMARY AND CONCLUSION

In summary, the literature review illuminated two common results of static stretching on performance. Namely, acute static stretching either tends to lead to significant decreases in performance, or acute static stretching has no performance effect. There were no studies that resulted in significant increases in performance.

The study methods were discussed in detail, including the participants themselves (age, mass, height, etc.), the equipment used (soccer ball, cameras, net, etc.), the procedures employed (stretching methods, stretching time, organization of the conditions, etc.), and the statistical analyses performed on the collected data (t test & Cohen's d).

The results of the present study indicated that a routine static stretch performed one time for 30 s, similar to athletic warm-up routines, had no statistically significant effect ($p = .102$, $d = .3$) on the velocity of the kicking foot immediately prior to impact with a soccer ball during the instep kick. There were, however, some potentially interesting results that were mentioned in the results chapter and elaborated upon in the discussion chapter. Additionally, further research ideas and some of the limits of the current study were discussed. Chief among these was that it was possible that the stretching regimen was not vigorous enough to elicit a performance effect. However, because the warm-up routine itself was the primary aim of this study (i.e., to mimic typical pre-performance preparation activities) and ROM was not assessed, it is unknown if the routine used in this study was sufficient enough to change ROM or assess the performance effects of changes in ROM.

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APPENDICES

Appendix A: Informed Consent Form

Informed Consent

CONSENT TO PARTICIPATE IN RESEARCH

Effects of Static Stretching on Foot Impact
Velocity During the Instep Soccer Kick

Introduction/ Purpose Professor Eadric Bressel and student Craig Workman in the Department of Health, Physical Education, and Recreation at Utah State University (USU) is conducting a research study to find out more about how stretching effects foot speed during soccer kick performance. You have been asked to take part because you are skilled a soccer player and will provide an excellent source of research participation. There will be approximately 20 total participants in this research.

Procedures If you agree to be in this research study, the following will happen to you. You will be asked to attend two test sessions separated by no less than 48 hours. During one test session you will be asked to jog at your own pace for five minutes as a warm up. After this self-paced jog, you will sit quietly for six minutes after which you will be asked to maximally kick a soccer ball from the ground three times into a net. The other session will follow this same procedure, except instead of sitting quietly for six minutes you will undergo a series of six stretches to your ankle knee and hip joints. You will be asked to avoid stretching and fatiguing activities other than those performed for normal team practice sessions on the days of your participation in this study. Each session will take place within a 30 minute period at the biomechanics laboratory (215A) in the HPER building

New Findings During the course of this research study, you will be informed of any significant new findings (either good or bad), such as changes in the risks or benefits resulting from participation in the research, or new alternatives to participation that might cause you to change your mind about continuing in the study. If new information is obtained that is relevant or useful to you, or if the procedures and/or methods change at any time throughout this study, your consent to continue participating in this study will be obtained again.

Risks Participation in this research study may involve some added risks or discomforts. For example, you will experience mild discomfort during stretching. However, since you are stretching to your own pain threshold, this discomfort should be minimized. No form of compensation for medical treatment is available for a study-related injury from USU. In the event of injury you will be referred to a treatment facility.

Benefits There may not be any direct benefit to you from these procedures. The investigator, however, may learn more about the effects of stretching on soccer kick performance. These effects may be beneficial to you in your choice of stretching or not stretching before a soccer match. We will provide a summary of your results and a summary of the study's findings upon your request.

Explanation & offer to answer questions Craig Workman has explained this research study to you and answered your questions. If you have other questions or research-related problems, you may reach Professor Eadric Bressel at (435) 797- 7216

Extra Cost(s) There will be no extra costs to you for your participation in this study.

Payment/Compensation You will not receive any payment as compensation for your participation in this study.

Voluntary nature of participation and right to withdraw without consequence
Participation in research is entirely voluntary. You may refuse to participate or withdraw at any time without consequence or loss of benefits. You may be withdrawn from this study without your consent by the investigator if:
1. In the event that a physical injury (i.e., muscle or ligament injury) should occur that is perceived by the investigators as severe enough to hinder a maximal kicking effort.
2. If the subject fails to follow the research protocol.
3. If the subject becomes pregnant.

Confidentiality Research records will be kept confidential, consistent with federal and state regulations. Only the investigators will have access to the data which will be kept in a locked file cabinet in a locked room. Personal, identifiable information will be kept for three months and then destroyed. Videotape information will also be kept for three months and then destroyed. The results of this study may be presented at professional meetings and published in professional journals.

IRB Approval Statement The Institutional Review Board for the protection of human participants at USU has approved this research study. If you have any pertinent questions or concerns about your rights or a research-related injury, you may contact the IRB Administrator at (435) 797-0567. If you have a concern or complaint about the research and you would like to contact someone other than the research team, you may contact the IRB Administrator to obtain information or to offer input.

Copy of consent You have been given two copies of this Informed Consent. Please sign both copies and keep one copy for your files.

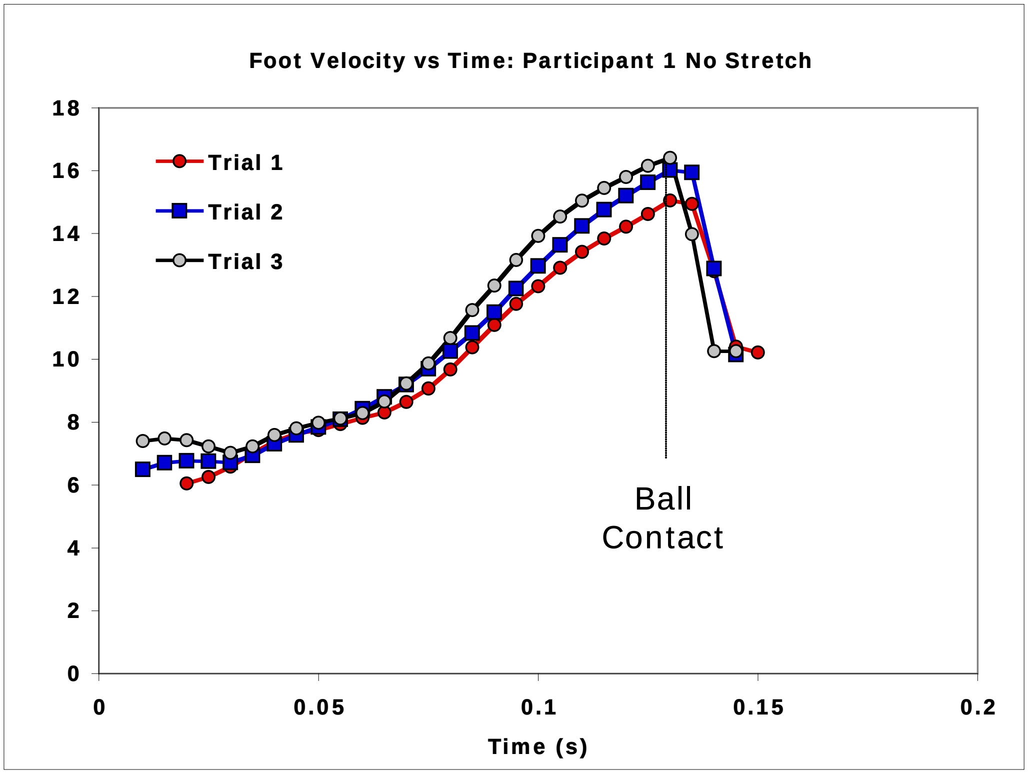
Investigator Statement "I certify that the research study has been explained to the individual, by me or my research staff, and that the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered."

Dr. Eadric Bressel, Principal Investigator	Craig Workman, Student Researcher
(435) 797-7216	craig.workman@aggiemail.usu.edu

Signature of Participant By signing below, I agree to participate.

Participant's signature	Date

Appendix B: Velocity Figures for Participants.



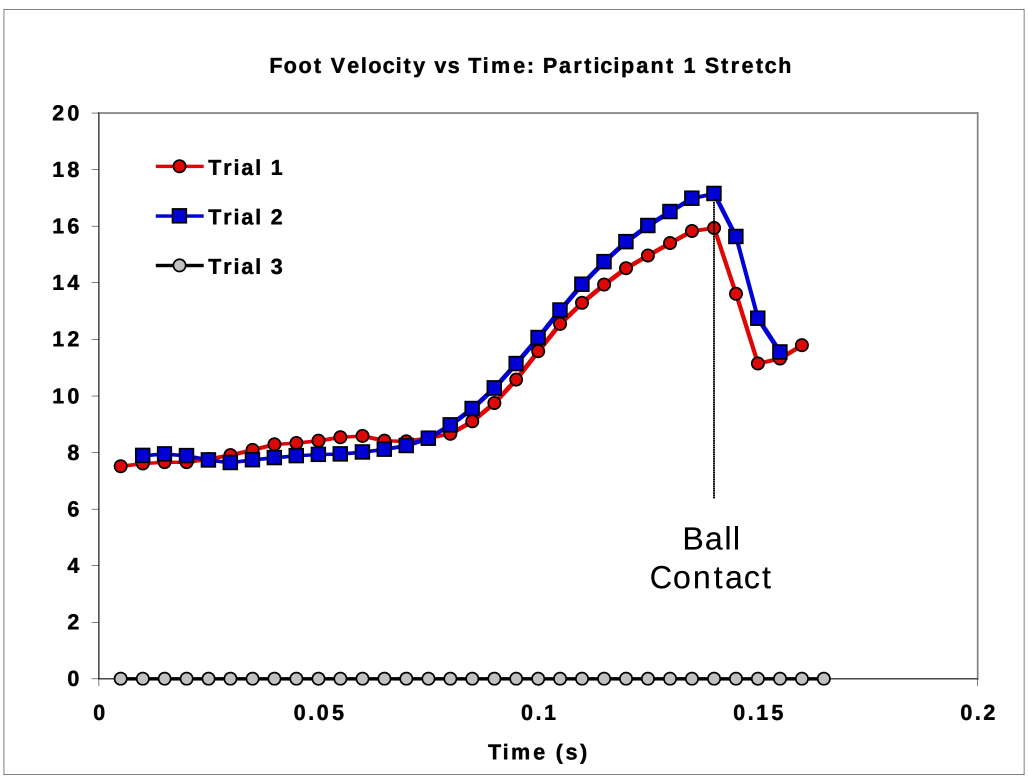
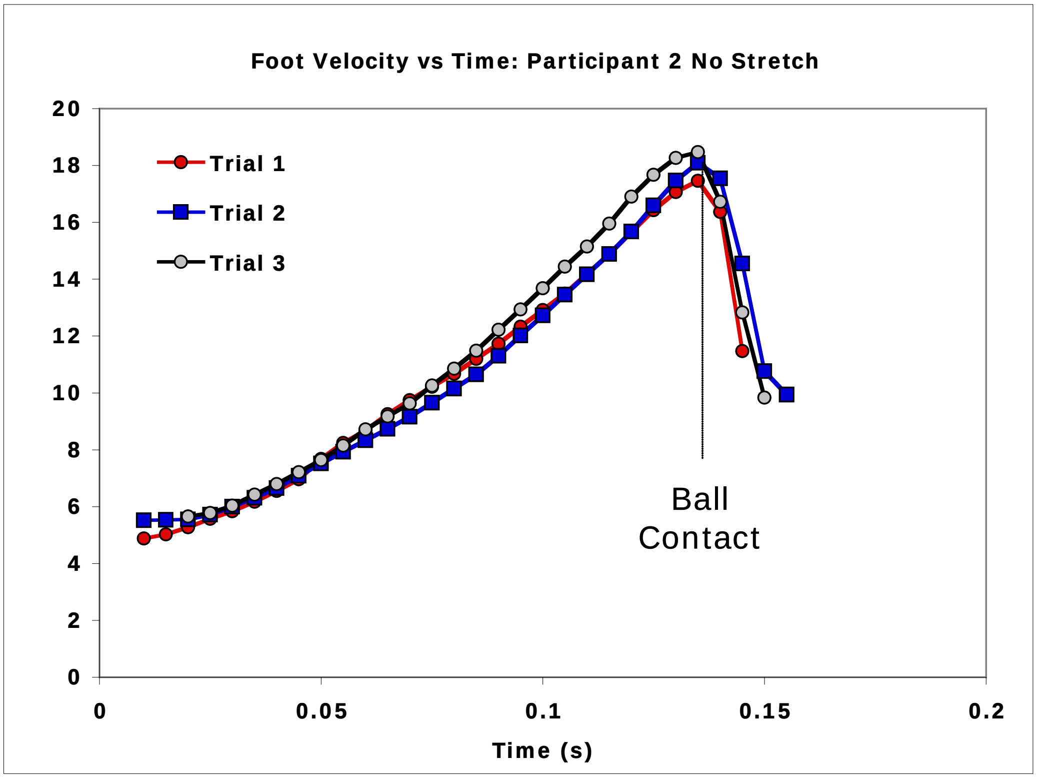


Figure 5. Foot velocity versus time, no stretch and stretch conditions (Participant 1).



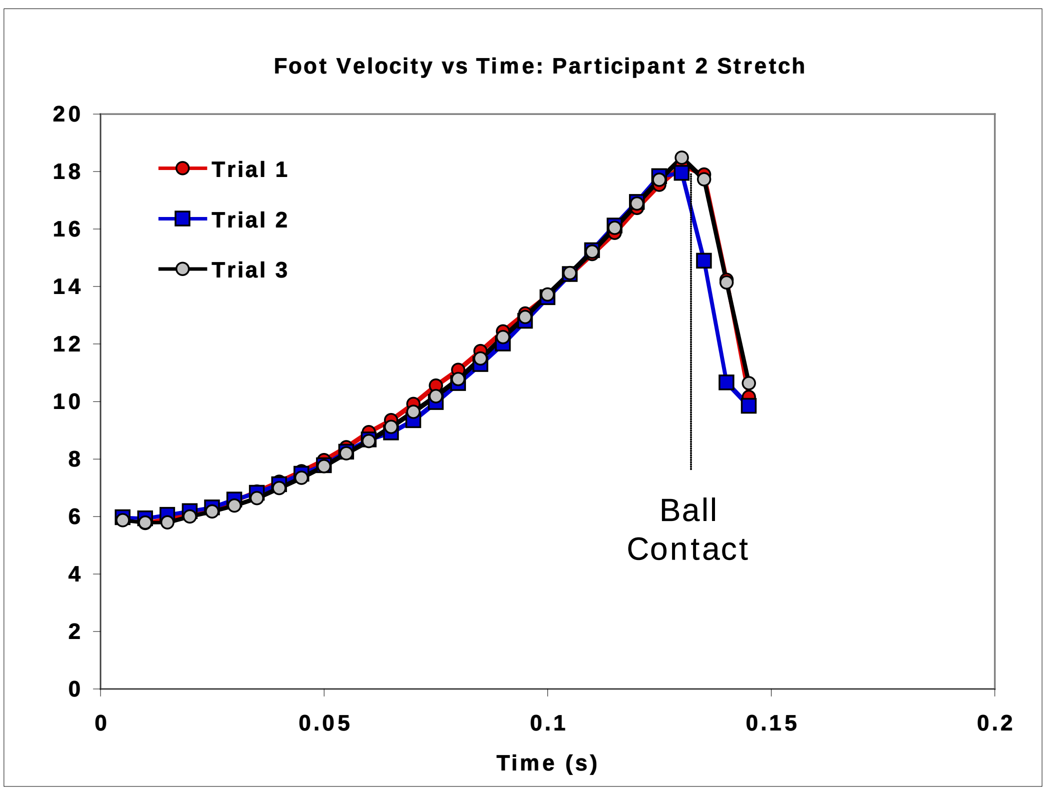


Figure 6. Foot velocity versus time, no stretch and stretch conditions (Participant 2).

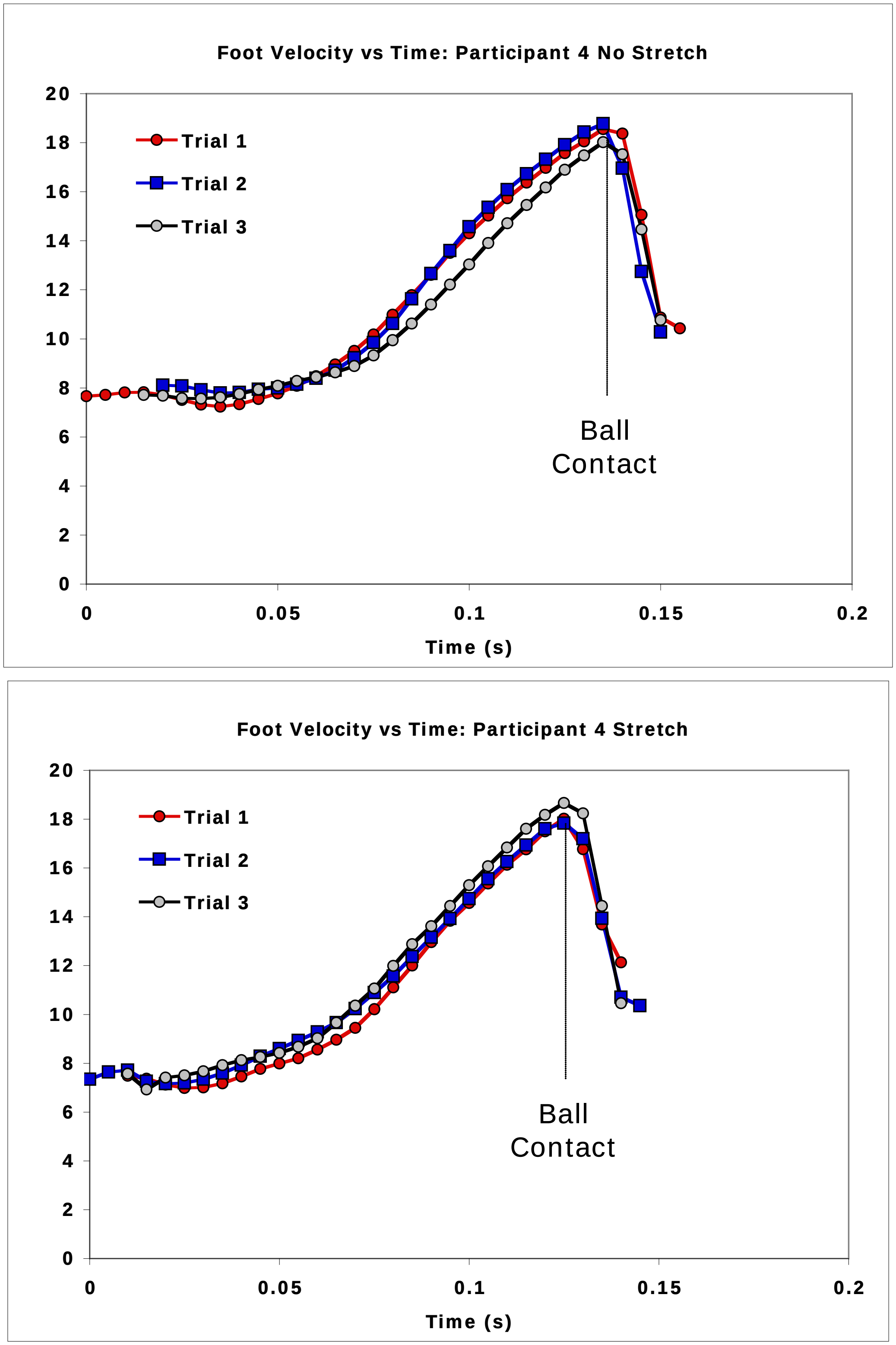
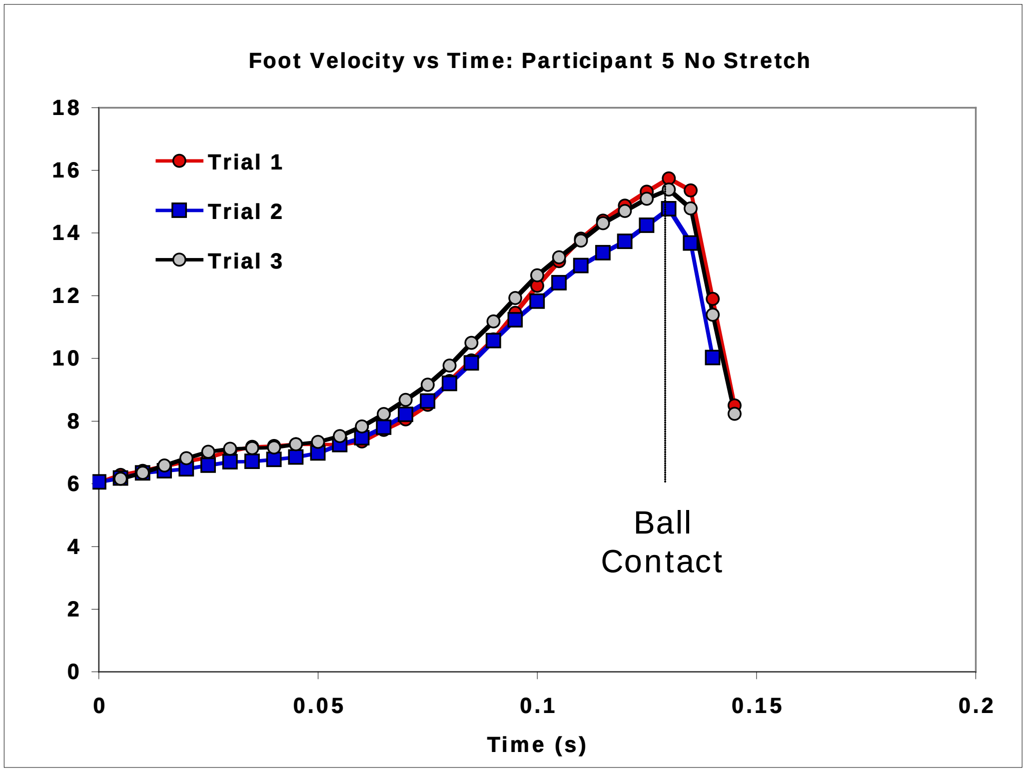


Figure 7. Foot velocity versus time, no stretch and stretch conditions (Participant 4).



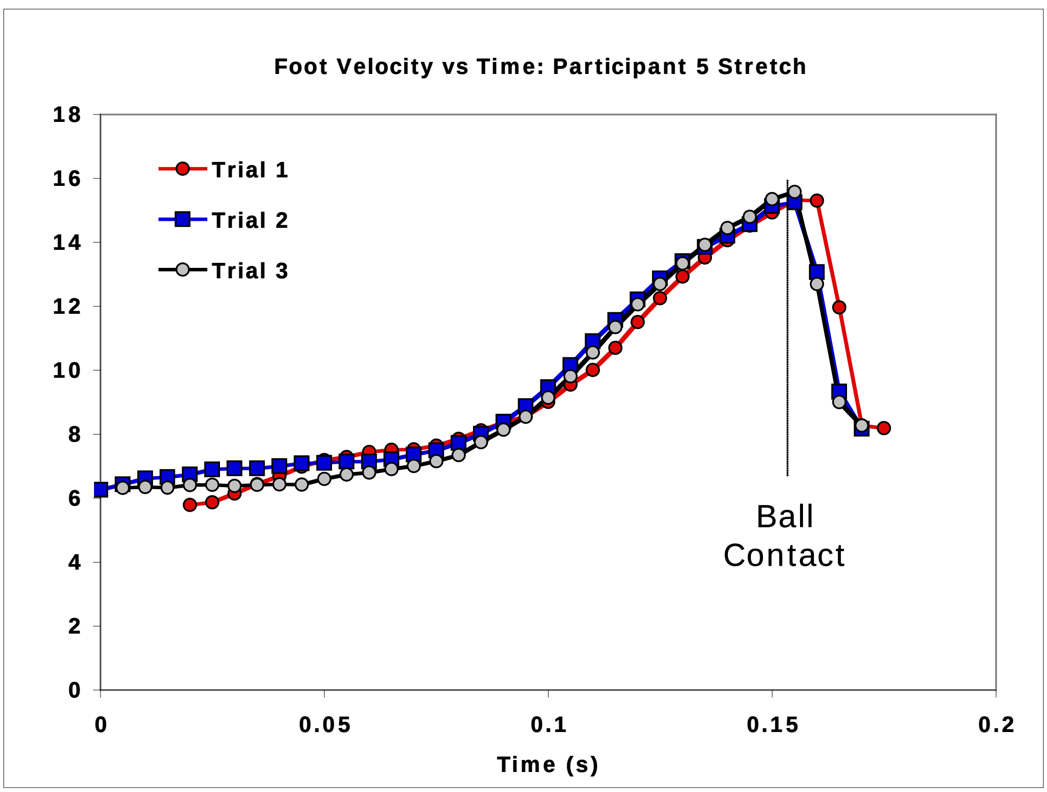
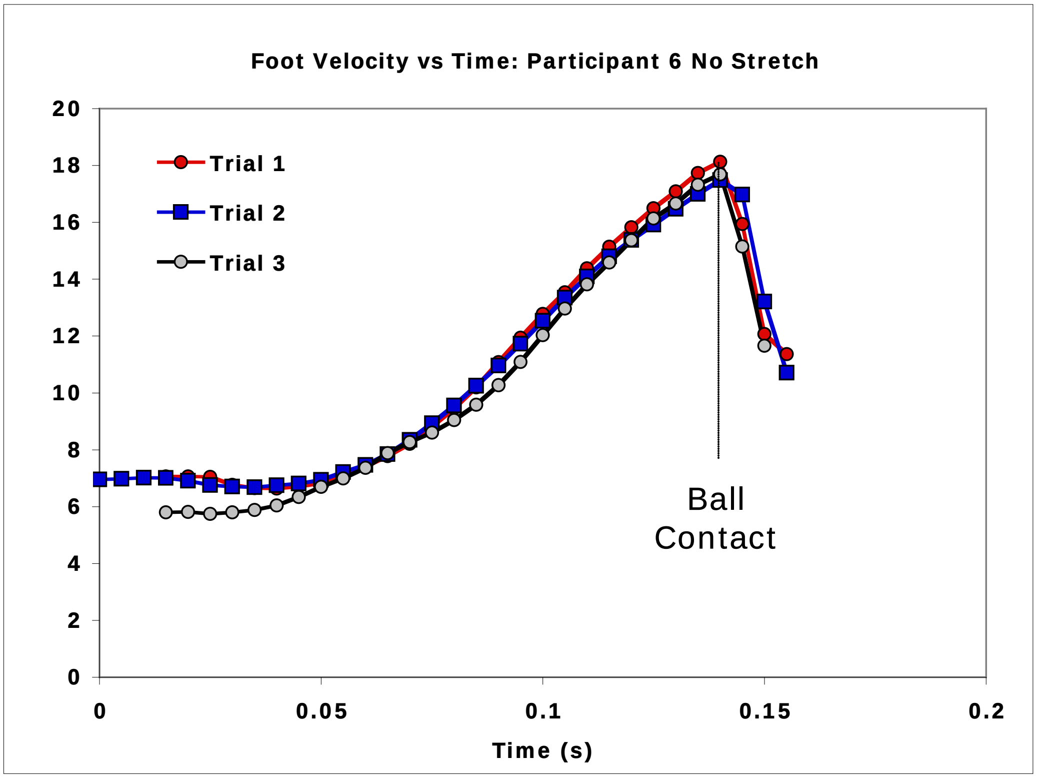


Figure 8. Foot velocity versus time, no stretch and stretch conditions (Participant 5).



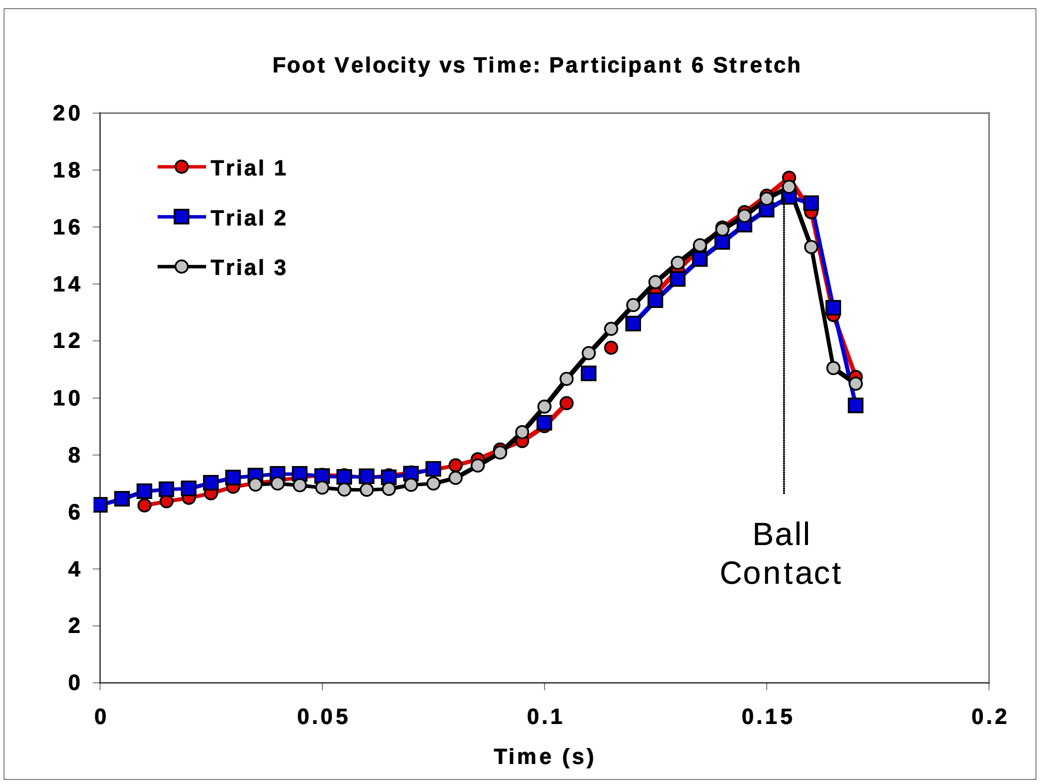
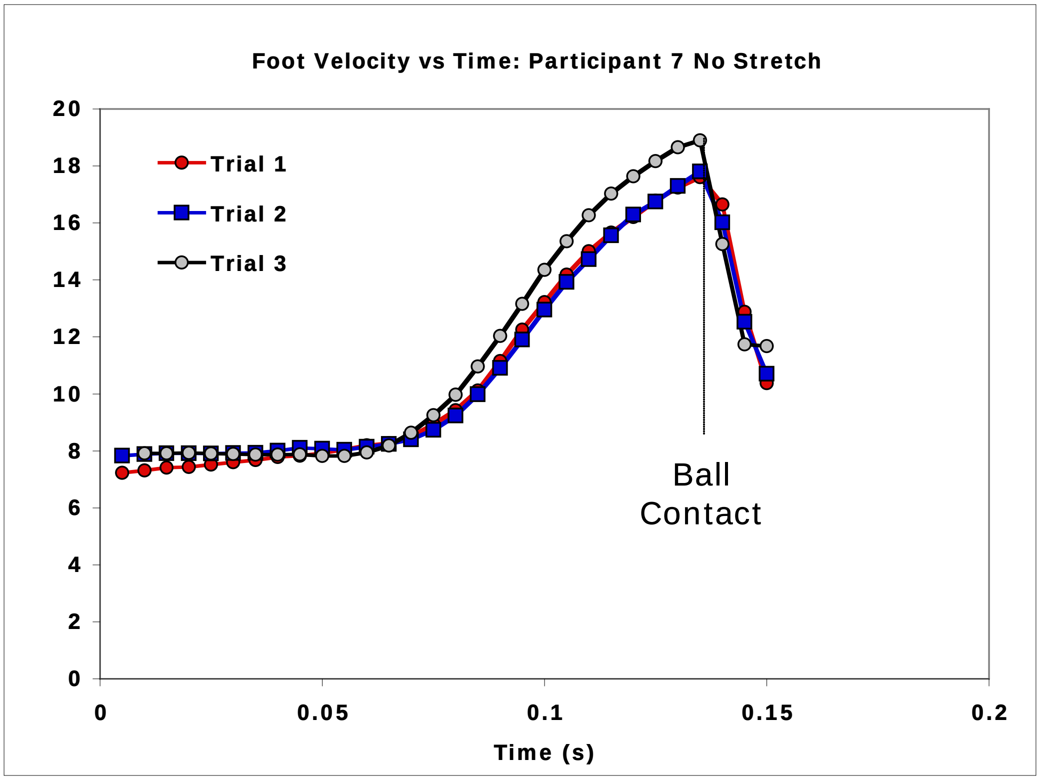


Figure 9. Foot velocity versus time, no stretch and stretch conditions (Participant 6).



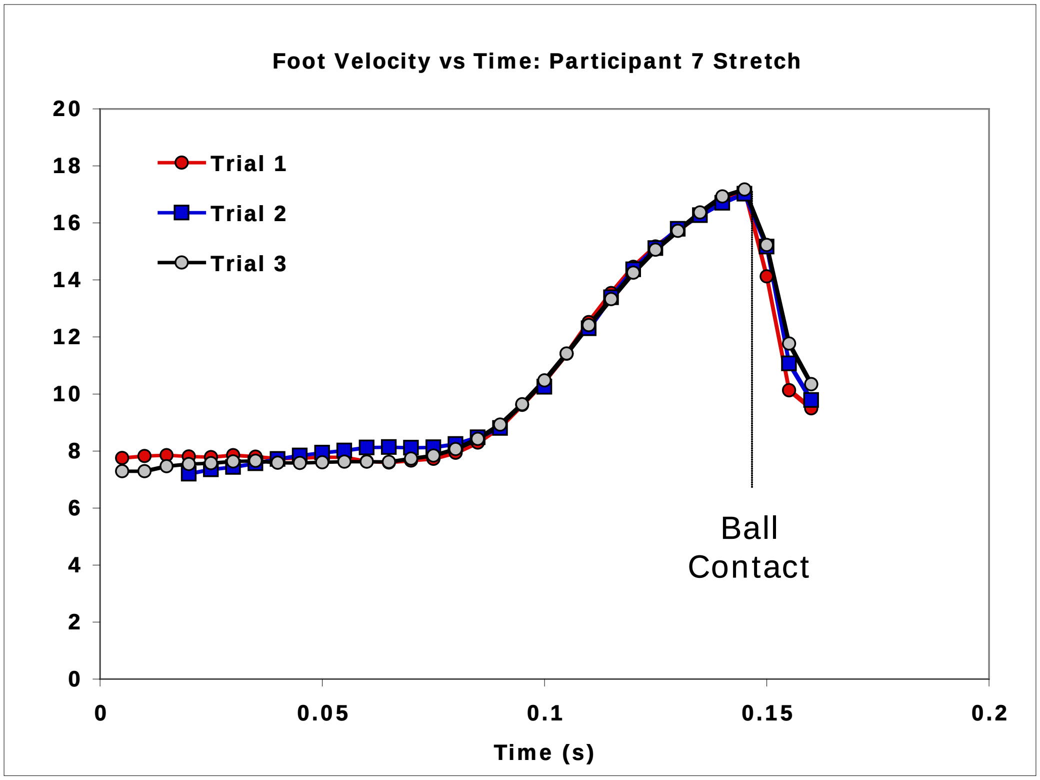
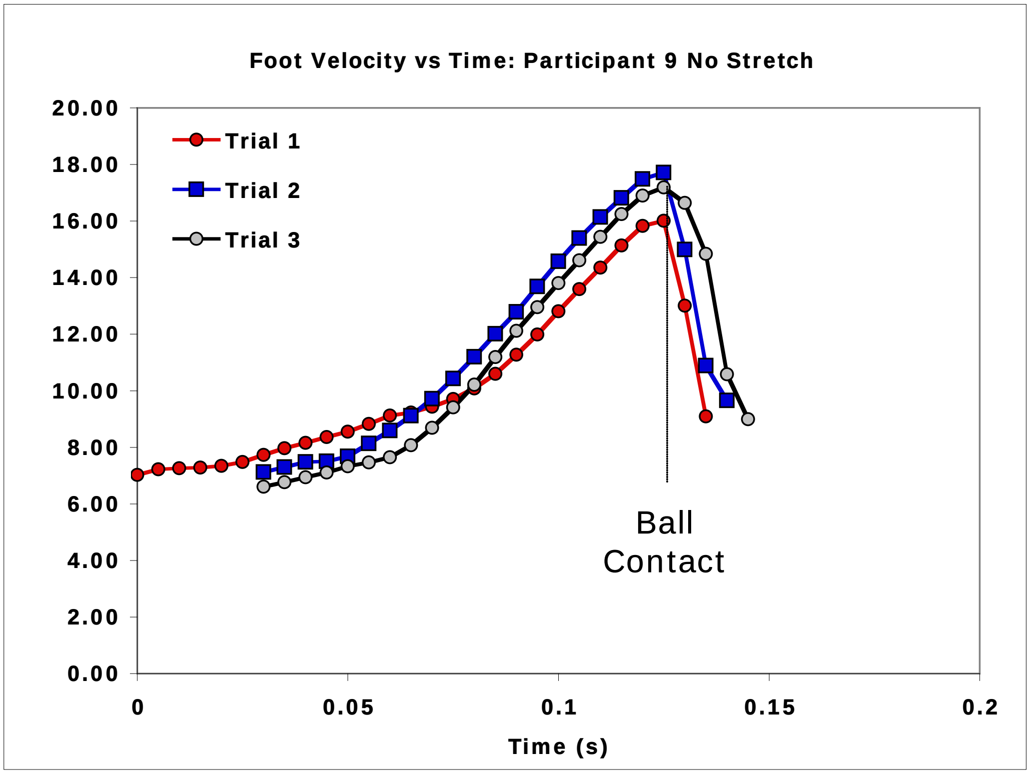


Figure 10. Foot velocity versus time, no stretch and stretch conditions (Participant 7).



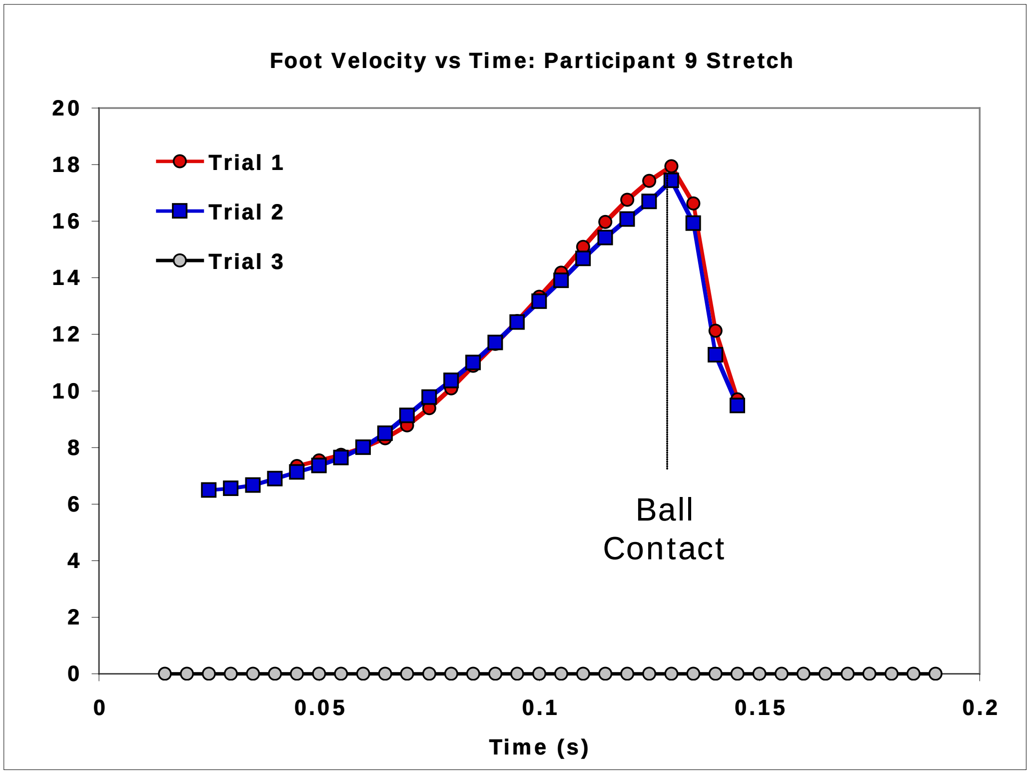
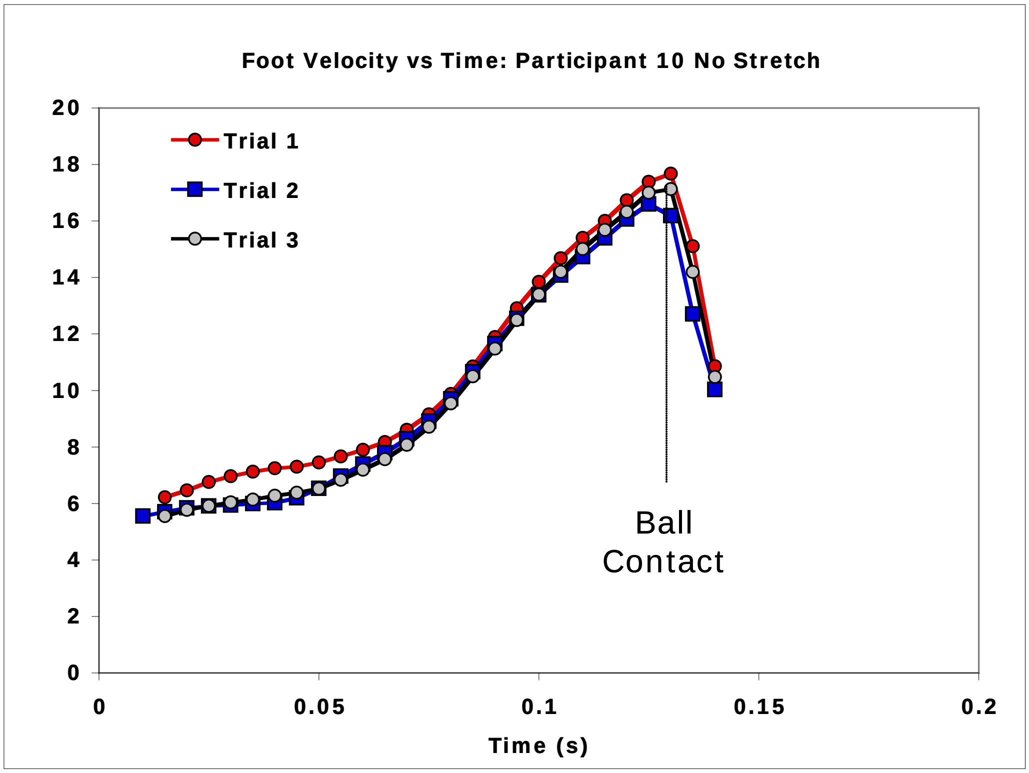


Figure 11. Foot velocity versus time, no stretch and stretch conditions (Participant 9).



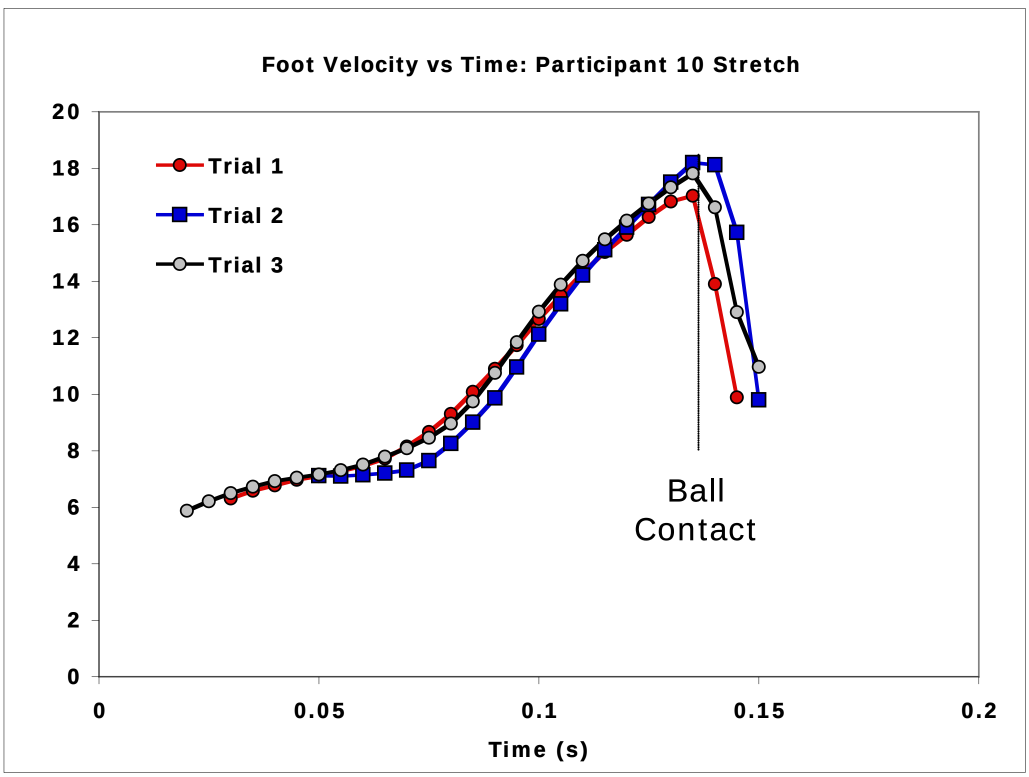
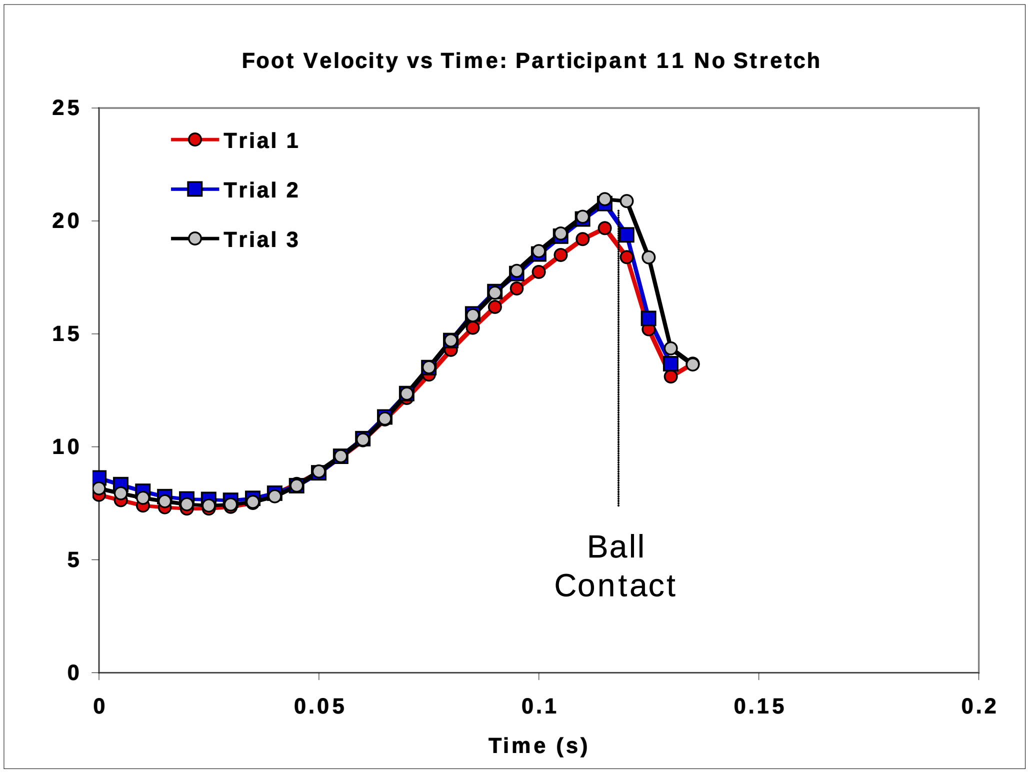


Figure 12. Foot velocity versus time, no stretch and stretch conditions (Participant 10).



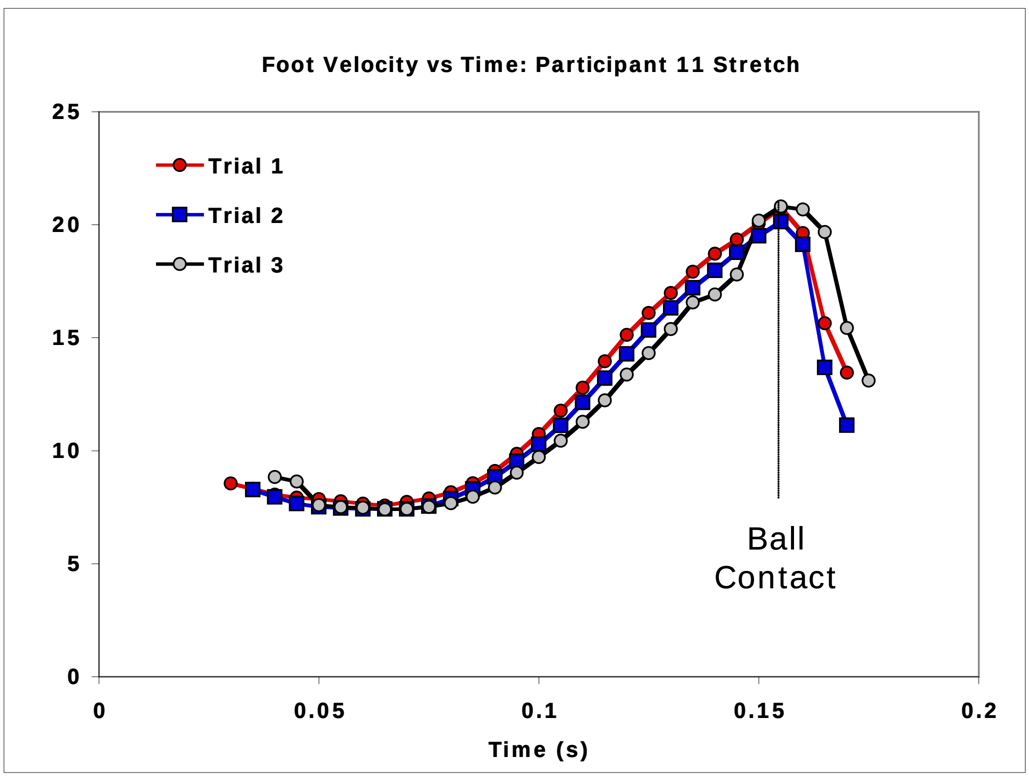
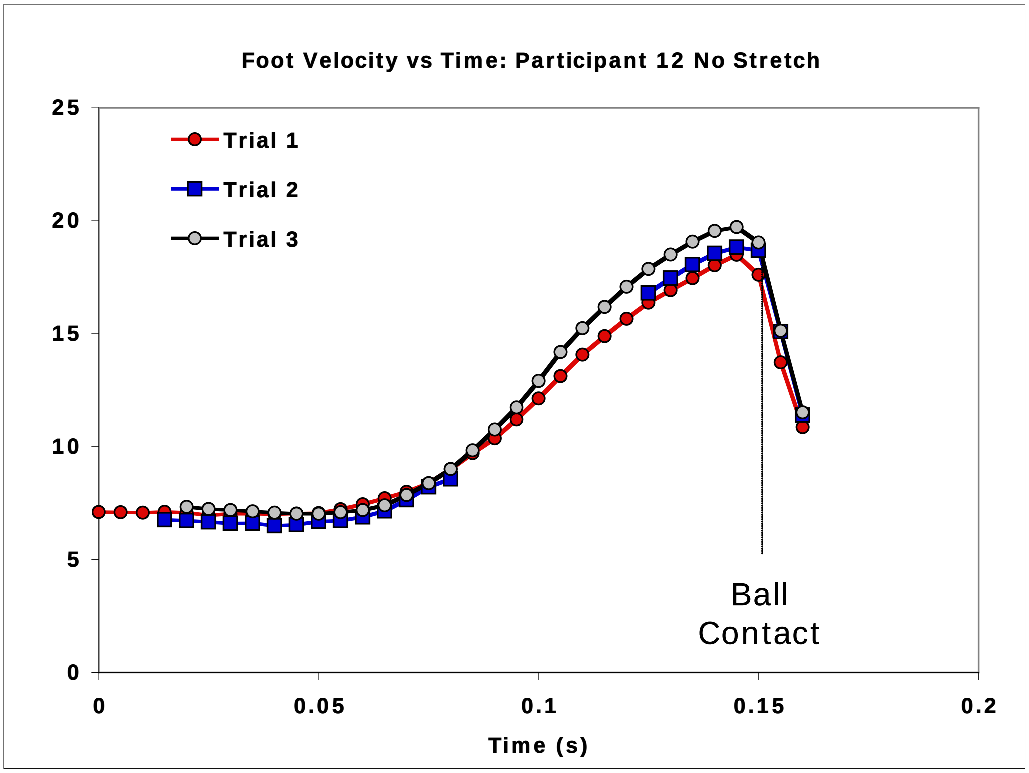


Figure 13. Foot velocity versus time, no stretch and stretch conditions (Participant 11).



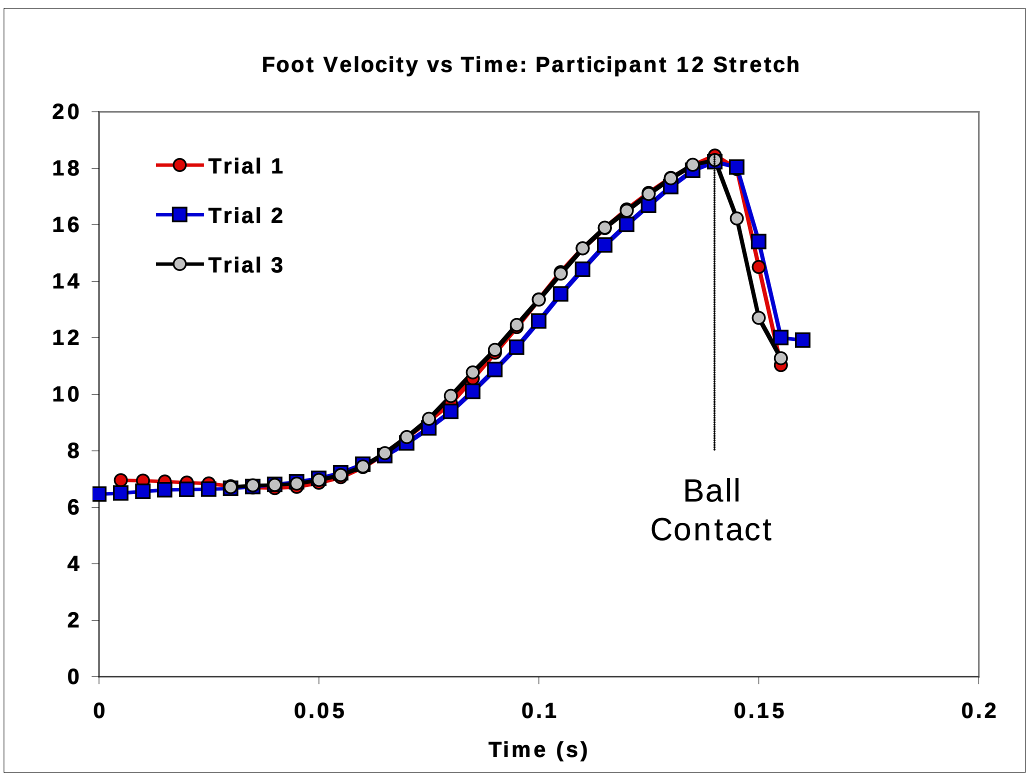


Figure 14. Foot velocity versus time, no stretch and stretch conditions (Participant 12).

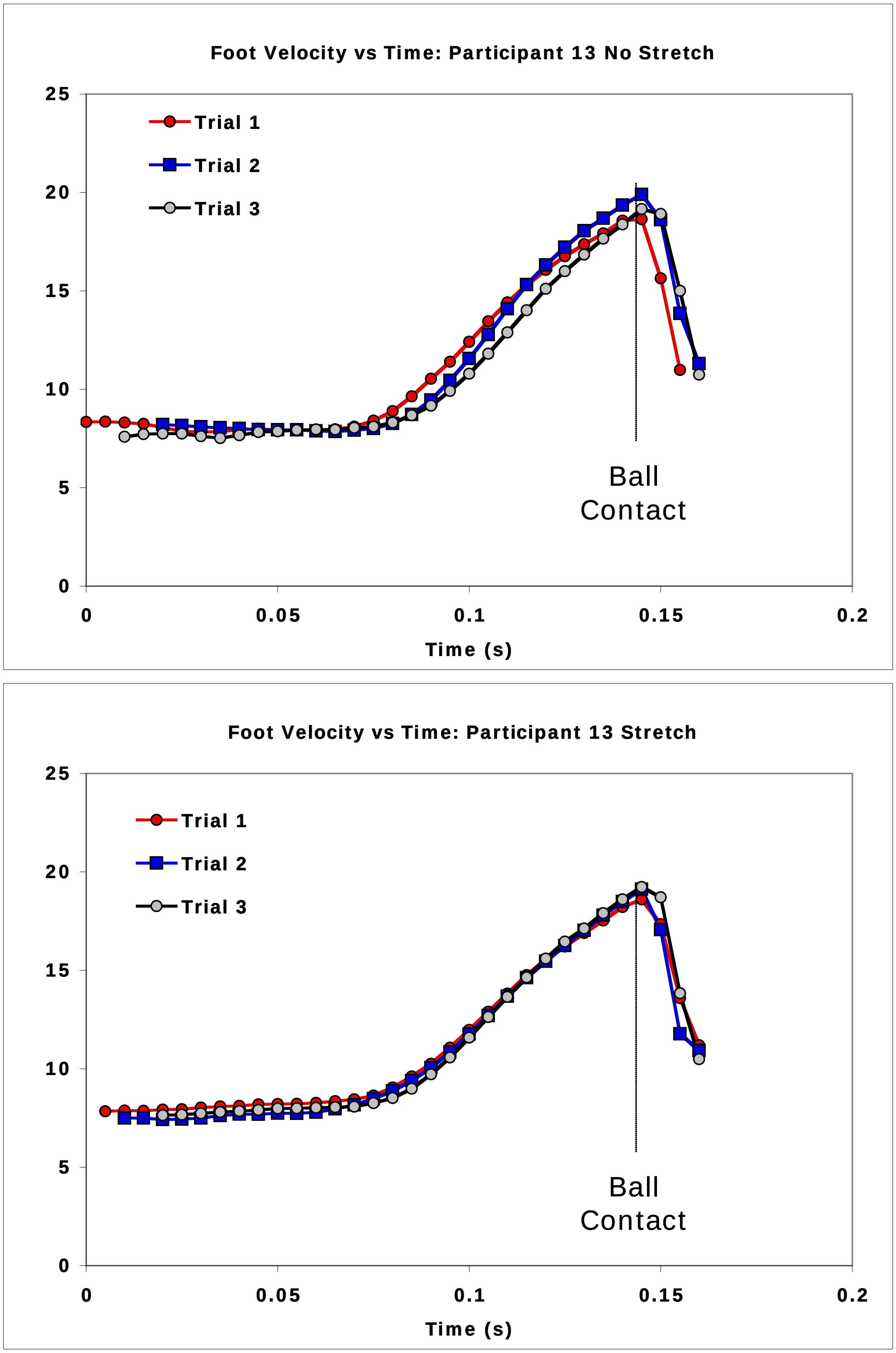
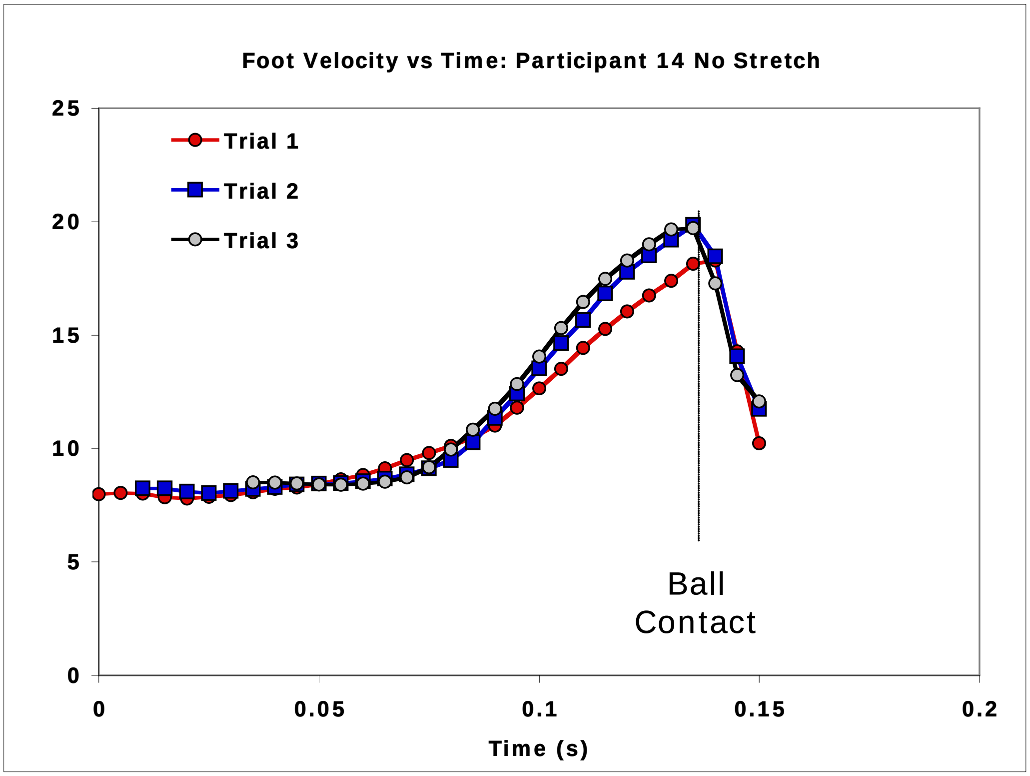


Figure 15. Foot velocity versus time, no stretch and stretch conditions (Participant 13).



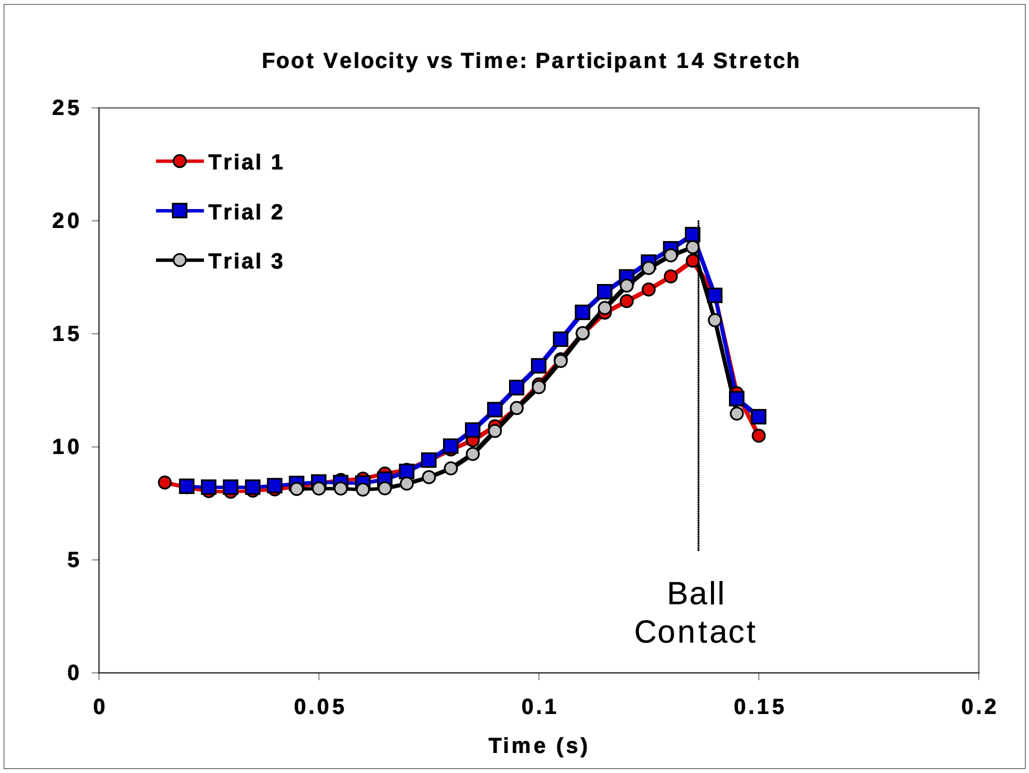


Figure 16. Foot velocity versus time, no stretch and stretch conditions (Participant 14).

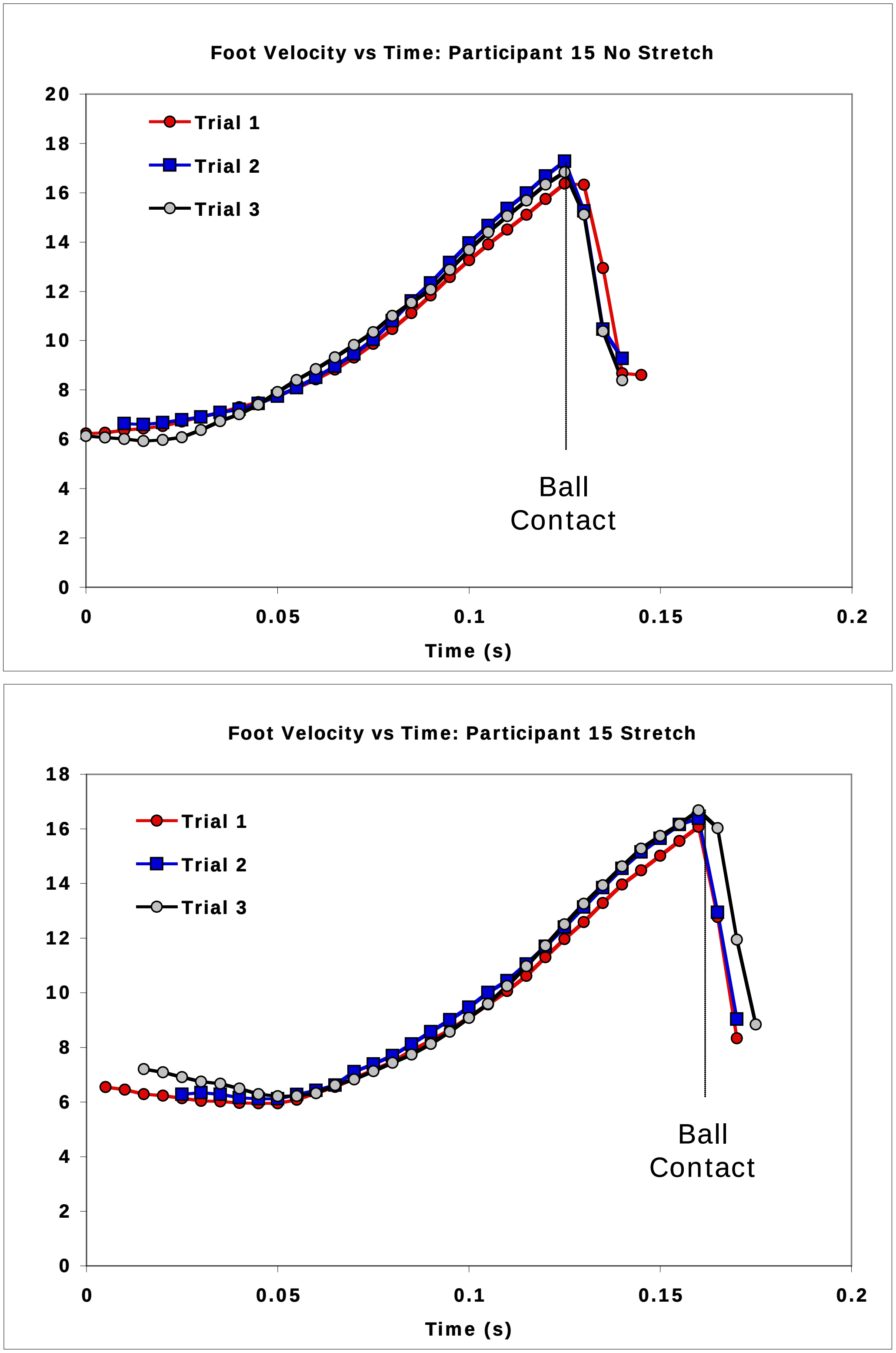
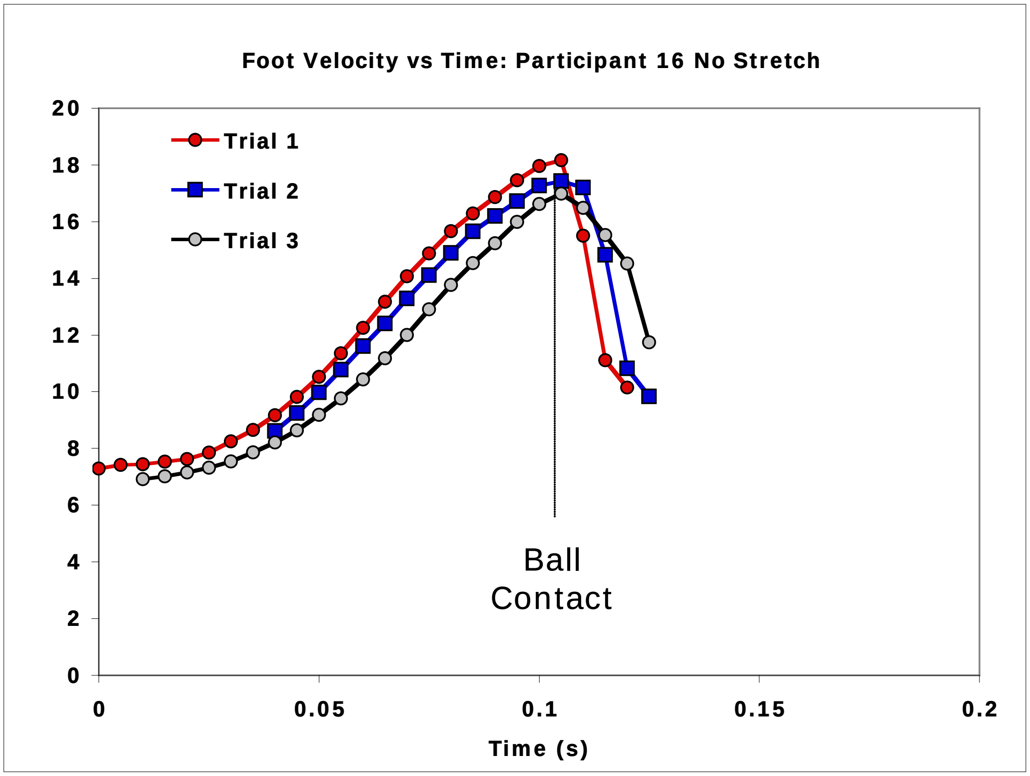


Figure 17. Foot velocity versus time, no stretch and stretch conditions (Participant 15).



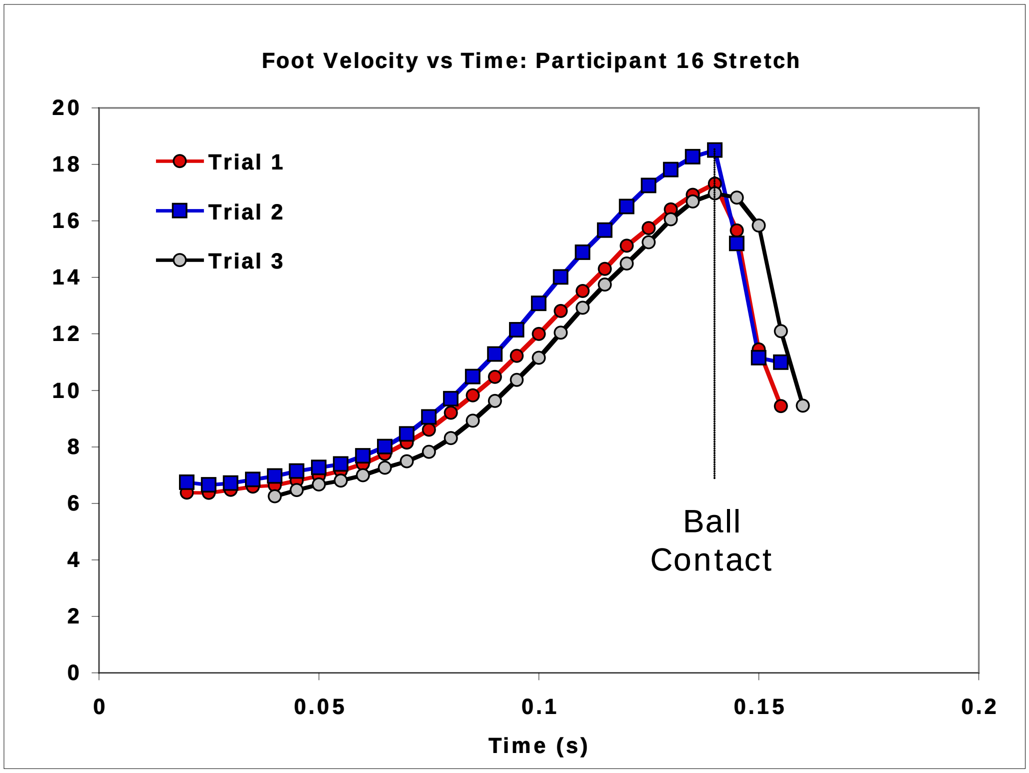
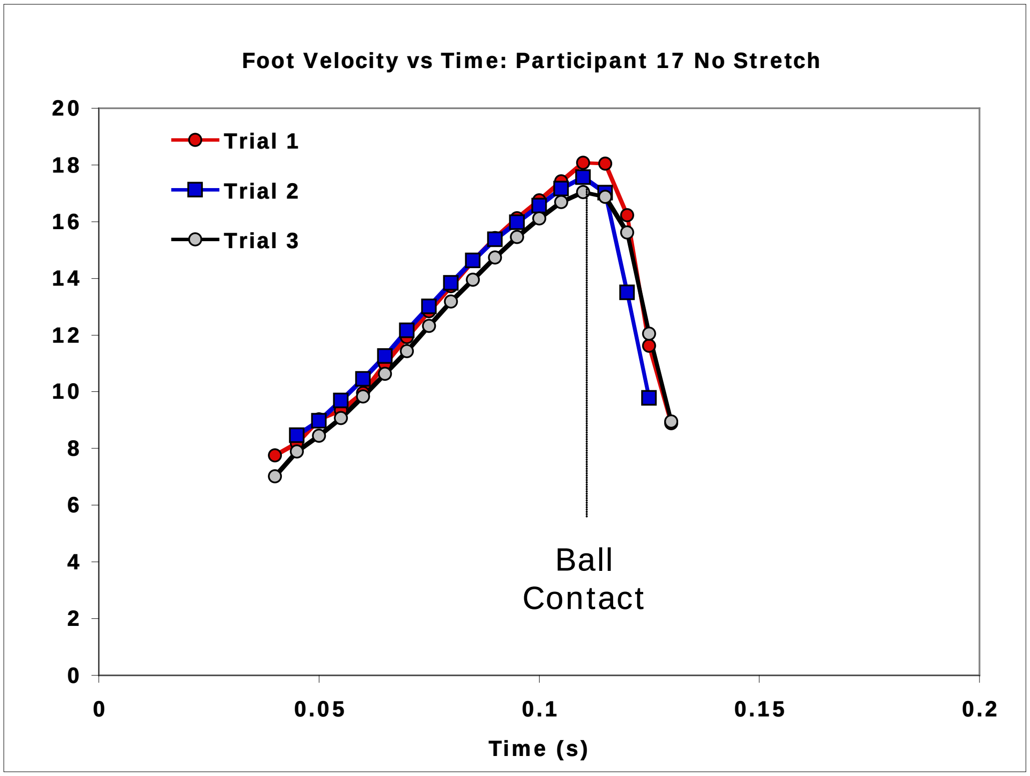


Figure 18. Foot velocity versus time, no stretch and stretch conditions (Participant 16).



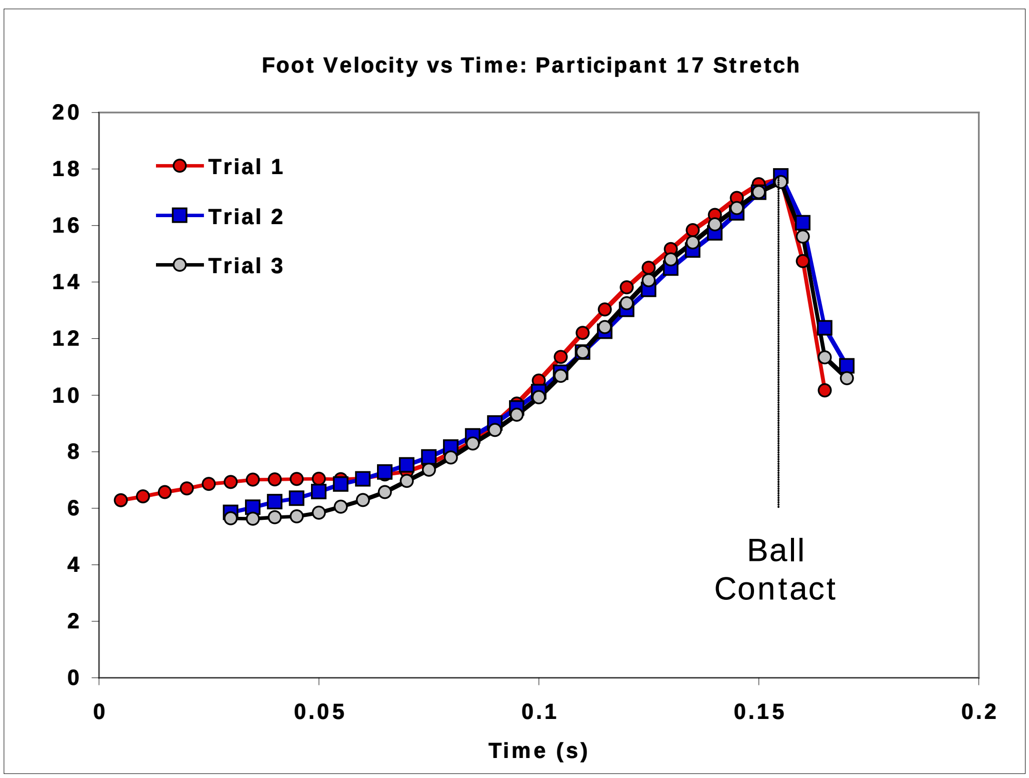


Figure 19. Foot velocity versus time, no stretch and stretch conditions (Participant 17).