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American Kettlebell Swing and the Risk of Lumbar Spine Injury

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American Kettlebell Swing and the Risk of Lumbar Spine Injury

Honors Thesis

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Submitted to the Movement Arts, Health Promotion and Leisure Studies Department at

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Abstract

CrossFit is a fitness routine that utilizes the American kettlebell swing in their workouts. The Russian swing has been the traditional swing movement performed with the kettlebell swung to chest height, but with the American swing the kettlebell is propelled to an overhead position, which may increase the risk for a lumbar spine injury. However, research has yet to evaluate the American kettlebell swing mechanics and its influence on spinal injuries. Therefore, the purpose of this study was to examine the kinematics of the lumbar spine from maximum hip extension to the overhead position of the American kettlebell swing with two different loads (16kg and 24kg), five subjects and three focus positions the hike, Russian height and overhead. Fourteen 3D joint reflective markers were placed on the right side of the body. A two-dimensional kinematic analysis of the lumbar spine, shoulder and elbow were conducted with DartFish Pro Suite v 6.0 on repetitions 2-4 with the results compared to a literature review of safe lumbar spine positions. Results determined lumbar extension and shoulder angles were highest during the OH position. Lumbar angles were fairly consistent between weights with the greatest mean amount of hyperextension approximately 25° past neutral. Shoulder angles were higher in all positions with the 16kg kettlebell in comparison to the 24kg kettlebell. Elbow angles were highest during the H position. Velocities ranged from approximately 550 deg/sec to -550 deg/sec with most results between 150 deg/sec to -150 deg/sec. Further research is needed to determine the lumbar spine injury risk.

Most adults will experience low back pain (LBP) at some point in their lives.[1] The causes for LBP may be related to normal activities, such as movement or exercise, but may not always be clear and then labeled nonspecific LBP. A variety of exercises, such as planks, bridges, bird dogs, pull-ups, deadlifts, rows and good mornings have been used to strengthen the back, but certain strengthening exercise movements, such as the squat have been linked to LBP.[2] This may be related to the individual's technique, movement pattern or load because body position and movement while under load significantly influence intradisc pressure.[2] The American kettlebell swing is a similar movement to the squat, but is performed at a higher velocity for many more repetitions and the load is moved independent from the body. Kettlebells have been used to improve strength, conditioning, movement patterns, and flexibility. Even though the American kettlebell swing movement is similar to the squat movement (hip and knee flexion, followed by hip and knee extension), the high velocity aspect of the movement has not been researched as thoroughly as the standard speed of the squat movement, so its value for preventing or rehabilitating LBP is relatively unknown. This lack of knowledge on kettlebell training may be concerning because acute low back injuries in athletes and chronic LBP conditions have been linked to repetitive (fatigue) weight training, which causes damage to vertebral bodies, growth plates and intervertebral discs.[2] The purpose of this research was to determine the lumbar flexion and extension angles and velocities of the American kettlebell swing from maximum hip extension to the overhead position (before kettlebell descent) and compare the lumbar angles to suggested safe positions for the lumbar spine.

Review of Literature

Current literature was reviewed to provide a better understanding of the potential risks or benefits of the American kettlebell swing as a rehabilitation exercise in comparison to the squat. The topics examined to answer this question involved spinal anatomy, low back pain, kettlebells, low back strength training and therapeutic exercise.

Spinal Anatomy: Structure and Function

A human spinal column consists of five vertebral sections: cervical, thoracic, lumbar, sacrum and coccyx, which have 26 irregular bones that interact to form a flexible curved structure that extends from the skull to the pelvis (Figure 1). The cervical section articulates with the skull and consists of seven vertebrae, followed inferiorly by the 12 thoracic vertebrae, five lumbar vertebrae, the sacrum and the coccyx to form the s-shaped vertebral column. The primary weight-bearing surface of each vertebra is the body, which has two pedicles projecting from the posterior to form the anterior portion of the neural arch, while the posterior portion of the arch is created by the lamina, which creates a protective tunnel for the spinal cord to pass through safely. The cervical section has a lordotic curve, is formed by the smallest vertebrae and offers the greatest range of motion. The thoracic section articulates with the ribs and each descending vertebrae increases in size. The lumbar section is located in the lower back and has a lordotic curve formed by five of the largest vertebrae in the body, which are designed as a functional shock absorbing and load bearing system for the body.

Figure 1. Spine (source:http://corechiropractic.co.uk/the-spine/the-spine/)

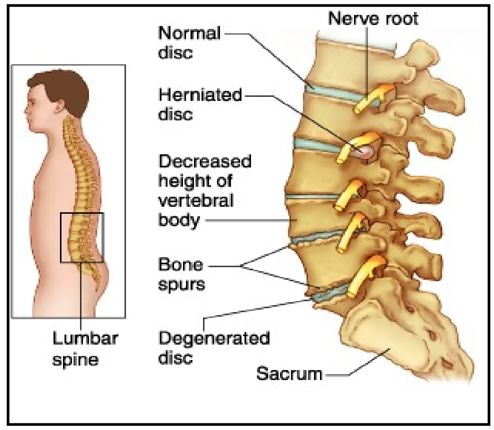


Figure 2. Lumbar Spine and Disc Disorders (source:http://www.mdguidelines.com/images/Illustrations/deg_lumb.jpg)

Intervertebral discs are located in between each vertebra to increase the total range of motion and act as shock absorbers for spinal compression. These discs have a tough, dense outer layer called the annulus fibrosus with a flexible inner layer known as the nucleus pulposus. Poor spine position or improper spinal loading can result in an intervertebral disc lesion, such as a protrusion, prolapse, extrusion or sequestration, which are increasing stages of the nucleus pulposus leaking into and finally through the annulus fibrosus (Figure 2).[3]

The American Medical Association (AMA) states normal range of motion (ROM) for the lumbar spine in an unloaded state is approximately 60˚ of flexion, 25˚ of extension and 25˚ of lateral flexion.[4] Repeated movements beyond the normal ROM may lead to tissue fatigue, then reduce the failure tolerance and eventually end with failure on the nth repetition or load.[5] This path to back injuries is more common and consists of accumulated trauma instead of an acute load that exceeds the failure tolerance of the tissue at one time.[5] A subfailure load with sustained stresses constantly over a period of time, such as a prolonged stooped posture can also lead to injury.[5] Compressive forces beyond 6800N to the lumbar spine will double the risk for a musculoskeletal injury.[5]

When in the upright standing posture, approximately 80% of the compressive force acting on the spine is resisted by the lumbar vertebral bodies and intervertebral discs.[2] The vertebral body is the first spinal structure that fails during compression.[2] This occurs with much lower forces during repetitive loading, such as multiple repetition exercises, which can lead to a reduction of 30% of the compressive strength of the vertebral body when ten loading cycles have been applied.[2] The age, sex, body mass and bone mineral density of an individual will determine the ability to resist compressive forces.[2] As little as 2º of lumbar extension under load increases the compressive stress by 16% within the posterior annulus, which is significant in comparison to an unloaded state.[2] Spinal compression increases with the distance of the load from the body and also will double the peak compressive force on the vertebral body when the load is lifted rapidly.[2] Starkey et al[6] indicated that 70% of adults will experience spine-related pain at one point in their lifetime.

Low Back Pain: Prevalence, Cost and General Treatment

LBP is the leading cause of disability, as well as a major socioeconomic and health problem.[7] The cost for healthcare among people with spinal pain increased by 65% from 1997 to 2005, which was faster than the increase in total healthcare costs.[8] LBP accounts for 9% of the overall healthcare cost in 2005.[8] This cost will increase as the number of people with back problems is expected to grow in the coming years.[9] As much as 85-90% of LBP diagnoses are considered nonspecific low back pain, which is defined as LBP not attributable to a recognizable, known specific pathology, such as an infection, tumor, osteoporosis or fracture.[9] When the source of the pain is in the spine or the supporting structures, it is defined as mechanical back pain and accounts for 80-90% of all LBP.[9] Exercise has been used to strengthen the supporting structures of the spine and may also reduce the risk for LBP.

The Kettlebell

Kettlebells are shaped like an iron ball with a handle and have been used for centuries as a tool for enhancing one's physical strength. The Russian dictionary first published the word "kettlebell" in 1704, but kettlebells may have been used during the times of Ancient Greece.[10] According to Ayash and Jones,[11] Turkish wrestlers have used kettlebells for over 200 years to strengthen their bodies in preparation for their grappling training. After a long period of obscurity in the United States, kettlebell usage has slowly grown since 1998 and continues to grow with the rise of CrossFit. The swing is considered one of the fundamental kettlebell exercise movements. Traditionally, the Russian swing style has been taught, which involves a hip hinge flexion movement with the kettlebell hiked between the legs (Figure 3a) and then aggressively swung forward with hip extension as the movement propels the kettlebell to the top position at approximately chest height (Figure 3b).[12]

An alternative swing style known as the American swing has become popular as the preferred swing movement

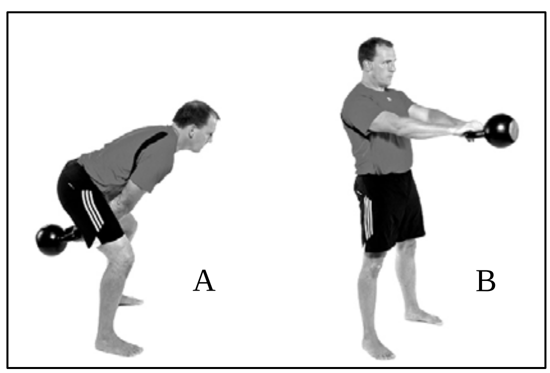


Figure 3. Russian Kettlebell Swing (http://www.strongfirst.com/wordpresswpcontent/uploads/2015/10Swingcenterofmass.jpg)

of CrossFit.[13] The American swing involves hiking the kettlebell backward with a squat movement and then swinging the kettlebell above the head.[13]

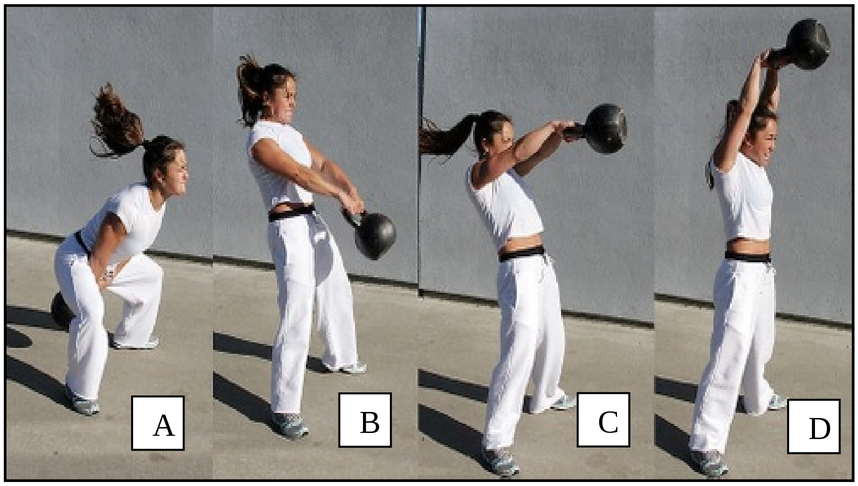


Figure 4. American (CrossFit) Kettlebell Swing
A) Hike position. B) Hip extension. C) Carry through.
D) Overhead position.
(source:http://crossfitrockwall.typepad.com/crossfit_rockwall/images/2008/02/24/anniekettlebellswing_2.jpg)

McGill and Marshall[14] indicated that kettlebell swings involve moving a weight at an accelerated speed and may increase the risk of spinal injury because of repeated compression of the spine in flexion, which is the mechanism that eventually leads to disc bulges. This may be important because movement flaws are prominent in the LBP population.[15] However, since the American swing involves bringing the kettlebell overhead with speed, it may pose a greater risk for lumbar spinal injury because more intervertebral spine joints are required to complete the swing and additional disc compression may be present when the load is above the head. Heavier loads are generally used for the squat, while lighter loads are generally used for the American kettlebell swing because the swing movement is performed at a much higher velocity than the squat. Previous research[2] determined that squatting under heavy loads significantly increases lumbar hyperextension, but this did not consider the effects of velocity on the movement. American kettlebell swings are performed with speed, so injury risk associated with the speed of the movement in relation to the hyperextended state at the lumbar spine is relatively unknown. The American kettlebell swing may also have a higher reliance on shoulder motion and spine mobility to complete the movement. Also, the load must be decelerated at the top of the movement, before aggressively bringing the weight back to the hike position (max hip flexion, knee flexion) for the next repetition. Decelerating the load at the top requires spinal stabilization and muscle activation, which may increase the risk for injury if not performed properly.

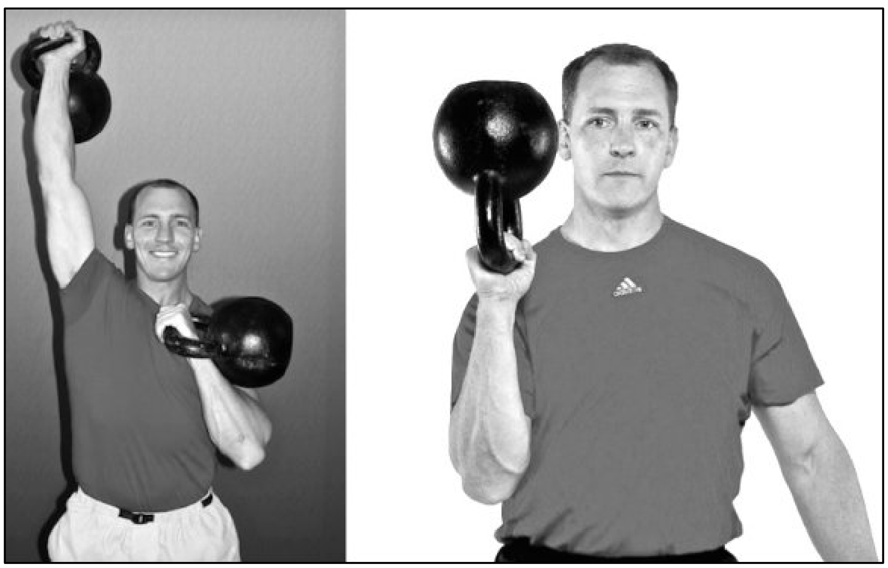
Some research has been conducted on the kettlebell swing in terms of physiological demands.[16,17] There was limited research found investigating the muscle demands of the kettlebell swing.[14,18] One study used electromyographic (EMG) equipment to measure the activity of the biceps femoris and the semitendinosus in 16 female athletes who performed the kettlebell swing and concluded that kettlebell swings target the semitendinosus muscle more than the biceps femoris muscle, which may help in the prevention of anterior cruciate ligament (ACL) injuries to the knee.[18] McGill and Marshall[14] determined that the kettlebell swing muscle activation sequence involves the latissimus dorsi, erector spinae, gluteal, hamstring, abdominal, oblique and quadriceps muscles. However, there was no research available that specifically examined the lumbar spine movements or muscle demands and risks during the American kettlebell swing. Further research is required to determine what the potential rehabilitation benefits or risks may be involved with the kettlebell swing. According to McGill, kettlebell exercises are ideal for functional training that mirrors the challenges of daily activities.[15] This type of training may also help reduce the risk for LBP or improve rehabilitation outcomes for LBP.

Low Back: Strength Training Risks and Concerns

The muscles that support the spine are commonly trained with a variety of exercises that involve an isometric contraction, such as a plank, or a pulling movement, such as a row, or a hip movement, such as a good morning. Total body exercises, such as the deadlift or squat may also strengthen the back musculature. Research has examined the kinematics of lumbar spine movement in squat exercises to determine the potential benefits and risks involved with the movement.[2] Squat exercises have been linked to a number of lumbar spine injuries such as muscle and ligamentous strains, ruptured intervertebral discs, spondylolysis, and spondylolisthesis, with improper and poor lifting techniques considered as the most common causes for lumbar spine injuries.[2] Walsh et al[2] conducted a research study on 48 athletes (28 men, 20 women) using a Zebris 3D motion analysis system to examine the lumbar spine movement in the back squat with the load carried on the shoulders (6 lifts at 40% max, 4 lifts at 60% max and 2 lifts at 80% max).[2] Findings indicated that that athletes hyperextended their lumbar spine to a significant degree with heavier loads (60%, 80% max).[2] Results also determined when loads were increased, subjects hyperextended their backs significantly during the concentric portion of the lift to maintain the line of gravity within their base of support.[2] Previous results already discussed, indicate that squatting with repetitive loading or lifting a weight rapidly can increase the risk of injury to the lumbar spine and this combination of repetition with velocity is similar to the movement pattern performed in the American kettlebell swing. However, the squat movements previously described were performed at a reduced velocity and with a heavier load in comparison to the kettlebell swing. These differences may affect the lumbar spine differently as the Kettlebell swing is performed with a lighter load and potential for higher velocity.

The unique design of the kettlebell allows the load to be carried closer to the body in comparison to a barbell when squatting and may help reduce the risk for lumbar hyperextension. According to McGill, an overhead position with the kettlebell also carries less risk for shoulder joint injury because the load is carried behind the hand (Figure 5a), which does not force the shoulder into full extension.[15] The "bottoms up" kettlebell position also promotes "steering" and strength control from the feet to the hands with an emphasis on spinal posture and bracing to balance the load (Figure 5b).[15]

Figure 5. A) Overhead position. B) Bottom-up position. (http://www.strongfirst.com/wordpress/wp-content/uploads/2015/10/bottoms-up-center-of-mass.jpg)



Further investigation is needed to determine if the high velocity and demands of the American kettlebell swing, place the lumbar spine at an increased risk for injury in comparison to the squat and the recommended safe ROM for spine training and rehabilitation.

Therapeutic Exercise

McGill has described the kettlebell swing as an example of a high-level therapeutic extension exercise that balances the torque distribution throughout the body linkage.[15] He also stated that Pavel Tsatsouline (kettlebell master) has the strongest pound-for-pound core that he has ever measured.[15] The kettlebell swing is also very similar in movement to the cable pull between the legs, which is a safer alternative to the hip extension machine.[15] Matthews and Cohen[19] explained that the kettlebell swing emphasizes a rapid eccentric loading of the hamstring muscles, which is followed by a rapid concentric contraction of the hamstring muscles to accelerate the kettlebell toward the highest position and train the stretch-shortening cycle in a manner that promotes effective hamstring injury prevention and rehabilitation. Kettlebell training has also been shown to improve postural coordination in a study involving 40 adults who were randomly assigned to a control or training group, which performed kettlebell swings three times a week for eight weeks.[20]

Summary

The human body is a complex system capable of handling a wide variety of tasks, but may fail when a task moves the body beyond the standard ROM, which may be classified as an acute injury or when a task involves minor stresses over a period of time, which may be classified as a chronic injury. These stressors may be why most people will experience LBP at some point in their lifetime, but the majority of people will not have a specific reason for their pain. LBP is the leading cause for disability and a huge financial drain on healthcare costs, with nonspecific LBP as the leading diagnosis. Exercise has been used to prevent and rehabilitate LBP, but has also been the cause of LBP in many people. The squat is a total body exercise with many benefits, but it has also been linked to LBP because of the heavy loads and demands placed on the spine. The American kettlebell swing is a similar movement to the squat, but consists of a lighter load performed at a higher velocity for more repetitions. Injury risks to the lumbar spine with kettlebell training are currently unknown. Considering the given potential for higher velocity in repetitive positions of maximum hip flexion and knee flexion (hike position), followed by hip and knee extension with maximum shoulder flexion (overhead position) while moving a load independently of the body.

Methods

Participants

Data were previously collected on five males with over five years of strength training experience between the ages of 28-50 who participated in the 2015 Adrian Tinsley Summer Undergraduate Research Grant Program involving the American kettlebell swing. This continuation of research focused on three positions of the American kettlebell swing: maximum hip extension (H), Russian kettlebell swing height (R) when the kettlebell is at chest level and the overhead (OH) position when the kettlebell is above the head before descent. All participants were free of injury or physical illness during their participation. Institutional Review Board approval (IRB #2015095) and written informed consent were obtained from each participant prior to the study.

Instruments

A JVC (Model: GR-D371V) video camera operating at 60 Hz with a 650W artificial spotlight was set up to capture the sagittal plane of the swing movement. First Place competition kettlebells (16kg, 24kg), Dell Desktop PC and Dartfish ProSuite v 6.0 software were used to complete the research.

Procedures

All participants wore tight-fitting clothes and performed a self-selected warmed up prior to testing. After the warm up, fourteen 3D joint reflective markers were placed on the right side of the body with #1 at the forehead, #2 at the chin, #3 at the shoulder (greater tubercle), #4 at the elbow (lateral epicondyle), #5 at the wrist (styloid process), #6 at the hip (greater trochanter), #7 at the knee joint (tibia femoral joint line), #8 at the ankle (lateral malleolus), #9 at the toe (base of 5th metatarsal), #10 at the spine of thoracic 6, #11 at lumbar 3, #12 at sacrum 1, #13 at the base of the kettlebell handle and #14 at the base of the kettlebell. After a demonstration, each participant performed five swing repetitions continuously with a 16 kg kettlebell and five swing repetitions continuously with a 24 kg kettlebell with the order of the loads randomized to reduce any order effect. A potential injury risk may present when a weight is lifted, so exercise form was carefully monitored during participation for safety purposes. Participants received no coaching during the trials and repetitions were limited to five trials with up to three minutes of rest between the two different loads to help prevent fatigue. Water was supplied to help maintain hydration, and the kettlebell weight did not exceed the sport standard of 24 kg. A cushioned mat was placed on the floor so the participants could safely release the kettlebell at any time during the testing.

Data Analysis

A standard two-dimension motion analysis was conducted for 30 video trials of the American kettlebell swing and analyzed with Dartfish ProSuite v 6.0 software. Repetitions 2-4 were analyzed at each load to account for any lack of warm-up or fatigue that may have been present. Lumbar angles were formed by markers (10,11,12) on the back and analyzed 5 frames before maximum hip extension to 5 frames after the overhead position. Lumbar angles were expressed as anterior angles with 180° equal to neutral and angles greater than 180° indicated hyperextension. Lumbar angular velocities were also calculated over this time. Both shoulder and elbow angles were calculated as well, with shoulder angles formed by markers (3,4) on the upper arm and shoulder flexion expressed in relation to the vertical. Elbow angles were formed by markers (3,4,5) on the arm with 180° equal to neutral position. Means and standard deviations were calculated for lumbar, shoulder and elbow angles at each position (H, R, OH) over 15 trials. Maximum angles were extracted from each position (H, R, OH) and a mean of the maximum angles was also calculated. The results were compared to current literature to determine the injury potential to the lumbar spine.

Results

Participants consisted of five males between the ages of 28-50 with a minimum of five years of strength training experience. All participants were familiar with kettlebells, but did not include them in their strength training programs or have a history of training with kettlebells.

Lumbar Angles

The mean lumbar angles at the hip extension (H), Russian height (R), and overhead position (OH) for the 16kg trials are presented in Table 1 along with the maximum lumbar extension angle. The results for the 24kg trials are presented in Table 2. Lumbar extension was highest during the OH position and maximum angles were also noted closest to this position (Appendices A and B). The lumbar angles were fairly consistent between weights with the greatest mean amount of hyperextension almost 25° past neutral.

Table 1. *16kg Mean Lumbar Spine Angles at Kettlebell Swing Positions*

Position	H	R	OH	Maximum
Mean ± SD (deg)	198.4 ± 5.9	194.8 ± 7.0	201.6 ± 7.0	203.1 ± 7.5

Table 2. *24kg Mean Lumbar Spine Angles at Kettlebell Swing Positions*

Position	H	R	OH	Maximum
Mean ± SD (deg)	198.2 ± 8.1	197.8 ± 8.0	200.3 ± 7.2	204.2 ± 8.6

Shoulder Angles

The mean shoulder flexion from the vertical at the hip extension (H), Russian height (R), and overhead position (OH) for the 16kg trials are presented in Table 3 along with the mean maximum shoulder flexion angles. The results for the 24kg trials are presented in Table 4. Shoulder angles were highest during the OH position and maximum angles were also measured closest to this position (Appendices A and B). Note that shoulder angles are higher in all positions with the 16kg kettlebell in comparison to the 24kg kettlebell. The H position contains the largest angle difference between weights with a difference of 25.5°. Also, the H position resulted in the greatest variability at 23.1 with the 24kg kettlebell.

Table 3. *16kg Mean Shoulder Angles at Kettlebell Swing Positions*

Position	H	R	OH	Maximum
Mean ± SD (deg)	109.5 ± 13.0	86.4 ± 8.7	144.3 ± 12.0	145.4 ± 12.2

Table 4. *24kg Mean Shoulder Angles at Kettlebell Swing Positions*

Position	H	R	OH	Maximum
Mean ± SD (deg)	84 ± 23.1	78.7 ± 7.5	138.2 ± 15.9	139.4 ± 16.7

Elbow Angles

The mean elbow angles at the hip extension (H), Russian height (R), and overhead position (OH) for the 16kg trials are presented in Table 5 along with the mean maximum elbow flexion angles. The results for the 24kg trials are presented in Table 6. Elbow angles were highest during the H position and maximum angles were also measured closest to this position (Appendices A & B). The elbow angles were fairly consistent between weights and positions with the greatest amount of flexion at the OH position.

Table 5. *16kg Mean Elbow Angles at Kettlebell Swing Positions*

Position	H	R	OH	Maximum
Mean ± SD (deg)	161.0 ± 8.6	160.7 ± 10.5	157.6 ± 8.2	164.4 ± 9.1

Table 6. *24kg Mean Elbow Angles at Kettlebell Swing Positions*

Position	H	R	OH	Maximum
Mean ± SD (deg)	164.6 ± 7.5	163.0 ± 8.4	160.7 ± 8.8	169.8 6.1±

Lumbar Velocities

The results of the lumbar spine velocities throughout the concentric lifting phase for the 16kg trials are presented in Appendix C and the 24kg trials are presented in Appendix D. The velocities ranged from approximately 550 deg/sec to -550 deg/sec with most results between 150 deg/sec to -150 deg/sec. Results were fairly consistent across subjects and trials with the exceptions of subject 1 trial 4 with the 16kg kettlebell (approximately -500 deg/sec) and subject 3 trials 2 and 4 with the 24kg kettlebell (approximately 550 deg/sec). Positive velocities indicated lumbar extension and negative velocities indicated lumbar flexion. It is important to note that these data were not been smoothed.

Discussion

The purpose of this research was to determine the lumbar flexion and extension angles and velocities of the American kettlebell swing from maximum hip extension to the overhead position in comparison to suggested safe positions of the spine with the intent to examine the benefits for LBP rehabilitation.

Lumbar Angles

Lumbar angles for all participants found that the lumbar spine was in an extended position during the American kettlebell swing from maximum hip extension to the overhead position. This extended position is concerning because poor spine position can result in intervertebral disc lesions.[3] Maximum extension was determined to be at the overhead position with a mean angle of 203.1° for the 16kg kettlebell and 204.2° for the 24kg kettlebell. These findings may suggest that extension of the lumbar spine was needed by the subjects to bring the load overhead. The duration of the extended position found in the American kettlebell swing may increase the risk for a lumbar spine injury because the repetitive motion is near the end point for safe ROM with the maximum mean angle recorded at approximately 25° past neutral, which is considered the safe limit for lumbar spine extension.[4] Movements performed near the safe limits may potentially create a subfailure load, which will increase the risk for injury over time and may not be recognized as an immediate cause for LBP or labeled nonspecific, which may delay technique corrections or termination of the movement..[5]

American kettlebell swings are commonly performed for a hundred or more repetitions in CrossFit workouts.[13] This high repetition count may be concerning because repetitive (fatigue) training has resulted in damage to vertebral bodies, growth plates and intervertebral discs.[2] This damage can be concerning because 80% of compressive force acting on the spine in an upright posture is also resisted by the same lumbar vertebral bodies and intervertebral discs that can be damaged with high repetition movements, such as the American kettlebell swing.[2] Vertebral bodies are also the first spinal structure to fail during compression and will do so with lower forces during multiple repetition exercises, resulting in a reduction of 30% of the vertebral bodies compressive strength when ten loading cycles have been applied.[2] Lumbar extension during the American kettlebell swing should also be concerning because 2° of lumbar extension beyond neutral under load increases the compressive stress by 16%.[2] Maximum lumbar angle results, about 25° beyond neutral (Table 1) in this study, suggest increased compressive stress of approximately 200% on the vertebral bodies when performing the American kettlebell swing. The American kettlebell swing requires both a rapid movement to propel the load above the head, which can double the peak compressive force on the vertebral body. Spinal compression may also be increased because the American kettlebell swing is performed with the load further from the body than traditional squat exercises.[2] Essentially, the extended lumbar position found during the American kettlebell swing increases the compressive stress on the spine. The combination of this compressive stress and the high repetition counts common to swing training may increase the risk of a lumbar injury.

Results from Tables 1 and 2 suggest that performing the Russian kettlebell swing is a safer alternative to the American kettlebell swing because it resulted in reduced lumbar extension (15-19° past neutral). Shoulder angles were found to be greater with the 16kg kettlebell in comparison to the 24kg kettlebell and may have been a result of the subjects prioritizing their upper body musculature to move the lighter load overhead. Elbow flexion was also highest during the overhead position and may suggest the subjects did not generate enough velocity to bring the kettlebell overhead or that elbow flexion was increased to compensate for limitations in shoulder flexion or to keep the load closer to the body.

Limitations

The small number of participants and the accuracy of the Dartfish analysis limited research. Placement of the 3D joint reflective markers on the subjects clothing may also have influenced results because of the possibility of markers shifting during movement. Also, the participants individual training programs were not considered during this research and may have influenced the results. Baseline tests for strength and ROM were not performed during research and may have limited the findings.

Further Investigation

Further investigation is needed to determine the benefits and risks of performing American kettlebell swings for high repetitions and for a longer period of time. A larger group size with experienced kettlebell lifters would also help determine if the extended lumbar position found is a result of inexperience with kettlebells or normal for the movement. A movement screen or baseline measurement may also help determine if the extended lumbar position found with the load overhead is normal for the subjects or a direct result of the kettlebell load in the overhead position. Further research is needed to determine if lumbar extension increases with heavier loads as found in squat research.[2] The impact of a high velocity movement, such as the American kettlebell swing, on lumbar injury risk, should also be investigated further.

Summary

American kettlebell swings are a popular movement within CrossFit and performed for a hundred or more repetitions with the 24kg kettlebell as part of CrossFit workouts. The purpose of this research was to determine the lumbar flexion and extension angles and velocities of the American kettlebell swing at maximum hip extension to the overhead position in comparison to safe positions for the spine in a group experienced with strength training, but inexperienced with the American kettlebell swing. Results from this study suggest that the American kettlebell swing is performed with up to 25° of lumbar spinal hyperextension from maximum hip extension to the overhead position. Lumbar spine extension has been shown to increase the risk for injury and may lead to an injury over time with high repetitions.

Based on the results of this research, lumbar extension increased with the load overhead, which suggests that the Russian swing is a safer version of the kettlebell swing. Further research is needed to determine if the lumbar extension results found are limited to the small sample size or related to the American kettlebell swing movement. People may benefit from learning foundational movements before performing the American kettlebell swing to build a baseline of strength, stability and ROM. The kettlebell deadlift, squat and press may help train the muscle groups used during the American kettlebell swing, but at a much slower velocity with reduced risk for lumbar spine injuries because the load is closer to the body and generally performed for less repetitions. Exercises that stabilize the core should also be considered in a training program to help reduce the risk for lumbar hyperextension when performing the American kettlebell swing. Baseline movement screening may also help determine ROM competency before performing the

American kettlebell swing. Further research is needed to determine if movement progressions and technique instruction reduces the risk for lumbar spine inuries when performing the American kettlebell swing.

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Appendix A (16kg Load Angles)

Table 7

Lumbar 16kg Subject	Trial	Hike [H]	Russian [R]	Overhead [OH]	Maximum	Location
1	2	199.9	191.3	202.3	202.5	OH> [1 frame post OH]
1	3	202.6	201	205.8	205.9	OH> [2 frame post OH]
1	4	204.8	204.8	212.7	214.7	OH> [1 frame post OH]
2	2	199.9	194.1	202.6	202.6	OH
2	3	195.4	187.5	196.9	196.9	OH
2	4	196.7	195.8	201.1	201.2	OH> [1 frame post OH]
3	2	199.4	193.3	206.6	209.3	H-OH [9 frame post H]
3	3	201.9	201.9	205.8	206.2	OH> [1 frame post OH]
3	4	210.4	210.4	213.3	217.5	R-OH [7 frame post R]
4	2	187.1	184.6	186.6	188	H-OH [3 frame post H]
4	3	190.3	190.3	193.6	195.3	OH> [5 frame post OH]
4	4	190.6	192.7	196.3	197.2	OH> [4 frame post OH]
5	2	198.6	188.5	196.9	200	H-OH [2 frame post H]
5	3	197.7	193.1	200.4	204.3	H-OH [4 frame post H]
5	4	200.3	191.9	202.6	204.3	H-OH [5 frame post R]
M		198.37	194.75	201.57	203.06	
SD		5.92	6.98	7.00	7.45	

Table 8

Elbow 16kg Subject	Trial	Hike [H]	Russian [R]	Overhead [OH]	Maximum	Location
1	2	159	164.3	157.1	164.3	R
1	3	158.4	157.6	154.9	158.4	H
1	4	172.2	172.2	161.7	172.5	<H/R [2 frame pre H/R]
2	2	161.3	164.6	162.3	164.6	R
2	3	160.7	162.8	162.3	162.5	H-OH [9 frame post H]
2	4	164.6	164	159.5	167.4	H-OH [2 frame post H]
3	2	160.9	162.5	154.1	163.1	<H [1 frame pre H]
3	3	158.8	158.8	154.3	161.2	R-OH [2 frame post R]
3	4	150.5	150.5	156.4	164.2	R-OH [5 frame post R]
4	2	166.4	170.2	165.1	172.1	<R [2 frame pre R]
4	3	175	175	173.2	180	<H/R [3 frame pre H/R]
4	4	175.4	173.3	167.6	180	<H [3 frame pre H]
5	2	153	146.4	144.4	154.6	H-OH [2 frame post H]
5	3	150.6	147.4	146.7	150.6	H
5	4	147.7	140.5	145.2	150.3	H-OH [7 frame post H]
M		160.97	160.67	157.65	164.39	
SD		8.64	10.49	8.21	9.09	

Table 9

Shoulder 16kg Subject	Trial	Hike [H]	Russian [R]	Overhead [OH]	Maximum	Location
1	2	113.3	75.6	127.3	127.3	OH
1	3	116.3	84	137.2	137.7	H-OH [9 frame post H]
1	4	89.3	89.3	135.8	138	OH> [5 frame post OH]
2	2	120.1	73	141.6	142.5	OH> [1 frame post OH]
2	3	120	88.2	149.2	149.2	OH
2	4	119.6	87.6	143.1	143.7	OH> [1 frame post OH]
3	2	124.9	90.8	153.4	156.6	H-OH [12 frame post H]
3	3	99.6	99.6	161.3	164	OH> [2 frame post OH]
3	4	87.1	87.1	154.4	154.8	R-OH [15 frame post R]
4	2	108.1	91	129.1	129.1	OH
4	3	99.8	99.8	129.7	132.5	OH> [1 frame post OH]
4	4	90	95.2	131.6	131.6	OH
5	2	114.7	74.2	157.9	157.9	OH
5	3	119.6	84.6	158.8	158.8	OH
5	4	120.5	75.5	154.6	156.5	<OH [1 frame pre OH]
M		109.53	86.37	144.33	145.35	
SD		12.97	8.69	12.03	12.27	

Appendix B (24kg Load Angles)

Table 10

Lumbar 24kg Subject	Trial	Hike [H]	Russian [R]	Overhead [OH]	Maximum	Location
1	2	200.8	200.8	194.6	206	R-OH [4 frame post R]
1	3	197.8	195.8	190.5	199.3	R-OH [2 frame post R]
1	4	195.1	201.5	200.1	206.9	R-OH [5 frame post R]
2	2	204	195.3	207.1	208.4	OH> [2 frame post OH]
2	3	197.7	194.2	197.8	198.1	R-OH [9 frame post R]
2	4	194.2	196.8	193	198.8	R-OH [2 frame post R]
3	2	217.6	217.6	213.1	224.8	R-OH [1 frame post R]
3	3	203.2	203.2	208.2	210.9	R-OH [11 frame post R]
3	4	204.9	210.5	210.6	214.3	H-OH [9 frame post H]
4	2	184.1	188.7	190.9	190.9	R-OH [1 frame pre OH]
4	3	188	190.8	193.7	194.6	R-OH [1 frame pre OH]
4	4	191.7	193.4	197	197.2	OH> [1 frame post OH]
5	2	200.4	194.5	203.2	206.2	H-OH [10 frame post H]
5	3	192.3	187.5	200.6	201.1	H-OH [10 frame post H]
5	4	201.2	195.7	203.9	206.5	H-OH [7 frame post H]
M		198.20	197.75	200.29	204.27	
SD		8.05	8.03	7.23	8.56	

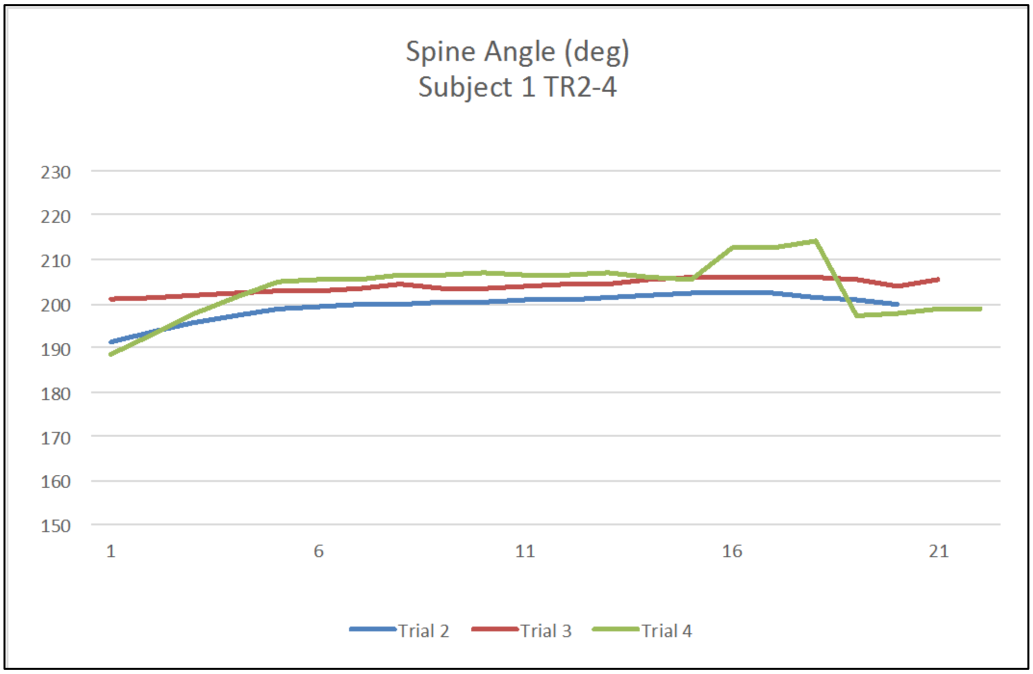
Table 11

Elbow 24kg Subject	Trial	Hike [H]	Russian [R]	Overhead [OH]	Maximum	Location
1	2	171.1	168.3	160.1	175.9	<H [4 frame pre H]
1	3	162.4	168	169.6	170.3	OH> [3 frame post OH]
1	4	166.6	166.5	162.8	171.5	R-OH [4 frame post R]
2	2	162.2	164.1	161.8	166.4	<R [2 frame pre R]
2	3	169.5	168.6	168.7	171.8	<R [5 frame pre R]
2	4	164.9	163.4	159.7	168.3	<R [5 frame pre R]
3	2	153.7	153.7	143.5	166.8	<H [4 frame pre H]
3	3	155.9	155.9	156.3	164.6	R-OH [8 frame post R]
3	4	156.4	155.9	155.2	169.8	H-OH [4 frame post H]
4	2	172.3	167.9	162.5	177.3	<H [5 frame pre H]
4	3	178	178.3	175.4	178.8	<H [2 frame pre H]
4	4	174.8	175.1	174.1	179.6	<H [3 frame pre H]
5	2	165.1	154.3	149.3	165.1	H
5	3	155	150.4	154.1	159.7	OH> [5 frame post OH]
5	4	160.9	155.7	156	160.9	H
M		164.59	163.07	160.61	169.79	
SD		7.52	8.36	8.82	6.16	

Table 12

Shoulder 24kg Subject	Trial	Hike [H]	Russian [R]	Overhead [OH]	Maximum	Location
1	2	69.9	86.1	129.1	129.1	OH
1	3	59	80.5	137.9	139.8	OH
1	4	49.9	81.5	152.6	153.8	R-OH [15 frame post R]
2	2	103.8	80.7	105.9	105.9	OH
2	3	128.7	77.5	129.2	129.2	OH
2	4	123.1	86.9	124.3	126.4	OH> [1 frame post OH]
3	2	69.3	69.3	152.9	155.2	R-OH [14 frame post R]
3	3	78	78	151.2	157.6	R-OH [14 frame post R]
3	4	83.8	71.2	154.4	155.6	OH> [1 frame post OH]
4	2	62.9	81	119.7	119.7	OH
4	3	62.9	72.9	128.7	128.7	OH
4	4	84.7	96.8	128	128	OH
5	2	93.1	69.3	158.3	158.3	OH
5	3	88.8	72.6	154	156	OH> [1 frame post OH]
5	4	102	76.7	147.3	147.3	OH
M		83.99	78.73	138.23	139.37	
SD		23.11	7.46	15.88	16.65	

Appendix C (16kg Kettlebell Angles and Velocities)


Spine Angle (deg)
Subject 1 TR2-4
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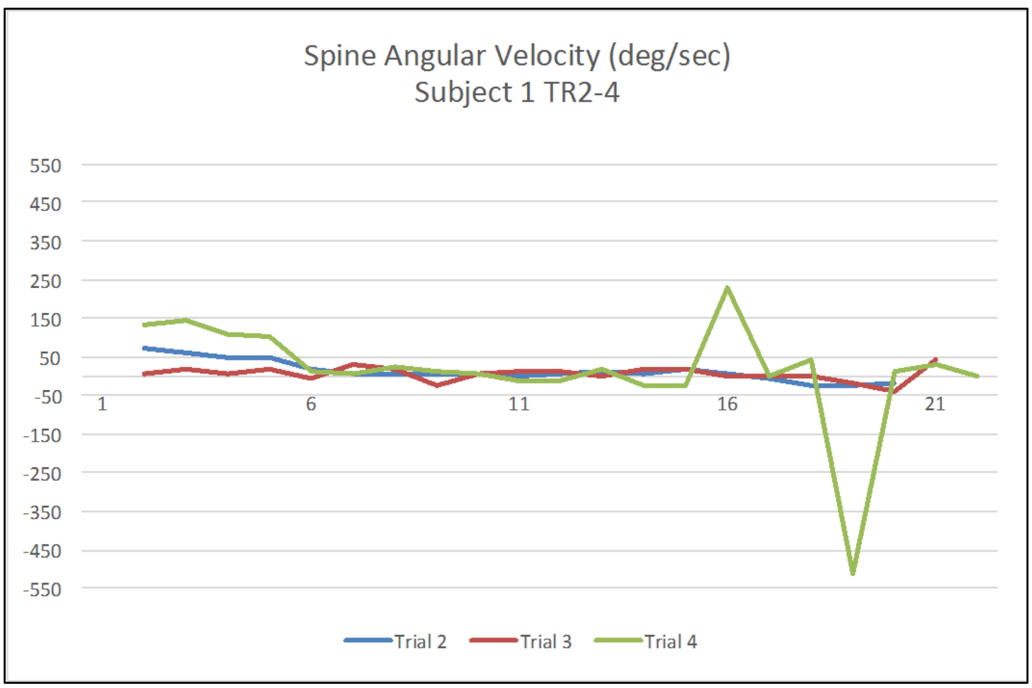
220
210
200
190
180
170
160
150
1
6
11
16
21
Trial 2
Trial 3
Trial 4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450
350
250
150
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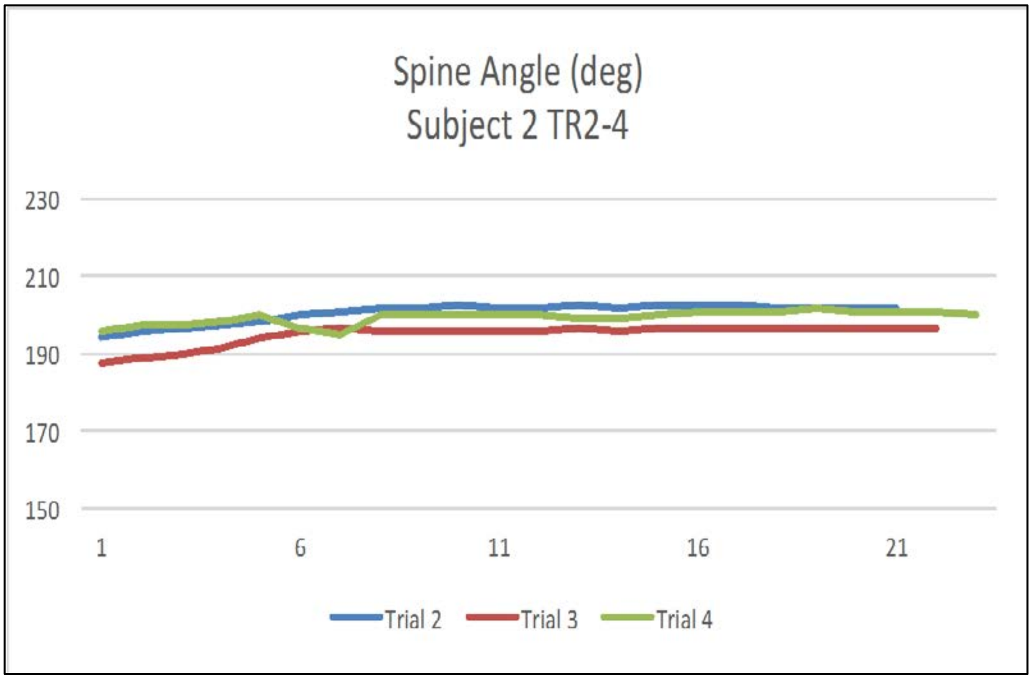
-50
-150
-250
-350
-450
-550
1
6
11
16
21
Trial 2
Trial 3
Trial 4


Spine Angle (deg)
Subject 2 TR2-4
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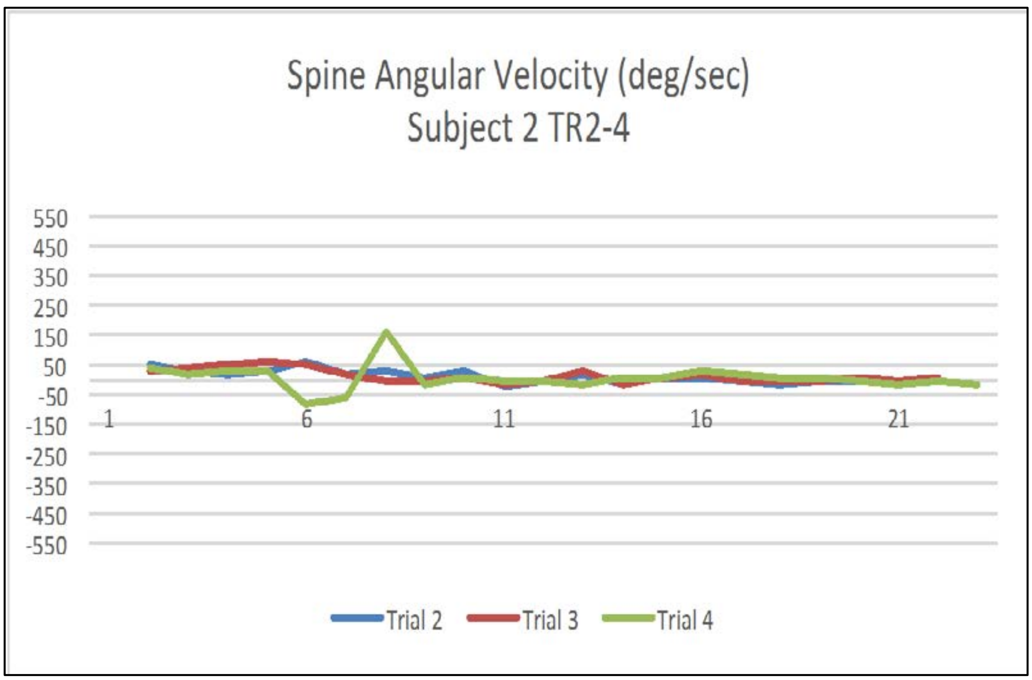
210
190
170
150
1
6
11
16
21
Trial 2
Trial 3
Trial 4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Subject 2 TR2-4
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450
350
250
150
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-50
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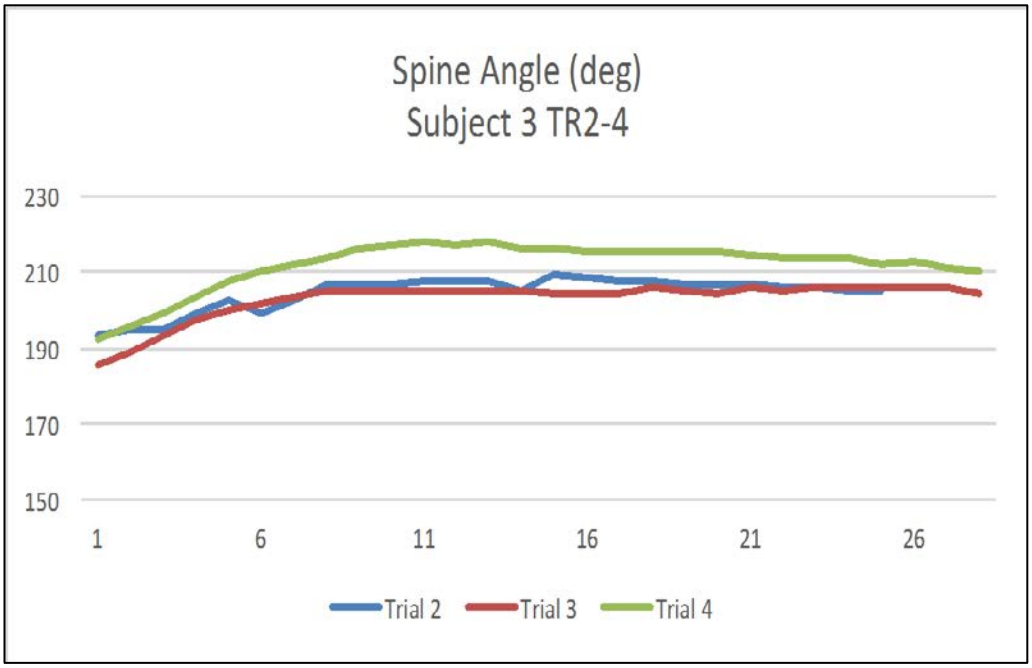
-250
-350
-450
-550
1
6
11
16
21
Trial 2
Trial 3
Trial 4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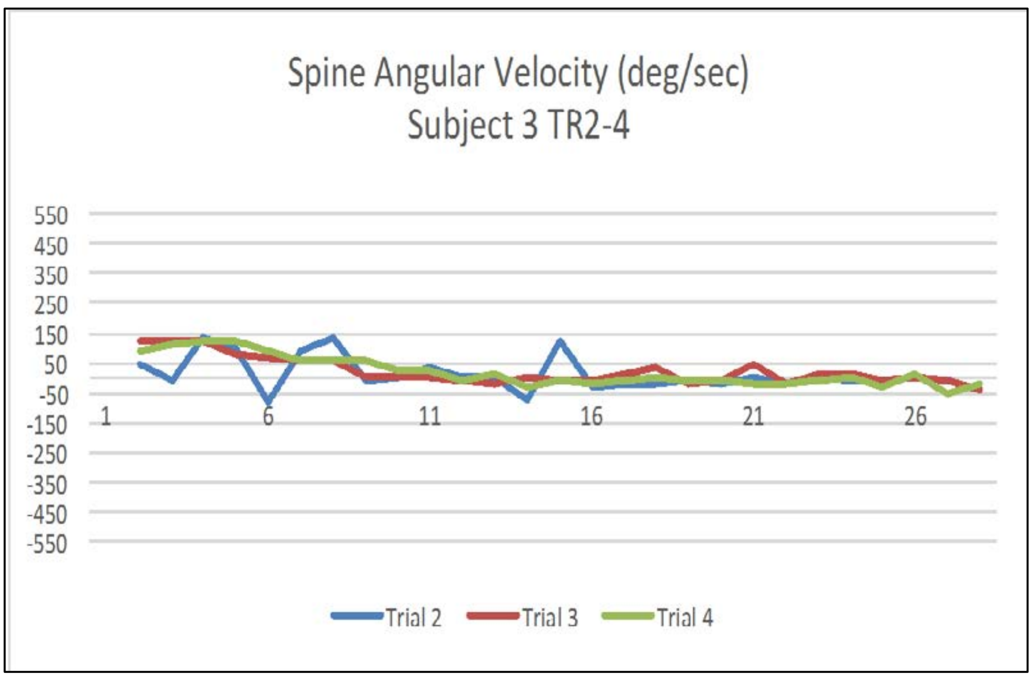
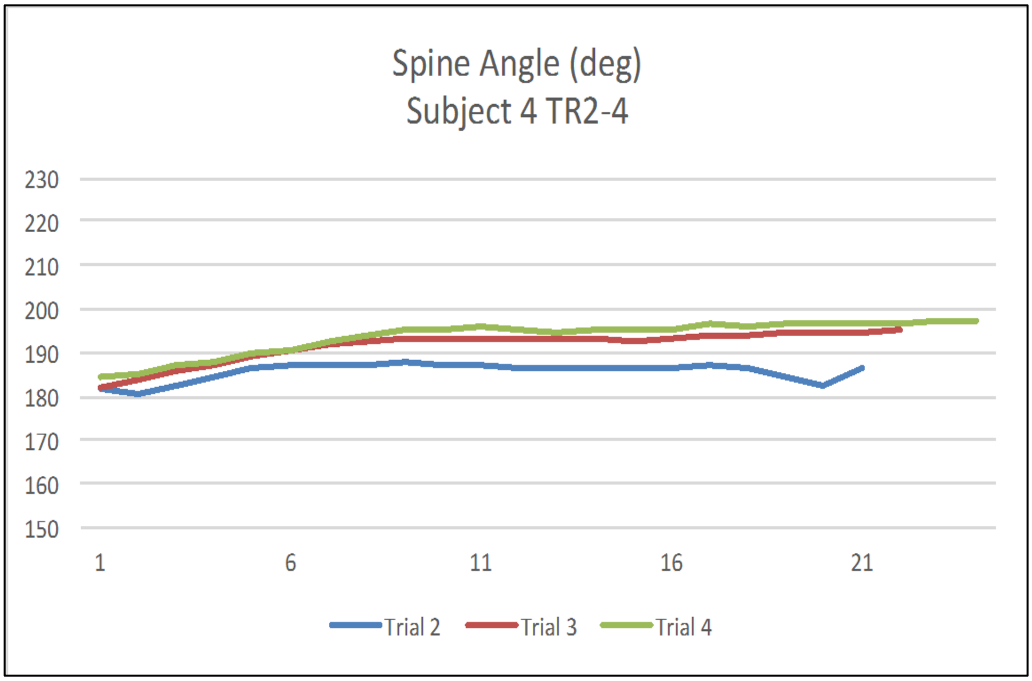
210
190
170
150
1
6
11
16
21
26
Trial 2
Trial 3
Trial 4


Spine Angular Velocity (deg/sec)
Subject 3 TR2-4
550
450
350
250
150
50
-50
-150
-250
-350
-450
-550
1
6
11
16
21
26
Trial 2
Trial 3
Trial 4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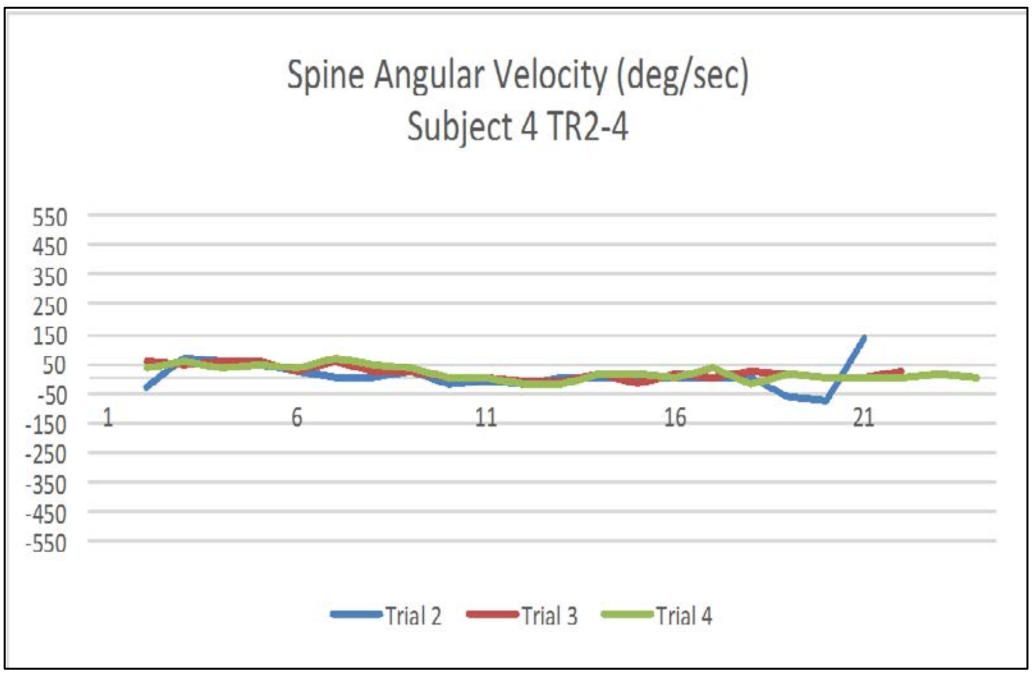
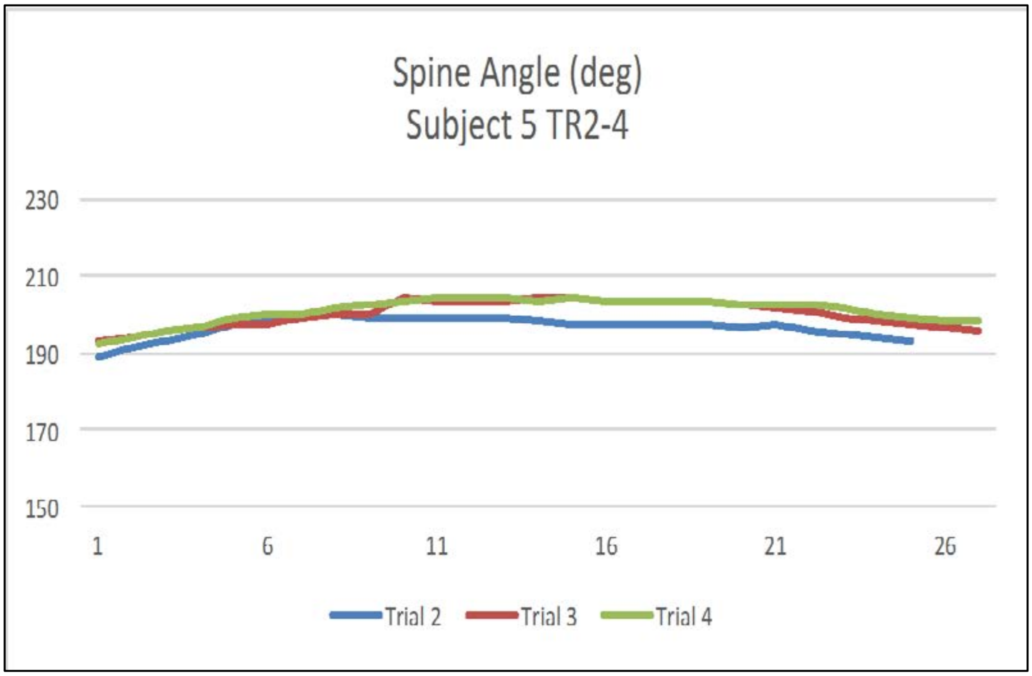
230
220
210
200
190
180
170
160
150
1
6
11
16
21
Trial 2
Trial 3
Trial 4


Spine Angular Velocity (deg/sec)
Subject 4 TR2-4
550
450
350
250
150
50
-50
-150
-250
-350
-450
-550
1
6
11
16
21
Trial 2
Trial 3
Trial 4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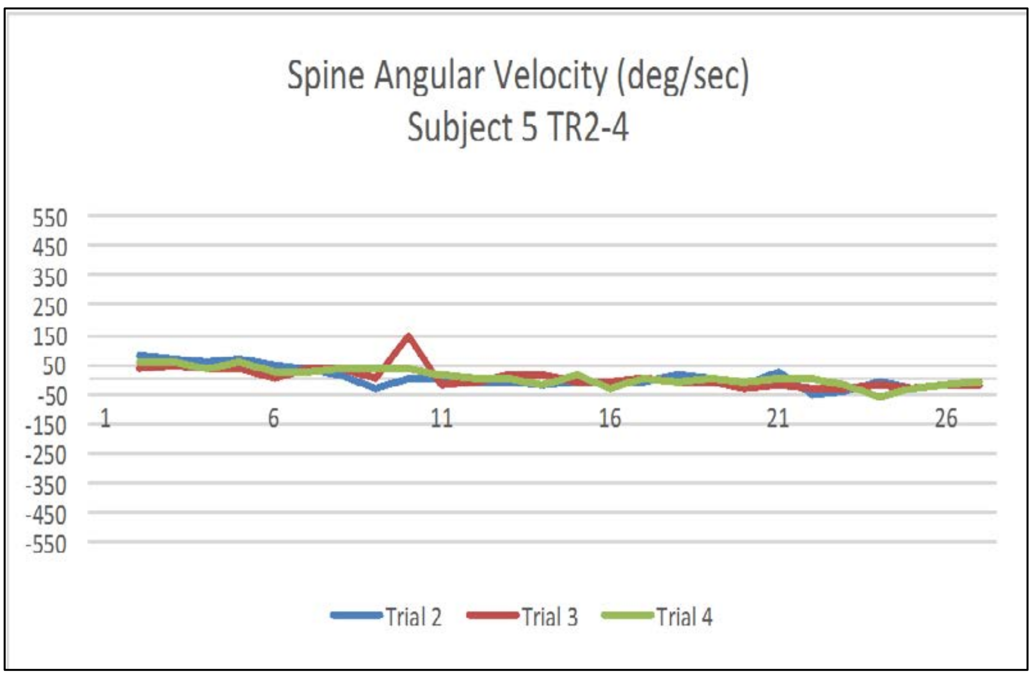
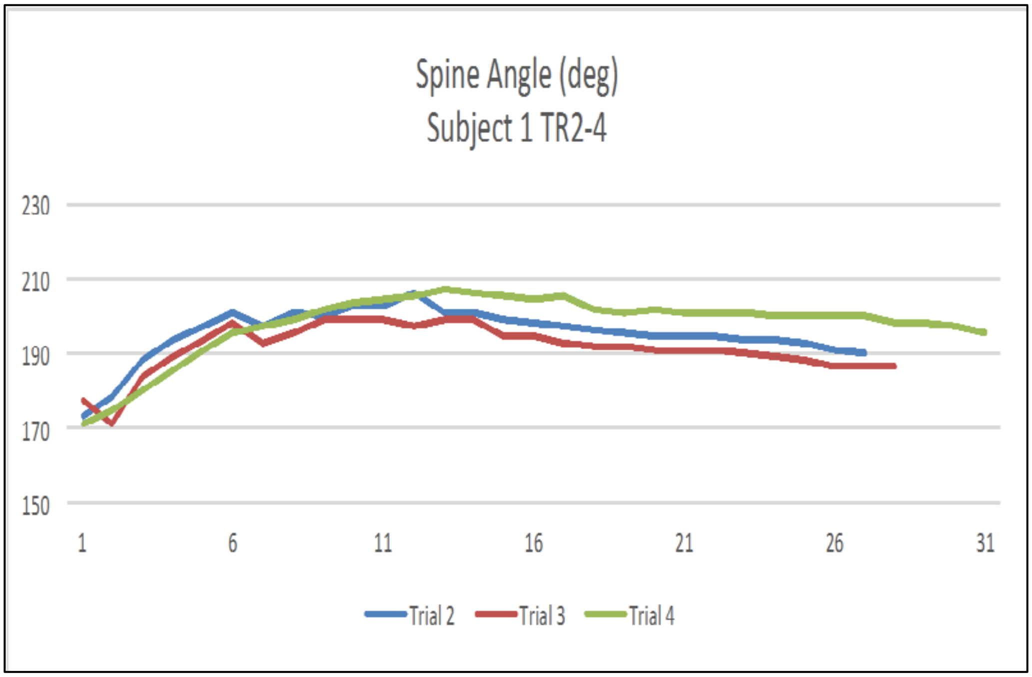
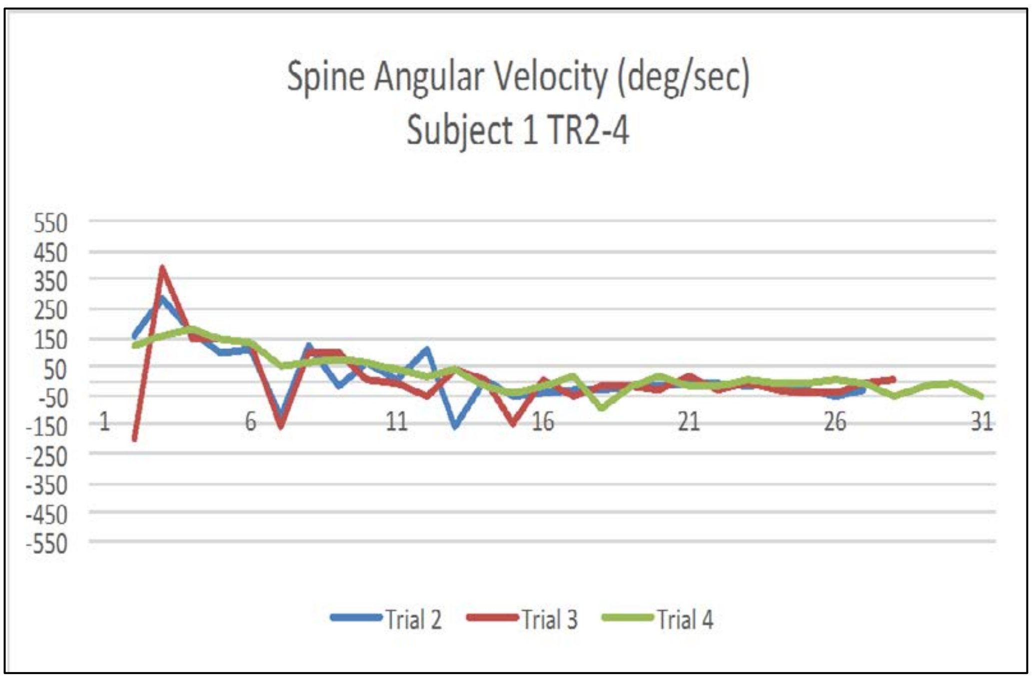
Subject 5 TR2-4
230
210
190
170
150
1
6
11
16
21
26
Trial 2
Trial 3
Trial 4


Spine Angular Velocity (deg/sec)
Subject 5 TR2-4
550
450
350
250
150
50
-50
-150
-250
-350
-450
-550
1
6
11
16
21
26
Trial 2
Trial 3
Trial 4

Appendix D (24kg Kettlebell Angles and Velocities)


Spine Angle (deg)
Subject 1 TR2-4
230
210
190
170
150
1
6
11
16
21
26
31
Trial 2
Trial 3
Trial 4


Spine Angular Velocity (deg/sec)
Subject 1 TR2-4
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450
350
250
150
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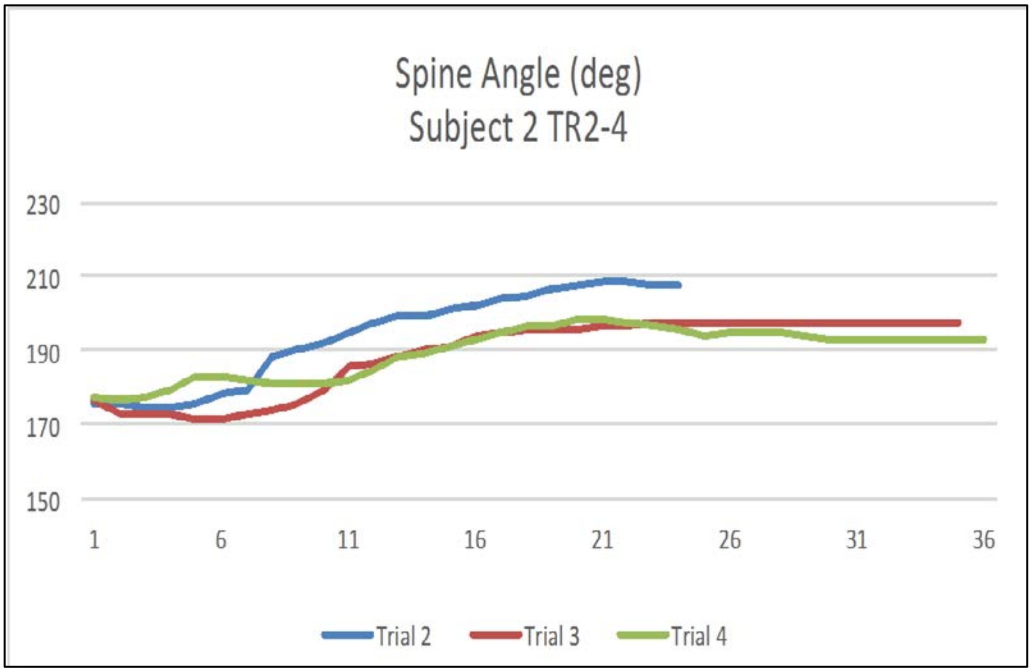
-50
-150
-250
-350
-450
-550
1
6
11
16
21
26
31
Trial 2
Trial 3
Trial 4



Spine Angle (deg)
Subject 2 TR2-4
230
210
190
170
150
1
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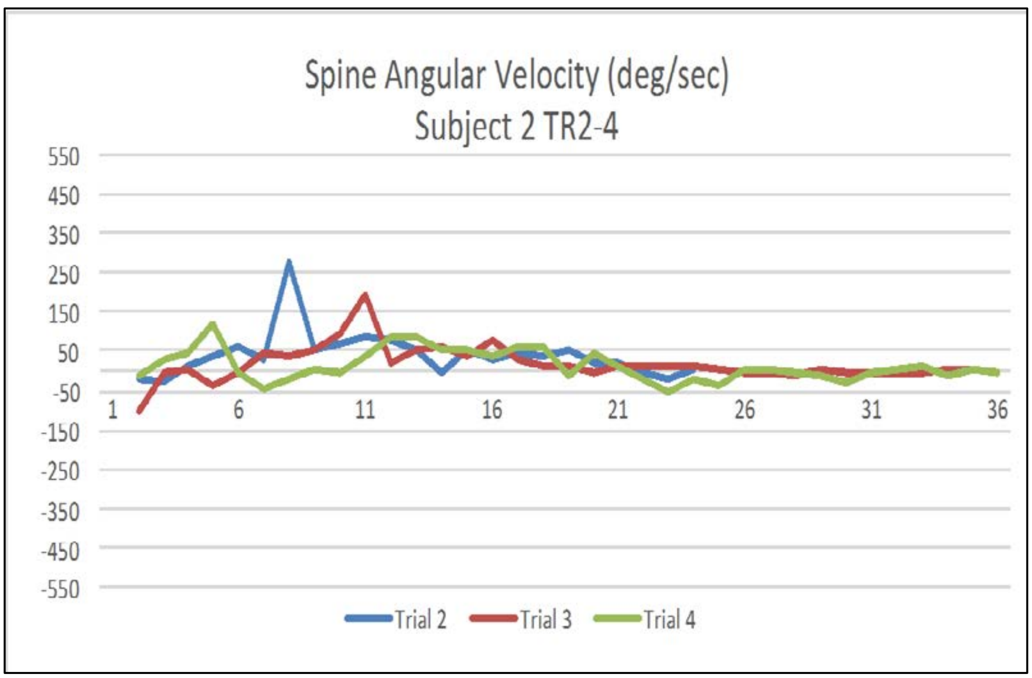
11
16
21
26
31
36
Trial 2
Trial 3
Trial 4



Spine Angular Velocity (deg/sec)
Subject 2 TR2-4
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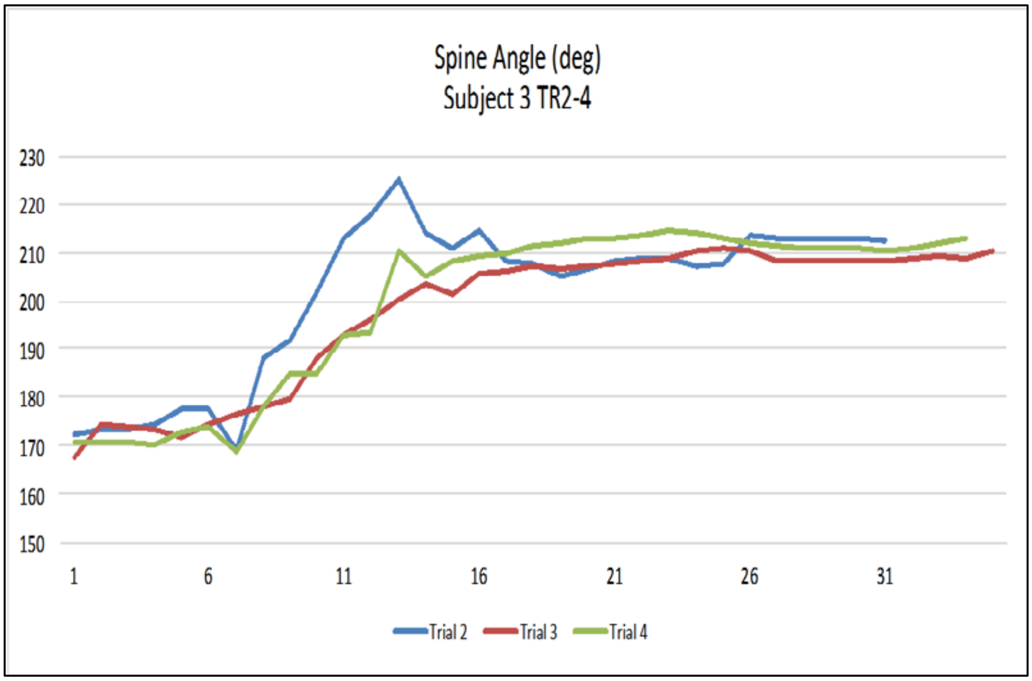
450
350
250
150
50
-50
-150
-250
-350
-450
-550
1
6
11
16
21
26
31
36
Trial 2
Trial 3
Trial 4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Subject 3 TR2-4
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220
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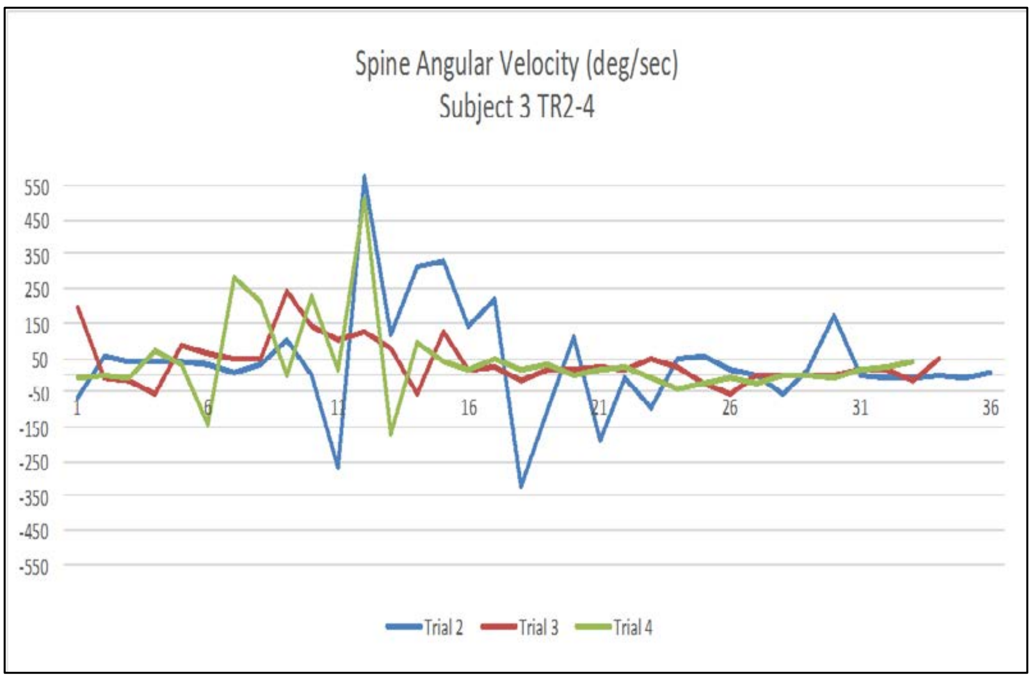
200
190
180
170
160
150
1
6
11
16
21
26
31
Trial 2
Trial 3
Trial 4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Subject 3 TR2-4
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350
250
150
50
-50
-150
-250
-350
-450
-550
1
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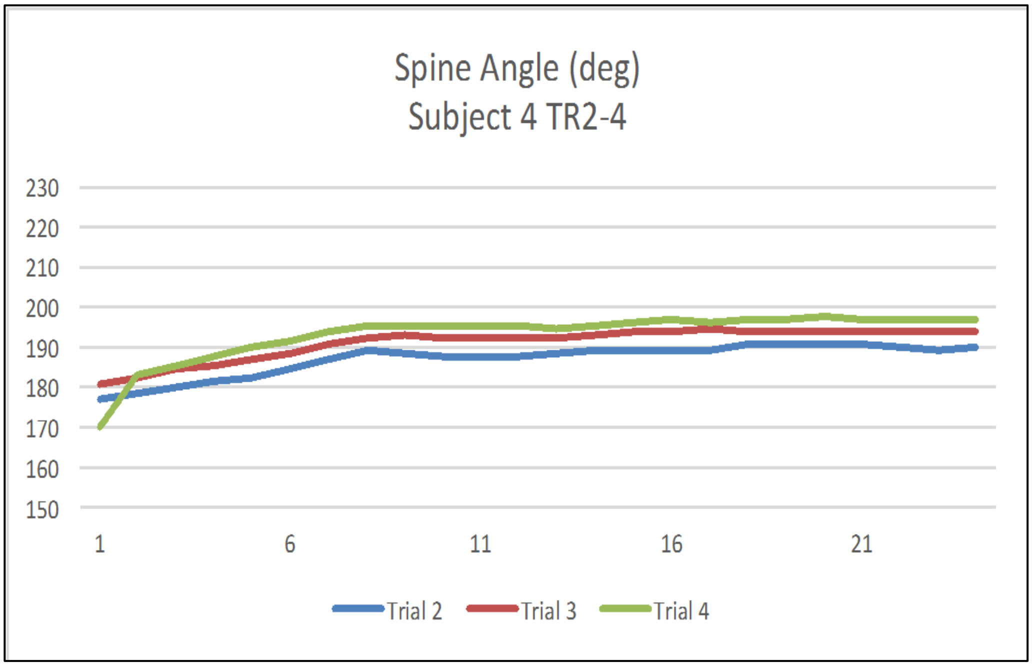
16
21
26
31
36
Trial 2
Trial 3
Trial 4


Spine Angle (deg)
Subject 4 TR2-4
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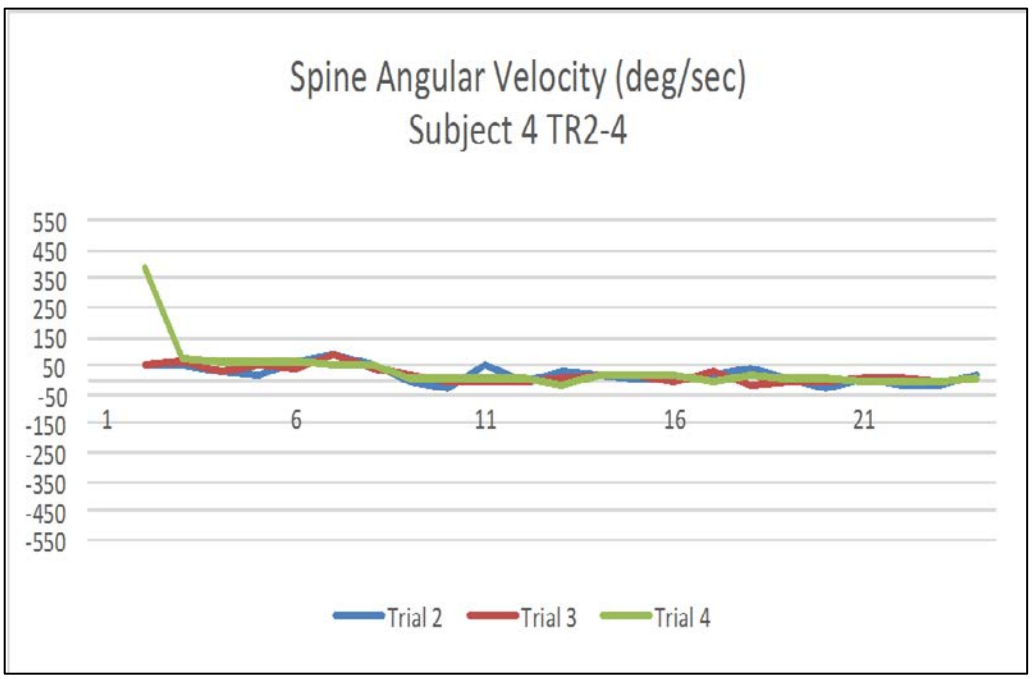
220
210
200
190
180
170
160
150
1
6
11
16
21
Trial 2
Trial 3
Trial 4


Spine Angular Velocity (deg/sec)
Subject 4 TR2-4
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450
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-150
-250
-350
-450
-550
1
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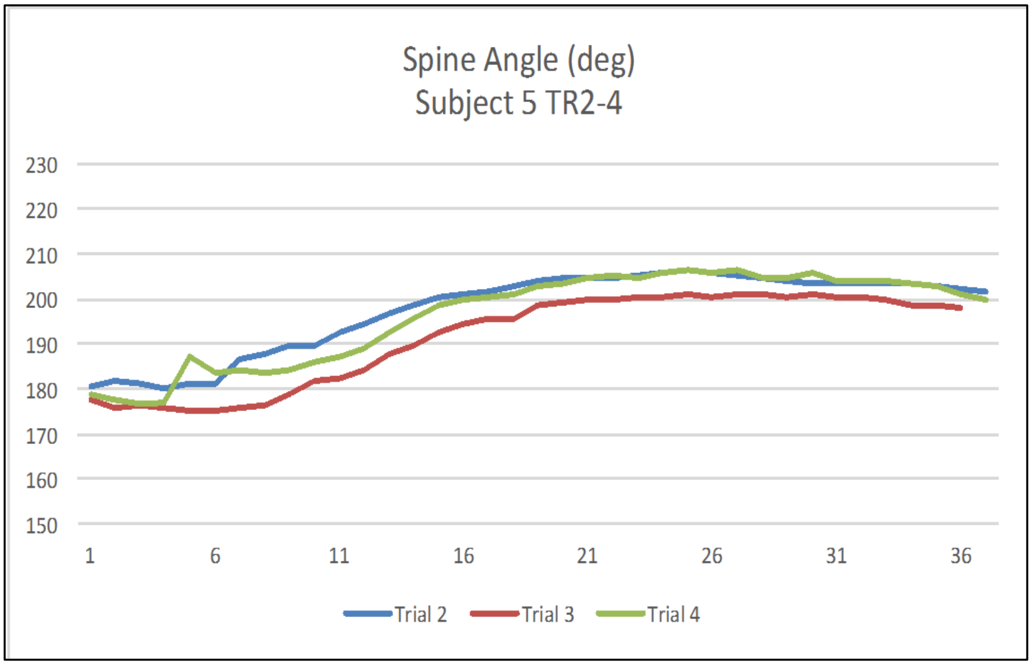
16
21
Trial 2
Trial 3
Trial 4


Spine Angle (deg)
Subject 5 TR2-4
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220
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190
180
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160
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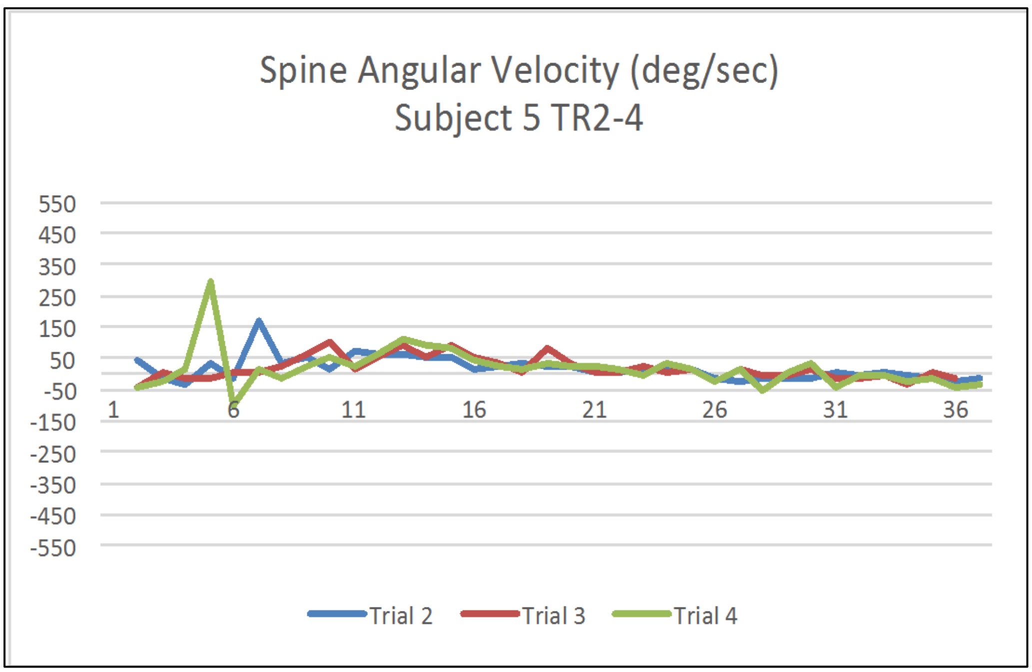
36
Trial 2
Trial 3
Trial 4


Spine Angular Velocity (deg/sec)
Subject 5 TR2-4
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450
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250
150
50
-50
-150
-250
-350
-450
-550
1
6
11
16
21
26
31
36
Trial 2
Trial 3
Trial 4