Analysis of performing the back squat exercise without shoes.

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Numerous studies have suggested that proper squat technique is necessary to reduce the risk of injury to the knees and back (1, 6- 8, 22, 45). Recent studies have even started to examine the acute effects of barefoot running (5, 13, 19, 23, 24, 27, 32, 34, 37, 39- 41, 43, 48, 50, 51) but there are no studies that have examined the effects of resistance training with or without shoes. The only known similar study (14) examined the differences between running shoes and weight lifting shoes when performing the back squat exercise.

Fry et. al., (15, 16) and others (42) have suggested that stature and flexibility are variables that effect foot contact during the squat exercise but one aspect of performing the squat that could potentially cause poor mechanics is shoe properties. Wearing shoes in the weight room is thought to help prevent minor injuries (e.g., dropping weight on toe, stubbing toe) to the feet and shoes help keep weight rooms sanitary (1, 5, 13). There are a variety of running shoes and they tend to vary according to the individual’s type of activity and needs. Running shoes never share consistent characteristics because manufacturers design thousands of shoes with a wide range of flexibility, rigidity along the sides, and cushioned heel inserts (13, 39, 50, 52). These aspects of running shoes may actually harm an individual’s feet and ankles or can make an individual more prone to injury during training (3-5, 13, 14, 19, 24, 37, 39, 41).

If an individual wears his or her running shoes while performing the lower body back squat exercise, this might alter foot and lower extremity mechanics that lead to excessive pronation and plantar flexion of the foot. Many running shoes are typically designed to put individuals in a slightly plantar flexed position because most running shoes have slightly cushioned or elevated heels to help absorb shock when running (3, 5, 9, 18, 50). The cushioned soles elevate the individual’s heel higher than any other part of the foot possibly altering mechanics during exercise (24, 32, 36, 37, 50, 52). The NCSA states that an individual should stay back on his or her heel during the back squat exercise (1, 6). This position statement also suggests that poor squatting technique could increase the risk of injuries, particular to the knees and low back (1, 6, 12, 14, 17, 20, 30, 31). It is hypothesized that the elevated heel of the running shoe will cause an individual’s heel to rise up from the floor during the squat exercise causing improper mechanics and the potential for injury.

Furthermore, many shoes don’t have specially designed medial arch supports to accommodate the applied forces during the squat exercise (37, 39, 41, 50). The medial part of the soles on running shoes often wear down because of a common foot strike pattern in runners as pronation occurs during the transition between heel strike (dorsi flexion) and take off (plantar flexion) when running (4, 5, 9, 50) . When continued wear and tear of the shoe occurs, the sole is no longer structured to support the vertical force received from the back squat exercise. A potential increase in pronation and eversion of the foot during the eccentric movement of the squat may lead to an increase in lower leg knee valgus angle. Previous research and literature suggests that minimizing knee valgus angles and reducing the amount of anterior lean is essential during resistance training especially when heavy weight is being lifted (1, 6, 14, 15- 17, 24, 30, 31, 52).

Previous research has also suggested that both beginning and intermediate lifters had greater tendency to lean forward during the squat exercise depending on the lifters height and placement of the barbell on the lifter’s back (e.g., high bar vs. low bar position) (15, 16, 17). Anterior tilt of the torso during the squat should be minimized to help reduce stress on the patella tendon and to help reduce the shearing force on the knee (1, 12, 14, 17, 52). It is clear that maximum torques of the knee occur at the bottom portion (eccentric) of the squat, while maximum flexion of the hips occurs during the second part of the concentric phase (1, 6, 18). Fortenbaugh, et al. (14) and others (6, 15- 17) have suggested guidelines for performing the proper squat technique which include keeping the shin and torso as vertical as possible to help reduce shear stress on the knee, hip, and lower lumbar (6, 12, 14, 17, 30, 31). However, when reviewing research there is conflicting evidence regarding the correct squat technique to enhance results and reduce safety risks (e.g., high bar vs. low bar placement on the lifters back) (1, 6, 12, 18, 17).

Andrew Fry, et al. (17) suggested that lifters might have a slight advantage when permitting the knees to go past the toes depending on the position of the barbell on the individual’s back. This suggestion assumes that the individual performing the exercise does not suffer from knee injuries because greater forces applied to the knees when leaning forward might aggravate any healing knee injury. Injuries included but were not limited to, chondromalacia, patellar tracking disorders, anterior or posterior cruciate ligament injuries, and injuries to the meniscus. If reducing patellar tendon stress and shearing forces at the knee through better mechanics were a result of training without running shoes than it might be beneficial for individuals to remove running shoes while performing the lower body back squat resistance training exercise.

If wearing running shoes while performing the back squat causes an individual to plantar flex onto his or her toes a greater shear force on knees is likely to occur (17, 30, 31, 52). Removing the individual’s running shoes should allow the individual to stay on the heels of his or her feet and reduce the amount of shear force on the knee as long as the individual’s torso stays in correct mechanics (1, 12, 17, 30, 31). The NSCA (1) has suggested that future research should examine the effects of shoe-surface interaction and to date only a few studies (4, 5, 13, 19, 23- 24, 27, 32, 34, 37, 39- 41, 43, 48, 50, 51) have examined the effects during running and none have compared shoe versus barefoot-surface interaction during resistance training.

Previous research has shown effects of training without shoes in ankle rehabilitation programs and in running populations (10, 11, 25, 26, 29, 35, 38). Other researchers suggest that modern running shoes and footwear generally reduce sensory feedback, apparently without diminishing the peak forces applied to the ground- a process described as the “perceptual illusion” of athletic footwear (19, 37, 39). The idea of “perceptual illusion” of athletic footwear is hypothesized to be associated to ankle and foot injuries because this perception gives the individual’s ankle and foot a false sense of protection (37). This is a result of proprioceptive receptors in the feet and ankle being unable to receive feedback from the feet to detect a stable surface because the feet are receiving feedback from the shoes (37). Proprioceptors are specialized sensory receptors located within joints, muscles, and tendons (1). Because these receptors are sensitive to pressure and tensions, they relay information concerning muscle dynamics to the conscious and subconscious parts of the central nervous system (CNS) (1). The brain is then provided with information concerning kinesthetic sense, or conscious appreciation of the position of body parts with respect to gravity (37). Most of this proprioceptive information, however, is processed at subconscious levels so individuals do not have to dedicate conscious activity toward tasks such as maintaining posture or position of body parts (1, 37). Several studies and articles suggest that once the natural foot structures are weakened by long-term footwear use, people have to rely on the external support of the footwear, but the support does not match that provided by a well functioning foot (4, 5, 9, 13, 19, 23, 32, 37, 39, 40, 41, 43, 48, 50, 51). Removing running shoes while performing the back squat might allow for greater proprioceptive feedback during exercise than when wearing shoes.

Purpose

The purpose of the study is to compare the lower body squat exercise without shoes to quantify “center of pressure” (∆COP) using a force plate. This study will also compared anterior/posterior movement and forces of the foot, medial/ lateral movement and forces of the foot, vertical forces of the foot, knee flexion, hip flexion, and ankle flexion. This study will also survey participants to determine which training method they preferred and which training method allowed them to perceive more stability throughout the entire squat exercise.

Hypotheses

1. It is hypothesized that anterior forces (Fy) of “center of pressure” will increase (p<0.05) when performing the squat with running shoes.
2. It is also hypothesized that posterior forces (Fy2) of “center of pressure” will be significantly greater when performing the squat exercise without running shoes (p < 0.05).
3. It is also hypothesized that medial force (Fx) of “center of pressure” will be significantly less when performing the squat without shoes (p<0.05).
4. It is also hypothesized that lateral force (Fx2) of “center of pressure” will be significantly greater when performing the squat without shoes (p<0.05).
5. It is also hypothesized that vertical force (Fz) of “center of pressure” will be significantly greater when performing the squat without shoes (p<0.05).
6. It is also hypothesized that medial movement (Mx) of “center of pressure” will be significantly less when performing the squat without shoes (p<0.05).
7. It is also hypothesized that lateral movement (Mx2) of “center of pressure” will be significantly less when performing the squat without shoes (p<0.05).
8. It is also hypothesized that anterior movement (My) of “center of pressure” will be significantly less when performing the squat exercise without shoes (p<0.05).
9. It is also hypothesized that posterior movement (My2) of “center of pressure” will be significantly less when performing the squat exercise without shoes (p<0.05).
10. It is also hypothesized that knee flexion (Kf) angles will increase when performing the squat without running shoes (p<0.05).
11. It is also hypothesized that ankle flexion (Af) angles will decrease when performing the squat without running shoes (p<0.05).
12. It is also hypothesized that hip flexion (Hf) angles will increase when performing the squat without running shoes (p<0.05).
13. It is also hypothesized that anterior knee displacement (Kd) will decrease when performing the squat without running shoes (p<0.05).
14. It is also hypothesized that subjects will perceive more stability when performing the squat without running shoes (Rate of comfort scale 1-5).

Operational Definitions

1. Center of Pressure (∆COP): the center of mass with the base of support provided by the foot measured by ground reaction forces from the force plates.
2. Proprioception: specialized sensory receptors located within joints, muscles, and tendons that provide the central nervous system with information needed to maintain muscle tone and perform complex coordinated movements. (1)

Delimitations

1. This study is delimited to injury free collegiate male students enrolled in a PFW weight training course during the spring/ summer session between the ages of 18-25.
2. This study is delimited to athletes/ individuals with previous resistant training < 2-3 years.
3. This study is delimited to having a constant type of running shoe, men’s sizes 10, 11, 11.5 and 12.
4. This study is delimited to participants who do not have complications of diabetes mellitus. Individuals with diabetes mellitus should avoid training without shoes.

Significance of the Study

This will be the first known study to examine if removing footwear during resistance training helps prevent improper motion mechanics compared to wearing shoes during the squat exercise. Decreasing anterior knee displacement and increasing stability during the squat exercise may help decrease shear forces applied to the knees which may help prevent injuries during training. Training without shoes may also allow athletes to become stronger by training their natural proprioceptive muscles in the foot/ankle region which may further prevent injuries to the lower extremities. Furthermore, shoes may cause an increase in knee valgus angle and reducing lower leg valgus angles during the squat exercise might help reduce the risk of knee related injuries during resistance training (17, 22, 30, 31). Another significance of this study is to determine if training barefoot increases stability throughout the lift. Resistance training without running shoes may improve motion mechanics of knee, hip, and ankle. Improved motion mechanics may increase flexibility, strength and reduce injuries of the lower body (1, 6- 8, 21, 22, 28, 30, 45, 47).

Methods

Subjects

Twenty male (n=20) volunteers will participate in this study. All participants were students enrolled in a weight training physical fitness and wellness (PFW) course at a Central Texas Division 1 University. This sample of subjects had previous experience in a resistance training program (> 2-3 years) and was representative of typical men in college. Descriptive characteristics of the participant are as followed, age (years): 18-25, resistance training (years): > 2-3, shoe sizes (men’s): 10-12, high school sports playing experience (years): 1-4.

Test or Instruments

AMTI® force/ motion plates (OR6-6-1000) and BioAnalysis® software version 2.2 will be used to examine the “center of pressure” (∆COP) of the athlete’s foot during the back squat exercise. DartFish® motion analysis and one digital recording video camera will collect data of the sagittal plane during the back squat exercise to analyze anterior knee displacement, knee flexion, ankle flexion, and hip flexion. Other equipment that will be used during this experiment is a squat rack with safety bars, a 45 pound barbell, free weights, and 4 constant types of running shoes, men’s sizes 10, 11, 11.5 and 12. There will also be 3 spotters present during the lift to help minimize the chance of any injury. Additional equipment necessary for this experiment is a spray bottle with sanitizer to disinfect force plates after each trail, antifungal shoe spray to disinfect shoes after each subject, 4-5 reflective markers, 50 ft. roll of 1 in. blue tape, and a towel to dry the force plates.

Equipment:

* A barbell, weight plates, and two safety locks (collars): enough total weight to accommodate 60% of the strongest lifters estimated 1 rep max and a variety of plate sizes to allow for 5 pound (2.5 kg) gradations in weight
* A sturdy squat rack with adjustable spotting bars to support the weight of the bar if the lifter is unable to complete the lift (as an alternative, one spotter can be used at each end of the bar).
* 4 pairs of the same men’s running shoe. (sizes: 10, 11, 11.5, 12)
* The force plates should fit inside of the squat rack to insure safety for the lifter.
* DartFish motions monitor equipment. (1 cameras and software equipment)
* Spray bottle with sanitizer to disinfect force plates after each trail, antifungal shoe spray to disinfect shoes after each subject, 4-5 reflective markers, 50 ft. roll of 1 in. blue tape, and a towel to dry the force plates.

Personnel:

* Thee spotters (one behind the lifter, one on each side of the lifter. Procedure should follow the spotting technique suggest by the NSCA for the squat exercise).
* Two recorders (one for collecting DartFish® camera #1 (sagittal view) and force plate.

Procedures

At the beginning of the testing procedure subjects will warm up when entering the gym/ weight room. The warm up will last 10-12 minutes and include a series of static stretches followed by a dynamic warm up targeting the lower body until the individual is comfortable to perform the squat lift (\*see warm up protocol). Following the warm up the experimenter should allow the individual to perform 1 set of 5 repetitions of back squats in order to become familiar with the testing procedure. During the familiarization session the experimenter will have the individual perform the squat exercise with the barbell only to check for correct mechanics to further reduce the risk of injuries. During the second day of testing the individual will perform the entire lift with his or her shoes on and off. During each successful trial the experimenter should focus on having the subject’s femur reach parallel to the floor at the bottom portion of the squat exercise (1, 12).

Testing procedure is as followed:

Subjects will be tested using random order. Each subject will be assigned a number which will serve as a reference number to compare lifting sessions after data has been collected.

Day 1:

Experimenter will record subject’s height, weight, shoe size, and estimated 1 repetition maximum for the squat exercise. This information will be collected in order to determine correct shoe size and the percentage the subject will be lifting in the following testing session. The test will be completed using the barbell free-weight squat. For all strength tests, the subjects will complete a warm-up and 1 set of 5 repetitions of the back squat using only the barbell. The 1RM (maximum load capable for 1 repetition) will be found to determine the lifters 60% training load. For each successful trial when finding the estimated 1RM the lifter will increase their load 10-20% with 3-5 minutes of rest between trials until the 1RM is determined.

Day 2:

During the 2nd testing session of the lower body back squat exercise the experimenter will collect data from the 2 force plates, perceived comfort scale (similar to rate of perceived exertion scale) and motion camera readings. There should be a minimum of 3 days after Day 1 testing. Waiting 3-4 days before retesting will help to eliminate the possibility of delayed onset muscle soreness (DOMS) and fatigue of the muscles which could possible hinder performance or skew the reliability of the data (1). During this testing session the experimenter will place the motion cameras directly to the right side of subject capturing the subject’s sagittal view in the video cameras frame. Subjects will be instructed to wear dark clothing in order to identify reflective markers. Reflective markers will be placed on the subject’s lateral (sagittal view) right hip, knee, and ankle prior to warming up. Testing this day will be performed with shoes on and off. After the warm up the subject will be instructed to stand on the force plate facing the positive “y” direction in the position the he will perform the squat. The experimenter will then place a piece of colored tape in front, behind and both sides of the subjects foot to identify where the subject will stand for both lifts. The experimenter will load 60% of the subjects estimated 1RM found on day 1 of testing and then secure safety collars on the barbell outside of the weight plates. After the weight has been loaded and secured all spotters will be instructed to spot the individual until the subject racks the weight or needs assistance. The subject will then unrack the barbell themselves using the high bar (upper 1/3 trapezius) position and place their shoes inside of the blue taped shoe outline. The subject will then perform 1 set of 5 repetitions @ 60% 1RM with shoes on and then rack the weights. The individual should then remove his shoes and socks for the next trail. The experimenter should allow no more than 3 minutes of recovery in between each set unless the subject requires additional recovery time. After the subject has recovered spotters will be instructed to spot the individual until the subject racks the weight at the end of their lift or needs assistance. The subject will then unrack the barbell themselves using the high bar (upper 1/3 trapezius) position and place their barefoot inside of the blue taped shoe outline. The subject will then perform 1 set of 5 repetitions @ 60% 1RM with shoes off and then rack the weights. After the subject racks the weights the experimenter and spotters will remove all weight from the barbell and put the weight plates in its appropriate place. The subject is free to put on their shoes after the barefoot testing has been collected. The subject will be instructed to complete a 3 question survey to and there is to be no communication of the answers between the subject and experimenter. The completed survey will be placed in a secured folder and not viewed until after all subjects have completed the survey. Between subjects the investigator will disinfect shoes and force plates with cleaner.

Design and Analysis

Dependent variables that will be examined are “center of pressure” (∆COP) force plate measures (Fx, Fy, Fz, Mx, My), anterior knee displacement, knee flexion, ankle flexion, and hip flexion. The independent variable in the study is the foot condition, trial A: with shoes, trial B: without shoes. Motion kinematics will be analyzed using DartFish® motion software and the “center of pressure” will be determined by using BioAnalysis® software version 2.2. The values of each dependent variables of the 2nd, 3rd, and 4th repetition of each trail will be recorded to determine a mean, maximum, and minimum value. The mean, maximum, and minimum values of both trails (shoes on vs. shoes off) will be compared to each other through statistical test. The statistical test that will be used to interpret these results will be a repeated measures t test for each dependent variable. The perceived comfort scale survey will be examined to determine preferred training method and used to determine perceived stability correlated with the subject’s motion mechanics. To determine if perceived stability correlated with motion mechanics the answers to questions #1 and 2 will be identified and compared to the statistical powers found from the repeated measures t test for each dependent variable. Question # 3 will be collected to determine the overall groups preferred method of training and if it correlated to the statistical findings.

Summary and Conclusion

In conclusion future research needs to examine physical activity (e.g., running, weight lifting, etc.) without running shoes to determine if this training method is appropriate for athletes and other populations. If stabilizer or proprioceptive muscle of the foot and ankle become more active during resistance training without running shoes there should be a positive correlation with greater strength, flexibility, and mechanics of these muscles which should also be tested in future research. Future research should also examine acute and chronic adaptations of the fascia, tendons, and ligaments of the foot/ankle region during resistance training without running shoes. Bone adaptations after resistance training without shoes should be examined in future studies lasting no less than 6 months. NSCA suggest that changes in BMD can occur in 6 months with progressive resistance training (1). BMD (Bone Mineral Density) should be examined using a DEXA® or other bone imagining device.

If benefits are found in BMD it is hypothesized that it is attributed to the specificity of loading the femur, tibia, and fibula during the squat exercise (1, 8, 28, 45, 47) (without running shoes). It is hypothesized that exercising with running shoes on might not be beneficial for certain resistance training exercises (e.g., squat) because the running shoes soles are designed to absorb the force or weight that is being placed on the shoe which lessens the direct force that is being applied to the bones, joints, tendons, and ligaments of the lower leg. Wearing running shoes and performing the squat exercise with heavier weights will put a greater amount of stress on the soles of the shoes possibly hindering performance (9, 14, 37, 39, 41, 50). It is likely that the running shoes soles will no longer be able to act as a stable surface because of the vertical force being applied to the individual from the weight on the barbell during the back squat exercise.

Training without or removing shoes while performing certain exercises and following a progressive overload resistance training program will allow for direct contact between the training surface and the joints, tendons, ligaments, and bones associated with the squat exercise. It is hypothesized that the progressive force applied to the bones, ligaments, and tendons from the direct contact with the surface should increase the BMD and the strength of the fascia and other ligaments which might help prevent injuries to the lower extremity. If there is an increase in BMD, stabilization, and range of motion from resistance training without shoes applied applications would be for children (postpubescent), athletes, and other active people to train without running shoes during certain exercises. If changes occur in BMD than training without running shoes may also assist in delaying the onset of osteoclasts and plantar fasciitis exhibited in later stages of life (1, 8, 28, 45, 47). Health professionals assume the responsibility to keep clients safe which is why studies are needed to examine the benefits and harms of training without shoes. Conducting quality research on training without shoes will be the only way to determine the proposed benefits and harms of this training technique.

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