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Exploring possible factors contributing to the onset of Osgood Schlatter disease

Justin Pruitt

EXPLORING POSSIBLE FACTORS CONTRIBUTING TO THE ONSET OF OSGOOD SCHLATTER DISEASE

by

JUSTIN PRUITT

A THESIS

**Submitted in partial fulfillment of the requirements
for the degree of Master of Science
in
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The University of Alabama in Huntsville
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to
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THESIS APPROVAL FORM

Submitted by Justin Pruitt in partial fulfillment of the requirements for the degree of Master of Science in Biology and accepted on behalf of the Faculty of the School of Graduate Studies by the thesis committee.

We, the undersigned members of the Graduate Faculty of The University of Alabama in Huntsville, certify that we have advised and/or supervised the candidate on the work described in this thesis. We further certify that we have reviewed the thesis manuscript and approve it in partial fulfillment of the requirements for the degree of Master of Science in Biology.

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ABSTRACT
The School of Graduate Studies
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Osgood Schlatter Disease (OSD) is a painful traction apophysitis that affects the secondary ossification center behind the tibial turberosity. Although it affects many adolescent athletes, no precise etiology has been confirmed, and there is a limited amount of literature describing attempts to do so. There is however, ample literature speculating possible etiologies. The goal of this study was to explore some of the possible causes of OSD. Two groups of adolescent males (Control and OSD) underwent a series of strength and flexibility tests. There were significant differences in passive knee flexion and in torque to body weight ratios at specific angles during knee extension of a slow speed isokinetic test. It was concluded that a deficiency in the quadriceps muscles near terminal knee extension could be a primary cause of OSD. More studies with larger samples should be done to confirm these results.

Abstract Approval: Committee Chair ____________

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CHAPTER I

THE PROBLEM

Introduction and Statement of the Problem

Osgood-Schlatter Disease (OSD) is a lesion on the tibial tuberosity first described independently by two orthopedic physicians, Robert Osgood and Carl Schlatter, in 1903. It is considered one of the most prevalent knee injuries among adolescents and is characterized by pain, swelling, and tenderness around the tibial tuberosity (Visuri et al., 2007). It most often affects children between the ages of ten and fifteen who participate in sports that involve sprinting, cutting, and jumping (Cassas and Cassettari-Wayhs, 2006). Typically, the pain can be alleviated with conservative measures such as rest, ice, and activity modification. The symptoms should subside completely with skeletal maturity (Gholve et al., 2007).

Most professionals agree Osgood Schlatter Disease is a traction apophysitis of the tibial tuberosity. This means that the inflammation and pain is caused by repetitive strain on the secondary ossification center, which is present just underneath the tibial tuberosity while a child is still growing (Gholve et al., 2007). However, the true cause of the extra strain placed on the insertion site of the patellar tendon is unknown (Cassas and Cassettari-Wayhs, 2006). Even though many theories exist, very few have been studied and documented. In fact, there is very little peer reviewed literature describing

experiments that test specific etiological theories. A "cure" cannot be found without a clear cause.

In addition to being very painful, OSD can affect athletic participation for an extended period of time which can be detrimental to a child's social development and self esteem (Reeves et al., 2006). In fact, a study done by Ross and Villard in 2003 shows patients can still be affected by OSD even years after the growth plate has closed (Ross and Villard, 2003). Still other more advanced cases can require surgery (DeBerardino et al., 2007). So, despite OSD being "self limiting" in most cases, OSD can have a more serious outcome, and since it affects a relatively large number of children it's worth exploring the true etiology in an attempt to ultimately lower the incidence of injury.

Purpose of the Study

The initial idea for this study comes from the work of Mark Noble, MS, who has been isokinetically testing athletes' muscular capabilities since the 1970's. While Mr. Noble never studied or compiled the data, he noticed a recurring theme that many OSD patients had quadriceps strength values well below what was considered normal limits. Of course this could have been due to pain, but Mr. Noble thought it should be looked at more closely. In addition to Mr. Noble's findings, many articles are published that suggest strengthening and stretching should be included in the rehab protocol. What is inconsistent however is the advice regarding what muscles need to be strengthened and stretched. Some articles suggest tight quadriceps are to blame, others accuse tight hamstrings and still others mention both. The same is true for the strength of these muscle groups. The primary purpose of this study is to test the speculations found in the literature using experimental and control subjects to determine if any or all of the

suggestions should be considered risk factors for developing OSD. The secondary goal of this study is to identify certain tests that can be used to screen for risk factors if any are identified.

Hypothesis

Based on Mr. Noble's prior work, it was hypothesized that a large percentage of OSD cases were caused at least in part by a lack of quadriceps strength coupled with a large amount of intense athletic activity. When the foot strikes the ground during the running gait, the quadriceps contract quickly and forcefully to help stabilize the knee and prevent buckling. It was my belief that if the quadriceps were too weak, or did not fire quickly enough, then more stress would be transferred to the inserting patellar tendon causing excess stain to be placed on the tibial tuberosity. It was expected that when tested in open chain knee extension / flexion using an isokinetic dynamometer, the OSD subjects would have lower strength to body weight ratios for peak torque, peak work, and average work per repetition especially at high speeds. A similar trend was expected when testing the one repetition maximum (1RM) of a single leg press. Some tightness in either the quadriceps or hamstrings was also expected, but only as a contributing factor to the lack of torque production rather than a main etiology.

Summary

Osgood Schlatter Disease is a self limiting knee injury resulting in pain and swelling around the tibial tuberosity. It most often affects adolescents who participate in organized sports, but can affect non-athletes as well. Conservative treatment can help alleviate pain until the growth plate is closed. Despite the theory that OSD is a traction apophysitis, the exact cause of the excess traction is unknown. This study aims to

address several common etiological theories involving the strength of the quadriceps and hamstrings, and flexibility of certain leg muscles.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

As mentioned in Chapter 1, there are many theories about the etiology of OSD, and the goal of this study was to test several of the hypotheses and identify which ones were supported by the results. Since OSD is a common injury, there are many websites or pages devoted to the defining of the injury as well as offering possible methods of prevention or treatment. With such materials so easily accessible to concerned parents and since so many of the treatment or prevention plans can be followed with relative convenience, it was important for us not only to review the academic literature, but also the literature that was available to parents. So the review of literature for this study includes a mixture of peer reviewed journals, public medical websites, and even personal pages of health professionals. Hopefully, by reviewing all of the possibilities and testing many of them, this study will be able to narrow down the list of probable etiologies.

Occurrence Information

One of the most comprehensive studies found on the incidence of OSD was done by Kujala et al. in 1985. That study showed an OSD incidence among the general population of adolescents to be at 12.9%. This was further analyzed to reveal that 21.2 % of athletes had suffered from OSD, while only 4.5% of non athletes had been diagnosed.

This clearly shows athletes are at more risk, but that non athletes can also be affected by this injury (Kujala et al., 1985). The literature also states 25 to 33 percent of cases are bilateral and that boys are more likely to be affected by OSD (Mital et al., 1980).

One review of records of the Turku Sports Medical Research Unit's Outpatient Sports Clinic in Finland provided interesting information about the occurrence of OSD. Over a six year period (1976-1981) the TSMRU Outpatient Sports Clinic was contacted by 412 adolescent athletes with a total of 586 complaints. It was determined that 68 (16.5%) of these athletes had OSD and were given a retrospective questionnaire. The average age of initial symptom onset was 13.1 years. All 68 were instructed to abstain from any and all pain soliciting activity for 2 months on average. The questionnaire, however, revealed that on average training was completely avoided for 3.2 months and pain still interrupted normal training for 7.3 months (Kujala et al., 1985).

Theories of Etiology

Several theories of etiology were found in the literature and they are discussed here one at a time and designated into subsections.

Hamstrings Tightness

A few articles list hamstrings tightness as a possible etiology during their review of literature (Reeves et al., 2006; Gerbino, 2006). David Edell, ATC, stated that while both hamstrings and quadriceps tightness are likely, he believes that hamstring tightness is the real problem. Since the hamstrings are antagonists to the quadriceps, tightness in them will cause the quadriceps to fire harder to fully extend the knee. Edell stated that it is the hamstring tightness not quadriceps tightness that causes the excessive traction of

the patellar tendon that leads to OSD (Edell, 2006). This theory also supports one of the secondary hypotheses of this study.

Quadriceps Tightness

Another possible etiology of OSD is quadriceps tightness. Reeves reports tight quadriceps muscles, caused by an increase in femur length during rapid growth spurts, may be a main contributor to excessive patellar tendon traction (Reeves et al., 2006). There are also several private web pages run by health professionals or healthcare organizations that make this claim (Labella, 2005; Saguil, 2008). Dr. Frank Liggio, M.D., recommends daily quadriceps stretching as part of the rehab program and claims it is the "most important aspect of treatment…" (Liggio, 2007).

IT Band Tightness

Along with speculation of abnormal tightness of the hamstrings and quadriceps muscles, one physical therapy reference website listed possible IT band tightness (Hill, 2010). The muscle associated with IT band tightness is the tensor fasciae latae which can be tested using Ober's Test (Magee, 1987).

Quadriceps Angle

There is also some literature that would suggest an increased quadriceps angle (Q-angle) plays a role in the development of OSD. A study by Sra in 2008 reported that anterior knee pain (AKP) could be a result of a larger than normal Q-angle. The study documented the Q-angles of 70 men with AKP compared with the Q-angles of 70 men without AKP. The patients had unilateral AKP and only the Q-Angle of the involved leg was measured (Sra et al., 2008). While the average age for this study was 24 and it did

not deal with OSD specifically, OSD does fall under the AKP category and thus an increased Q-Angle could be a contributing factor in the development of OSD.

Muscle Weakness

Several articles list quadriceps and hamstrings strengthening as an important part of rehabilitation and prevention, but no data has been found to support these claims. (Gerbino, 2006; Cassas and Cassettari-Wayhs, 2006). In Reeves' et al. review of literature, they state that strengthening the quadriceps should be one of the main focuses of a rehab program (Reeves et al., 2006).

Summary

The review of literature identified the population at risk of developing OSD and several etiological theories. It is cited that athletes are four to five times more likely to get OSD than non-athletes, and boys are possibly affected more than girls. The possible etiologies include muscle tightness in the hamstrings, quadriceps, and tensor fasciae latae (IT band). It is also speculated that a larger quadriceps angle could be a factor contributing to OSD development. Finally, there are rehab protocols that recommend strengthening of the hamstrings and quadriceps muscles. However, despite all these theories, no literature was found describing any experiments that specifically tested any of these theories.

CHAPTER III

METHODOLOGY

Introduction

The study design was created with the assistance of one exercise physiologist, two orthopedic surgeons, two physical therapists, and two PhD faculty members from UAHuntsville. The protocol included a questionnaire, six range of motion tests, a single leg press on an open kinetic chain machine, and an open kinetic chain isokinetic test of knee extension / flexion. All subjects underwent the same set of experiments in the same chronological order. The questionnaire was used to gather specific information and summarize how OSD had affected them. The six range of motion tests were chosen based on the various theories of etiology described in the review of the literature. The leg press was done in an attempt to identify an easily accessible test that could be used to screen entire teams for risk factors if knee extensor strength was shown to contribute to the onset of OSD. Finally, the isokinetic test was done to quantify the amount of torque the quadriceps and hamstrings muscle groups were able to produce, which tested the primary hypothesis.

Population Sample

Since there is a higher incidence of OSD reported in males, only male subjects were used for this study to avoid any gender dependant variation. Any male who had

recently been diagnosed with OSD by either his family physician, or in many cases an orthopedic specialist, and was still experiencing symptoms, was accepted into the OSD group. The control group consisted of any male that was currently participating in organized sports at least three days a week and did not have a previous or current knee injury. Acceptable sports were basketball, baseball, football, soccer, tennis, and track and field.

Every attempt was made to collect an unbiased control sample. Emails, phone calls, and even personal visits were used as a means of recruiting control subjects. Both club and school affiliated teams of various sports, including baseball, basketball, football, and soccer, from all over Madison County, Alabama, were contacted. However, without the ability to offer compensation (other than test results), it was very difficult to get people to donate their time. Also, since the subjects had to be in season and practicing a minimum of three days a week, often times the subjects did not have any days to spare. These unavoidable circumstances made it difficult to get an unbiased, diverse control group.

The OSD group consisted of both Caucasian and African American males from Madison and Jackson Counties in Alabama. They played a variety of sports and were currently involved in basketball, baseball, soccer, football and/or track. They had an average age of 13 years 9 months ±1 year 8 months (11yrs. 7mo. – 16 yrs. 5 mo.) and a mean weight of 139.4 ± 22.8 pounds.

The Control group consisted of Caucasian males from Madison County, Alabama. They played a variety of sports and were currently involved in baseball, soccer, and/or basketball. Three of the subjects were from the same all-star baseball team

as one of the OSD subjects. The other three were participants of the same soccer training group, although they were on different teams during the season. They had an average age of 12 years 6 months ± 6 months (11yrs. 11mo. – 13yrs. 3mo.) months and a mean weight of 97.3 ± 14.8 pounds.

The mean weight and age of the two groups were different. The difference in weight could be attributed to at least one of several factors. First, increased weight could be considered a risk factor for OSD. Second, the difference may only have existed because the sample size was so small. The weights could have been different because the ages were different. Finally, the method used for finding control subjects could have introduced a bias based on the types of sports played. Any of these scenarios is possible and hopefully future studies will reveal the more likely culprit. The difference in age could be a result of the parameters set for the control group. No control subjects over 14 years of age were allowed, but 3 OSD subjects were over 14 (one of which was nearly 16 and one who was over 16). Allowing Control subjects up to age fifteen in future studies might be a way to avoid a difference in the mean sample age.

Protection of Human Subjects

This study used human subjects, who legally were minors, and thus required the approval of all institutions involved as well as the consent of both the subjects and their parents. Before research, an application was submitted to both the UAHuntsville Institutional Review Board and the Huntsville Hospital Institutional Review Committee. The proposed study design was also presented live to the Huntsville Hospital IRC committee members. After completing the due process of UAHuntsville and Huntsville Hospital, each institution granted permission to continue with the study as planned.

Copies of the Approval Letters as well as the Informed Consent form can be found in Appendix A.

Pre-Test Procedures

A detailed history of athletic involvement, previous injuries, and personal effects of OSD, as well as a few physical facts were collected using a questionnaire. This questionnaire was then used to determine if there was any correlation between any of the collected data and the development of OSD. One such point of particular interest was frequency of athletic participation, since some literature describes OSD as merely an overuse injury. The questionnaire was also used to identify eligible controls subjects. Control subjects who did not claim to practice at least 3 days a week, or who had suffered a previous knee injury were not allowed to participate in the study. The complete questionnaire can be seen in Figure 3.1.

The strength test data was normalized using the subject's body weight, so each subject was weighed prior to any tests being done. The subject wore the same clothes he would be wearing for the tests and also kept his shoes on during the measurement. This was done so the weight measured would most accurately reflect the entire weight of the subject both during athletic participation and during the strength tests (shoes were worn during these tests).

Participant Information and Questionnaire

Information: Please do not discuss your current physical condition with the tester. In order to make this a double blind study the tester does not need to know if you currently have an injury.

Instructions: Please circle the correct answer for each question and place the completed questionnaire in the folder provided.

1. Have you recently been diagnosed with Osgood Schlatter's Disease? **Yes No**

   a. If so, which knee is affected? **Right Left Both**

2. What activities cause pain? (Circle all that apply)
   Running, Jumping, Walking, Kneeling, Walking Down Stairs, Walking Up Stairs, Bumping your knee, Constant pain (all of the above), Other (list)_______________
   ____

3. Circle all sports that you play. **Baseball/Softball, Basketball, XC, Football, Hockey, Soccer, Swimming, Tennis, Track, Volleyball,**
   Other____

4. What sport are you currently playing? **Baseball/Softball, Basketball, XC, Football, Hockey, Soccer, Swimming, Tennis, Track, Volleyball,**
   Other____

5. What is your dominant arm? **Right Left**
   Dominant Leg? **Right Left**

6. How many days a week do you normally practice? **0-2, 3-5, 6-7**

7. Have you recently reduced your amount of running and jumping for any reason including, but not limited to injury? **Yes No**

   a. If so, list reason(s) for limiting activity.________________________________

   b. List ways you have limited your activity. (ex. Skipped all practices, cross trained, etc.)
   ____

   c. For how long have you been altering or limiting you activity?
   ____

Figure 3.1 Background information questionnaire completed by all subjects.

Range of Motion Procedures

Six range of motion tests (ROM) were done. The first two were done to determine if the knee had what was considered complete or normal range of motion. The next four were done to test various hypotheses of etiology that were identified during the review of the literature. No warm up was done prior to the flexibility screen in order to eliminate variability. While these tests did not necessarily test the primary hypothesis of this study, it was decided that any easily tested hypothesis found in the literature should be tested while the subjects were available.

Knee Extension

This test was done to determine if the subject had full range of motion at the knee joint. It did not test any group of muscles in particular. The protocol used was described by Norkin and White (2003). First, the subject lay on a table in the supine position and a rolled up towel was placed under the ankle of the same leg as the knee being examined. The center of the goniometer was placed over the lateral femoral epicondyle. The proximal arm was aligned with the greater trochanter of the femur and the distal arm was aligned with the lateral malleolus of the fibula (Figure 3.2). The patient was asked to completely relax so that the knee would fully extend. The end feel was firm due to the tension in the posterior joint capsule (Norkin and White, 2003). Full extension was identified as 0 degrees. Any knee that failed to fully extend would have had a value greater than 0 degrees.

Figure 3.2 Knee extension range of motion test.

Knee Flexion

This test was also done to determine if the subject had normal knee motion. According to Norkin and White (2003) studies show the normal range to be between 132 and 150 degrees. First, the patient was asked to lay supine on the table, flex the hip of the leg being tested, and relax the quadriceps muscles. The center of the goniometer was then placed over the lateral femoral epicondyle. The proximal arm was aligned with the greater trochanter of the femur and the distal arm was aligned with the lateral malleolus of the fibula. The examiner used one hand to move the lower leg toward the buttocks until it would no longer move (Figure 3.3). The end feel was typically soft on the account of the calf pressing against the back of the thigh (Norkin and White, 2003). When the end feel was reached, the angle was recorded.

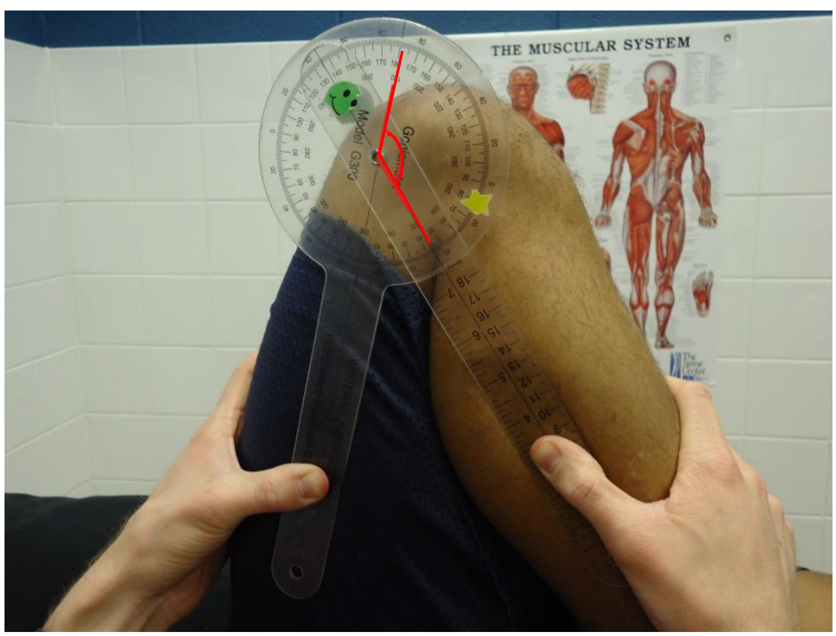


Figure 3.3 Knee flexion range of motion test.

Hamstrings

This test was done to identify any abnormal tightness in the hamstring muscles. The protocol used was described by Norton and White (2003). The subject was asked to lie in the supine position and flex the hip being tested to 90 degrees. He was then asked to completely relax his leg muscles. The center of the goniometer was placed over the lateral femoral epicondyle. The proximal arm was aligned with the greater trochanter of the femur and the distal arm was aligned with the lateral malleolus of the fibula. The examiner used one hand to keep the hip flexed and the other to move the lower leg slowly toward extension until the leg would no longer move without excessive force (Figure 3.4). The end feel was firm due to the tension in the hamstring muscles. Norkin and White describe a study that found the average angle in a group of healthy adult males to be 149 degrees (Norkin and White, 2003).

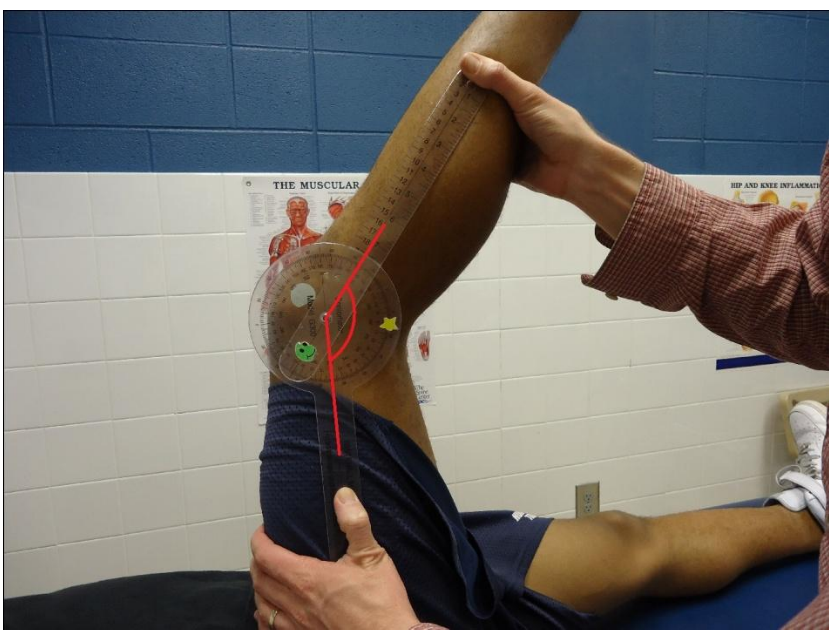


Figure 3.4 Hamstring muscles flexibility test.

Quadriceps

This test was done to identify any abnormal tightness of the quadriceps muscles, most specifically the rectus femoris. The protocol used was similar to the Ely test described by Norkin and White (2003). The subject was asked to lie in the prone position and completely relax his leg muscles. The center of the goniometer was placed over the lateral femoral epicondyle. The proximal arm was aligned with the greater trochanter of the femur and the distal arm was aligned with the lateral malleolus of the fibula. The examiner then used one hand to move the lower leg toward the buttocks (Figure 3.5). This was done until the hip began to visibly flex. As soon as the hip began to flex, the motion was stopped and the angle was recorded. According to Norkin and White the knee should be able to flex beyond 90 degrees (Norkin and White, 2003). This protocol was adopted during the study, so this particular test had a lower sample number than the others.

Figure 3.5 Quadriceps muscles flexibility test.

Ober's Test

Ober's test was used to assess the length of the tensor fasciae latae. The protocol used was similar to that described by Magee (1987). The subject was placed in the side lying position and the lower leg was slightly flexed at the hip. The examiner then gently abducted and extended the upper leg at the hip which caused the iliotibial band (IT band) to pass over the greater trochanter (Figure 3.6). The examiner then attempted to slowly lower the upper leg. If the leg readily lowered towards the mat, to the point where the knee was below horizontal when compared to the hip, the test was considered negative. A positive sign was recorded if the leg was "fixed" in the slightly abducted position, and the knee was not able to be moved below horizontal (Magee, 1987).

Figure 3.6 Ober's test.

Quadriceps Angle

The quadriceps angle (Q-angle) or patellofemoral angle was measured using the technique described by Magee (1987). The patient stood bare foot with heels six inches apart and toes facing forward. A dot was placed in the middle of the patella. A line was drawn from the tibial tuberosity through the dot and another line from the dot toward the Anterior Superior Iliac Spine. The goiniometer was placed on the dot and superior angle was measured as is shown in Figure 3.7. According to Magee (1987) the average Q-Angle for males is 13 degrees (Magee, 1987). This protocol was added after the first subjects had been tested, so its results will contain a different sample number than the other tests.

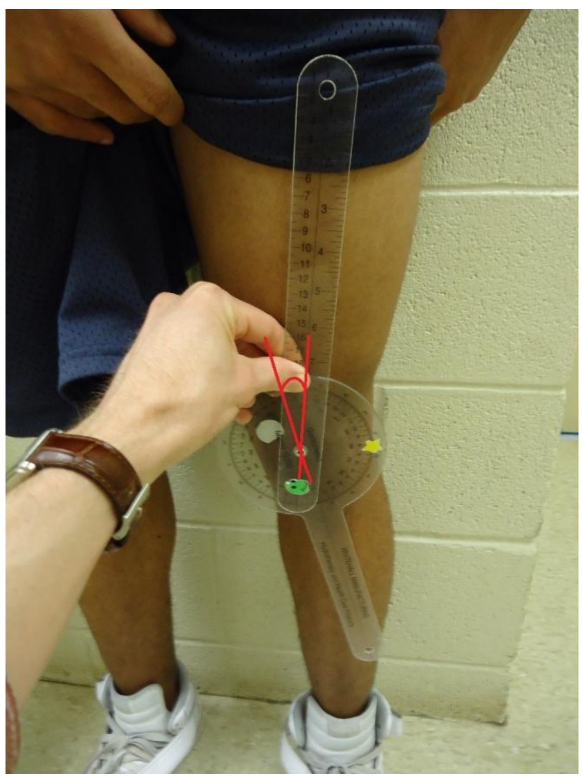


Figure 3.7 Quadriceps-angle test.

Strength Test Procedures

The subjects warmed up for 3 minutes on a stationary bike prior to participating in the strength tests. They were told to pedal at a comfortable rate and the resistance was set on the lowest setting. This was done as a precautionary measure to lower the possibility of being injured during the strength tests.

Leg Press

The one repetition maximum (1RM) for a single leg press was determined for each leg. The machine used for this test was a Cybex VR2, Product # 4605, Serial # 4605915262832. It is an opened chain machine similar to the kind found in most middle or high school weight room facilities. The reason this machine was chosen will be discussed more in Discussions and Conclusions. This protocol was added while the study was underway, so the number of subjects did not match that of the other tests.

First, the back of the seat was adjusted to the middle setting. The subject then sat in the seat of the machine and placed the foot to be tested on the footplate and rested the other on an immovable part of the machine. The foot on the plate was carefully aligned with the knee and hip and then positioned with the heel three inches from the bottom of the plate. The foot plate was then adjusted so that the leg being tested would be flexed 90 degrees at the point during the motion the weight stack became engaged (The footplate moved about an inch with little resistance so this was accounted for when measuring starting position). The subject was asked to the fold his hands across his chest and rest his head against the back of the machine. The proper starting position can be seen in Figure 3.8 with the exception of the actor's neck position. The finishing position as well as proper neck alignment can be seen in Figure 3.9.

Once the subject was properly aligned, 5 warm up repetitions were done with the weight stack set at approximately 25% of the subject's body weight to warm up and familiarize the subject with the proper mechanics of the lift. The subject was queued to exhale slowly while lifting the weight until the knee was fully extended but not "locked out," and then to inhale while slowly lowering the weight. After the warm up repetitions, during which proper technique had been taught and ensured, the subject then performed one repetition at a time. The initial weight was set at approximately 50% of the subject's body weight, and between successful repetitions the weight was increased by 5-15 pounds each time until only one repetition could be completed. The weight that corresponded to this was recorded as the 1RM. This protocol was done for both legs.

While an attempt was made to increase the weight by a certain percentage of body weight each time, that method was found to be impractical and instead the examiner used his best judgment in determining the weight used during the next attempt. If the previous lift seemed effortless the weight was increased by 15 pounds, but if the previous lift was very difficult then the weight was increased by 5 pounds.

Figure 3.8 Starting position for the leg press test.

Figure 3.9 Finishing position for the leg press test.

Isokinetic Knee Extension / Flexion

The primary hypothesis of this study involved the torque production of the quadriceps muscles, and this was tested specifically using a Cybex Isokinetic Dynamometer. The machine used was a Cybex340, serial # 30003604. HUMAC Version 3.3.5 software was used to calculate and interpret raw data obtained by the dynamometer.

There was only one type of test done on this machine for each leg, but it was done at two different speeds. The test evaluated torque and work production during knee extension and knee flexion. For the first run the dynamometer was set to move at 60 degrees per second (slow speed), and for the second run it was set to move at 300 degrees per second (fast speed).

The subject sat down in the testing chair and was asked to sit up tall with his back against the chair back. In some cases the chair would have to be adjusted for this to be possible. The subject was then strapped into the chair using the shoulder / hip harness, and the thigh harness on the leg being tested. Next the axis of rotation of the dynamometer was lined up with the axis of rotation of the knee. This was done by adjusting the height of the dynamometer and moving chair either forward or backward as needed. Once the two axes of rotation were aligned, the arm of the dynamometer was strapped to the ankle of the leg being tested, and the leg not being tested was placed behind a restraining bar. The subject was again asked to sit up straight and cross his arms over his chest. Next the computer asked that the knee being tested be flexed to 90 degrees for calibration. This was done and measured with a goniometer to ensure accuracy.

Once proper alignment was ensured, the knee was flexed until the heel of the leg being testing rested on the starting pad. Instructions were given and testing commenced. The starting position can be seen in Figure 3.10. The subject was told to extend the leg as far as possible ("all the way up") and flex until his foot hit the pad ("all the way down") on each repetition. The 60 degrees per second test was done first followed by the 300 degrees per second test. A 4 repetition warm up was done prior to each test. There was a minimum twenty second rest period after the warm up until the actual test began. For the 60 degrees per second test, 6 repetitions were done and the computer kept 5 of them. The 300 degrees per second test included 18 repetitions from which 15 were kept by the computer. The subject received vocal encouragement during the warm up and test. This consisted of a standard repeated phrase. "All the way up, all the way down. That's it. As hard as you can go…" After the warm up, any questions or concerns were addressed and then the recorded test began. If the machine detected that the test was invalidated due to human error (a large difference in ROM between reps), then an error message would appear and the test would have to be redone. On two occasions the examiner used his judgment to redo a test when it was obvious the subject didn't perform to his best either because of a misunderstanding of the procedure or improper execution of the procedure.

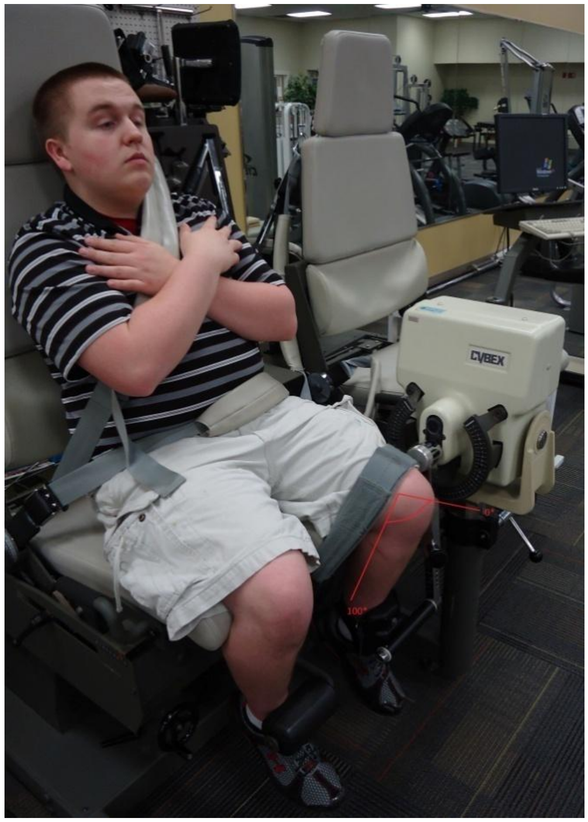


Figure 3.10 Starting position for the isokinetic knee extension and flexion tests.

Data Analysis

The data was analyzed differently for the ROM test and strength tests. The methods used for analysis are described below in the appropriate subsections.

Frequency of Participation

A 2x2 chi^2 contingency table was used to check for a difference in activity level between the two groups. There were three categories of participation frequency (0 to 2 days, 3 to 5 days, and 6 to 7 days). However, since the Control subjects were screened against practicing 0-2 days a week, only the latter two choices were tested with the contingency table.

Range of Motion Tests

The ROM data was collected passively and in a manner that did not aggravate the symptoms of OSD. Therefore, there was no fear of the results actually being affected by the symptoms or effects of the injury. This allowed for all of the ROM data to be analyzed equally. All of the ROM tests were analyzed the following way except the Ober's test (described in the next paragraph). To compare the Control knees to the Experimental knees, without neglecting the fact that knees come in pairs, the values (measured in degrees) obtained for the right and left knees of each individual were averaged together.

First, a paired t-test (critical value .05) was used to compare the right and left knees within each group to ensure there was no difference. In the absence of a difference, the right and left knees were averaged together and the two groups were compared using a two sample t-Test. Prior to performing the two sample t-Test, an F-Test was done to determine if the variances were estimated to be equal. The t-Test was then done with the variance assumption based on the results of the F-Test.

Ober's Test did not test for a particular angle, but rather for a positive or negative sign instead. Therefore, the best way to analyze this data was using a 2 x 2 chi^2 contingency table.

Strength Tests

All of the machines measured weight in pounds, and torque and work in foot pounds. Most data was normalized and presented as a unit-less percentage of body weight, as recommended by Davies (Davies, 2004). However, while analyzing the

normalization technique, some data presented was not normalized. To avoid the potential for errors in the conversion process, the results were kept in the same units as the original data. Pounds can be converted to kilograms by multiplying the value by 0.45. Foot pounds can be converted to Newton meters by multiplying the value by 1.3.

The nature of the strength tests, created the possibility that pain from the injury could affect the test results. Every precaution was made to discard any results that could have been altered due to pain, but it was decided that the best way to prevent pain from affecting results was to not actually include the results of the legs affected by OSD. Since the main purpose of the study was to determine risk factors that a child could be screened for prior to the onset of OSD, keeping the results of only the unaffected legs from the patient group seemed to be the best way to analyze the results.

Just like in the flexibility tests, the right and left legs of the control group were compared using a Paired t-test. If no differences were found, the results of the right and left legs were averaged together and then compared to the unaffected OSD legs using a Two Sample t-test assuming equal variance. Again, an F-Test was done first to determine if the variances should be assumed to be equal or unequal. This method was used for analyzing the leg press results and the isokinetic knee extension and flexion results.

Summary

The testing session for each subject lasted about 45 minutes. It consisted of signing the informed consent form, completing a questionnaire, and undergoing six range of motion tests and two different types of strength tests. Following the testing session, the subject and his parents received a full explanation of the study and his individual

results. If any abnormal muscle tightness or weakness was recognized, then a list of stretches and exercises that could be done at home to address the inadequacy was distributed to the subject.

CHAPTER IV

RESULTS

Introduction

The OSD group had eleven subjects, three of which had bilateral cases. For the ROM tests, the data of all eleven subjects was used. However, to prevent the injury itself from affecting the results, the strength test data of only the unaffected legs from the eight unilateral patients was analyzed. Seven control subjects were tested, but one data set was discarded because he did not meet the minimum practice requirements as described in the methods section. So, the final control group had a sample size of six. Also, some tests were added or modified after the experiment was underway, as was described in the methods section, and is the reason some data sets may have a different sample number than the ones listed here.

Frequency of Participation

Osgood Schlatter Disease is often considered an overuse injury. If that was the case, then one might expect all of the OSD subjects in this study to have spent a similar amount of time training or practicing each week. A significant difference between the two groups in the amount of practice days would also support this theory. However, the data collected from the questionnaire showed an even distribution between all choices (Table 4.1). None of the Control subjects practiced 0 to 2 days per week because

eligible control subjects had to have a minimum participation level of three days per week. A chi^2 value of 1.17 provided evidence that the two groups were not significantly different.

Table 4.1 Frequency of participation data for the Control group and Osgood Schlatter Disease (OSD) group. Control Subjects were required to be practicing a minimum of three days a week.

	Control	OSD
0 to 2 days	NA	4
3 to 5 days	3	3
6 to 7 days	3	4

Range of Motion Tests

The range of motion tests results and associated statistical tests and graphs are located in this section. They are divided into appropriate subsections.

Knee Extension

Every subject examined had full knee extension.

Knee Flexion

The six control subjects had an average of 151.8 ± 3.43 degrees of flexion in the left knee and an average of 150.0 ± 3.74 degrees of flexion in the right knee. These means were compared using a Paired t-Test. The t value equaled 2.31 and the P value equaled 0.07 (Table 4.2). Therefore, the means of the left and right knees were not significantly different. They were averaged together, and the Control group mean was determined to be 150.9 ± 3.46 degrees.

The eleven OSD patients had an average of 141.4 ± 5.32 degrees of flexion in the left knee and 141.5 ± 4.89 degrees of flexion in the right knee. These means were compared using a Paired t-Test. With a t value of 0.10, and a P value of 0.92, the means of the left and right knees were not significantly different (Table 4.2). They were averaged together, and the OSD group mean was calculated to be 141.4 ± 4.88 degrees.

Table 4.2 Comparison of passive knee flexion between left and right knees within the Control and Osgood Schlatter Disease (OSD) groups. t-Test was performed for each group.

	Control		OSD	
	Left	Right	Left	Right
Mean	151.8	150.0	141.4	141.5
Variance	11.80	14.00	28.30	23.90
Standard Deviation	3.43	3.74	5.32	4.89
Sample Number	6	6	11	11
Degrees Freedom	5		10	
t	2.31		0.10	
t Critical two-tail	2.57		2.23	
P	**0.07**		**0.92**	

After determining there were no significant differences between the left and right knees of each group, the Control and OSD groups were compared against each other (Figures 4.1 and 4.2) An F-Test was done which confirmed the variances of the two groups were equal. Next, the group means were compared using a two sample t-Test assuming equal variances. With a t value of 4.20 and P value of $7.70\text{x}10^{-4}$, the analysis showed the OSD group had significantly less passive knee flexion than the Control group (Table 4.3).

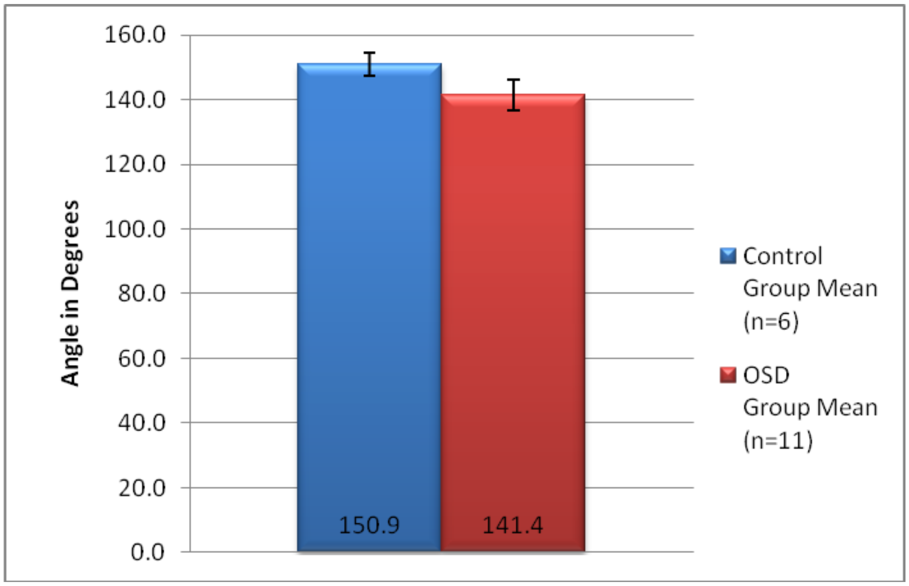


Figure 4.1 Mean ± 1 standard deviation of passive knee flexion for the Control and Osgood Schlatter Disease (OSD) groups.

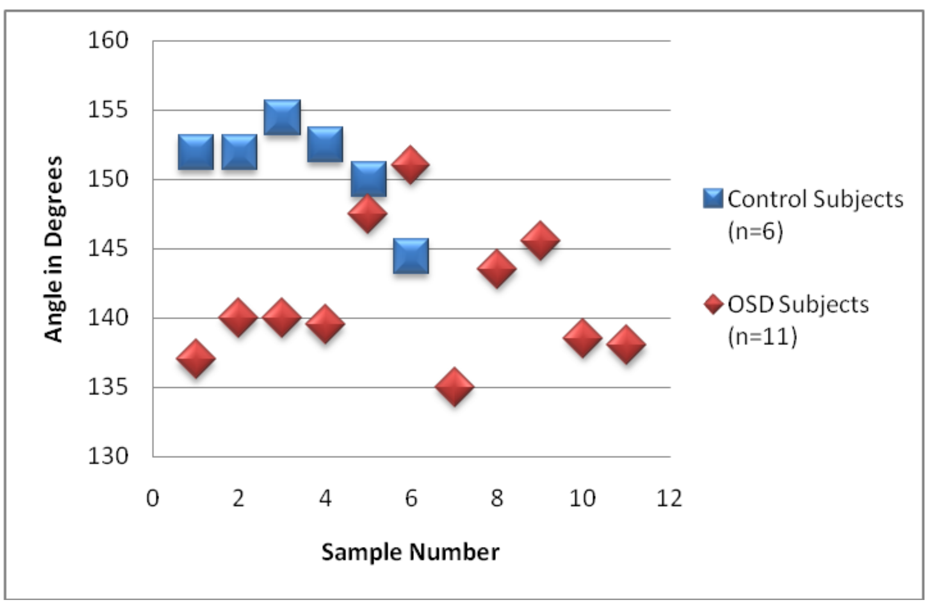


Figure 4.2 Individual subject means of passive knee flexion for the Control and Osgood Schlatter Disease (OSD) groups. Each point represents the mean value of each subject's left and right knees.

Table 4.3 Comparison and statistical analysis of passive knee flexion between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	150.9	141.4
Variance	11.94	23.84
Standard Deviation	3.46	4.88
Sample Number	6	11
Degrees Freedom	15	
t	4.20	
t Critical two-tail	2.13	
P	**7.70×10^{-4}**	
F	2.00	
F Critical one-tail	4.74	
P(F<=F Crit) one-tail	**0.23**	

Hamstrings

Using the Hamstrings flexibility protocol, the six control subjects had an average angle of 137.2 ± 5.04 degrees in the left knee and 139.2 ± 7.76 degrees in the right knee. When compared using a Paired t-Test, the t value equaled 0.53, and the P value equaled 0.62 (Table 4.4). Therefore, the means of the left and right knees were not significantly different. They were averaged together, and the Control group mean was determined to be 138.2 ± 4.59 degrees.

The eleven OSD patients had an average angle of 142.2 ± 9.33 degrees in the left knee and 140.7 ± 7.62 degrees in the right knee. These means were compared using a Paired t-Test. With a t value of 0.89 and a P value of 0.39, the means of the left and right knees were not significantly different (Table 4.4). They were averaged together and the OSD group mean was determined to be 141.5 ± 8.07 degrees.

Table 4.4 Comparison of hamstrings flexibility between left and right knees within the Control and Osgood Schlatter Disease (OSD) groups. t-Test was performed for each group.

	Control		OSD	
	Left	Right	Left	Right
Mean	137.2	139.2	142.2	140.7
Variance	25.37	60.17	86.96	58.02
Standard Deviation	5.04	7.76	9.33	7.62
Sample Number	6	6	11	11
Degrees Freedom	5		10	
t	0.53		0.89	
t Critical two-tail	2.57		2.23	
P	**0.62**		**0.39**	

After determining there were no significant differences between the left and right knees of each group, the Control and OSD groups were compared against each other (Figures 4.3 and 4.4) An F-Test was done which confirmed the variances of the two groups were equal. Next, the group means were compared using a two sample t-Test assuming equal variances. With a t value of 0.91 and P value of 0.38, the analysis showed there was no significant difference between the group means despite the OSD group having slightly more flexible hamstring muscles (Table 4.5).

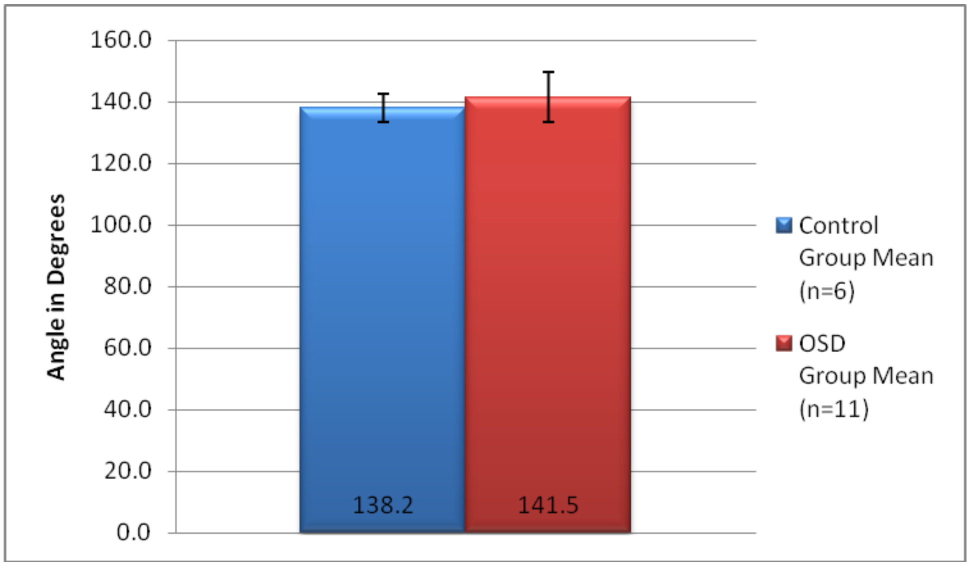


Figure 4.3 Mean ± 1 standard deviation of hamstrings flexibility for the Control and Osgood Schlatter Disease (OSD) groups.

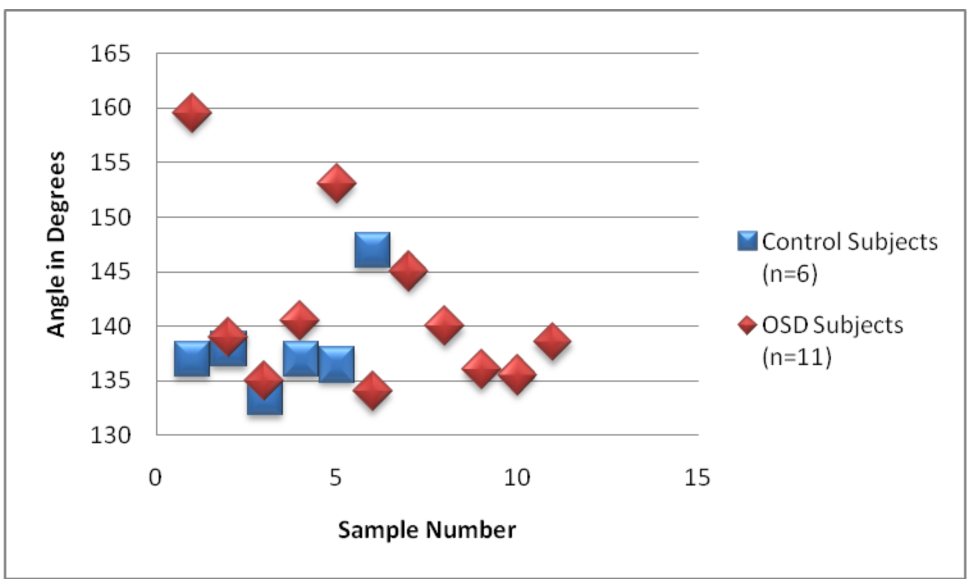


Figure 4.4 Individual subject means of hamstrings flexibility for the Control and Osgood Schlatter Disease (OSD) groups. Each point represents the mean value of each subject's left and right knees.

Table 4.5 Comparison and statistical analysis of hamstrings flexibility between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	138.2	141.5
Variance	21.07	65.17
Standard Deviation	4.59	8.07
Sample Number	6	11
Degrees Freedom	15	
t	0.91	
t Critical two-tail	2.13	
P	**0.38**	
F	3.09	
F Critical one-tail	4.74	
P(F<=F Crit) one-tail	**0.11**	

Quadriceps

Using the Quadriceps flexibility protocol, the six Control subjects had an average angle of 140.5 ± 8.69 degrees in the left knee and 139.2 ± 7.60 degrees in the right knee. When compared using a Paired t-Test, the t value equaled 1.20, and the P value equaled 0.29 (Table 4.4). Therefore, the means of the left and right knees were not significantly different. They were averaged together, and the Control group mean was determined to be 139.8 ± 8.05 degrees.

The five OSD patients had an average angle of 134.0 ± 9.19 degrees in the left knee and 132.6 ± 5.73 degrees in the right knee. These means were compared using a Paired t-Test. With a t value of 0.88 and a P value of 0.43, the means of the left and right knees were not significantly different (Table 4.4). They were averaged together and the OSD group mean was determined to be 133.3 ± 7.45 degrees.

Table 4.6 Comparison of quadriceps flexibility between left and right knees within the Control and Osgood Schlatter Disease (OSD) groups. t-Test was performed for each group.

	Control		OSD	
	Left	Right	Left	Right
Mean	140.5	139.2	134.0	132.6
Variance	75.50	57.77	84.50	32.80
Standard Deviation	8.69	7.60	9.19	5.73
Sample Number	6	6	5	5
Degrees Freedom	5		4	
T	1.20		0.88	
t Critical two-tail	2.57		2.78	
P	**0.29**		**0.43**	

After determining there were no significant differences between the left and right knees of each group, the Control and OSD groups were compared against each other (Figures 4.5 and 4.6) An F-Test confirmed the variances of the two groups were equal. Next, the group means were compared using a two sample t-Test assuming equal variances. With a t value of 1.39 and P value of 0.20, the analysis showed there was no significant difference between the group means despite the Control group having slightly more flexible quadriceps muscles (Table 4.7).

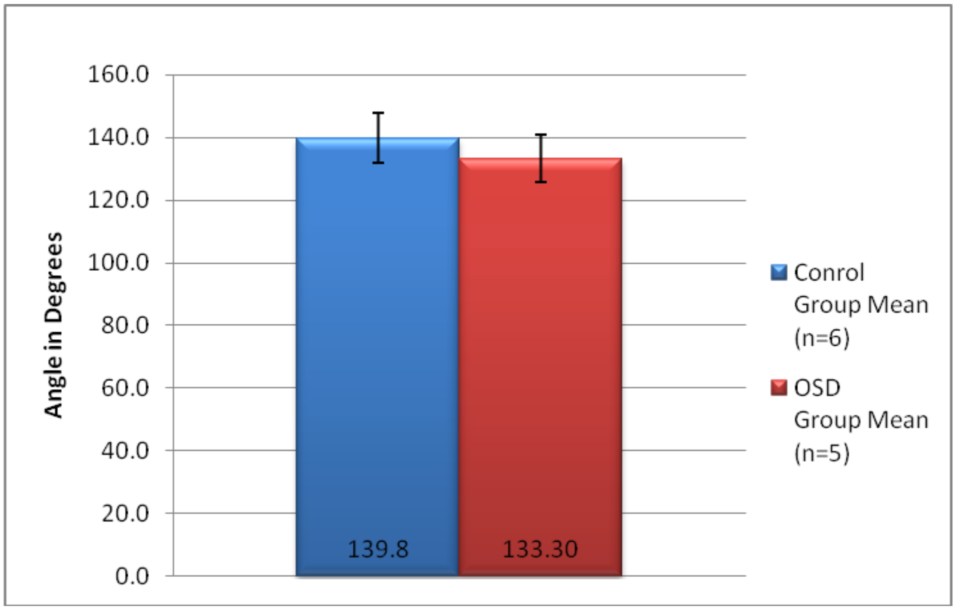


Figure 4.5 Mean ± 1 standard deviation of quadriceps flexibility for the Control and Osgood Schlatter Disease (OSD) groups.

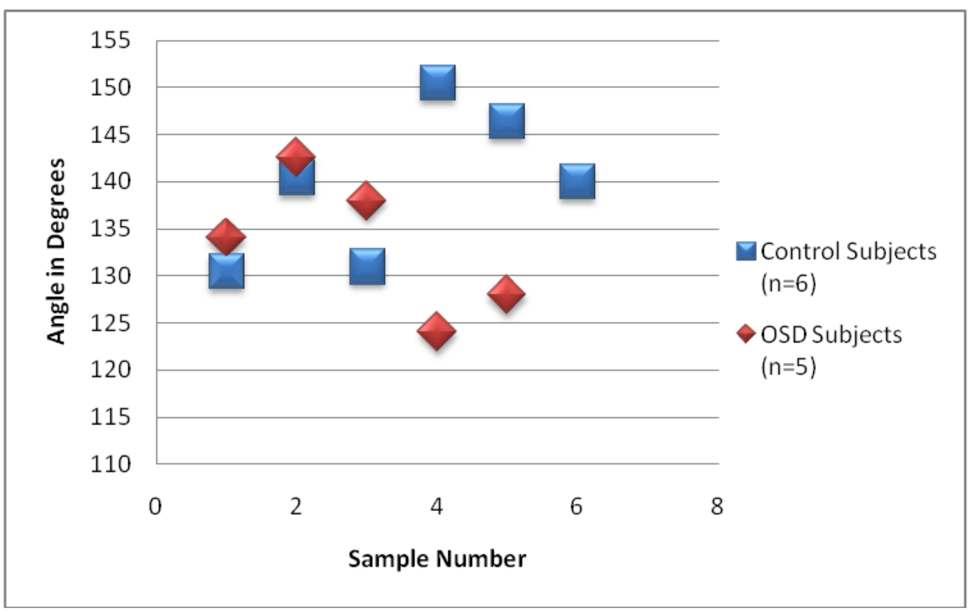


Figure 4.6 Individual subject means of quadriceps flexibility for the Control and Osgood Schlatter Disease (OSD) groups. Each point represents the mean value of each subject's left and right knees.

Table 4.7 Comparison and statistical analysis of quadriceps flexibility between the Control and OSD groups.

	Control	OSD
Mean	139.8	133.3
Variance	64.77	55.45
Standard Deviation	8.05	7.45
Sample Number	6	5
Degrees Freedom	9	
t	1.39	
t Critical two-tail	2.26	
P	**0.20**	
F	1.17	
F Critical one-tail	6.26	
P(F<=F Crit) one-tail	**0.45**	

Quadriceps-Angle

The six Control subjects had an average left side Q-angle of 15.5 ± 3.73 degrees and a right side Q-angle of 15.7 ± 3.67 degrees. When compared using a Paired t-Test, the t value equaled 0.54, and the P value equaled 0.61 (Table 4.8). Therefore, the means of the left and right side Q-angles were not significantly different. They were averaged together, and the Control group mean was determined to be 15.6 ± 3.68 degrees.

The seven OSD patients had an average left side Q-angle of 14.4 ± 2.94 degrees and a right side Q-angle of 14.4 ± 2.51 degrees. These means were compared using a Paired t-Test. With a t value of 0.00 and a P value of 1.00, the means of the left and right side Q-angles were not significantly different (Table 4.8). They were averaged together and the OSD group mean was determined to be 14.4 ± 2.65 degrees.

Table 4.8 Comparison of the quadriceps angle (Q-angle) between left and right knees within the Control and Osgood Schlatter Disease (OSD) groups. t-Test was performed for each group.

	Control		OSD	
	Left	Right	Left	Right
Mean	15.5	15.7	14.4	14.4
Variance	13.90	13.47	8.62	6.29
Standard Deviation	3.73	3.67	2.94	2.51
Sample Number	6	6.00	7	7
Degrees Freedom	5		6	
t	0.54		0.00	
t Critical two-tail	2.57		2.45	
P	**0.61**		**1.00**	

After determining there were no significant differences between the left and right sides of each group, the Control and OSD groups were compared against each other (Figures 4.7 and 4.8) An F-Test was done which confirmed the variances of the two groups were equal, and then group means were compared using a two sample t-Test. With a t value of 0.66 and P value of 0.52, the analysis showed there was no significant difference between the group means despite the Control group having a slightly greater Q-angle (Table 4.9).

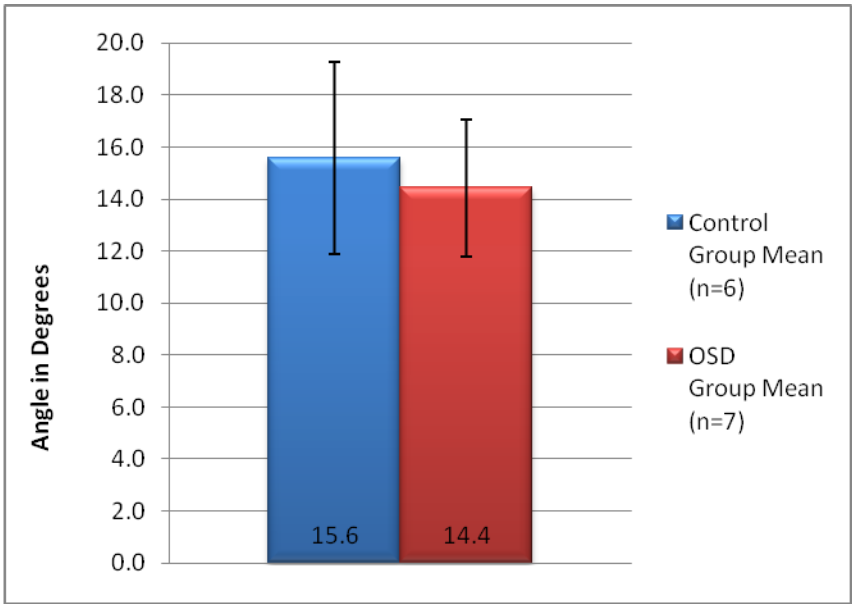


Figure 4.7 Mean ± 1 standard deviation of the quadriceps angle (Q-angle) for the Control and Osgood Schlatter Disease (OSD) groups.

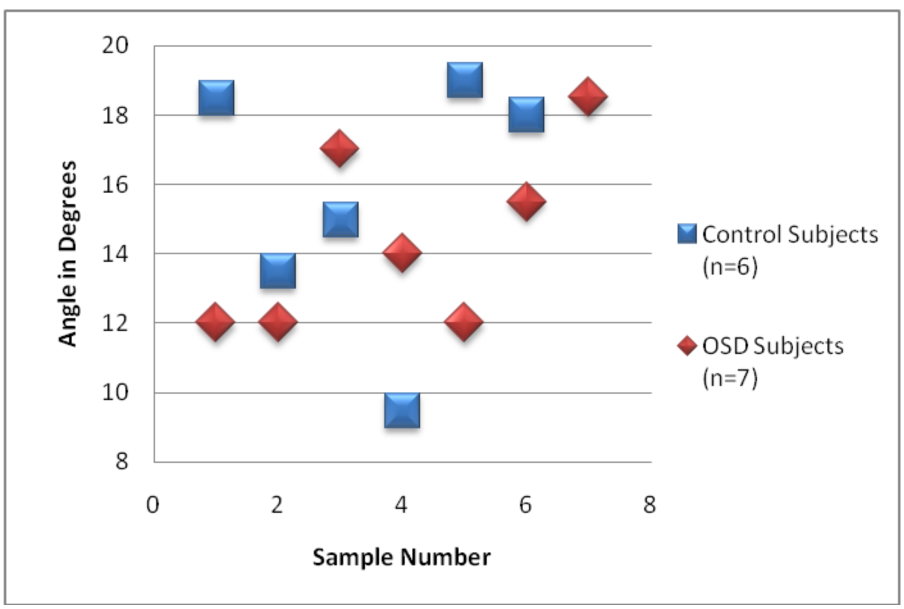


Figure 4.8 Individual subject means of the quadriceps angle (Q-angle) for the Control and Osgood Schlatter Disease (OSD) groups. Each point represents the mean value of each subject's left and right knees.

Table 4.9 Comparison and statistical analysis of the quadriceps angle (Q-angle) between the Control and OSD groups.

	Control	OSD
Mean	15.6	14.4
Variance	13.54	7.04
Standard Deviation	3.68	2.65
Sample Number	6	7
Degrees Freedom	11	
t	0.66	
t Critical two-tail	2.20	
P	**0.52**	
F	1.92	
F Critical one-tail	4.39	
P(F<=F Crit) one-tail	**0.22**	

Ober's Test

There were six pair of Control legs and eleven pair of OSD legs tested using Ober's technique. Both legs in each pair had the same result. Since there were no differences within each pair, the outcome of the pairs was analyzed. The control group had 4 negative tests and 2 positive tests. The OSD group had 7 negative tests and 4 positive tests. X^2 Stat was found to be 0.165 so the null hypothesis, stating the development of OSD was not dependent on tensor fasciae latae length, was accepted. The Chi squared table can be seen in Table 4.10.

Table 4.10 Chi Squared contingency table for Ober's test. Comparison of the Control and Osgood Schlatter Disease (OSD) groups.

	Negative	Positive	Total
Control	4	2	6
OSD	7	4	11
Total	11	6	17

Leg Press Test

The four control subjects had an average normalized left leg press 1 RM of 119.2% ± 31% body weight and an average normalized right leg 1RM of 118.8% ± 24% body weight. When compared using a paired t-test, the t value was 0.05 and the P value was 0.96, so the null hypothesis was accepted (Table 4.11). Since the numbers were not significantly different, the right and left values of each subject were averaged together and the group mean of these was determined to be 119.0% ± 27% body weight.

Table 4.11 Comparison of the single leg press mean one repetition maximum (1RM) between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	119.2%	118.8%
Variance	0.10	0.06
Standard Deviation	0.31	0.24
Sample Number	4	4
Degrees Freedom	3	
t	0.05	
t Critical two-tail	3.18	
P	**0.96**	

The eight unaffected legs of the unilateral OSD subjects had a normalized mean 1RM of 92.5% ± 35% of body weight. The two group means were then compared (Figures 4.9 and 4.10). An F-test was done which confirmed the variances were equal, and a two sample t-Test revealed a t value of 1.34 and a P value of 0.21. Therefore, there was no significant difference in the normalized 1RM value between the Control and OSD groups (Table 4.12).

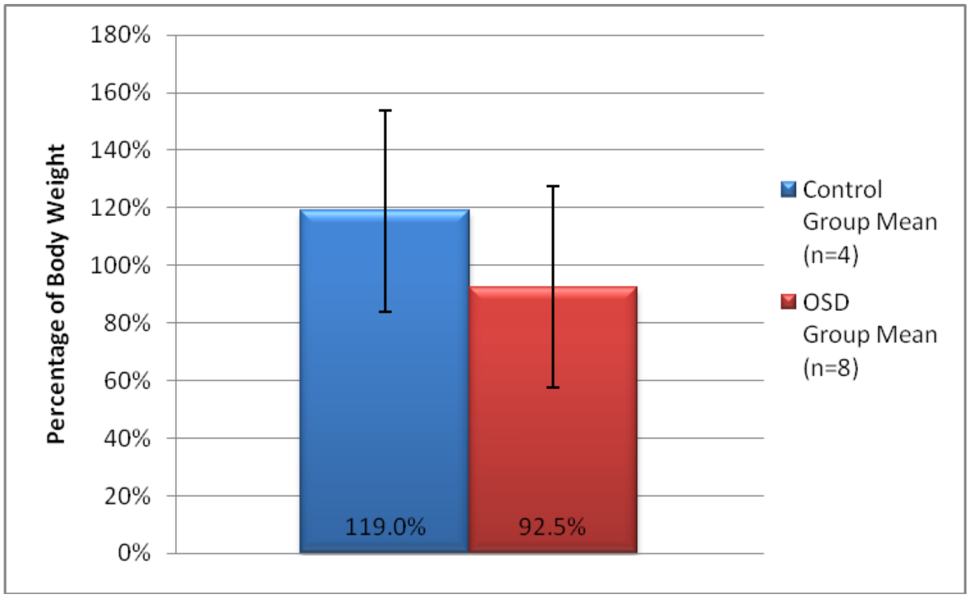


Figure 4.9 Mean ± 1 standard deviation of the single leg press mean one repetition maximum (1RM) for the Control and Osgood Schlatter Disease (OSD) groups.

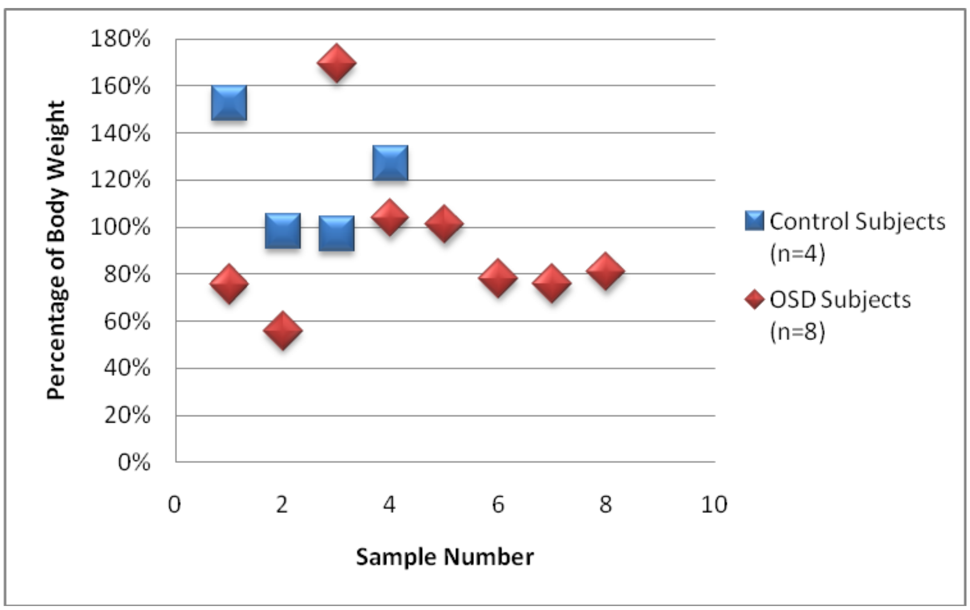


Figure 4.10 Individual subject means of the single leg press one repetition maximum (1RM) for the Control and Osgood Schlatter Disease (OSD) groups. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.12 Comparison and statistical analysis of the single leg press mean one repetition maximum (1RM) between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	119.0%	92.5%
Variance	0.07	0.12
Standard Deviation	0.27	0.35
Sample Number	4	8
Degrees Freedom	10	
T	1.34	
t Critical two-tail	2.23	
P	**0.21**	
F	1.69	
F Critical one-tail	8.89	
P(F<=F Crit) one-tail	**0.36**	

Isokinetic Tests

The results of the isokinetic tests were analyzed many different ways. Peak torque was defined as the maximum amount of torque produced during any one of the repetitions of a test. Work was defined as the area underneath the torque curve, and peak work was the defined as the most work done during any single repetition. Finally, average work per repetition was defined as the total work done throughout the entire test, divided by the number of repetitions. Both torque and work were calculated in the unit of foot pounds.

Peak torque and peak work were computed for both knee extension and flexion during the slow speed (60 degrees per second) test. Peak torque and average work per repetition were calculated for the fast speed (300 degrees per second) test. A flexion / extension ratio of the respective torque and work values was also calculated for each test. Also, in addition to presenting the raw data, the computer normalized all of the

aforementioned values as a percentage of the subject's body weight. This was how most of the results were initially analyzed. The flexion / extension ratio was calculated using the actual torque and work values.

In addition, the single knee extension repetition that produced the peak torque value during the slow speed test was evaluated further. A graph of the single repetition was produced and the mean torque to body weight percentage at three specific angles was analyzed. The specific angles of the peak repetition that were analyzed were 60 degrees, 30 degrees, and 15 degrees of knee flexion.

In an attempt to justify the normalization technique used, the peak torque and the torque produced at the three specified angles during slow speed extension were also plotted as actual values (foot pounds) versus body weight (pounds). This was done to determine if torque produced increased at a constant rate as body weight increased. If the normalization technique was justified by the data, then the normalized results would be more credible. Similar rates of torque increase across the entire range of body weights would show that the normalized results were not contingent on body weight alone, since there was a significant difference in the body weights of the Control and OSD groups.

Finally, an alternate normalization technique was presented for analyzing the torque produced at the specific angles of slow speed knee extension. The actual torque value at each angle was divided by the actual torque value at the 60 degree angle. This was done to again analyze the data in a way that was independent of body weight.

Normalized Peak Torque during Extension of the Slow Speed Test

The left legs of the Control group produced a mean normalized peak torque value of 75.1% ± 10% body weight during knee extension of the slow speed isokinetic test.

The right legs produced a mean normalized peak torque value of 71.7% ± 7%. When compared using a paired t-test, t was calculated to be 2.12 and P was 0.09 (Table 4.13). Since the values were not significantly different, they were averaged together to equal 73.4% ± 8%, and compared against the mean of the unaffected OSD legs.

Table 4.13 Comparison of mean normalized peak torque during extension of the 60 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	75.1%	71.7%
Variance	0.01	0.01
Standard Deviation	0.10	0.07
Sample Number	6	6
Degrees Freedom	5	
t	2.12	
t Critical two-tail	2.57	
P	**0.09**	

The eight unaffected legs of the unilateral OSD subjects produced a mean normalized peak torque value of 80.1% ± 13% body weight during knee extension. When the Control and OSD groups were compared, the OSD group had a higher normalized peak torque value (Figures 4.11 and 4.12). However, following an F-Test that confirmed the variances were equal, a two sample t-Test showed that t equaled 1.12 and P equaled 0.28 (Table 4.14). Therefore, despite a difference in the two means, the two groups were not significantly different.

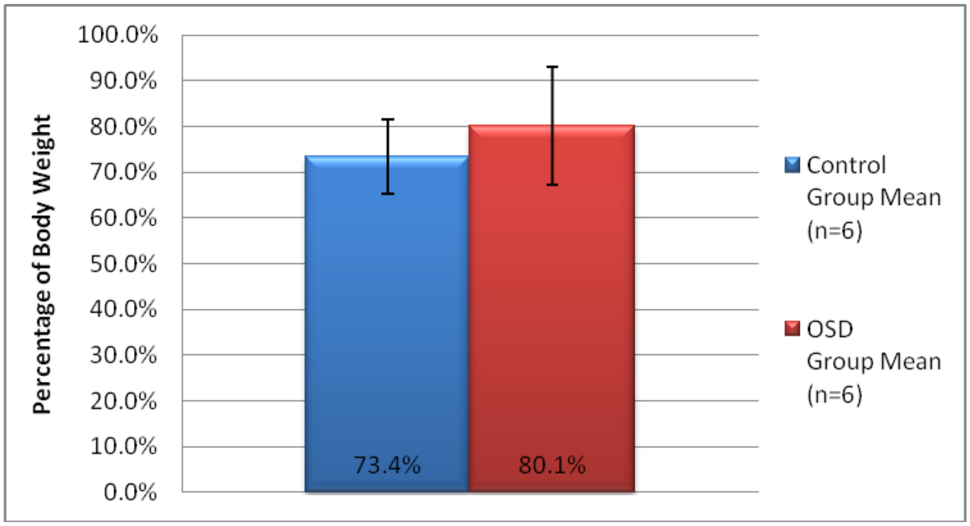


Figure 4.11 Mean normalized peak torque ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups during extension of the 60 degrees per second isokinetic test.

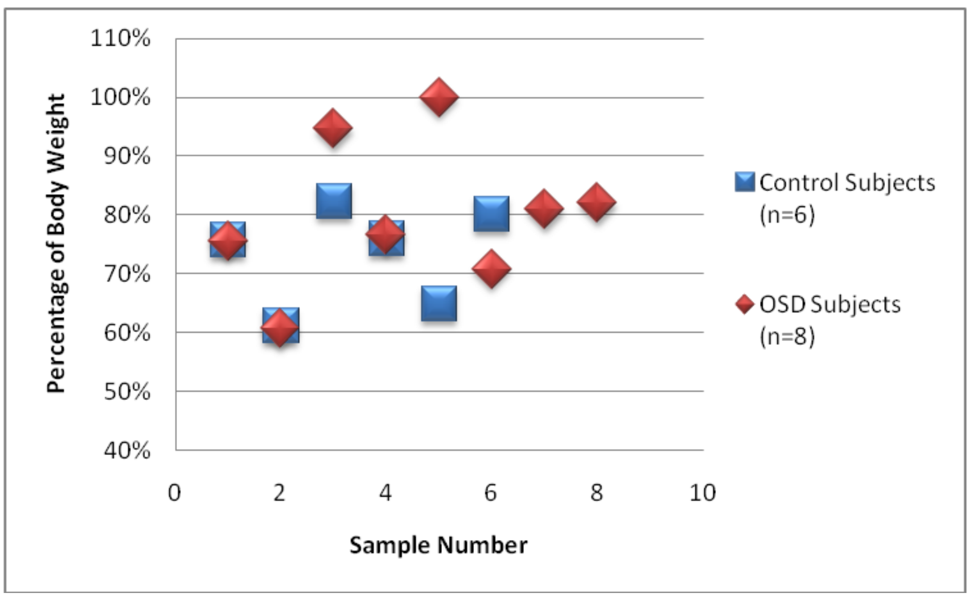


Figure 4.12 Individual normalized peak torque values produced by the Control and Osgood Schlatter Disease (OSD) groups during extension of the 60 degree per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.14 Comparison and statistical analysis of the mean normalized peak torque during extension of the 60 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	73.4%	80.1%
Variance	0.01	0.02
Standard Deviation	0.08	0.13
Sample Number	6	8
Degrees Freedom	12	
t	1.12	
t Critical two-tail	2.18	
P	**0.28**	
F	2.23	
F Critical one-tail	4.88	
P(F<=F Crit) one-tail	**0.20**	

Normalized Torque at 60 Degrees during Extension of the Slow Speed Test

The single repetition that produced the peak normalized torque value for each subject was analyzed more thoroughly by measuring the normalized torque produced at three specific angles (knee flexed 60, 30, and 15 degrees). At 60 degrees the six control subjects produced a mean normalized torque of 64.9 % ± 7% body weight with the left legs and 63.5% ± 5% with the right legs. When compared using a Paired t-test, t equaled 0.45 and P equaled 0.68, so the null hypothesis was accepted (Table 4.15). Since there was no difference in the torque values produced by the left and right legs, they were averaged together and the group mean of these values was determined to be 64.2% ± 5% body weight.

Table 4.15 Comparison of normalized torque at a knee angle of 60 degrees during extension of the 60 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	64.9%	63.5%
Variance	0.01	2.87×10^{-3}
Standard Deviation	0.07	0.05
Sample Number	6	6
Degrees Freedom	5	
T	0.45	
t Critical two-tail	2.57	
P	**0.68**	

The eight unaffected OSD legs of the unilateral OSD subjects, when analyzed at 60 degrees, had a mean normalized torque value of 64.1% ± 7% body weight. This value was then compared to the mean control value of 64.2 ± 5% (Figures 4.13 and 4.14). An F- Test was done which confirmed the variances were equal. Using a Two sample t-test, it was found that the t value equaled .028 and the P value equaled 0.99 (Table 4.16). Therefore, the null hypothesis was accepted because there was no difference between the means of the Control and OSD groups.

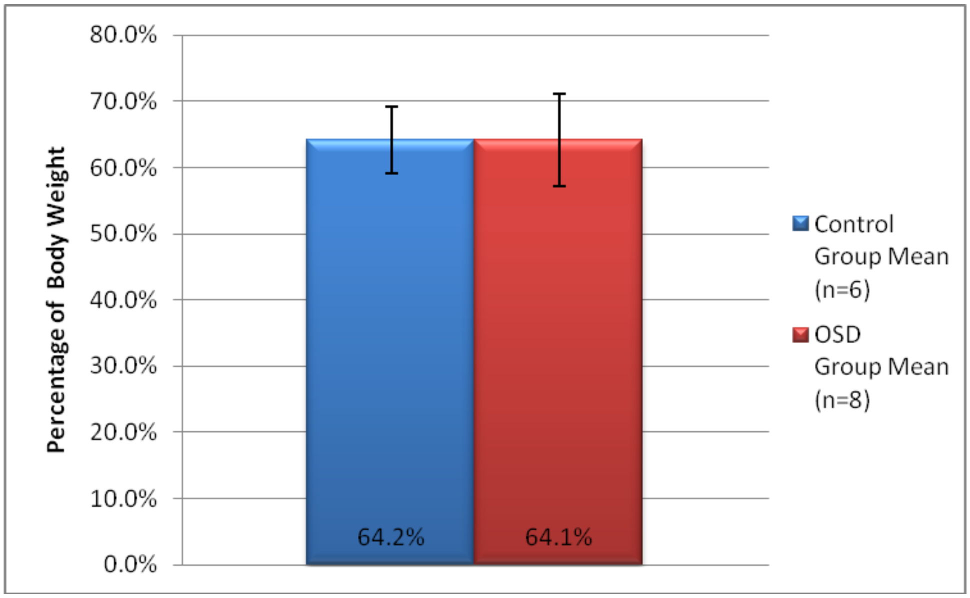


Figure 4.13 Mean normalized torque ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups at a knee angle of 60 degrees during extension of the 60 degrees per second isokinetic test.

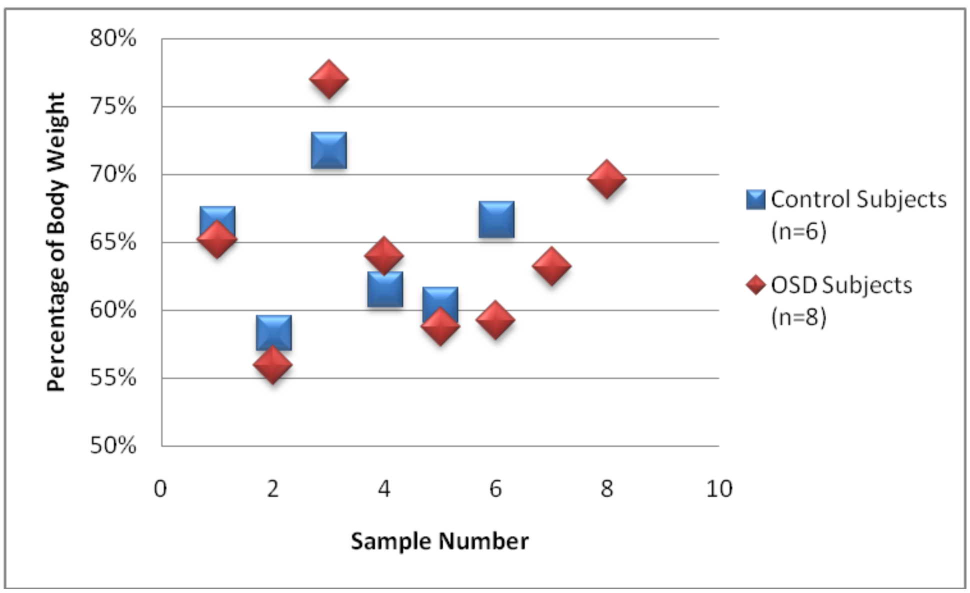


Figure 4.14 Individual normalized torque values produced by the Control and Osgood Schlatter Disease (OSD) groups at a knee angle of 60 degrees during extension of the 60 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.16 Comparison and statistical analysis of the mean normalized torque produced at a knee angle of 60 degrees during extension of the 60 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	64.2%	64.1%
Variance	2.48×10^{-3}	$4.52 \times 10\text{-}^{3}$
Standard Deviation	0.05	0.07
Sample Number	6	8
Degrees Freedom	12	
t	0.03	
t Critical two-tail	2.18	
P	**0.99**	
F	1.83	
F Critical one-tail	4.88	
P(F<=F Crit) one-tail	**0.26**	

Normalized Torque at 30 Degrees during Extension of the Slow Speed Test

At 30 degrees, the six control subjects produced a mean normalized torque of 29.7% ± 9% body weight with the left legs and 34.1% ± 4% with the right legs. When compared using a Paired t-test, t was 0.97 and P was 0.38 (Table 4.17). Since there was no difference in the torque values produced by the left and right legs, they were averaged together and the group mean of these values was determined to be 31.9% ± 4% body weight.

Table 4.17 Comparison of normalized torque at a knee angle of 30 degrees during extension of the 60 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	29.7%	34.1%
Variance	0.01	1.36×10^{-3}
Standard Deviation	0.09	0.04
Sample Number	6	6
Degrees Freedom	5	
T	0.97	
t Critical two-tail	2.57	
P	**0.38**	

The eight unaffected OSD legs of the unilateral OSD subjects, when analyzed at 30 degrees, had a mean normalized torque value of 19.4% ± 9% body weight. This value was then compared to the mean control value (Figures 4.15 and 4.16). An F-Test was done and the P value was 0.04 (Table 4.18). Therefore, the means were analyzed using a two sample t-Test assuming unequal variances. The t value was calculated to be 3.47 and the P value was 0.01, which indicated the Control subjects produced significantly more normalized torque than the OSD subjects at 30 degrees (Table 4.18).

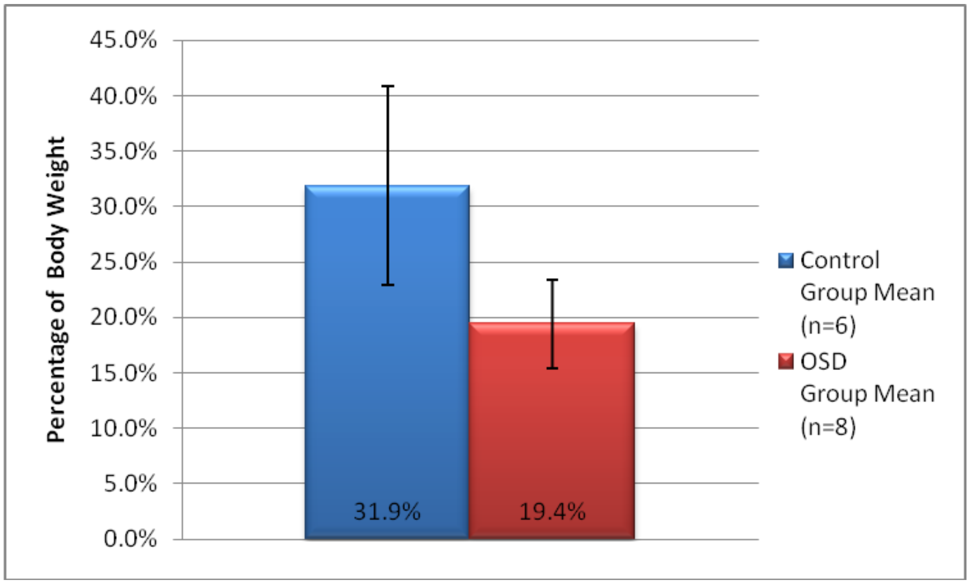


Figure 4.15 Mean normalized torque ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups at a knee angle of 30 degrees during extension of the 60 degrees per second isokinetic test.

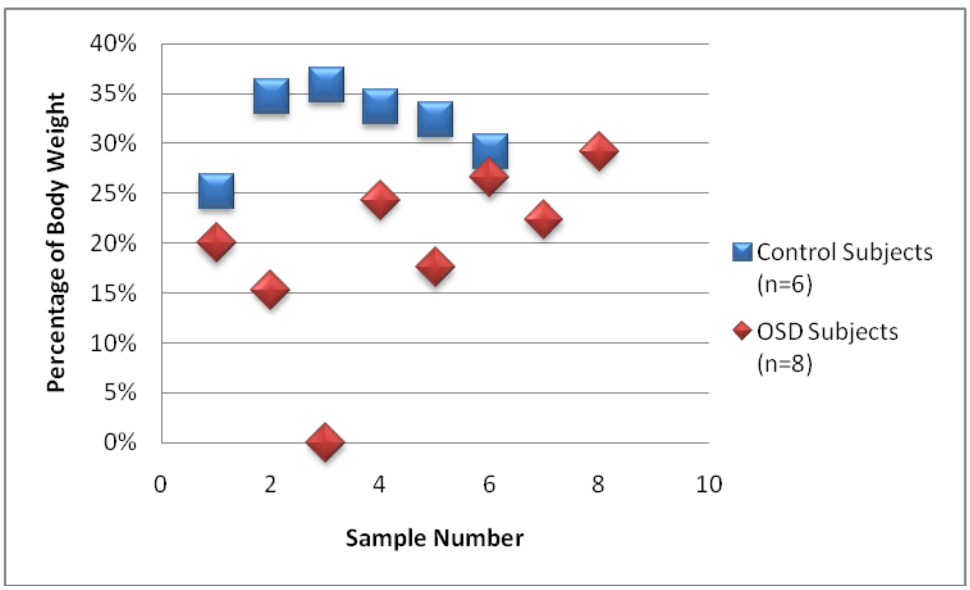


Figure 4.16 Individual normalized torque values produced by the Control and Osgood Schlatter Disease (OSD) groups at a knee angle of 30 degrees during extension of the 60 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.18 Comparison and statistical analysis of the mean normalized torque produced at a knee angle of 30 degrees during extension of the 60 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	31.9%	19.4%
Variance	1.60×10^{-3}	0.01
Standard Deviation	0.04	0.09
Sample Number	6	8
Degrees Freedom	10	
T	3.47	
t Critical two-tail	2.23	
P	**0.01**	
F	5.15	
F Critical one-tail	4.88	
P(F<=F Crit) one-tail	**0.04**	

Normalized Torque at 15 Degrees during Extension of the Slow Speed Test

At 15 degrees, the six Control subjects produced a mean normalized torque of 9.6% ± 8% body weight with the left legs and 11.9% ± 8% with the right legs. When compared using a paired t-test, the t value was 0.86 and the P value was 0.43 (Table 4.19). Since there was no significant difference in the torque values produced by the left and right legs, the values were averaged together and the Control group mean was determined to be 10.7% ± 7% body weight.

Table 4.19 Comparison of normalized torque at a knee angle of 15 degrees during extension of the 60 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	9.6%	11.9%
Variance	6.11×10^{-3}	7.01×10^{-3}
Standard Deviation	0.08	0.08
Sample Number	6	6
Degrees Freedom	5	
T	0.86	
t Critical two-tail	2.57	
P	**0.43**	

The eight unaffected legs of the unilateral OSD subjects, when analyzed at 15 degrees, had a mean normalized torque value of 1.3% ± 2% body weight. This value was then compared to the mean Control value (Figures 4.17 and 4.18). An F-Test was done and the P value was determined to be 3.70×10^{-4} (Table 4.20). Therefore, the means were analyzed using a two sample t-Test assuming unequal variances. The t value equaled 3.07, and the P value equaled 0.03 (Table 4.20). This indicated the two sample means were significantly different, with the Control subjects having produced significantly more normalized torque than the OSD subjects at 15 degrees.

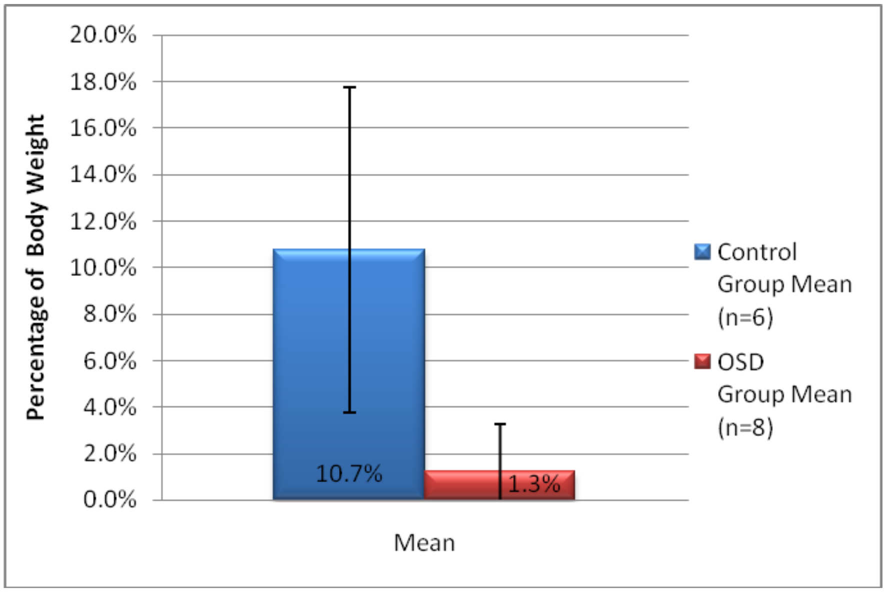


Figure 4.17 Mean normalized torque ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups at a knee angle of 15 degrees during extension of the 60 degrees per second isokinetic test.

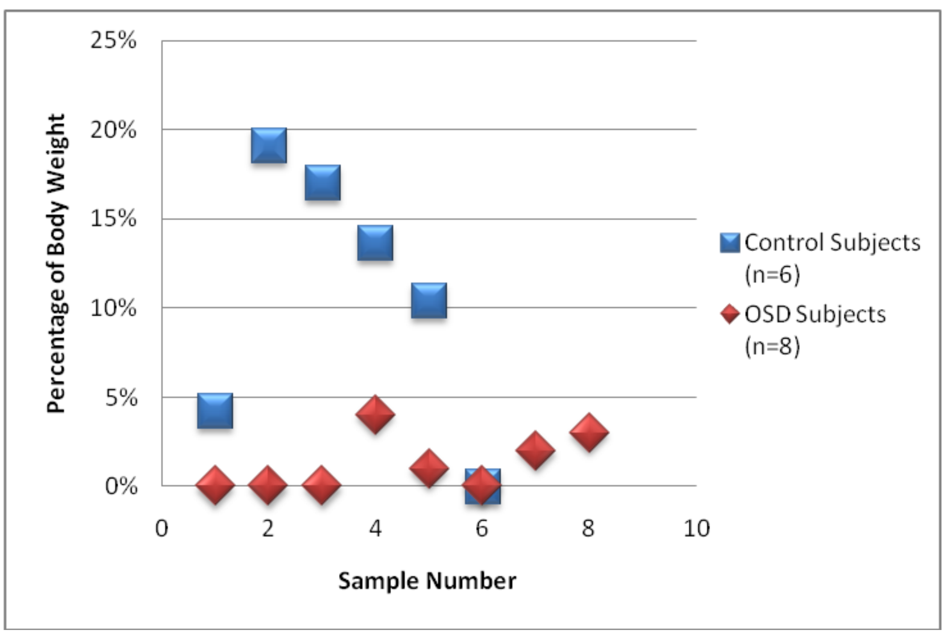


Figure 4.18 Individual normalized torque values produced by the Control and Osgood Schlatter Disease (OSD) groups at a knee angle of 15 degrees during extension of the 60 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.20 Comparison and statistical analysis of the mean normalized torque produced at a knee angle of 15 degrees during extension of the 60 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	10.7%	1.3%
Variance	5.54×10^{-3}	2.5×10^{-4}
Standard Deviation	0.07	0.02
Sample Number	6	8
Degrees Freedom	5	
t	3.07	
t Critical two-tail	2.57	
P	**0.03**	
F	22.15	
F Critical one-tail	3.97	
P(F<=F Crit) one-tail	**3.70×10^{-4}**	

Analysis of Normalization

As previously mentioned, normalizing torque and work values as a percentage of the subject's body weight, is a common practice when evaluating isokinetic strength tests. The normalization of torque and work values is based on the theory that as one's body weight increases, then force production must also increase at a linear rate to support the added weight. This seemed reasonable, but to be thorough, this theory was tested using the data from this study. The actual torque values produced during the slow speed test were plotted against body weight. This was done for peak torque during knee extension and torque at 60, 30, and 15 degrees throughout the motion (Figures 4.19, 4.20, 4.21, and 4.22). The graph of the control group was expected to have a linear slope showing that torque increases at a rate that is proportional to the increase of body weight.

The case for the normalization method would be weakened if the torque values of the Control subjects did not represent a constant linear slope.

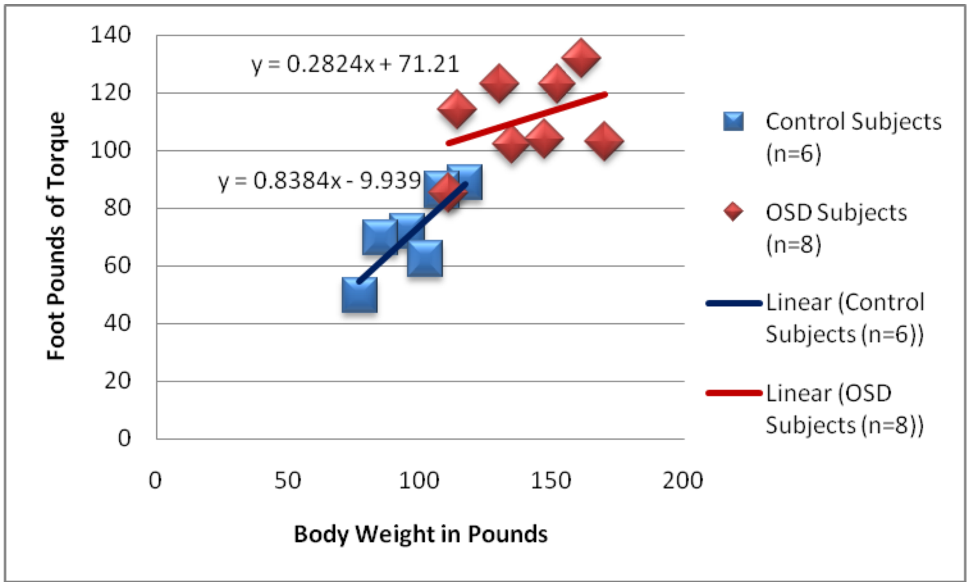


Figure 4.19 Individual peak torque plotted against body weight. Values were produced by the Control and Osgood Schlatter Disease (OSD) groups during extension of the 60 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

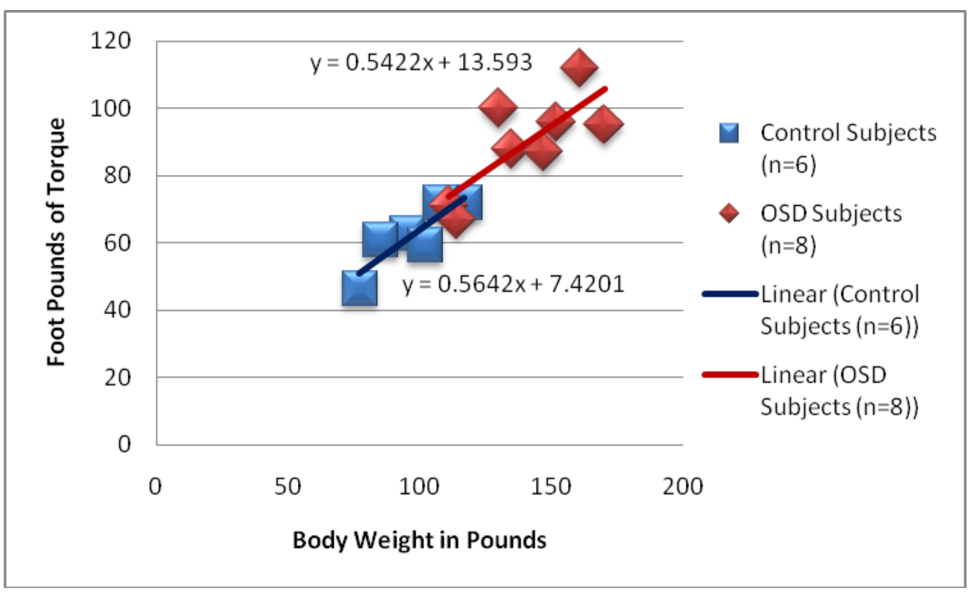


Figure 4.20 Individual torque values at a knee angle of 60 degrees plotted against body weight. Values were produced by the Control and Osgood Schlatter Disease (OSD) groups during extension of the 60 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

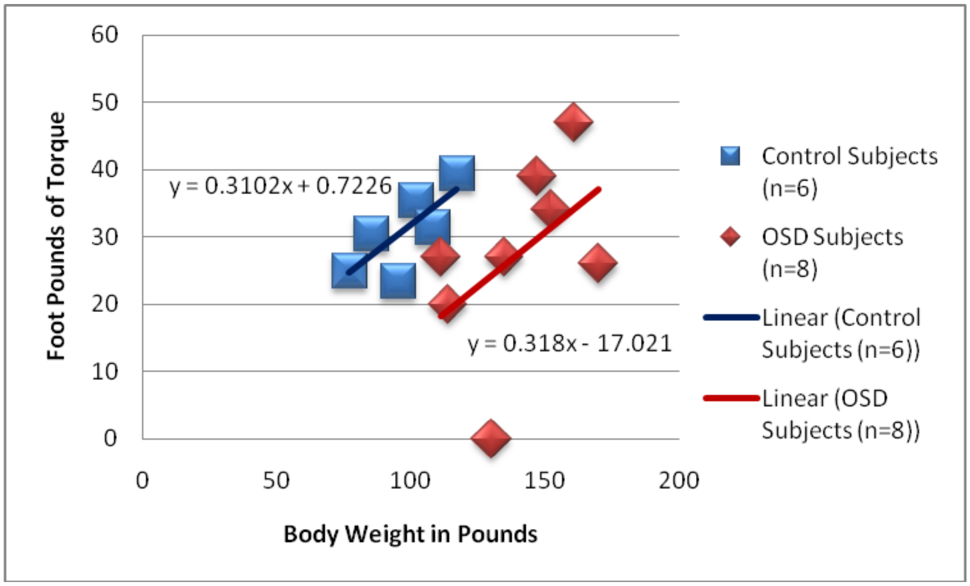


Figure 4.21 Individual torque values at a knee angle of 30 degrees plotted against body weight. Values were produced by the Control and Osgood Schlatter Disease (OSD) groups during extension of the 60 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

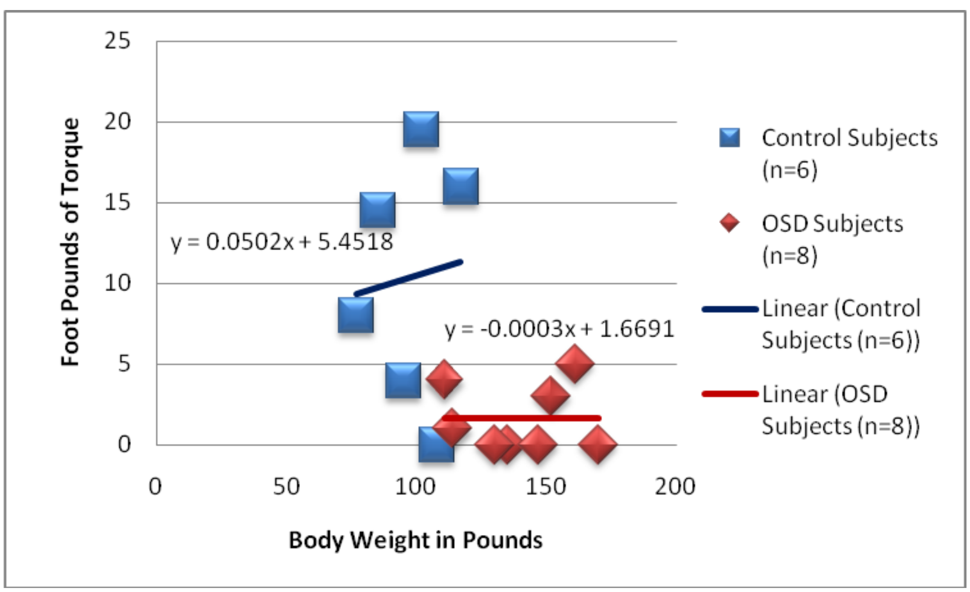


Figure 4.22 Individual torque values at a knee angle plotted against body weight. Values were produced by the Control and Osgood Schlatter Disease (OSD) groups during extension of the 60 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

When peak torque was plotted against body weight, two things were immediately apparent. First the OSD group had heavier subjects. Second, the OSD group trend line had a shallower slope than that of the control group. However, five of the eight OSD values followed the trend line of the Control group. So, this graph could be interpreted a few ways. The differences in slope could be viewed as evidence that the linear relationship of torque to body weight ratios does not remain intact across a broad range of bodyweights. The shallower slope in the OSD group could also be evidence of a strength deficiency. However, it could simply the result of a small sample number being overly influenced by outliers. The graph showing the torques produced at 60 degrees support the latter interpretation. The slopes in this graph (Figure 4.20) were nearly identical and the OSD trend line was a near exact continuation of the Control trend line. This supported the original method of normalization and suggested there were not any real differences between the two groups in peak torque or torque produced at 60 degrees.

The next two graphs showed that as the knee came closer to full extension, the OSD group did not follow the same trend as it did in the first two graphs. At 30 degrees the trend lines of the two groups had a similar slope, but the OSD line was parallel to the Control line rather than a continuation. At 15 degrees the OSD group has a slope of nearly zero.

The comparison of Figures 4.19 through 4.22 led to three conclusions. First, it showed that the OSD group was indeed heavier than the Control group. Second, it showed that normalizing the torque values by body weight was a reasonable method for this study. Finally, it showed that the normalized torque production differences seen at

30 and 15 degrees were not simply due to a difference in body weight, but rather a deficiency that could play a part in the onset of OSD.

In addition justifying the torque to body weight normalization, an alternative normalization method was used. In an effort to gather some information as to how the torque curve changed throughout the range of motion during extension for each group, the actual torque values produced at 60, 30, and 15 degree knee angles were normalized by the torque produced at 60 degrees. First, the torque at 60 degrees was used as the starting point and was divided by itself to equal 100%. Then the torque values produced 30 and 15 degrees were divided by the 60 degree value. This method of normalization shows the percentage of change from the 60 degree position, and is independent of body weight (Figure 4.23). A log scale was used on the Y axis for ease of interpretation.

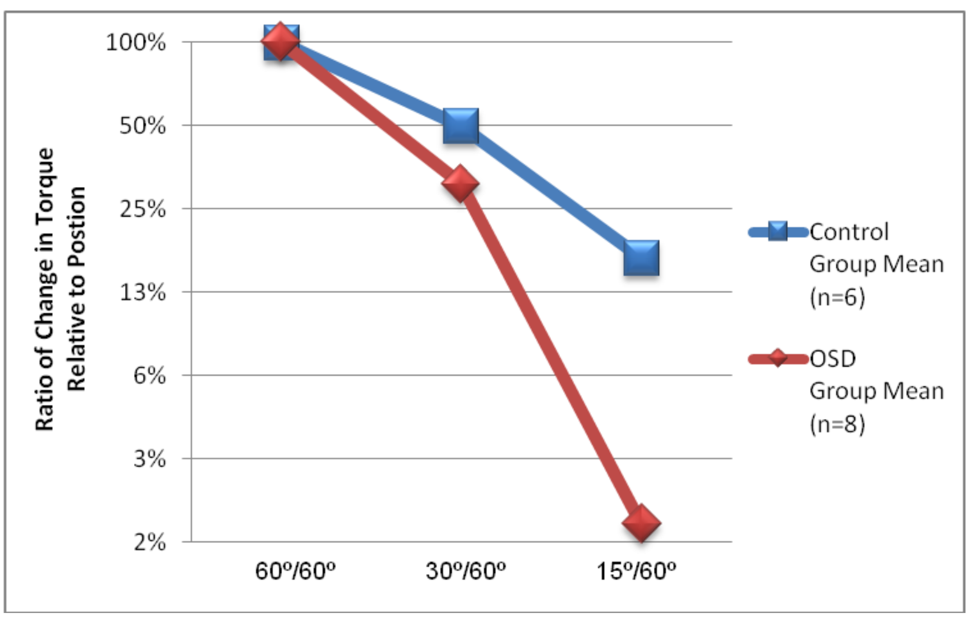


Figure 4.23 An alternative method of normalization that converted the actual torque values produced at knee angles of 60, 30 and15 degrees during the peak extension repetition of the 60 degrees per second isokinetic test into a percentage of the torque value produced at sixty degrees. This was done for both the Control and Osgood Schlatter Disease (OSD) groups.

Normalized Peak Torque during Flexion of the Slow Speed Test

The left legs of the Control group produced a mean normalized peak torque value of 53.8% ± 6% body weight during knee extension of the slow speed test. The right legs produced a mean normalized peak torque value of 49.7% ± 10%. When compared using a Paired t-test, t was 1.07 and P was 0.33 (Table 4.21). Since there was no significant difference between the values of the left and right legs, they were averaged together and the group mean was determined to be 51.7% ±7%.

Table 4.21 Comparison of mean normalized peak torque during flexion of the 60 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	53.8%	49.7%
Variance	3.81×10^{-3}	0.01
Standard Deviation	0.06	0.10
Sample Number	6	6
Degrees Freedom	5	
t	1.07	
t Critical two-tail	2.57	
P	**0.33**	

The eight unaffected legs of the unilateral OSD subjects had a mean normalized peak torque value of 53.1% ± 14% body weight. This value was then compared to the mean control value (Figures 4.24 and 4.25). An F-Test was done and the variances were confirmed to be equal. When compared using a two sample t-Test, the t value was calculated to be 0.22 and the P value was 0.83. This indicated the two sample means were not significantly different (Table 4.22).

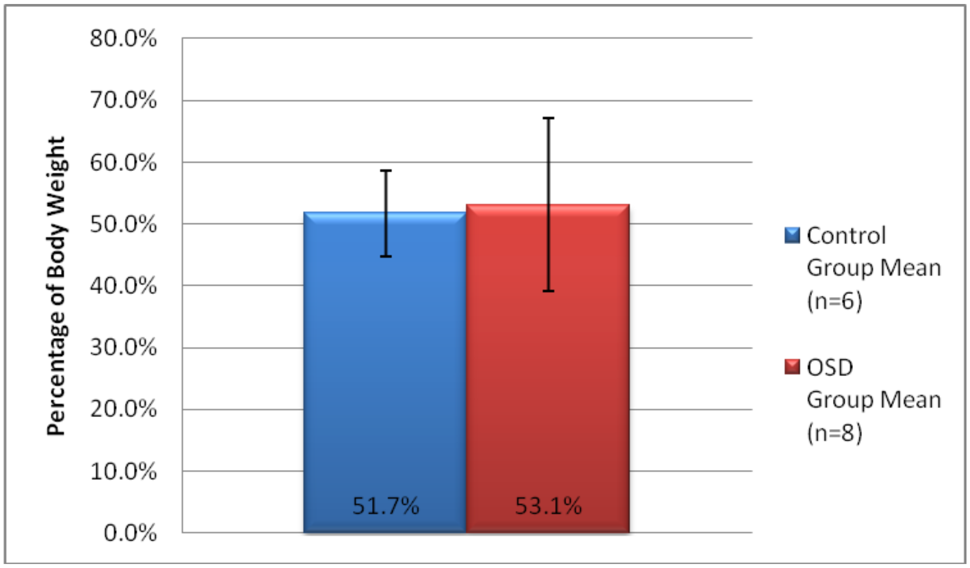


Figure 4.24 Mean normalized peak torque ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups during flexion of the 60 degrees per second isokinetic test.

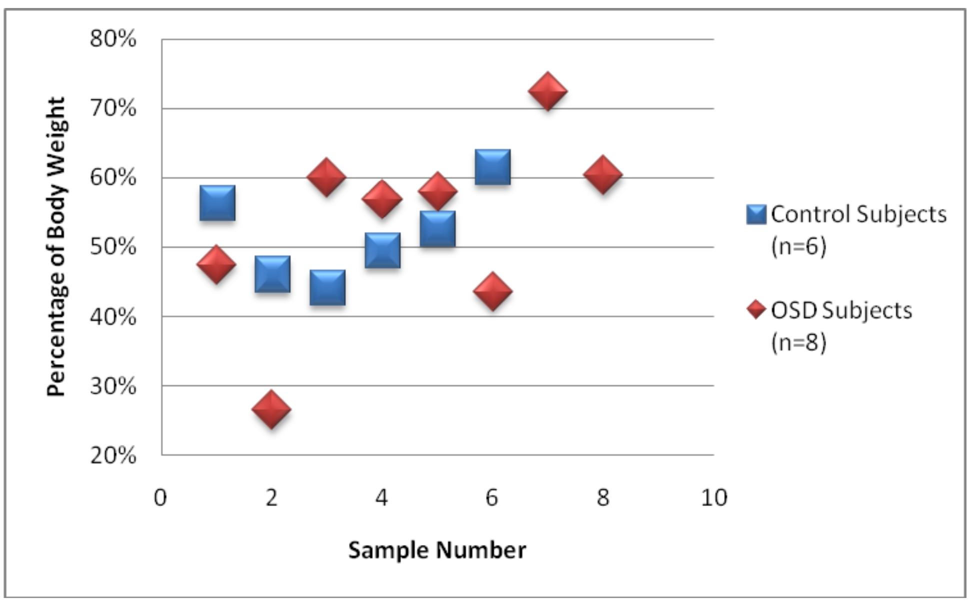


Figure 4.25 Individual normalized peak torque values produced by the Control and Osgood Schlatter Disease (OSD) groups during flexion of the 60 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.22 Comparison and statistical analysis of the mean normalized peak torque during flexion of the 60 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	51.7%	53.1%
Variance	4.26×10^{-3}	0.02
Standard Deviation	0.07	0.14
Sample Number	6	8
Degrees Freedom	12	
t	0.22	
t Critical two-tail	2.18	
P	**0.83**	
F	4.49	
F Critical one-tail	4.88	
P(F<=F Crit) one-tail	**0.06**	

Peak Torque Flexion / Extension Ratio of the Slow Speed Test

During the slow speed test, the six Control subjects produced a mean peak torque flexion / extension ratio of 71.9% ± 5% in the left legs and 70.2% ± 16% in the right legs. When compared using a Paired t-test, t equaled 0.35 and P equaled 0.74, so the null hypothesis was accepted (Table 4.23). Since these values were not significantly different, they were averaged to equal 71.0% ± 10 % and compared against the mean of the unaffected OSD legs.

Table 4.23 Comparison of the mean peak torque flexion / extension ratio from the 60 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	71.9%	70.2%
Variance	2.39×10^{-3}	0.03
Standard Deviation	0.05	0.16
Sample Number	6	6
Degrees Freedom	5	
t	0.35	
t Critical two-tail	2.57	
P	**0.74**	

The eight unaffected legs of the unilateral OSD subjects had a mean peak torque flexion / extension ratio of 65.8% ± 13%, which was less than the 71.0% ± 10% produced by the six Control subjects (Figures 4.26 and 4.27). An F-Test was done which determined the variances of the two groups were equal. A two sample t-Test produced a t value of 0.80, and a P value of 0.44 (Table 4.24). So, the small difference between the two groups was not statistically significant.

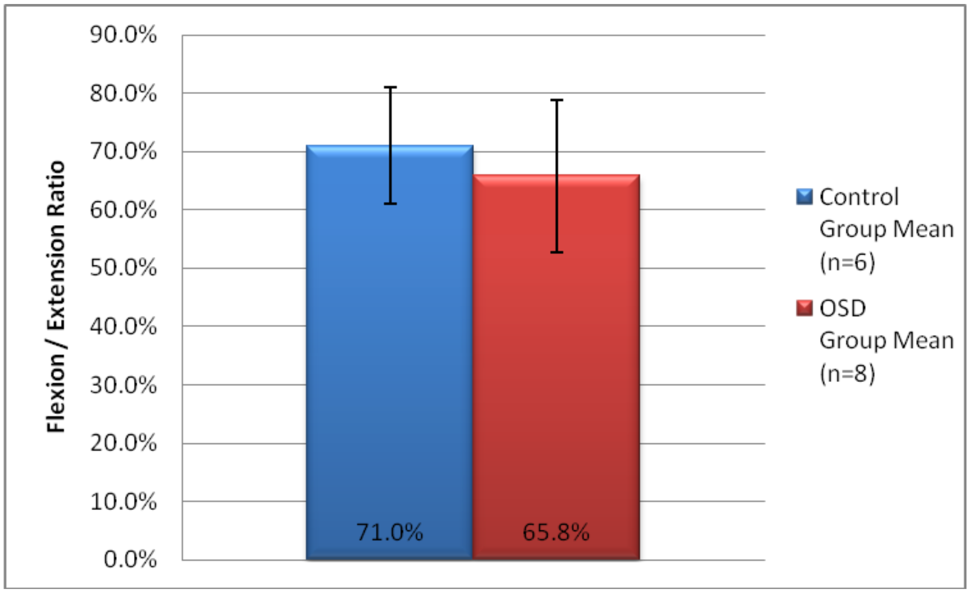


Figure 4.26 Mean peak torque flexion / extension ratio ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups during the 60 degrees per second isokinetic test.

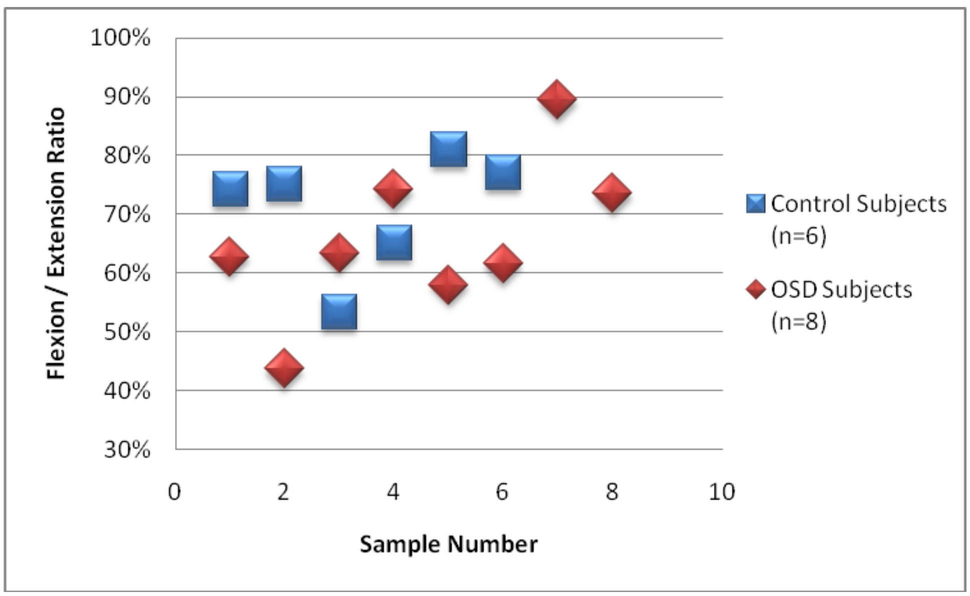


Figure 4.27 Individual peak torque flexion / extension ratios produced by the Control and Osgood Schlatter Disease (OSD) groups during the 60 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.24 Comparison and statistical analysis of the peak torque flexion / extension ratio of the 60 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	71.0%	65.8%
Variance	0.01	0.02
Standard Deviation	0.10	0.13
Sample Number	6	8
Degrees Freedom	12	
t	0.80	
t Critical two-tail	2.18	
P	**0.44**	
F	1.78	
F Critical one-tail	4.88	
P(F<=F Crit) one-tail	**0.27**	

Normalized Peak Work during Extension of the Slow Speed Test

The left legs of the Control group produced a mean normalized peak work value of 70.6% ± 9% body weight during knee extension of the slow speed test. The right legs produced a mean normalized peak work value of 74.1% ± 8% . When compared using a paired t-test, t equaled 1.77 and P equaled 0.14, which showed these values were not significantly different (Table 4.25). They were then averaged together and the group mean was determined to be 72.3% ± 8%.

Table 4.25 Comparison of mean normalized peak work during extension of the 60 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	70.6%	74.1%
Variance	0.01	0.01
Standard Deviation	0.09	0.08
Sample Number	6	6
Degrees Freedom	5	
t	1.77	
t Critical two-tail	2.57	
P	**0.14**	

The eight unaffected legs of the unilateral OSD subjects had a mean normalized peak work value of 73.0% ± 11% body weight. This value was then compared to the mean control value (Figures 4.28 and 4.29). An F-Test was done and the variances were confirmed to be equal. When compared using a two sample t-Test, the t value was calculated to be 0.14 and the P value was 0.89 (Table 4.26). This indicated the two sample means were not significantly different.

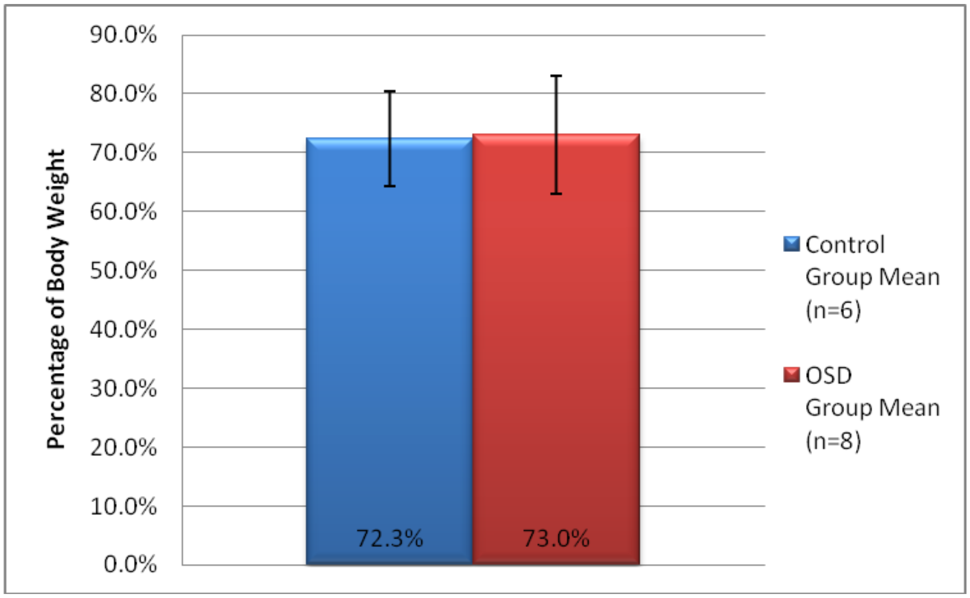


Figure 4.28 Mean normalized peak work ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups during extension of the 60 degrees per second isokinetic test.

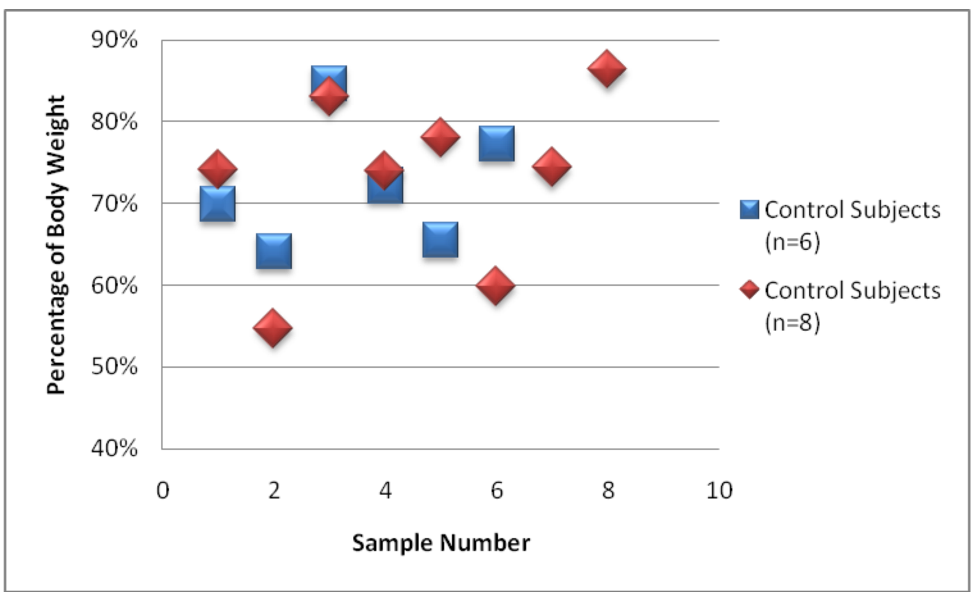


Figure 4.29 Individual normalized peak work values produced by the Control and Osgood Schlatter Disease (OSD) groups during extension of the 60 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.26 Comparison and statistical analysis of the mean normalized peak work during extension of the 60 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	72.3%	73.0%
Variance	0.01	0.01
Standard Deviation	0.08	0.11
Sample Number	6	8
Degrees Freedom	12	
t	0.14	
t Critical two-tail	2.18	
P	**0.89**	
F	1.98	
F Critical one-tail	4.88	
P(F<=F Crit) one-tail	**0.24**	

Normalized Peak Work during Flexion of the Slow Speed Test

The left legs of the Control group produced a mean normalized peak work value of 63.4% ± 12% body weight during knee flexion of the slow speed test. The right legs produced a mean normalized peak work value of 58.3% ± 12%. When compared using a Paired t-test, t was 0.99 and P was 0.37, which showed these values were not significantly different. They were then averaged together and the group mean was determined to be 60.8% ± 10%.

Table 4.27 Comparison of mean normalized peak work during flexion of the 60 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	63.4%	58.3%
Variance	0.01	0.01
Standard Deviation	0.12	0.12
Sample Number	6	6
Degrees Freedom	5	
t	0.99	
t Critical two-tail	2.57	
P	**0.37**	

The eight unaffected legs of the unilateral OSD subjects had a mean normalized peak work value of 57.9% ± 18% body weight. This value was then compared to the mean control value (Figures 4.30 and 4.31). An F-Test was done, and the variances were confirmed to be equal. When compared using a two sample t-Test, the t value was calculated to be 0.35 and the P value was 0.73 (Table 4.28). This indicated the two sample means were not significantly different.

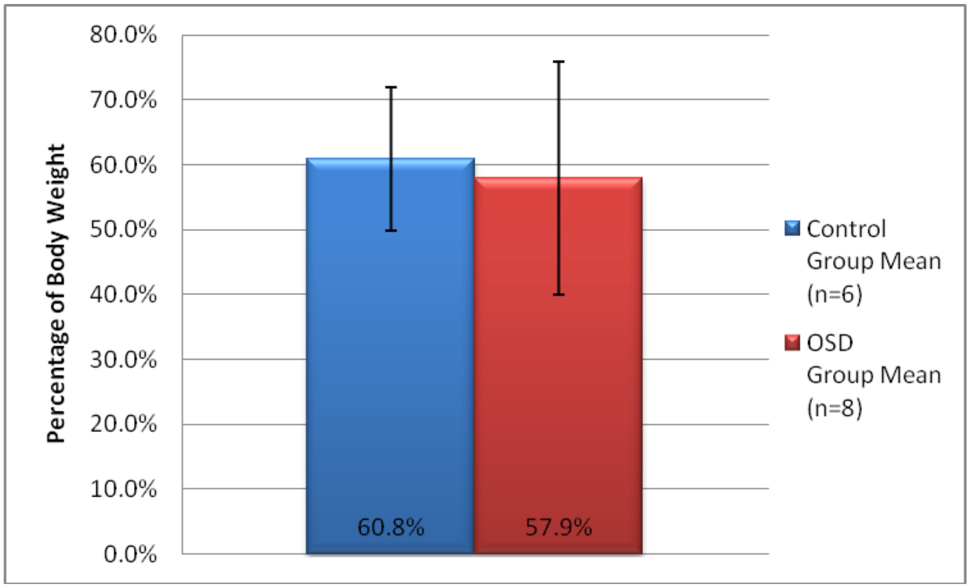


Figure 4.30 Mean normalized peak work ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups during flexion of the 60 degrees per second isokinetic test.

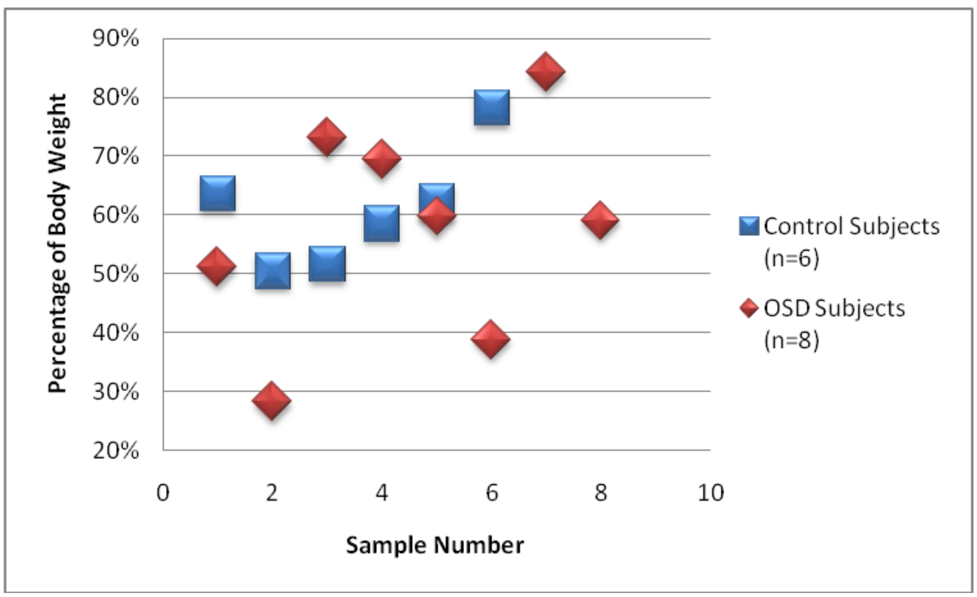


Figure 4.31 Individual normalized peak work values produced by the Control and Osgood Schlatter Disease (OSD) groups during flexion of the 60 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.28 Comparison and statistical analysis of the mean normalized peak work during flexion of the 60 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	60.8%	57.9%
Variance	0.01	0.03
Standard Deviation	0.10	0.18
Sample Number	6	8
Degrees Freedom	12	
t	0.35	
t Critical two-tail	2.18	
P	**0.73**	
F	3.31	
F Critical one-tail	4.88	
P(F<=F Crit) one-tail	**0.10**	

Peak Work Flexion / Extension Ratio of the Slow Speed Test

During the slow speed test, the six Control subjects produced a mean peak work flexion / extension ratio of 89.8% ± 11% in the left legs and 79.8% ± 19% in the right legs. When compared using a Paired t-test, t equaled 1.68, and P equaled 0.15, so the null hypothesis was accepted (Table 4.29). Since these values were not significantly different, they were averaged to equal 84.8% ± 14 % and compared against the mean of the unaffected OSD legs.

Table 4.29 Comparison of the mean peak work flexion / extension ratio from the 60 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	89.8%	79.8%
Variance	0.01	0.04
Standard Deviation	0.11	0.19
Sample Number	6	6
Degrees Freedom	5	
t	1.68	
t Critical two-tail	2.57	
P	**0.15**	

The eight unaffected legs of the unilateral OSD subjects had a mean peak work flexion / extension ratio of 78.2% ± 19%, which was compared against the Control group mean (Figures 4.32 and 4.33). An F-Test was done which determined the variances of the two groups were equal. A two sample t-Test produced a t value of 0.70 and a P value of 0.49 (Table 4.30). This showed the group means were not significantly different.

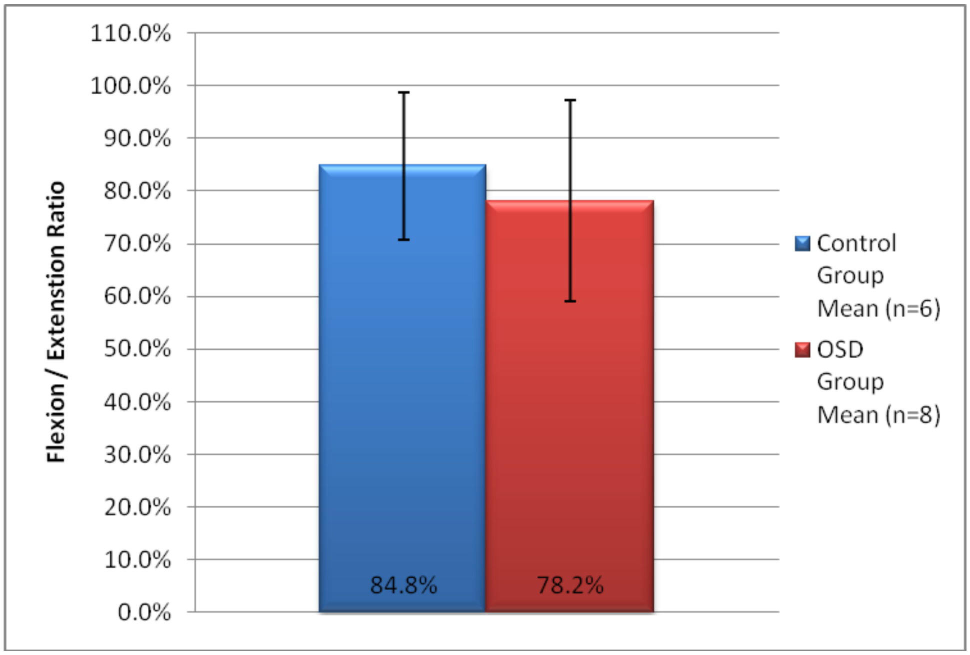


Figure 4.32 Mean peak work flexion / extension ratio ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups during the 60 degrees per second isokinetic test.

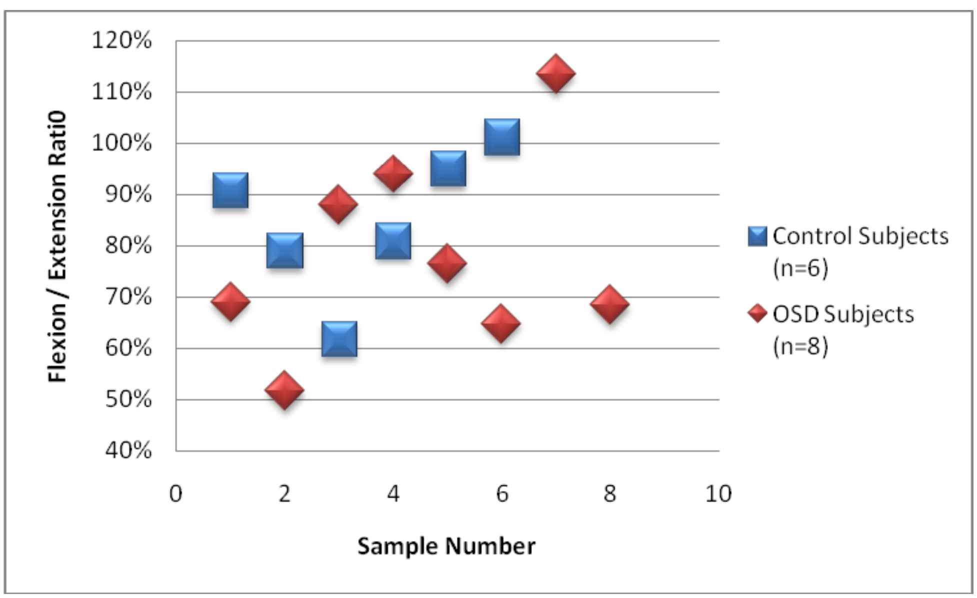


Figure 4.33 Individual peak work flexion / extension ratios produced by the Control and Osgood Schlatter Disease (OSD) groups during the 60 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.30 Comparison and statistical analysis of the peak work flexion / extension ratio of the 60 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	84.8%	78.2%
Variance	0.02	0.04
Standard Deviation	0.14	0.19
Sample Number	6	8
Degrees Freedom	12	
t	0.70	
t Critical two-tail	2.18	
P	**0.49**	
F	1.91	
F Critical one-tail	4.88	
P(F<=F Crit) one-tail	**0.25**	

Normalized Peak Torque during Extension of the Fast Speed Test

At the faster speed of 300 degrees per second, the six Control subjects produced a mean normalized peak torque during knee extension of 32.8% ± 6% body weight with the left legs and 34.1% ± 4% with the right legs. A paired t-test revealed that t equaled 0.72 and P equaled 0.50, which showed these values were not significantly different (Table 4.31). They were then averaged together to equal 33.4% ± 5% and that was compared against the mean of the unaffected OSD legs.

Table 4.31 Comparison of mean normalized peak torque during extension of the 300 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	32.8%	34.1%
Variance	3.64×10^{-3}	1.92×10^{-3}
Standard Deviation	0.06	0.04
Sample Number	6	6
Degrees Freedom	5	
t	0.72	
t Critical two-tail	2.57	
P	**0.50**	

The eight unaffected legs of the unilateral OSD subjects had a mean normalized peak torque value during knee extension of 42.4% ± 11% body weight, which was greater than the 33.4% ± 5% produced by the Control group (Figures 4.34 and 4.35). An F-Test was done and P equaled 0.04, meaning the variances were unequal. A two sample t-Test assuming unequal variances resulted in a t value of 2.04 and a P value of 0.07. So, despite the OSD group having a higher mean, the difference was not statistically significant (Table 4.32).

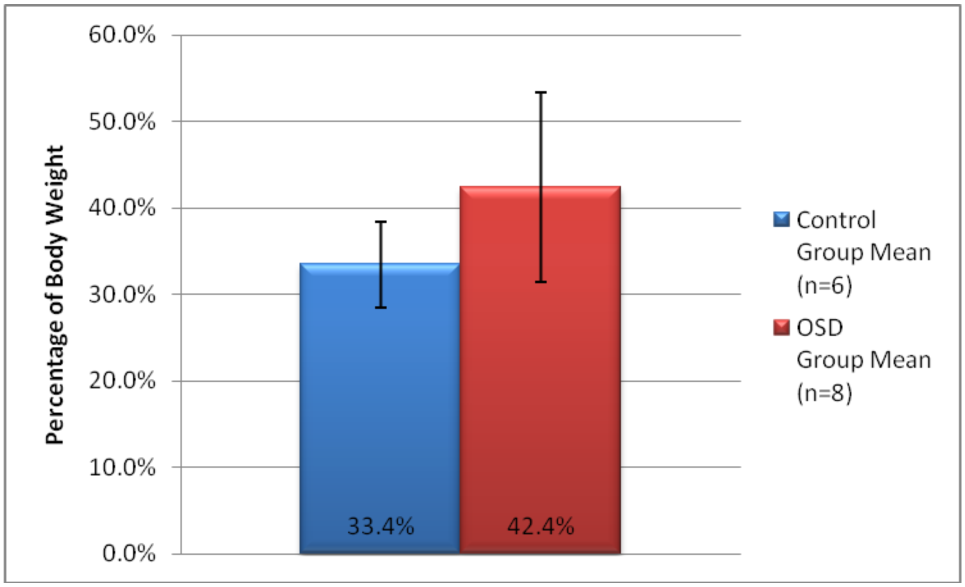


Figure 4.34 Mean normalized peak torque ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups during extension of the 300 degrees per second isokinetic test.

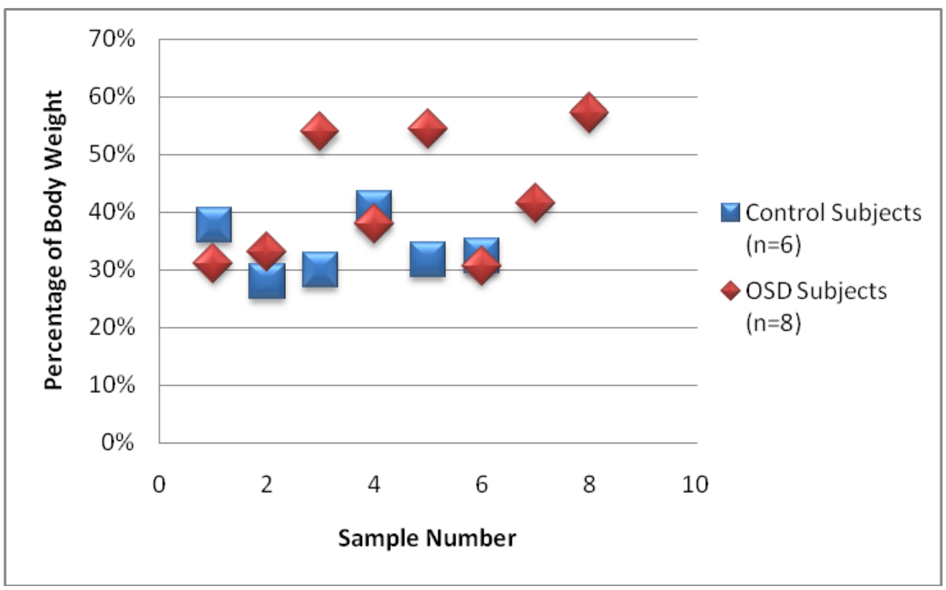


Figure 4.35 Individual normalized peak torque values produced by the Control and Osgood Schlatter Disease (OSD) groups during extension of the 300 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.32 Comparison and statistical analysis of the mean normalized peak torque during extension of the 300 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	33.4%	42.4%
Variance	2.34×10^{-3}	0.01
Standard Deviation	0.05	0.11
Sample Number	6	8
Degrees Freedom	10	
t	2.04	
t Critical two-tail	2.23	
P	**0.07**	
F	5.32	
F Critical one-tail	4.88	
P(F<=F Crit) one-tail	**0.04**	

Normalized Peak Torque during Flexion of the Fast Speed Test

The left legs of the six Control subjects produced a mean normalized peak torque value of 26.4% ± 8% body weight during knee flexion of the fast speed test. The right legs produced a mean normalized peak torque value of 28.1% ± 4%. Since a paired t-test showed t equaled 0.94 and P equaled 0.39, these values were not significantly different (Table 4.33). They were then averaged together to equal 27.3% ± 6% for comparison to the OSD group.

Table 4.33 Comparison of mean normalized peak torque during flexion of the 300 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	26.4%	28.1%
Variance	5.98×10^{-3}	1.74×10^{-3}
Standard Deviation	0.08	0.04
Sample Number	6	6
Degrees Freedom	5	
t	0.94	
t Critical two-tail	2.57	
P	**0.39**	

The eight unaffected legs of the unilateral OSD subjects had a mean normalized peak torque value during knee flexion of 34.2% ± 8% body weight which was compared against the Control group mean of 27.3% ± 6% (Figures 4.36 and 4.37). An F-Test confirmed the variances were equal. When the means were analyzed using a two sample t-Test, the t value equaled 1.73 and the P value equaled 0.11 (Table 4.34). Therefore, despite the OSD group having a higher mean, the difference was not statistically significant (Table 4.32).

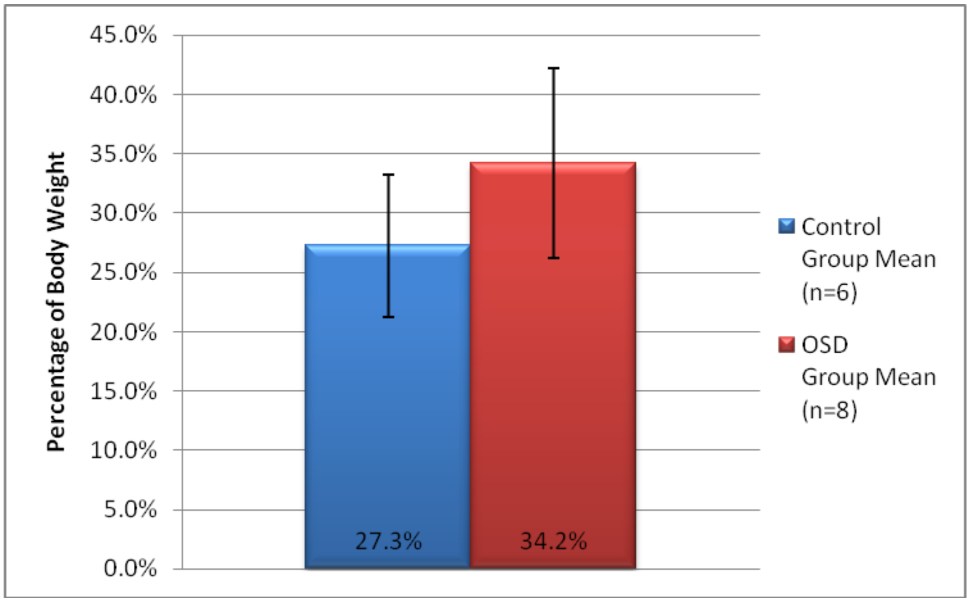


Figure 4.36 Mean normalized peak torque ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups during flexion of the 300 degrees per second isokinetic test.

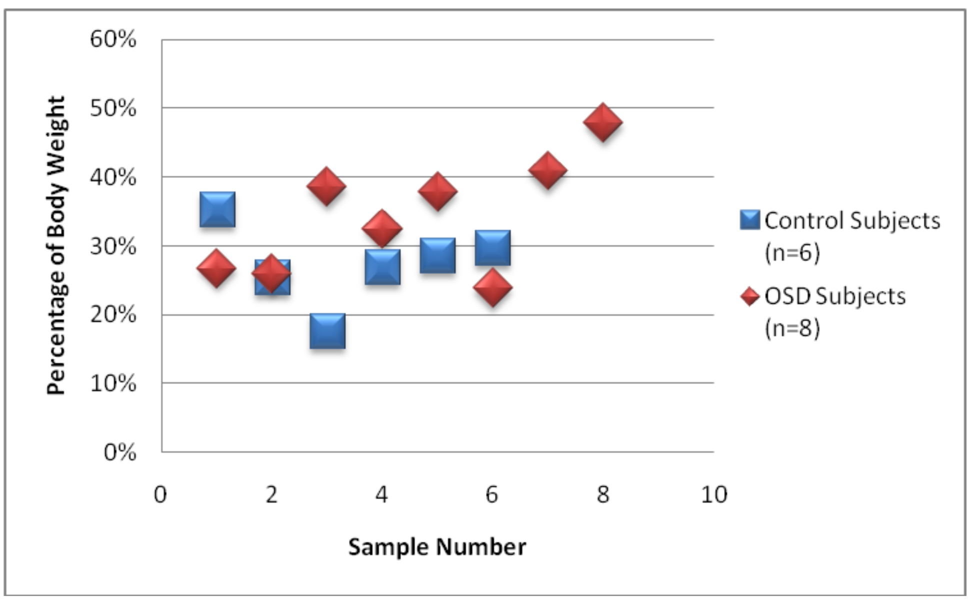


Figure 4.37 Individual normalized peak torque values produced by the Control and Osgood Schlatter Disease (OSD) groups during flexion of the 300 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.34 Comparison and statistical analysis of mean normalized peak torque during flexion of the 300 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	27.3%	34.2%
Variance	3.34×10^{-3}	7.10×10^{-3}
Standard Deviation	0.06	0.08
Sample Number	6	8
Degrees Freedom	12	
t	1.73	
t Critical two-tail	2.18	
P	**0.11**	
F	2.12	
F Critical one-tail	4.88	
P(F<=F Crit) one-tail	**0.21**	

Peak Torque Flexion / Extension Ratio of the Fast Speed Test

The left legs of the six Control subjects produced a mean peak torque flexion / extension ratio of 80.3% ± 20 % and the right legs produced a ratio of 83.3% ± 13%. Since a paired t-test showed t equaled 0.56 and P equaled 0.60, these values were not significantly different. They were averaged together to equal 81.8% ± 15% and compared against the mean of the unaffected OSD legs.

Table 4.35 Comparison of the mean peak torque flexion / extension ratio from the 300 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	80.3%	83.3%
Variance	0.04	0.02
Standard Deviation	0.20	0.13
Sample Number	6	6
Degrees Freedom	5	
t	0.56	
t Critical two-tail	2.57	
P	**0.60**	

The eight unaffected legs of the unilateral OSD subjects had a mean peak torque flexion / extension value of 81.3% ± 0.09%, which was compared against the mean of the Control group (Figures 4.38 and 4.39). An F-Test confirmed the variances were equal. When the means were analyzed using a two sample t-Test, t equaled 0.07 and P equaled 0.94. Therefore, the null hypothesis was accepted because the two means were not significantly different (Table 4.36).

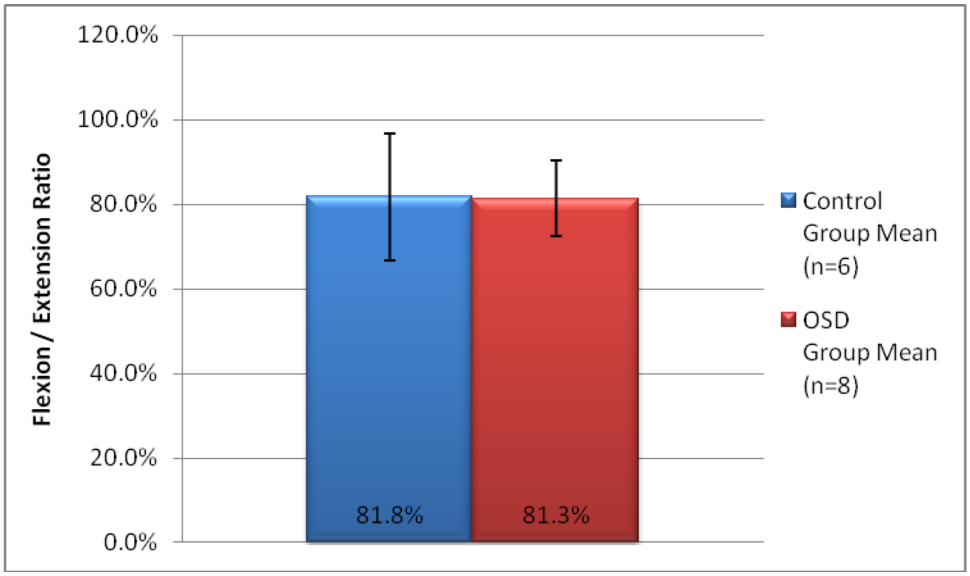


Figure 4.38 Mean peak torque flexion / extension ratio ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups during the 300 degrees per second isokinetic test.

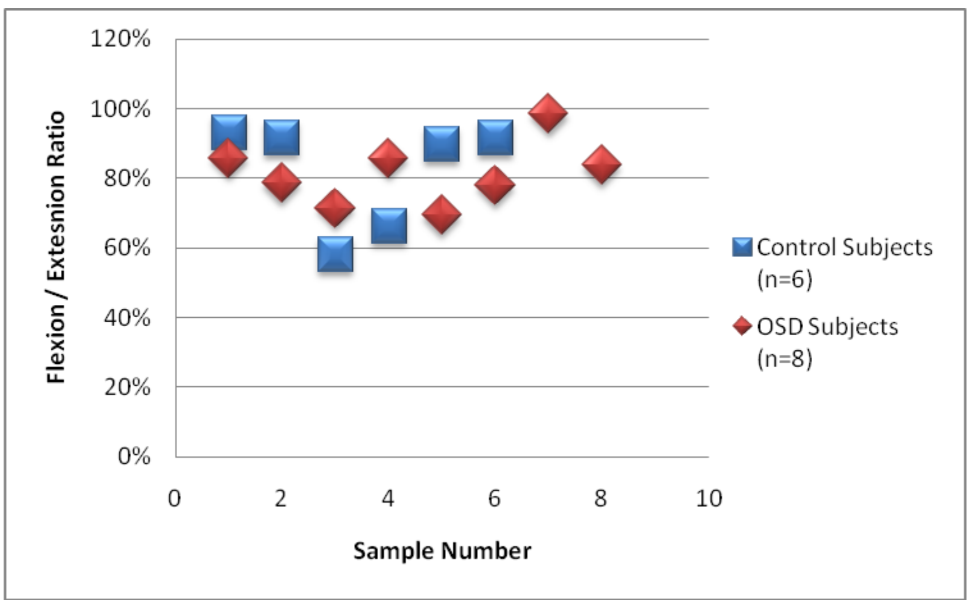


Figure 4.39 Individual peak torque flexion / extension ratios produced by the Control and Osgood Schlatter Disease (OSD) groups during the 300 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.36 Comparison and statistical analysis of the peak torque flexion / extension ratio for the 300 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	81.8%	81.3%
Variance	0.02	0.01
Standard Deviation	0.15	0.09
Sample Number	6	8
Degrees Freedom	12	
t	0.07	
t Critical two-tail	2.18	
P	**0.94**	
F	2.80	
F Critical one-tail	3.97	
P(F<=F Crit) one-tail	**0.11**	

Normalized Average Work per Repetition during Extension of the Fast Speed Test

The left legs of the Control group produced a mean normalized average work per repetition value of 23.2% ± 6% body weight during knee extension of the fast speed test. The right legs produced a mean value of 25.9% ± 4%. A paired t-Test produced a t value of 2.04 and a P value of 0.10, which revealed the left and right means were not significantly different (Table 4.37). They were then averaged together and compared against the mean of the unaffected OSD legs.

Table 4.37 Comparison of mean normalized average work per repetition during extension of the 300 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	23.2%	25.9%
Variance	3.55×10^{-3}	1.94×10^{-3}
Standard Deviation	0.06	0.04
Sample Number	6	6
Degrees Freedom	5	
t	2.04	
t Critical two-tail	2.57	
P	**0.10**	

The eight unaffected legs of the unilateral OSD subjects had a mean normalized average work value of 26.3 % ± 9%. This was compared to the Control group mean of 24.5% ± 5% (Figures 4.40 and 4.41). An F-Test was done which confirmed the variances were equal. When compared using a two sample t-Test, t equaled 0.42 and P equaled 0.68, so the null hypothesis was accepted (Table 4.38) There was no significant difference between the two group means.

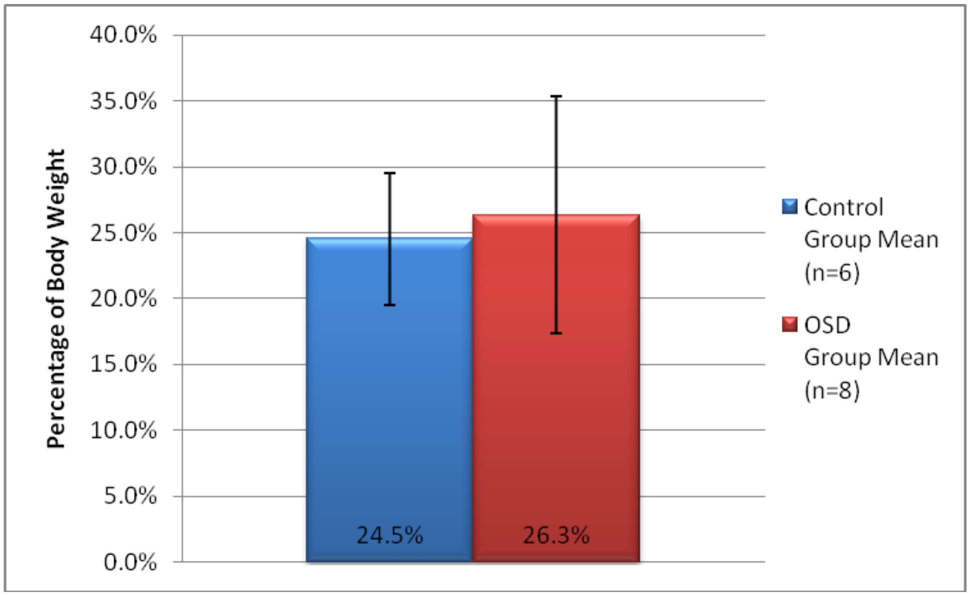


Figure 4.40 Mean normalized average work per repetition ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups during extension of the 300 degrees per second isokinetic test.

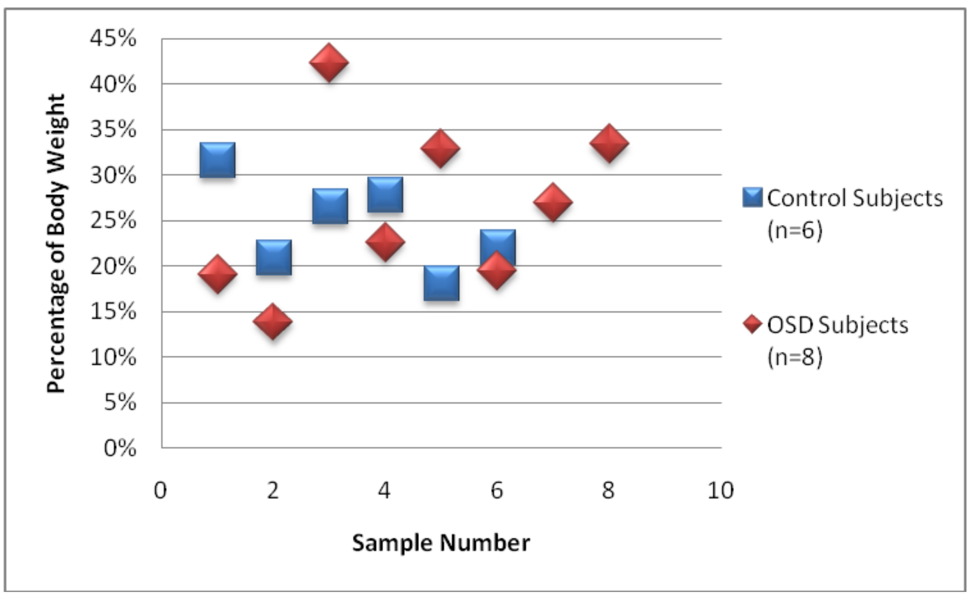


Figure 4.41 Individual normalized average work per repetition values produced by the Control and Osgood Schlatter Disease (OSD) groups during extension of the 300 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.38 Comparison and statistical analysis of the mean normalized average work per repetition during extension of the 300 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	24.5%	26.3%
Variance	2.49×10^{-3}	0.01
Standard Deviation	0.05	0.09
Sample Number	6	8
Degrees Freedom	12	
t	0.42	
t Critical two-tail	2.18	
P	**0.68**	
F	3.54	
F Critical one-tail	4.88	
P(F<=F Crit) one-tail	**0.09**	

Normalized Average Work per Repetition during Flexion of the Fast Speed Test

The left legs of the Control group produced a mean normalized average work per repetition value of 19.5% ± 10% body weight during flexion of the fast speed test. The right legs produced a mean normalized average work value of 21.7% ± 7%. A Paired t-Test showed that t equaled 1.11 and P equaled 0.32. This meant these values were not significantly different (Table 4.39). They were then averaged together and compared against the mean of the unaffected OSD legs.

Table 4.39 Comparison of mean normalized average work per repetition during flexion of the 300 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	19.5%	21.7%
Variance	0.01	4.47×10^{-3}
Standard Deviation	0.10	0.07
Sample Number	6	6
Degrees Freedom	5	
t	1.11	
t Critical two-tail	2.57	
P	**0.32**	

The eight unaffected legs of the unilateral OSD subjects had a mean normalized average work value of 21.2% ± 8%. This was compared to the Control group mean of 20.6% ± 8% (Figures 4.42 and 4.43). An F-Test was done which confirmed the variances were equal. When compared using a two sample t-Test, t equaled 0.12 and P equaled 0.90, so the null hypothesis was accepted (Table 4.40). There was no significant difference between the two group means.

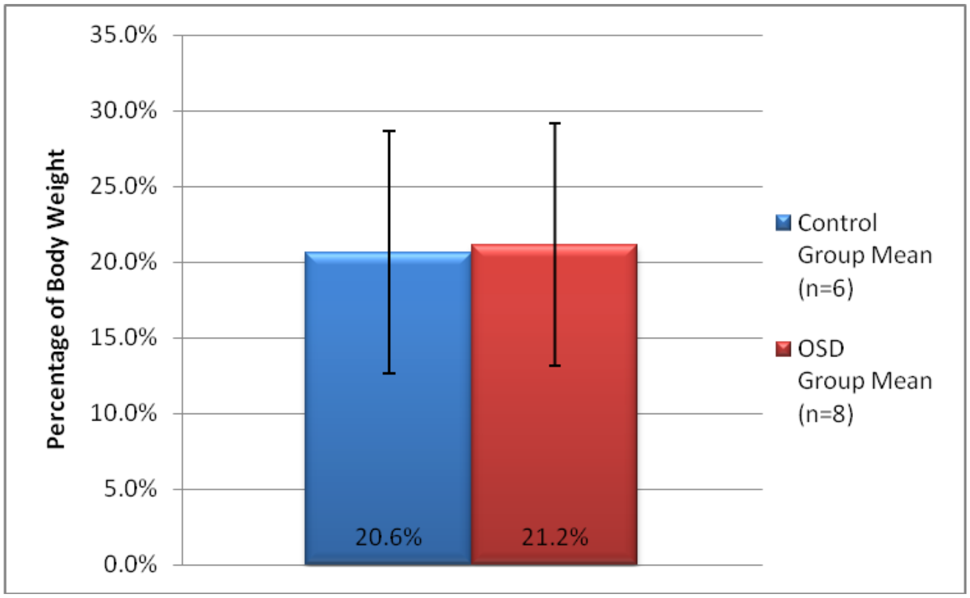


Figure 4.42 Mean normalized average work per repetition ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups during flexion of the 300 degrees per second isokinetic test.

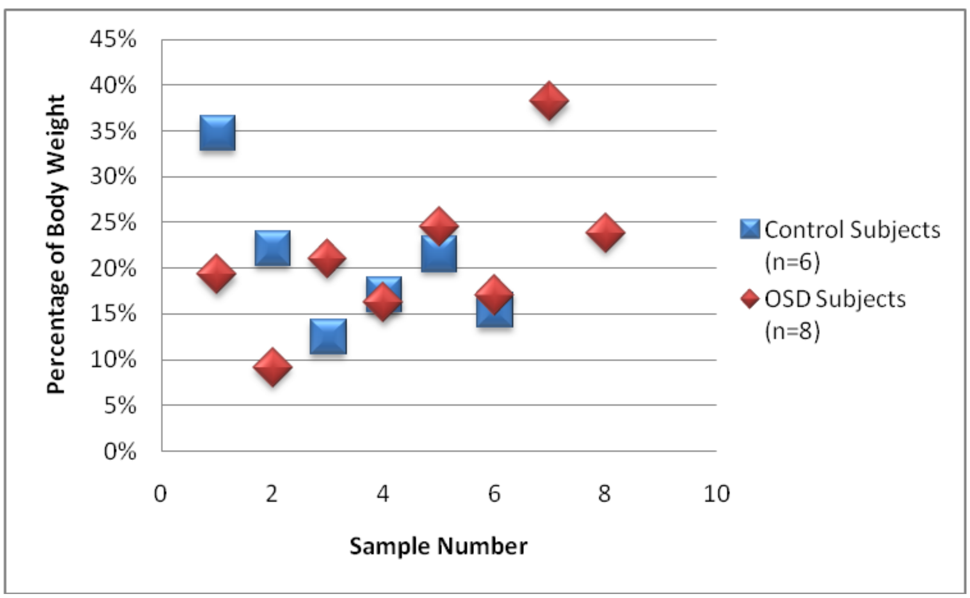


Figure 4.43 Individual normalized average work per repetition values produced by the Control and Osgood Schlatter Disease (OSD) groups during flexion of the 300 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.40 Comparison and statistical analysis of the mean normalized average work per repetition during flexion of the 300 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	20.6%	21.2%
Variance	0.01	0.01
Standard Deviation	0.08	0.08
Sample Number	6	8
Degrees Freedom	12	
t	0.12	
t Critical two-tail	2.18	
P	**0.90**	
F	1.15	
F Critical one-tail	4.88	
P(F<=F Crit) one-tail	**0.45**	

Average Work per Repetition Flexion / Extension Ratio of the Fast Speed Test

The left legs of the six Control subjects produced a mean average work per repetition flexion /extension ratio of 87.2% ± 41% and the right legs produced a ratio of 85.3% ± 24%. Since a paired t-test showed t equaled 0.17 and P equaled 0.87, these values were not significantly different (Table 4.41). The left and right means were averaged together to equal 86.2% ± 31% and compared against the mean of the unaffected OSD legs.

Table 4.41 Comparison of the mean average work per repetition flexion / extension ratio from the 60 degrees per second isokinetic test between left and right legs within the Control group. t-Test was performed.

	Control	
	Left	Right
Mean	87.2%	85.3%
Variance	0.17	0.06
Standard Deviation	0.41	0.24
Sample Number	6	6
Degrees Freedom	5	
t	0.17	
t Critical two-tail	2.57	
P	**0.87**	

The eight unaffected legs of the unilateral OSD subjects had a mean average flexion / extension value of 82.9% ± 28%, which was compared against the Control mean of 86.2% ± 31% (Figures 4.44 and 4.45). An F-Test confirmed the variances were equal. When the means were analyzed using a two sample t-Test, t equaled 0.21 and P equaled 0.84. Therefore, the null hypothesis was accepted because the two means were not significantly different (Table 4.42).

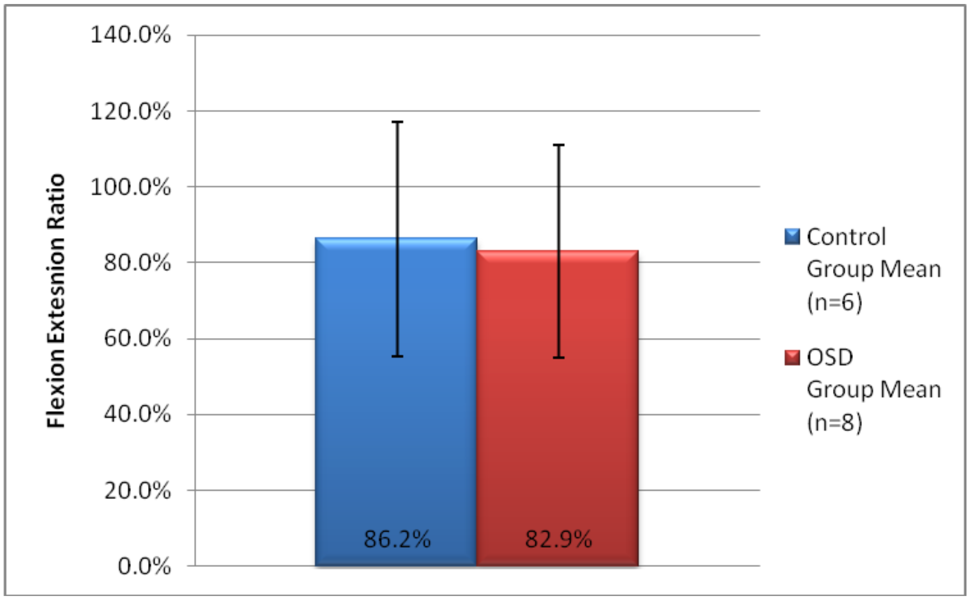


Figure 4.44 Mean average work per repetition flexion / extension ratio ± 1 standard deviation produced by the Control and Osgood Schlatter Disease (OSD) groups during the 300 degrees per second isokinetic test.

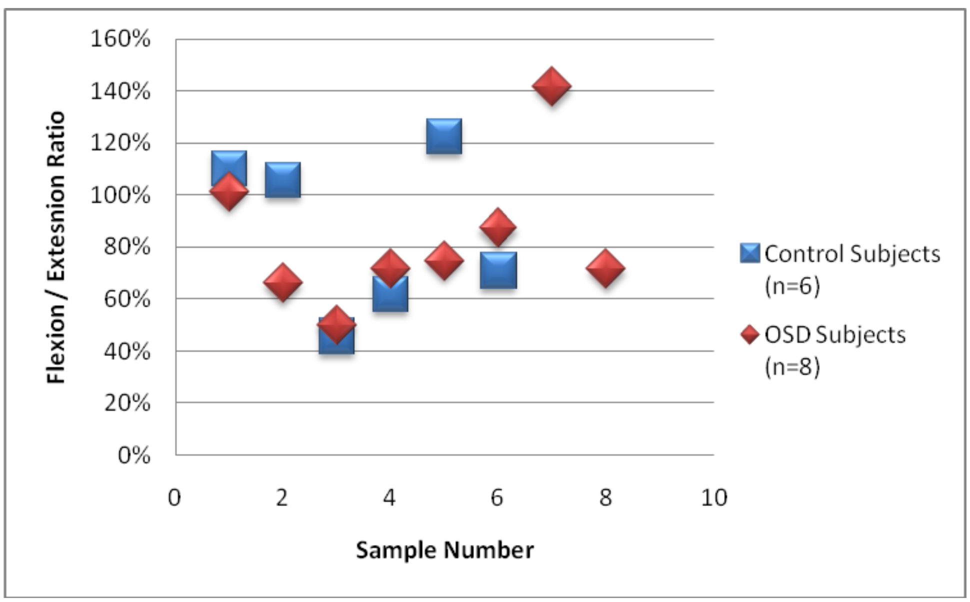


Figure 4.45 Individual average work per repetition flexion / extension ratios produced by the Control and Osgood Schlatter Disease (OSD) groups during the 300 degrees per second isokinetic test. Each Control point represents the mean value of each subject's left and right knees. Each OSD point represents the value produced by the subject's leg that was not affected by OSD.

Table 4.42 Comparison and statistical analysis of the average work per repetition flexion / extension ratio of the 300 degrees per second isokinetic test between the Control and Osgood Schlatter Disease (OSD) groups.

	Control	OSD
Mean	86.2%	82.9%
Variance	0.09	0.08
Standard Deviation	0.31	0.28
Sample Number	6	8
Degrees Freedom	12	
t	0.21	
t Critical two-tail	2.18	
P	**0.84**	
F	1.20	
F Critical one-tail	3.97	
P(F<=F Crit) one-tail	**0.40**	

Summary

There was little difference in ROM between the Control group and OSD. The Control group did have more passive knee flexion than the OSD group, but both groups were nearly in the normal range, and it was the OSD group that was actually in the center of the normal range. The control group was less than one degree above the upper end of the normal range.

The slow speed isokinetic knee extension test results differed between the two groups in normalized torque production at specific angles. As the angle of knee flexion decreased (as the knee was extending) the OSD patients produced significantly less normalized torque than the Controls. At 30 degrees of knee flexion the Control group produced a normalized torque value equal to 160% that of the OSD group. And at 15 degrees of knee flexion, that difference was over 800%. Following these findings, the normalization method was examined and found to be reasonable for data comparison.

CHAPTER V

DISCUSSION AND CONCLUSIONS

Introduction

This chapter provides an explanation of the results presented in Chapter 4. Each test resulting in statistically different sample means is discussed in detail along with the overall conclusions that were derived from this study. Recommendations are made for confirming results, improving future studies, and addressing the deficiencies discovered in this study.

Discussion of Hypotheses

Even though several theories of the etiology of OSD were investigated in this study, only a few tests were hypothesized to reveal any differences between the Control and OSD groups. The primary hypothesis stated that the Control group would produce higher normalized peak torque values than the OSD group during knee extension for both the slow and fast speed tests. This difference was expected to become even greater as the angle of knee flexion decreased (the more the knee extended). However, only part of this hypothesis was supported by the results. Actually, it was the OSD group that produced greater normalized peak torque values for knee extension during the slow and fast speed tests, but the differences were not statistically significant.

Despite a peak torque result that was in contrast to the hypothesis, the second component of the hypothesis was convincingly supported by the results. When the single knee extension repetition that produced the normalized peak torque value for each subject was analyzed by angle, the possible culprit for excessive traction quickly became exposed. As the knee became more extended, the normalized torque values produced by the OSD group became significantly less than the Control group. At 30 degrees the Control subjects produced over one and a half times more normalized torque than the OSD group. At 15 degrees the Control group's normalized peak torque value was more than eight times greater than that of the OSD group. The alternate normalization method also produced similar differences which provided evidence that the difference was not simply due to differing body weights.

These findings are the clearest distinction between the two groups seen throughout the entire study. There is little overlap between the two groups and, what little overlap there is, could likely be the result of subject error. For example one of the Control subjects produced a normalized torque of 0% at 15 degrees during his peak repetition, but actually produced a normalized torque of 8% at 8 degrees during the same repetition. He simply "zoned out" briefly and then quickly continued his effort until full extension. This was the only repetition in which he did this, but it happened to be the one which he produced his peak torque. Of course this possibility for error existed within the OSD group as well, but given the tests were done in the exact same manner, the statistical analysis shows it is not probable that the differences in the sample means were due solely to error.

The secondary hypothesis stating a possibility for the hamstrings and quadriceps muscles of the OSD group to be tighter than the Control group was not supported by the results. In fact the OSD group had more flexible hamstrings than the control group, but the difference was not significant. This does not support the claim that muscle tightness is the main contributor to increasing patellar tendon traction in OSD patients. Of course, based on the sliding filament theory, which is the most accepted theory of how a muscle contracts, muscle fiber length can play a role in force production. So, it is still possible that muscle tightness plays a role in OSD development in some cases, but more likely as a factor contributing to the decrease of torque production as opposed to causing a direct increase in tendon traction.

Finally, one test produced a significantly different result that had not been hypothesized. The Control group had nearly ten degrees more passive knee flexion than the OSD group. This test was done simply to determine if the knee had a normal full range of motion, and did not specifically test the length of the quadriceps because of the flexion in the hip joint. The OSD group was actually within the normal range and the Control group was just above normal. The angle of passive knee flexion can be affected by body tissue. The back of the thigh and calf come in contact with each other which can limit the ROM. This could have contributed to the difference between the two groups. However, since the OSD group was actually in the middle of the normal range and control group was slightly above normal, this finding is not expected to be a direct contributing factor to the development OSD.

Conclusions

After careful evaluation of all the theories concerning the etiology of OSD, and the results of this study, the evidence supports the theory that an inadequate torque to body weight ratio produced by the quadriceps muscles near terminal knee extension plays a significant role in the development of OSD. There are of course several factors involved in torque production normalized as a function of body weight. Nerve conduction, muscle length (of both the agonists and antagonists), muscle type, number of fibers, size of fibers, and body weight. Some of these can be altered and some cannot. In some cases some of the unalterable factors may be to blame, but for the majority of cases torque/body weight ratios should be able to be improved through strength training, and in special cases weight loss. Although there was a significant difference between the sample means of passive knee flexion, it is unlikely this is a primary factor contributing to the development of OSD.

Based on the results of this study, testing the torque to body weight ratios of the quadriceps muscles is the best way to identify if a young athlete is at risk of developing OSD. It should be stated that due to insufficient funds and manpower this study had a small sample size and subsequent studies are needed to support this claim. However, this study has shed some light on which etiological theories need to be studied more in the future. While hamstrings and quadriceps tightness can affect torque production, this possibility needs to be assessed on an individual basis after a deficiency in torque production has been identified. The overlap of data points in this study for these two tests suggest that neither one is a primary cause of OSD development.

Recommendations

This study provided statistical evidence that a lack of torque production by the quadriceps muscles near terminal knee extension could be a primary contributing factor to the development of OSD. As stated above, the sample numbers for this study were low and hopefully more studies with larger sample numbers will be done soon to further validate these results. This section suggests which tests should be redone, what new tests should be added and how the deficiencies found in the study can be addressed.

Experiments that Should be Repeated

Based on the findings of this study the following ROM tests do not need to be repeated: knee extension, hamstrings test, Q-Angle test, and Ober's test. There was no statistically significant difference between the Control and OSD groups for any of these tests and there was a lot of overlap in the individual data points. It would not be time or cost efficient to look at these any further. However, knee flexion and the quadriceps flexibility test should be done again in a follow up study. Knee flexion should be looked at again to confirm the different results. Even though the quadriceps test did not show a significant difference in the two groups, there was a difference and since there was so much literature listing it as a possible etiology it would be worthwhile to take another look at it with a larger sample size.

The isokinetic test at both fast and slow speeds should be redone, but the extensive data analysis that was done this time would not be necessary. The only analysis worth repeating is normalized peak torque and normalized torque at specific angles during the peak repetition. This should be done with a larger sample size to validate the results of this study.

Additional Experiments and Study Improvements

In addition to repeating certain tests from this study, future studies should aim to make improvements to this protocol in an attempt to build a stronger case for terminal knee extension weakness being an etiology of OSD. First, if the software has this capability, the normalized torque should be analyzed at specific angles during each repetition (not only the one that produced peak torque) and an average value should be calculated. This would decrease the chance for subject error to influence the results. This should be done at both slow and fast speeds if possible.

Also, an isotonic knee extension machine could be used to determine the 1RM at a starting position of 30 degrees of knee flexion. If this test produced results similar to the isokinetic test, it could be used as a more accessible alternative for testing a large number of children in a short amount of time.

Finally, it is understood that running is defined as a closed kinetic chain activity, and duly noted that this experiment did not contain any closed chain tests. It was decided the best way to analyze the strength and torque production of the quadriceps and hamstrings was with an isokinetic dynamometer. As far as the leg press is concerned, the open chain model was chosen because it is most similar to what is often found in school weight rooms. The leg press was added to this study in an attempt to select an easily accessible strength test that could identify at risk athletes. Therefore, the machine to which young athletes would have the most access was chosen. A future test could be done on a close chain leg press machine although it is recommended that the starting point be with the knee flexed between 40 and 30 degrees.

Addressing Weaknesses in Terminal Knee Extension

As previously stated, more studies are needed to support the theory that terminal knee extension weakness is the primary cause of OSD, but it is important to still list a way to address the deficiencies seen in this study. There is an ongoing debate about whether or not specific muscles of the quadriceps complex participate more or less at specific angles of knee flexion. One theory is that the vastus medialis oblique (VMO) is primarily responsible for terminal knee extension. However, there are also many studies that dismiss this idea as fallacy (Oatis, 2004) (Boling, 2006). The point of this is not to argue which muscle is involved but rather to improve the deficiency. The best way to address this deficiency is to do strength exercises that specifically target the identified angles. Terminal knee extension can be done in a variety of ways including both closed and open chain exercises. An isotonic knee extension machine, six inch steps ups, or even lifting a gym bag while sitting on the bed are ways of strengthening terminal knee extension. Of course, there are many more ways to attempt to improve torque production in terminal knee extension, and another study could be used to determine the most effective methods.

Summary

After reviewing the results it was concluded that the inability of the quadriceps muscles to produce adequate torque (when compared to body weight) near terminal knee extension is a likely cause of the increased patellar tendon traction that is believed to lead to the development of Osgood Schlatter Disease. None of the other etiologies tested is thought to be a primary cause of the excess traction. It is recommended however, that all tests showing significant differences in the sample means of the two tested groups be

replicated in future studies (as well as the quadriceps ROM test). It is advisable that these future studies include a larger sample number if possible. Improvements could also be made to the analysis methods of the isokinetic tests (if the software is capable). Normalized torque values at specific angles (at least 30 and 15 degrees) should be recorded during each repetition as opposed to analyzing specific angles for only one repetition. Other tests that could be done include a 1RM on an isotonic leg extension machine with a starting position of 30 degrees of knee flexion. A 1RM on either an open or closed chain leg press machine with a knee angle starting position of 30 degrees could also be added. The main reason for the addition of these last two tests would be to find a more accessible way of testing terminal knee extension strength. Finally, if future studies do support the claim that weak terminal knee extension is a primary etiology of OSD, then it would be recommended that individuals found to be at risk begin a light strength training program targeting the last 30 degrees of knee extension. The specific methods of such a program should also be the focus of a future study.

APPENDICES

APPENDIX A

Human Subject Forms

UAH
The University of Alabama in Huntsville

Department of Philosophy
College of Liberal Arts

Huntsville, Alabama 35899
Phone: (256) 824-6555

Justin Pruitt
Department of Biology
UAHuntsville
Huntsville, AL 35899
March 10, 2008

Dear Mr. Pruitt,

The UAH IRB Human Subjects Committee, has reviewed your proposal, *Incidence of Osgood Schlatter's Disease as it Relates to Strength to Body Weight Ratios of the Quadriceps and Hamstrings* and have found it meets the necessary criteria for **full review** according to 45 CFR 46. We have approved this proposal, and you may commence your research. Please note that this approval is good for one calendar year from the date above. If data collection lasts beyond this period, a renewal application must be filed.

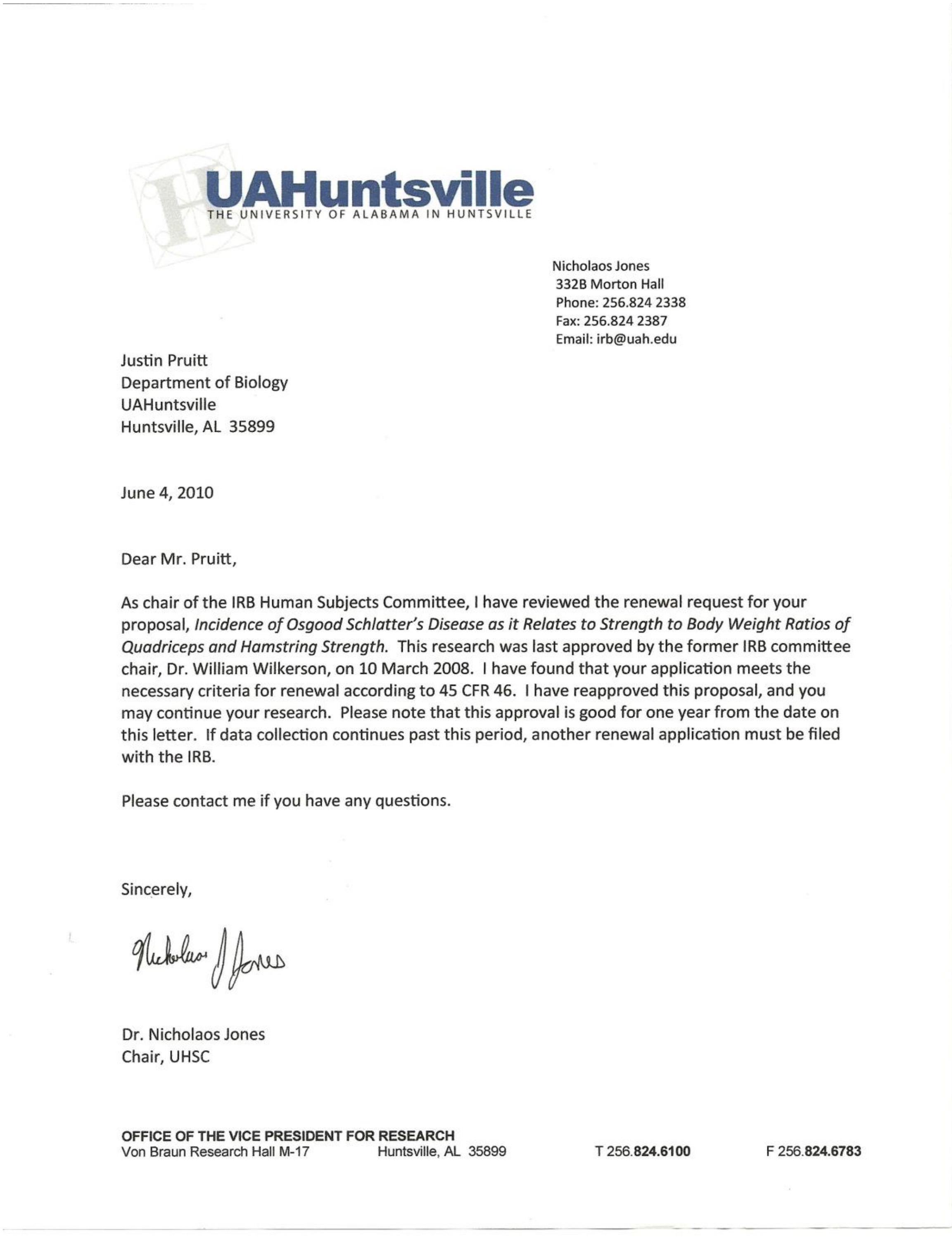
Contact me if you have any questions.

Sincerely,

Dr. William Wilkerson,
Chair, UHSC

A Space Grant College
An Affirmative Action/Equal Opportunity Institution

Figure A.1 Original approval letter from the Institutional Review Board Human Subjects Committee of the University of Alabama in Huntsville.



UAHuntsville
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Nicholaos Jones
332B Morton Hall
Phone: 256.824 2338
Fax: 256.824 2387
Email: irb@uah.edu

Justin Pruitt
Department of Biology
UAHuntsville
Huntsville, AL 35899

June 4, 2010

Dear Mr. Pruitt,

As chair of the IRB Human Subjects Committee, I have reviewed the renewal request for your proposal, *Incidence of Osgood Schlatter's Disease as it Relates to Strength to Body Weight Ratios of Quadriceps and Hamstring Strength.* This research was last approved by the former IRB committee chair, Dr. William Wilkerson, on 10 March 2008. I have found that your application meets the necessary criteria for renewal according to 45 CFR 46. I have reapproved this proposal, and you may continue your research. Please note that this approval is good for one year from the date on this letter. If data collection continues past this period, another renewal application must be filed with the IRB.

Please contact me if you have any questions.

Sincerely,

Nicholaos J Jones

Dr. Nicholaos Jones
Chair, UHSC

OFFICE OF THE VICE PRESIDENT FOR RESEARCH
Von Braun Research Hall M-17 Huntsville, AL 35899 T 256.**824.6100** F 256.**824.6783**

Figure A.2 Renewal request approval letter from the Institutional Review Board Human Subjects Committee of the University of Alabama in Huntsville.

HUNTSVILLE
HOSPITAL

101 Sivley Road • Huntsville, Alabama 35801 • 256/265-1000

INSTITUTIONAL REVIEW COMMITTEE - CERTIFICATION FORM
IDENTIFICATION AND CERTIFICATION OF RESEARCH
PROJECTS INVOLVING HUMAN SUBJECTS

Huntsville Hospital's Institutional Review Committee (IRC) has an approved Federal Wide Assurance with the Office for Human Research Protections (OHRP) (FWA # 00003286; IRB # 00002730). The IRC is also in compliance with The Common Rule and Subparts B, C, and D of the HHS Regulations at 45 CFR Part 46. This is to certify that the IRC has reviewed/approved the named project. Review was conducted in accordance with applicable guidelines/assurance and will be subject to continuing review.

Principal Investigator: Justin Pruitt, UAH Student

Protocol Name/Title/Number: The Relationship Between Single Leg Strength and Development of Osgood Schlatter Disease

Action Taken: Approval of New Protocol, Informed Consent.

Expedited Review Date:

IRC Approval Date: February 12, 2008

Continuing Review Due: August 2008

John B. Cox, MD, Chair
Institutional Review Committee

Robert W. Chappell, Jr., MD, MBA
VP/Chief Medical Officer/Chief Quality Officer

Investigators please note:

- The IRC approved the consent form (if applicable) that contains the stamped IRC approval date. Only the stamped consent form may be used for study participants.
- The IRC approval is given for twelve months unless otherwise noted above. For projects subject to continuing review, activities may not continue past this twelve-month anniversary.
- Any modifications in the study methodology, protocol, consent form, and/or investigator's drug brochure must be submitted for review and approval by the IRC prior to implementation.
- Global and local Serious Adverse Events (SAEs) and/or unanticipated risks to subjects or others at Huntsville Hospital or other participating institutions must be reported promptly to the IRC in accordance with the guidelines outlined in the Huntsville Hospital Institutional Review Committee Policies and Procedures, a copy of which is supplied to all Principal Investigators.
- Current IRC Policies and Procedures can be viewed on Huntsville Hospital's website under Policies and Procedures or can be obtained from the IRC Coordinator.
- Questions regarding IRC activities may be directed to:
  Allison Greene, IRC Coordinator, Huntsville Hospital, 101 Sivley Road, Huntsville, AL 35801
  (256) 265-6990 (Telephone); (256) 265-8920 (Fax); allisong@hhsys.org (Email)

Figure A.3 Original approval letter from the Institutional Review Committee of Huntsville Hospital.

HUNTSVILLE HOSPITAL

101 Sivley Road • Huntsville, Alabama 35801 • 256/265-1000

INSTITUTIONAL REVIEW COMMITTEE - CERTIFICATION FORM
IDENTIFICATION AND CERTIFICATION OF RESEARCH
PROJECTS INVOLVING HUMAN SUBJECTS

Huntsville Hospital's Institutional Review Committee (IRC) has an approved Federal Wide Assurance with the Office for Human Research Protections (OHRP) (FWA # 00003286; IRB # 00002730). The IRC is also in compliance with The Common Rule and Subparts B, C, and D of the HHS Regulations at 45 CFR Part 46. This is to certify that the IRC has reviewed/approved the named project. Review was conducted in accordance with applicable guidelines/assurance and will be subject to continuing review.

Principal Investigator: Justin Pruitt, UAB Graduate Student

Protocol Name/Title/Number: The Relationship Between Single Leg Strength and Development of Osgood Schlatter Disease (02/12/08)

Action Taken: Approval of Revised Research Design.

Expedited Review Date:

IRC Approval Date: June 10, 2008

Continuing Review Due:

John B. Cox, M.D.

John B. Cox, MD, Chair
Institutional Review Committee

Robert W. Chappell, Jr., MD, MBA
VP/Chief Medical Officer/Chief Quality Officer

Investigators please note:

- The IRC approved the consent form (if applicable) that contains the stamped IRC approval date. Only the stamped consent form may be used for study participants.
- The IRC approval is given for twelve months unless otherwise noted above. For projects subject to continuing review, activities may not continue past this twelve-month anniversary.
- Any modifications in the study methodology, protocol, consent form, and/or investigator's drug brochure must be submitted for review and approval by the IRC prior to implementation.
- Global and local Serious Adverse Events (SAEs) and/or unanticipated risks to subjects or others at Huntsville Hospital or other participating institutions must be reported promptly to the IRC in accordance with the guidelines outlined in the Huntsville Hospital Institutional Review Committee Policies and Procedures, a copy of which is supplied to all Principal Investigators.
- Current IRC Policies and Procedures can be viewed on Huntsville Hospital's website under Policies and Procedures or can be obtained from the IRC Coordinator.
- Questions regarding IRC activities may be directed to:
  Allison Greene, IRC Coordinator, Huntsville Hospital, 101 Sivley Road, Huntsville, AL 35801
  (256) 265-6990 (Telephone); (256) 265-8920 (Fax); allisong@hhsys.org (Email)

Figure A.4 Approval letter for revised protocol from the Institutional Review Committee of Huntsville Hospital.

HUNTSVILLE HOSPITAL

101 Sivley Road • Huntsville, Alabama 35801 • 256/265-1000

INSTITUTIONAL REVIEW COMMITTEE - CERTIFICATION FORM
IDENTIFICATION AND CERTIFICATION OF RESEARCH
PROJECTS INVOLVING HUMAN SUBJECTS

Huntsville Hospital's Institutional Review Committee (IRC) has an approved Federal Wide Assurance with the Office for Human Research Protections and Federal Drug Administration (OHRP/FDA) (FWA # 00003286; IRB # 00002730). The IRC is also in compliance with The Common Rule and Subparts B, C, and D of the HHS Regulations at 45 CFR Part 46. This is to certify that the IRC has reviewed/approved the named project. Review was conducted in accordance with applicable guidelines/assurance and will be subject to continuing review.

Principal Investigator: Justin Pruitt

Protocol Name/Title/Number: The Relationship Between Single Leg Strength and Development of Osgood Schlatter Disease (02/12/08)

Action: Acceptance of Permanent Study Closure.

Expedited Review Date:

IRC Approval Date: May 10, 2011

Continuing Review Expires:

John B. Cox, MD, Chair
Institutional Review Committee

Robert W. Chappell, Jr., MD, MBA
VP/Chief Medical Officer/Chief Quality Officer

Investigators please note:

- The IRC approved the consent form (if applicable) that contains the stamped IRC approval date. Only the stamped consent form may be used for study participants.
- The IRC approval is given for twelve months unless otherwise noted above. For projects subject to continuing review, activities may not continue past this twelve-month anniversary.
- Any modifications in the study methodology, protocol, consent form, and/or investigator's drug brochure must be submitted for review and approval by the IRC prior to implementation.
- Global and local Serious Adverse Events (SAEs) and/or unanticipated risks to subjects or others at Huntsville Hospital or other participating institutions must be reported promptly to the IRC in accordance with the guidelines outlined in the Huntsville Hospital Institutional Review Committee Policies and Procedures, a copy of which is supplied to all Principal Investigators.
- Current IRC Policies and Procedures can be viewed on Huntsville Hospital's website under Policies and Procedures or can be obtained from the IRC Coordinator.
- Questions regarding IRC activities may be directed to:
  Allison Greene, IRC Coordinator, Huntsville Hospital, 101 Sivley Road, Huntsville, AL 35801
  (256) 265-6990 (Telephone); (256) 265-8920 (Fax); allison.e.greene@hhsys.org (Email)

Figure A.5 Approval letter for permanent closure of study from the Institutional Review Committee of Huntsville Hospital.

HH IRC February 1, 2008

FEB 1 2 2008

APPROVED

Informed Consent

Study Information and Possible Risks

This study involves research to gather information about the cause of Osgood Schlatter Disease. The examination will require approximately 30 minutes and will include three main parts; including a written questionnaire, a flexibility evaluation, and an isokinetic strength test of the quadriceps and hamstrings through the plane of knee extension / flexion. The strength test will be performed at maximal effort and risks that are associated with such an effort include delayed onset muscle soreness, muscle strain, and muscle tearing. Muscle strains and tears are extremely rare, but possible. Delayed onset muscle soreness is not common but occurs more often than muscle strain or tearing and usually begins the day after the test and can last a few days.

Study Benefits

Direct: The subject will receive about $150 of testing for free. The results of the tests will be explained to the subject in an understandable manner and suggestions for improving muscle weaknesses or tightness that could lead to injury will be provided.

Indirect: This study will hopefully identify specific risk factors for developing OSD, which will lead to further studies that could give parents, coaches, and trainers the knowledge to reduce risk factors in the young athlete, and ultimately decrease the incidence of OSD for young athletes.

Confidentiality

Every effort will be made to keep all results confidential in accordance with HIPAA guidelines. The subject will be assigned a study identification number and will be indentified by that numbers rather than by name. Once the data has been collected it will be used in the study.

Contact Information

Questions involving the study can be directed to the lead student researcher Justin Pruitt, BS at (256) 490-7592, advising faculty member Mark Noble, MS at Huntsville Hospital Sports Max program at (256) 509-0860, or Huntsville Hospital Institutional Review Committee Chairman, John B. Cox, M.D. at (256) 265-6990.

Participation

Participation is voluntary and refusal to participate will not result in any penalty or legal action. The subject may discontinue the tests at anytime during the testing session without fear of penalty.

Consent

I, ________________________, and my child___________________, understand all of the above information including but not limited to the study procedures, risks, and benefits. I assume all responsibility for my child during this study and will not hold Huntsville Hospital, TOC, UAH, Justin Pruitt, Mark Noble, or any other persons or employees of these institutions involved with the study responsible or liable for any injury that may occur during the study, including but not limited to, delayed onset muscle soreness, muscle strain, or muscle tear. I understand that Huntsville Hospital has made no provision of monetary compensation to me in the event of physical injury resulting from the research procedures. Should physical injury occur, medical treatment is available, but treatment is not provided free of charge.

Parent/Guardian Signature: ____________________________________ Date: _________________

Subject Signature: ____________________________________ Date: _________________

Figure A.6 Approved informed consent form.

APPENDIX B

Raw Data

Table B.1 Background information: All subjects.

OSD Study #	OSD?	Dominant Arm	Dominant Leg	Involved Side	Body Weight	Age	Sport (**Bold = Currently Playing**)	Days of Practice
OSD 1	Yes	Right	Right	Left	135	12 yrs. 7 mo.	Basketball, Football, Tennis	0 to 2
OSD 2	Yes	Right	Right	Right	170	12 yrs. 9 mo.	**Basketball**	3 to 5
OSD 3	Yes	Left	Left	Right	130	15 yrs. 11 mo.	**Basketball**, Swimming	6 to 7
OSD 4	Yes	Right	Right	Both	168	14 yrs. 0 mo.	Baseball, Basketball, **Soccer**, Swimming, Track	0 to 2
OSD 5	Yes	Right	Right	Left	111	11 yrs. 7 mo.	**Basketball**, Football	0 to 2
OSD 6	Yes	Right	Right	Left	114	14 yrs. 7 mo.	Football	0 to 2
OSD 7	Yes	Left	Right	Left	147	12 yrs. 4 mo.	**Baseball**, Football	3 to 5
OSD 8	Yes	Right	Right	Left	152	16 yrs. 5 mo.	**Soccer**	6 to 7
OSD 9	Yes	Right	Right	Both	105	12 yrs. 9 mo.	Cross Country, Hockey, **Soccer**, **Track**	6 to 7
OSD 10	Yes	Right	Right	Both	140	11 yrs. 11 mo.	**Baseball, Basketball, Football, Golf**	6 to 7
OSD 16	Yes	Right	Right	Right	161	12 yrs. 7 mo.	**Basketball**, Football, Track	3 to 5
OSD 11	No	Left	Right	NA	95	12 yrs. 2 mo.	**Baseball**, Basketball	6 to 7
OSD 12	No	Left	Right	NA	102	12 yrs. 9 mo.	**Baseball**, Basketball, Swimming	6 to 7
OSD 13	No	Right	Right	NA	85	12 yrs. 9 mo.	**Baseball**, **Basketball**, Football	6 to 7
OSD 14	No	Right	Right	NA	117	13 yrs. 3 mo.	**Soccer**	3 to 5
OSD 17	No	Right	Right	NA	77	11 yrs. 11 mo.	Basketball, Cross Country, **Soccer**	3 to 5
OSD 18	No	Right	Left	NA	108	12 yrs. 3 mo.	Baseball, Basketball, **Soccer**, **Swimming**	3 to 5
OSD 15	No	VOID	VOID	VOID	VOID	VOID	VOID	VOID

Table B.2 Range of motion: Control legs.

OSD Study #	Leg	Knee Extension	Knee Flexion	Hamstrings	Active Dorsi Flexion	Active Plantar Flexion	Quadriceps	IT Band	Passive Dorsi Flexion	Q-Angle
OSD 11	R	0	152	137	16	40	130	N	14	19
OSD 11	L	0	152	137	15	40	131	N	19	18
OSD 12	R	0	151	146	13	46	142	Y	11	13
OSD 12	L	0	153	130	17	48	139	Y	15	14
OSD 13	R	0	154	127	13	47	130	N	11	15
OSD 13	L	0	155	140	10	50	132	N	7	15
OSD 14	R	0	150	139	23	40	148	Y	18	10
OSD 14	L	0	155	135	23	50	153	Y	19	9
OSD 15	VOID	VOID	VOID	VOID	VOID	VOID	VOID	VOID	VOID	VOID
OSD 17	R	0	150	137	20	45	145	N	16	19
OSD 17	L	0	150	136	21	45	148	N	18	19
OSD 18	R	0	143	149	20	45	140	N	14	18
OSD 18	L	0	146	145	14	45	140	N	14	18

Table B.3 Range of motion: Uninvolved OSD legs.

OSD Study #	Leg	Knee Extension	Knee Flexion	Hamstrings	Active Dorsi Flexion	Active Plantar Flexion	Quadriceps	IT Band	Passive Dorsi Flexion	Q-Angle
OSD 1	R	0	135	155	4	45	-	Y		-
OSD 2	L	0	140	140	0	50	-	N	6	-
OSD 3	L	0	140	135	4	50	-	N	13	-
OSD 5	R	0	146	151	15	49	-	N	19	13
OSD 6	R	0	151	133	18	50	-	Y	23	12
OSD 7	R	0	135	148	8	57	133	Y	15	17
OSD 8	R	0	145	139	9	65	140	N	9	13
OSD 16	L	0	135	144	14	14	128	N	11	19

Table B.4 Range of motion: Involved OSD legs.

OSD Study #	Leg	Knee Extension	Knee Flexion	Hamstrings	Active Dorsi Flexion	Active Plantar Flexion	Quadriceps	IT Band	Passive Dorsi Flexion	Q-Angle
OSD 1	L	0	139	164	4	45	-	Y		-
OSD 2	R	0	140	138	1	45	-	N	14	-
OSD 3	R	0	140	135	3	50	-	N	13	-
OSD 4	R	0	138	144	6	55	-	N	13	-
OSD 4	L	0	141	137	4	55	-	N	8	-
OSD 5	L	0	149	155	13	49	-	N	18	11
OSD 6	L	0	151	135	16	50	-	Y	20	12
OSD 7	L	0	135	142	13	63	135	Y	11	17
OSD 8	L	0	142	141	11	65	145	N	11	15
OSD 9	R	0	145	136	16	50	136	N	18	12
OSD 9	L	0	146	136	16	43	140	N	20	12
OSD 10	R	0	140	136	10	44	126	Y	9	16
OSD 10	L	0	137	135	10	45	122	Y	11	15
OSD 16	R	0	141	133	10	40	128	N	9	18

Table B.5 Leg press: 1 repetition maximum for Control legs.

OSD Study #	Body Weight	Leg	1RM	%BW
OSD 11	95	R	-	-
OSD 11	95	L	-	-
OSD 12	102	R	-	-
OSD 12	102	L	-	-
OSD 13	85	R	130	153%
OSD 13	85	L	130	153%
OSD 14	117	R	120	103%
OSD 14	117	L	110	94%
OSD 15	VOID	VOID	VOID	VOID
OSD 17	77	R	80	104%
OSD 17	77	L	70	91%
OSD 18	108	R	125	116%
OSD 18	108	L	150	139%

Table B.6 Leg press: 1 repetition max for uninvolved OSD legs.

OSD Study #	Body Weight	Leg	1RM	%BW
OSD 1	135	R	-	-
OSD 2	170	L	95	56%
OSD 3	130	L	220	168%
OSD 5	111	R	115	104%
OSD 6	114	R	115	101%
OSD 7	147	R	130	88%
OSD 8	152	R	130	86%
OSD 16	161	L	180	112%

Table B.7 Leg press: 1 repetition maximum for involved OSD legs.

OSD Study #	Body Weight	Leg	1RM	% BW
OSD 1	135	L	-	-
OSD 2	170	R	PAIN	PAIN
OSD 3	130	R	190	145%
OSD 4	168	R	120	71%
OSD 4	168	L	120	71%
OSD 5	111	L	PAIN	PAIN
OSD 6	114	L	100	88%
OSD 7	147	L	125	85%
OSD 8	152	L	PAIN	PAIN
OSD 9	105	R	PAIN	PAIN
OSD 9	105	L	PAIN	PAIN
OSD 10	140	R	PAIN	PAIN
OSD 10	140	L	PAIN	PAIN
OSD 16	161	R	PAIN	PAIN

Table B.8 Isokinetic tests: Peak torque values of the Control legs.

OSD Study #	Body Weight	Leg	Extension @60 Peak Torque	%BW	Extension @300 Peak Torque	%BW	Flexion @60 Peak Torque	%BW	Flexion @300 Peak Torque	%BW
OSD 11	95	R	69	73%	37	39%	52	55%	33	35%
OSD 11	95	L	75	79%	35	37%	55	58%	34	36%
OSD 12	102	R	64	63%	32	31%	49	48%	28	27%
OSD 12	102	L	61	60%	25	25%	45	44%	24	24%
OSD 13	85	R	69	81%	27	32%	28	33%	19	22%
OSD 13	85	L	71	84%	24	28%	47	55%	11	13%
OSD 14	117	R	87	74%	47	40%	56	48%	30	26%
OSD 14	117	L	91	78%	48	41%	60	51%	33	28%
OSD 15	VOID	VOID	VOID	VOID	VOID	VOID	VOID	VOID	VOID	VOID
OSD 17	77	R	49	64%	25	32%	41	53%	23	30%
OSD 17	77	L	51	66%	24	31%	40	52%	21	27%
OSD 18	108	R	82	76%	32	30%	66	61%	31	29%
OSD 18	108	L	91	84%	38	35%	67	62%	33	31%

Table B.9 Isokinetic tests: Peak torque values of the uninvolved OSD legs.

OSD Study #	Body Weight	Leg	Extension @60 Peak Torque	%BW	Extension @300 Peak Torque	%BW	Flexion @60 Peak Torque	%BW	Flexion @300 Peak Torque	%BW
OSD 1	135	R	102	76%	42	31%	64	47%	36	27%
OSD 2	170	L	103	61%	56	33%	45	26%	44	26%
OSD 3	130	L	123	95%	70	54%	78	60%	50	38%
OSD 5	111	R	85	77%	42	38%	63	57%	36	32%
OSD 6	114	R	114	100%	62	54%	66	58%	43	38%
OSD 7	147	R	104	71%	45	31%	64	44%	35	24%
OSD 8	152	R	123	81%	63	41%	110	72%	62	41%
OSD 16	161	L	132	82%	92	57%	97	60%	77	48%

Table B.10 Isokinetic tests: Peak torque values of the involved OSD legs.

OSD Study #	Body Weight	Leg	Extension @60 Peak Torque	%BW	Extension @300 Peak Torque	%BW	Flexion @60 Peak Torque	%BW	Flexion @300 Peak Torque	%BW
OSD 1	135	L	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 2	170	R	84	49%	53	31%	58	34%	51	30%
OSD 3	130	R	114	88%	63	48%	73	56%	59	45%
OSD 4	168	R	118	70%	58	35%	77	46%	38	23%
OSD 4	168	L	110	65%	69	41%	79	47%	56	33%
OSD 5	111	L	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 6	114	L	P	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 7	147	L	86	59%	42	29%	52	35%	35	24%
OSD 8	152	L	P	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 9	105	R	69	66%	38	36%	54	51%	27	26%
OSD 9	105	L	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 10	140	R	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 10	140	L	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 16	161	R	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN

Table B.11 Isokinetic test: Torque at specific angles throughout the peak repetition during knee extension for the Control legs.

OSD Study #	Body Weight	Leg	0*	0* %BW	15*	15* %BW	30*	30* %BW	60*	60* %BW
OSD 11	95	R	0	0%	8	8%	35	37%	59	62%
OSD 11	95	L	0	0%	0	0%	12	13%	67	71%
OSD 12	102	R	4	4%	25	25%	40	39%	64	63%
OSD 12	102	L	0	0%	14	14%	31	30%	55	54%
OSD 13	85	R	1	1%	15	18%	29	34%	60	71%
OSD 13	85	L	0	0%	14	16%	32	38%	62	73%
OSD 14	117	R	0	0%	12	10%	39	33%	75	64%
OSD 14	117	L	2	2%	20	17%	40	34%	69	59%
OSD 15	VOID	VOID	VOID	VOID	VOID	VOID	VOID	VOID	VOID	VOID
OSD 17	77	R	0	0%	8	10%	22	29%	42	55%
OSD 17	77	L	0	0%	8	10%	28	36%	51	66%
OSD 18	108	R	0	0%	0	0%	35	32%	72	67%
OSD 18	108	L	0	0%	0	0%	28	26%	72	67%

Table B.12 Isokinetic test: Torque at specific angles throughout the peak repetition during knee extension for the uninvolved OSD legs.

OSD Study #	Body Weight	Leg	0*	0* %BW	15*	15* %BW	30*	30* %BW	60*	60* %BW
OSD 1	135	R	0	0%	0	0%	27	20%	88	65%
OSD 2	170	L	0	0%	0	0%	26	15%	95	56%
OSD 3	130	L	0	0%	0	0%	0	0%	100	77%
OSD 5	111	R	0	0%	4	4%	27	24%	71	64%
OSD 6	114	R	0	0%	1	1%	20	18%	67	59%
OSD 7	147	R	0	0%	0	0%	39	27%	87	59%
OSD 8	152	R	0	0%	3	2%	34	22%	96	63%
OSD 16	161	L	0	0%	5	3%	47	29%	112	70%

Table B.13 Isokinetic test: Torque at specific angles throughout the peak repetition for the involved OSD legs.

OSD Study #	Body Weight	Leg	0*	0* %BW	15*	15* %BW	30*	30* %BW	60*	60* %BW
OSD 1	135	L	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 2	170	R	0	0%	0	0%	5	3%	73	43%
OSD 3	130	R	0	0%	0	0%	37	28%	108	83%
OSD 4	168	R	0	0%	0	0%	0	0%	93	55%
OSD 4	168	L	0	0%	0	0%	32	19%	85	51%
OSD 5	111	L	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 6	114	L	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 7	147	L	0	0%	0	0%	27	18%	74	50%
OSD 8	152	L	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 9	105	R	0	0%	0	0%	36	34%	68	65%
OSD 9	105	L	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 10	140	R	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 10	140	L	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 16	161	R	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN

Table B.14 Isokinetic tests: Work values of the Control legs.

OSD Study #	Body Weight	Leg	Extension @60 Peak Work	%BW	Extension @300 AVG Work	%BW	Flexion @ 60 Peak Work	%BW	Flexion @300 AVG Work	%BW
OSD 11	95	R	68	72%	30	32%	66	69%	32	34%
OSD 11	95	L	65	68%	30	32%	55	58%	34	36%
OSD 12	102	R	71	70%	24	24%	53	52%	25	24%
OSD 12	102	L	60	59%	19	18%	50	49%	20	20%
OSD 13	85	R	75	88%	25	29%	35	41%	14	16%
OSD 13	85	L	69	81%	21	24%	53	62%	7	8%
OSD 14	117	R	83	71%	34	29%	60	51%	18	15%
OSD 14	117	L	86	74%	31	27%	77	66%	22	19%
OSD 15	VOID	VOID	VOID	VOID	VOID	VOID	VOID	VOID	VOID	VOID
OSD 17	77	R	52	68%	16	21%	49	64%	17	22%
OSD 17	77	L	49	64%	12	15%	47	61%	17	21%
OSD 18	108	R	83	77%	23	21%	78	72%	20	19%
OSD 18	108	L	84	78%	25	23%	91	84%	13	12%

Table B.15 Isokinetic tests: Work values of the uninvolved OSD legs.

OSD Study #	Body Weight	Leg	Extension @60 Peak Work	%BW	Extension @300 AVG Work	%BW	Flexion @ 60 Peak Work	%BW	Flexion @300 AVG Work	%BW
OSD 1	135	R	100	74%	26	19%	69	51%	26	19%
OSD 2	170	L	93	55%	24	14%	48	28%	16	9%
OSD 3	130	L	108	83%	55	42%	95	73%	27	21%
OSD 5	111	R	82	74%	25	23%	77	69%	18	16%
OSD 6	114	R	89	78%	38	33%	68	60%	28	25%
OSD 7	147	R	88	60%	29	20%	57	39%	25	17%
OSD 8	152	R	113	74%	41	27%	128	84%	58	38%
OSD 16	161	L	139	86%	54	33%	95	59%	38	24%

Table B.16 Isokinetic tests: Work values of the involved OSD legs.

OSD Study #	Body Weight	Leg	Extension @60 Peak Work	%BW	Extension @300 AVG Work	%BW	Flexion @ 60 Peak Work	%BW	Flexion @300 AVG Work	%BW
OSD 1	135	L	PAIN	PAIN	PAIN	PAIN	P	P	P	P
OSD 2	170	R	74	44%	24	14%	58	34%	28	17%
OSD 3	130	R	104	80%	46	35%	76	58%	45	35%
OSD 4	168	R	105	63%	33	20%	86	51%	15	9%
OSD 4	168	L	110	65%	46	27%	79	47%	30	18%
OSD 5	111	L	PAIN	PAIN	PAIN	PAIN	P	P	P	P
OSD 6	114	L	PAIN	PAIN	PAIN	PAIN	P	P	P	P
OSD 7	147	L	82	56%	24	16%	53	36%	20	13%
OSD 8	152	L	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 9	105	R	72	69%	27	26%	55	52%	20	19%
OSD 9	105	L	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 10	140	R	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 10	140	L	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN
OSD 16	161	R	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN	PAIN

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