Effect of Drop Jumping and Knee Extension on Femoral Cartilage Thickness

by

Will Goodwin

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Will Goodwin

Greenville, NC

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Approved by:

Anthony Kulas

Department of Kinesiology, College of Health and Human Performance

Abstract

Post Traumatic Osteoarthritis (PTOA) is a form of osteoarthritis that occurs after injury to the anterior cruciate ligament (ACL) from high force impact. Individuals who land with higher knee extension at initial contact, which is known to increase risk for ACL injury, would have force of impact pass directly through the femoral cartilage, possibly increasing cartilage deformation. The purpose of this study is to investigate the effects of knee extension angle during initial impact on changes in femoral cartilage thickness. 20 females and 10 males who were healthy and recreationally active, had ultrasound images of their knee taken before, in between and after completing two sets of ten drop jumps from a height of 30 cm. The jumps were filmed, and the three most representative jumps were analyzed in Kinovea to determine the extent of knee extension at initial contact. Only five subjects were found to land with high knee extension at initial contact and no statistically significant changes in cartilage thickness were found after loading the femoral cartilage. The study appears to be statistically underpowered due to the low sample size and a larger sample size with appropriate statistical power will either confirm or refute the findings of this study. If future findings go to support the hypothesis that higher levels of knee extension cause higher levels of FCT deformation, then this could be a first step in helping treat PTOA.

Introduction

Knee osteoarthritis (OA) is a disease affecting a large percentage of the world population. Knee OA typically presents itself as the breakdown of the femoral articular cartilage, and the pain that follows this breakdown. To treat knee OA a lot of people turn to cortisone shots and knee replacements. Most of the people suffering from knee OA first see symptoms in their late 50s and early 60s with 85% of individuals by the age of 55–65.(Radin et al., 1990). The financial burden of this is felt on the insurance companies and patients who have to pay for these knee replacements and shots. According to Dr. Robert Schmerling, an estimated nine billion dollars are spent on knee replacements alone each year in the US (Robert H. Shmerling, 2021). It is important to recognize this issue is not just localized to the older demographic.

OA has the ability to afflict younger populations who have a history of previous knee injury. Specifically, those who have been previously injured with an anterior cruciate ligament (ACL) tear, and who have had reconstructive surgery are at risk for developing post-traumatic osteoarthritis (PTOA) as early as 10 years following reconstruction. (Luc et al., 2014). This means if a student athlete tears his ACL at 18 years old, by the time he is 30 years old he will have a high probability of developing PTOA.

In order to lessen the development of knee PTOA, it is necessary to understand the responses of knee cartilage to loading in healthy vs. injured populations. Since the knee joint is a weight-bearing joint, loading can happen through a variety of daily activities such as walking, running, or jumping and landing, to name a couple. These tasks affect the cartilage of healthy and injured populations differently.

Background

In a healthy population the cartilage of the knee becomes compressed through the day. This compression is normal as gravity's pull during daily activity causes the cartilage to become thinner. For example, a study done by Ekerstein et al. found a 6% and 5% reduction in patella cartilage volume after 50 and 100 knee bends. (Eckstein et al., 1998). Eckstein also found that "The cartilage displayed almost full recovery (98%) after approximately 4 hours" (Eckstein et al., 2006). This means when a person sleeps or spends a long period of time without weight being placed on the knee cartilage it will expand back almost to its regular thickness.

The ACL injured population still completes the same daily activities as the healthy person, yet the injured population has a much higher probability of developing PTOA within ten years of the ACL reconstruction (ACLR) surgery. In a study done by Bjornson et al. individuals who had ACLR had their cartilage measured before and after walking 3000 steps. The study found that ACLR individuals who exhibit an acute increase in anterior medial femoral articular cartilage cross-sectional area following 3000 steps of walking demonstrate lower KAM (knee abduction moments) and greater KEM (knee extension moments) in early stance (Bjornsen et al., 2023). From this it can be reasoned that those who had a decrease in cartilage had on average higher KAM and lower KEM in early stance. The higher KAM is associated with medial compartment loading and because of more compression of the medial cartilage. This suggests that the natural form of walking is altered after ACLR (Bjornsen et al., 2023). The altered walking patterns could be a source of the early development of PTOA. This points to an importance of technique while loading the knee and how that technique affects knee cartilage thickness.

Landing technique is important to understanding knee joint loads and cartilage deformation. Changes in knee joint loading due to knee extension is a known risk factor for ACL injuries. Knee extension at initial contact is also a possible risk factor for cartilage deformation. Individuals who have torn their ACL and had reconstructive surgeries are at a high risk of developing PTOA within ten years of injury. Knee extension at initial contact is also a possible risk factor for cartilage deformation and could possibly be a source of PTOA in ACLR individuals. If a person were to land with a more extended knee, the force of impact would pass more directly through the knee and could lead to higher cartilage compression. This study will investigate the possible association of knee extension at initial contact with cartilage deformation in a healthy population. If this study determines there is an association between knee extension and FCT deformation, then there would need to be further studies comparing FCT deformation in both healthy and ACLR individuals.

Purpose of the Study

The purpose of this study is to investigate the effects of knee extension angle during initial impact on changes in femoral cartilage thickness. By measuring the change in thickness of the cartilage after the jumps we will determine if more knee extension at initial contact leads to more cartilage compression in comparison to those who land with more knee flexion.

Hypothesis

Because the majority of ACL injuries occur from landing after jumping as opposed to walking. This points to a possible connection between cartilage compression and landing technique. It is hypothesized that landing with more knee extension leads to higher levels of femoral cartilage thickness deformation.

Methodology

20 recreationally active females and 10 recreationally active males between the ages of 18 and 25, with no prior knee injuries, were analyzed in this study. Out of the 30 subjects 23 (13 females and 10 males) were used for analysis. As this is an IRB approved research study, the research subject completed the informed consent documents, as well as filled out the KOOS knee survey and then indicated their level of physical activity. This is to ensure the subject has no knee injuries or other conditions which would have excluded them from the study and that the subject met the required level of physical activity. After this the subject had ultrasound images of both knees taken to establish baseline cartilage thickness. Figure 1 is an example of the ultrasound image and where the measurements are made. Subjects then performed two sets of ten

drop jumps from a height of 30 cm. In between each set of jumps, ultrasound images were taken of both knees. After the final set of jumps, ultrasound images were again taken of both knees. A total of four sets of images will be taken, two control and two experimental. The jumps were video recorded in the frontal and sagittal plane. These videos were analyzed in Kinovea, a biomechanical data analysis software. Three total jumps most representative of the subject's performance were analyzed. Using the sagittal plane view of the subject, the angle of knee flexion will be measured, these measurements are shown in figure 2. The knee angles from the three chosen videos will be averaged. Subjects with an average knee flexion angle below 30 degrees will be marked error present, and subjects with an average knee flexion angle above 30 degrees will be marked no error present as defined by the landing error scoring system.

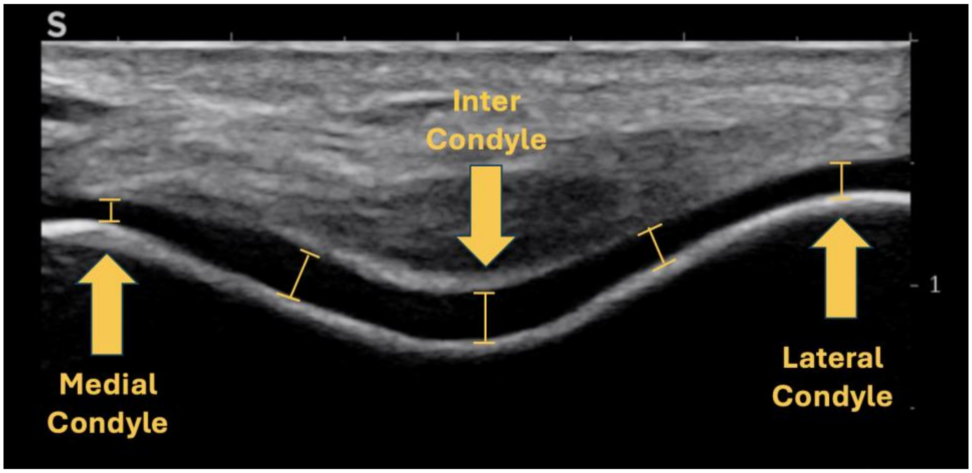
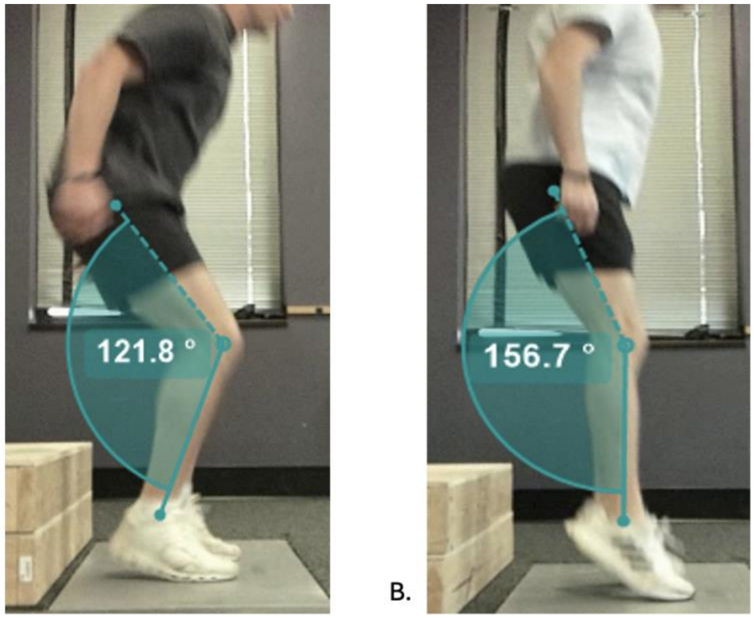


Figure 1. An ultrasound image of the knee showing the three condyles and where measurements will be taken.

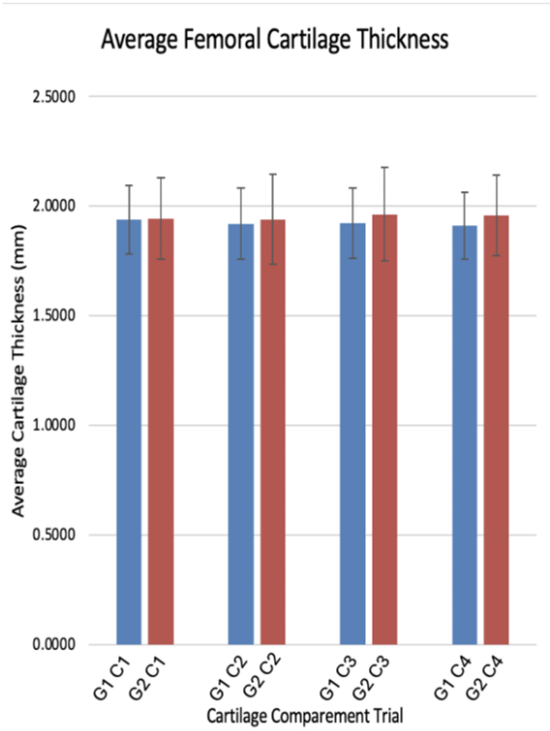
A. 

B.

Figure 2. Images of initial contact taken from the sagittal plane view.
A. demonstrates knee flexion above 30 degrees and B. demonstrates flexion below 30 degrees.

Results

Only five subjects were found to land with less than 30 degrees of knee flexion at initial contact. During analysis subjects were separated into two groups: no error present (based on the LESS criteria), those who landed with more than 30 degrees flexion, and error present, those who landed with less than 30 degrees of flexion. In figure 3 the average FCT of the error not present group was compared to the average FCT of the error present group over the 4 sets of imaging. There was no statistically significant difference ($p>0.05$) in cartilage change between the two groups over the four sets of imaging. In figure 4 the average FCT after the second set of jumps of each group was compared with the two control thicknesses. Both the error present group and the error not present group showed no statistically significant difference ($p>0.05$) in cartilage thickness from the control thicknesses to the final thickness.



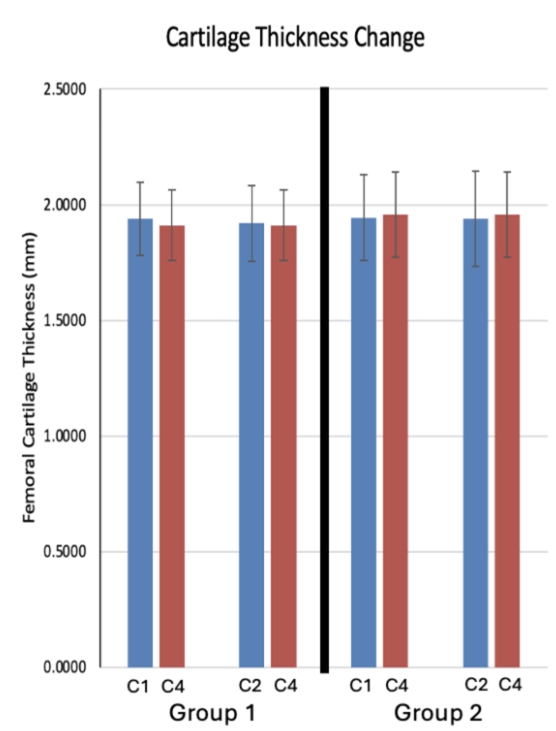


Figure3: Mean cartilage thickness across each image set. Figure 4: Change in cartilage thickness from control to final image. *Group 1/ G1 is knee flexion above 30 degrees, Group 2/ G2 is knee flexion below 30 degrees.

Discussion

The results showed no statistically significant changes in cartilage between the error present and the error not present group across the four sets of imaging. When the groups were separated and the average FCT from the two control image sets were compared to the average FCT from the final image set, there were no statistically significant changes in cartilage thickness in either group. While the results of the investigation were not statistically significant it is important to recognize this study is limited by its small sample size, which makes the study appear to be statistically underpowered. Further analysis of a larger sample size with appropriate statistical power will support or refute these findings.

The intensity of loading should also be reviewed in future investigations into landing techniques on FCT changes. In this study, loading was induced through 20 drop jumps from a height of 30 cm. This was chosen to represent more the functional load commonly observed in sports. However, there is a possibility the loading done in the study was not enough to properly cause changes in cartilage thickness. In the study completed by Eckstein et. al in 1998 50 - 100 knee bends were required to show knee changes in cartilage. The study completed by Bjornson et all had participants walk 3000 steps to load the cartilage. Both studies had high loading requirements to show minimal changes in cartilage thickness. By either increasing the amount of jumps or the height from which the subject jumps, it is possible there would be an increase in FCT changes for this study.

Lastly, other landing technique errors could contribute to FCT changes. The LESS identifies 17 possible errors that increase the possibility of ACL injury. Other landing errors defined by the LESS could increase FCT deformation and should be further investigated. While this study did not find statistically significant results, future studies should still further investigate landing techniques' effect on FCT changes in an effort to better understand and determine if joint loading as a function of landing technique may predispose a person from developing PTOA as a result from ACL injury.

Conclusion

While the study's results show no significant changes in FCT as a result of knee flexion below 30 degrees, the results should not be fully discredited. The study was limited by its small sample size and a larger data set with an appropriate level of statistical power has the possibility of supporting or refuting the findings of this study. Further research is needed on this topic to fully understand knee extension's effect on changes in FCT. If future findings go to support the hypothesis that higher levels of knee extension cause higher levels of FCT deformation, then this could be a first step in helping treat PTOA.

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