

Effects of Cigarette Smoking on Quadriceps Tendon Stiffness Using Ultrasound Elastography

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ABSTRACT

The present study aimed to find Quadriceps Tendon (QT) stiffness variation due to cigarette smoking by using Ultrasound Elastography (UE). The UE depicts the tendon stiffness in terms of Strain Ratio (SR). Mature and healthy individuals were incorporated in the present study. Strict exclusion criteria were followed. Nine individuals were recruited in the present study out of which seven were non-smokers or control group and two were smokers. Each subject's QT stiffness was measured using the UE technique. All participants had the right side of their body as their dominant side. The mean age was 20.9 ± 1.3 years, height was 177.3 ± 6.0 centimeters, weight was 76.3 ± 9.5 kilograms and BMI was 24.3 ± 3.0 . Presence of statistically significant difference in SR values was present between non-smokers and smokers. Moreover, difference in QT length and thickness values was also present. The present study revealed that the QT stiffness was statistically significantly higher among smokers in comparison to non-smokers, whereas QT length and thickness were lesser in smokers when compared with non-smokers. Therefore, from the present study it is apparent that cigarette smoking effects quadriceps tendon stiffness, length and thickness.

Keywords: Cigarette smoking, Strain ratio, Tendon stiffness, Quadriceps tendon, Ultrasound elastography.

INTRODUCTION

The knee joint acts as a fundamental synovial articulation in the human body. It acts as the assembly point between the femur, patella, and tibia [1]. It has a significant size and complex anatomy that is essential for bearing weight and enabling movements of the human body. The knee joint consists of the femur, fibula, and tibia. The cartilage articular shells these bony surfaces by reducing friction and enabling smooth motion. The knee joint also consists of two meniscuses (anterior and posterior) and four ligaments (anterior, posterior, lateral, and medial) which facilitate shock absorbers with stability and side-to-side motion, respectively.

The knee joint is also connected with the quadriceps tendon (QT) and patellar tendon. The QT is of significant importance within the musculoskeletal system and the human body [2]. Thus, QT plays an important role in the biomechanics in the lower limb. The QT comprises of the four quadriceps femoris muscles which are rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius. The QT is important for numerous knee joint functions such as body balance and movements from sitting to standing transition, walking, and running [3].

Moreover, it assists in the stabilization of the patella and knee joint by acting as its superior border. Thus, during jumping and lifting heavy loads QT contracts. The most considerable use of the QT in daily life is the transition from sitting to standing movement, where it generates the necessary force from the knee joint to elevate the human body. A healthy and sound QT is imperative for enhancing lower limb functions and evading the risk of knee joint injuries [4]. Cigarette smoking (CS) has a devastating effect on the human body, earlier studies have mentioned that CS is the root cause behind various preventable diseases among physiological systems [5, 6]. Physiological systems that are mostly affected by CS are the respiratory system, cardiovascular system, digestive system, musculoskeletal system, central nervous system, reproductive system, etc., in the present study we will focus on CS's effect on the QT.

Earlier studies found that CS affects tendon strength and properties specifically tendon stiffness in most cases [7, 8]. Tendon stiffness plays a vital role during movements and wait bearing activities deformation or loss of stiffness can result in an injury [9]. The present literature is not sufficient for the CS effect on the QT, whereas sufficient studies are available to demonstrate the CS effect on cardiovascular and respiratory health. Collagen disruptions could be considered as the primary component for affecting the tendon stiffness caused by CS [10].

Moreover, CS also exhibits chronic inflammation which hinders the body's natural healing process [11]. Like other connective tissues, tendons also depend on regulated inflammatory response for healing which could be compromised by CS as well as tendon mechanical properties [8]. The vasoconstrictive effect is also caused by CS which leads to reduced flow of the blood to tissues and so to tendons [12].

Thus, it hinders the optimum supply of oxygen and essential nutrients to tendons which affects their mechanical characteristics. Currently, in literature, the effect of CS on QT stiffness is rarely available. Therefore, more studies would be able to open a new trajectory for QT stiffness linked with CS. There are various modalities available to study QT stiffness, however, we opted for Ultrasound Elastography. Ultrasound elastography (UE) is a non-invasive approach that can be used in real-time on the patient. It is safe and harmless and doesn't require complex operating techniques. It gives quantitative evaluations of tissue elasticity or rigidity using sound waves. There are two types of Ultrasounds elastography, strain elastography and the second one is shear wave elastography, for the present study we opted for the prior one.

Although SE has been previously used many times for the analysis of other tendons of the lower limbs. However, to date, there is no significant literature available that establishes a relation between QT stiffness with CS. In the present study, the QT tendon stiffness of smokers and non-smokers was determined by using UE, which depicts stiffness in terms of SR.

MATERIALS AND METHODS

Design of the Study

The current study design was conducted at the Biomedical Technology Department, College of Applied Medical Sciences (CAMS), King Saud University, Riyadh, Saudi Arabia. The present study was approved by the institutional review board of the university and was approved before the start of the experimental phase. Helsinki Declaration guidelines were followed throughout the experimental phase. Additionally, a signed consent form was obtained from the participating individuals before the start of the experiment.

Participants

Mature and healthy individuals were incorporated in the present study. Strict exclusion criteria were followed such as individuals used/using steroids, previous lower limb injury/surgeries, suffering from inflammatory diseases, and individuals suffering from lower back or leg pain. All participating volunteers were undergraduate male students with the right side as their dominant side. Nine individuals were recruited in the present study out of which seven were non-smokers (or control group) and two were smokers (smoker group). All individuals were of the age of 21.4 ± 0.9 years and had a body mass index (BMI) of 24.3 ± 3 .

Experimental Setting

Firstly, an induction meeting was conducted with all the prospective individuals to accustom them to the study, its protocol, and its aim. Later a consent form was distributed among the participants and their signature was acquired. Secondly, height was measured for all the individuals followed by a body composition analysis carried out using a body composition analyzer (InBody 720, InBody Corporation Limited, Cerritos, CA, USA). Thirdly, the length and thickness from the mid-point of the QT were measured using the B-mode of the ultrasound machine (Ultrasonix SonixTouch Q+, Analogic Corporation, 8 Centennial Drive, Peabody, MA, USA). A high-frequency transducer was used along with the fixed setting of 10 Mega Hertz.

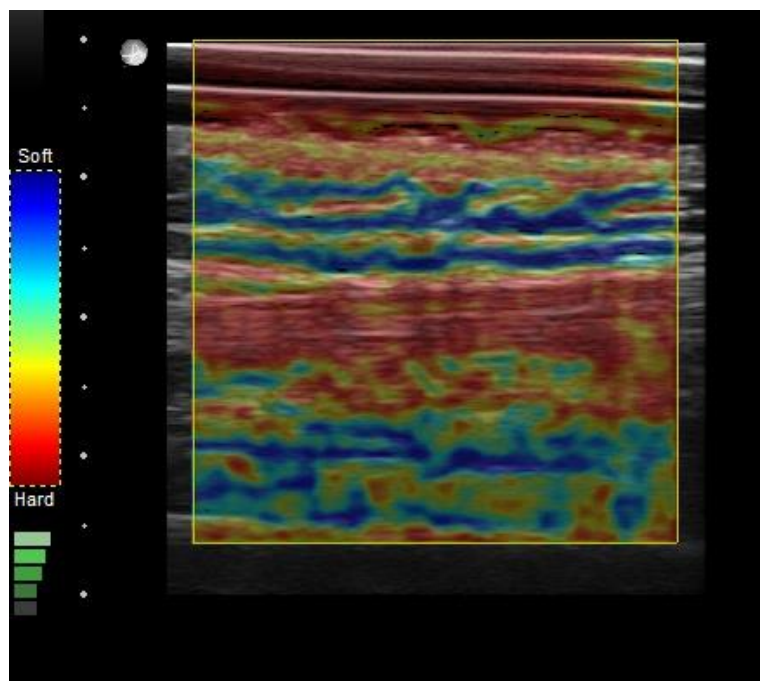


Figure 1: Strain ratio measurement of the quadriceps tendon using ultrasound elastography.

Fourthly, all the measurements of the length and thickness were carried out in the longitudinal plane, where the notch of the probe was facing the subject's face. All the subject was requested to lay down on the examination table in the supine position with knee flexed around 30 degrees. Each measurement of the length and the thickness was carried out thrice to increase reliability, and the mean was calculated and used in the present study. Lastly, for SR measurements was recorded from the same US machine in the same posture that is supine position with the knee flexed 30 degrees in Elasto-Mode while using a reference material over the QT, see figure 1. All the SR measurements were carried out in the longitudinal plane from the mid-point of the QT, where the notch of the probe was facing the subject's face. Each SR reading was taken 3 times and the mean value was calculated and used in the present study.

Statistical Analysis

The SPSS Software (SPSS, version 28, IBM Corporation, Armonk, NK, USA) was used for doing statistical analysis. All the parameters throughout the experiment were kept constant in the ultrasound machine and wherever possible. The *t*-test was performed to analyze the SR values between non-smokers and smokers, where a *p*-value of less than 0.05 was considered to have a level of significance.

RESULTS

Nine male healthy and untrained individuals volunteered for the present study, seven were non-smokers and two were smokers. All participants had the right side of their body as their dominant side the mean age was 20.9 ± 1.3 years, height was 177.3 ± 6.0 centimeters, weight was 76.3 ± 9.5 kilograms and BMI was 24.3 ± 3.0 . All ultrasound and SR measurements were taken on the dominant side of each participant's lower limb. Presence of statistically significant difference in SR values was recorded between non-smokers and smokers. In Figure 2, the mean BMI for the non-smokers (21.68) and the smokers (24.25) is shown, where smokers tend to have more BMI in comparison to non-smokers. The absence of a statistically significant difference was recorded between non-smokers and smokers for the BMI values.

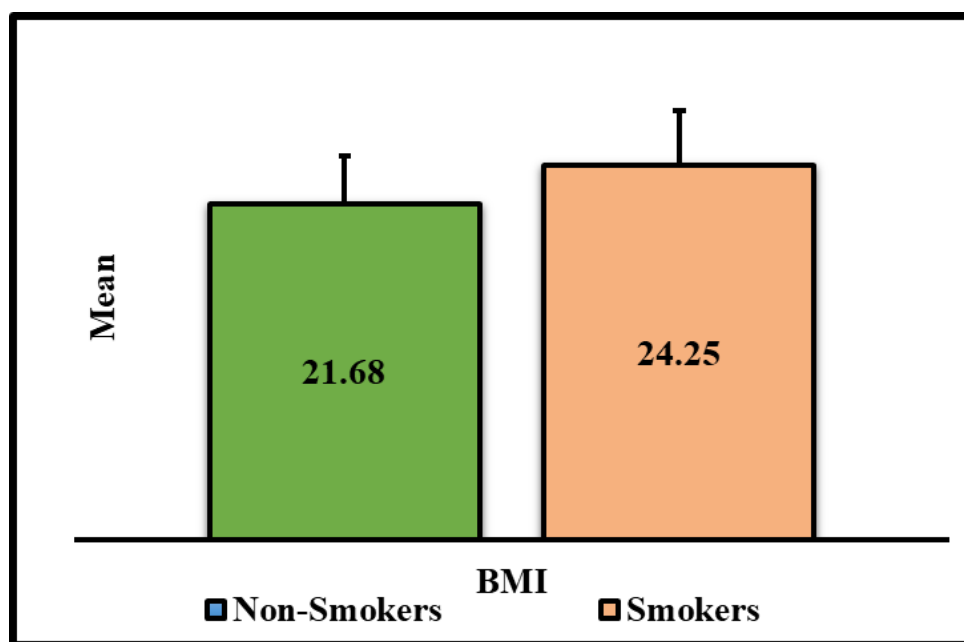


Figure 2: Mean BMI for the non-smokers and the smokers.

The values of the length of the QT in smokers display a decrease in the mean values of the length in non-smokers. The presence of a statistically insignificant difference between the length values was observed between non-smokers and smokers which can be seen in Figure 3.

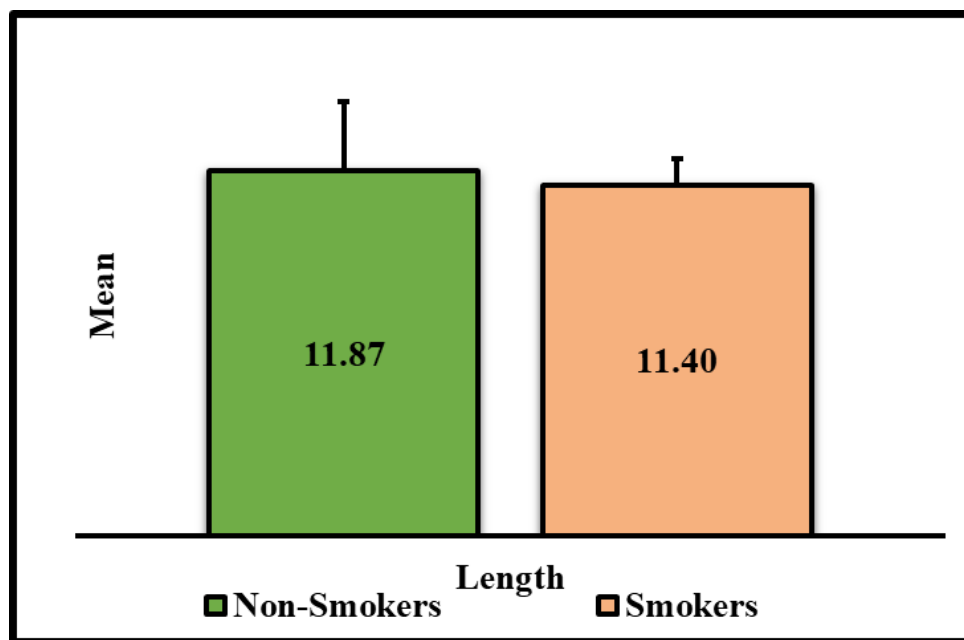


Figure 3: Mean length of the QT for the non-smokers and the smokers.

Figure 4 shows the mean thickness of the QT, the mean thickness of the QT decreases in the smokers when compared with the non-smokers. Moreover, a lack of statistically significant difference was recorded between non-smokers and smokers for the thickness values.

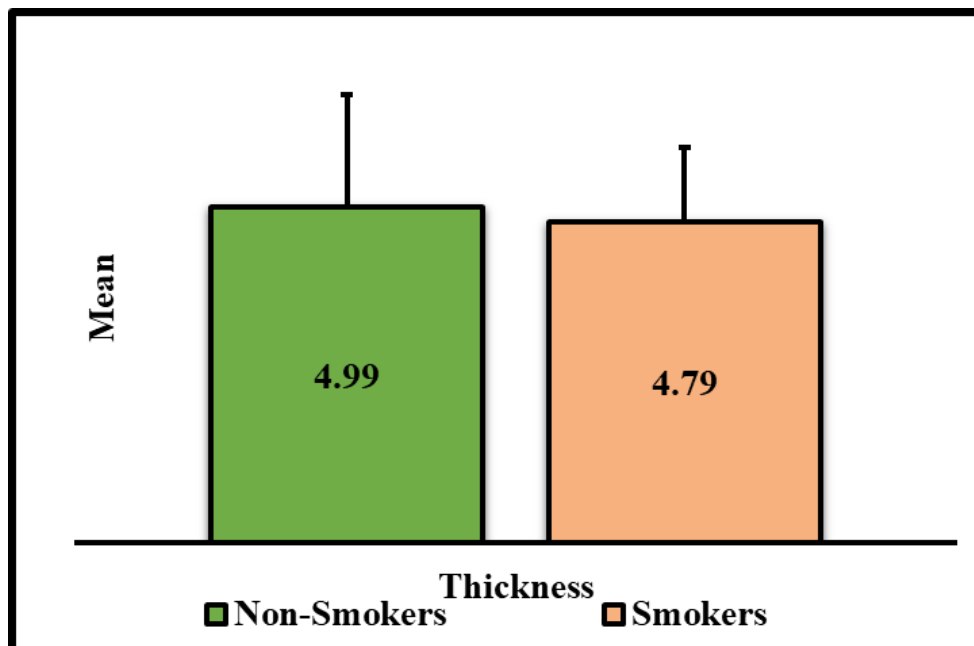


Figure 4: Mean thickens length of the QT for the non-smokers and the smokers.

The mean values of the SR of the QT indicate a higher numerical measurement in the smoker when compared to non-smokers (see figure 5). Additionally, the presence of a statistically significant difference between the SR values was recorded between the non-smokers and the smokers.

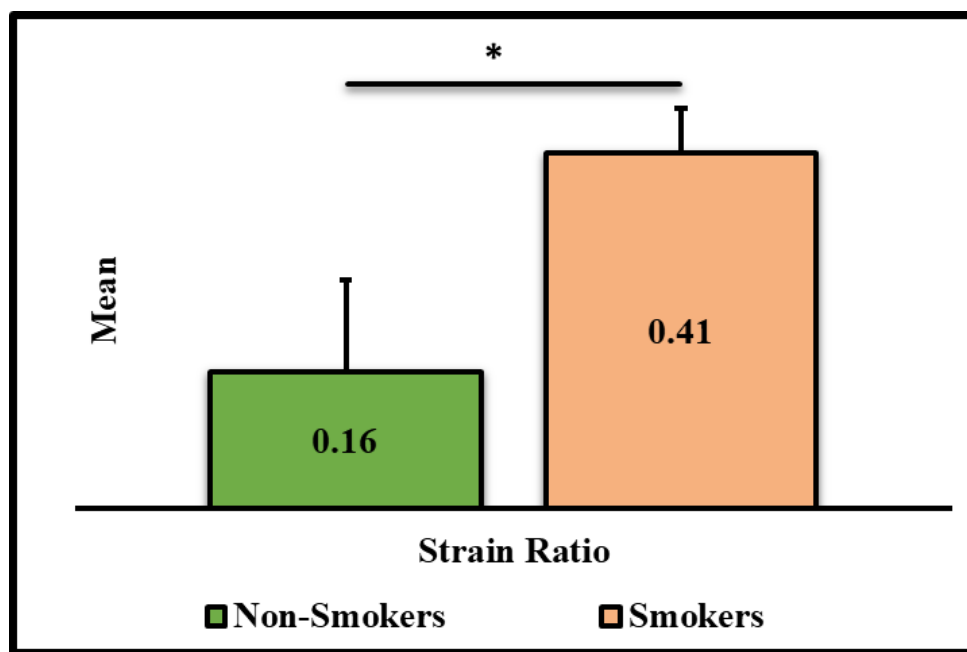


Figure 5: Mean SR of the QT for the non-smokers and the smokers.

* Indicates statistically significance difference between the non-smokers and smokers

DISCUSSION

The current study was designed to identify the effect of CS on the QT of healthy individuals using UE. The UE was preferred over other modalities as it is accurate, economical, and real-time [13]. Moreover, isoechoic B-mode images do not identify tendon diagnosis or tendon stiffness thus UE opted. In the present study, the accuracy and reliability of the tendon stiffness reading were improved by measuring each SR reading thrice. Moreover, using external reference material when measuring SR values of the QT is superior to using subcutaneous tissue [2] which was followed in the current study. In addition, earlier studies also suggested to use of external reference material instead of adjacent (subcutaneous) tissues when measuring strain elastography as the stiffness of the adjacent tissue can vary from one individual to another due to physical activity and body weight [14, 15].

Increased weight and BMI of a person also indicate health risks such as high levels of cholesterol and blood pressure that can lead to coronary heart disease and osteoarthritis [16]. Moreover, earlier studies mentioned that increased BMI is a considerable health hazard [17]. Soft tissues are affected by CS, thus to understand the effect of the CS on soft tissues present study was focused on QT due to essential utilization in day-to-day life and also as the vital element in the knee joint. The present study revealed that there was an increase in the BMI of the smokers in comparison to the non-smokers, in contrast, the length and the thickness of the smokers for the QT was lesser than non-smokers. The length and the thickness of the QT for smokers are lesser than the non-smokers due to obvious reasons as degeneration of soft tissues, such as muscles, organs, and tendons caused by CS [16] which strengthens our findings. Additionally, our

findings for the QT stiffness also displayed statistically higher significant SR values for smokers when compared to non-smokers. Earlier studies revealed that apoptotic cell concentration and inflammation in the tendon are increased due to CS [18, 19], which supports our findings for the higher SR values in smokers. It is worth mentioning that nicotine is the primary component in CS that harms the biological structures. Weakening or degradation of soft tissues or tendon fibers would result in a weak tendon and can cause an unwanted tendon injury or tendonitis [19]. Moreover, elastic properties and stiffness of the QT are also decreased when an individual is smoking which is in line with our findings. However, the stiffness of the QT can also be increased other than CS, factors such as an increase in the body fat content and weight-lifting can also influence higher stiffness in the QT. It could be due to the increased synthesis of collagen in the QT [10]. The higher SR values of the QT among smokers would also alter tissue morphology.

CONCLUSION

The present study was carried out on healthy young male subjects. It would be interesting if future studies could include more subjects, different age groups, and both genders. The present study findings interpreted the QT stiffness is significantly higher among smokers in comparison to non-smokers.

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